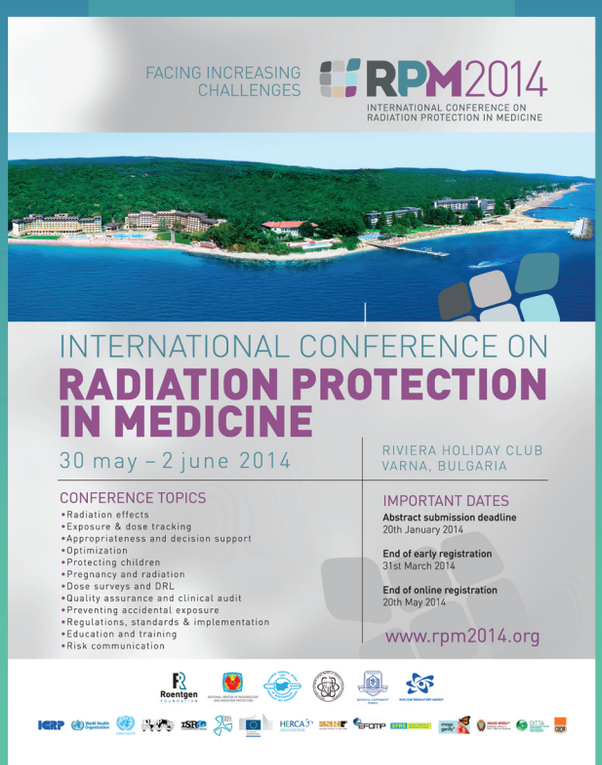
MEDICAL PHYSICS
International



A Journal of the International Organization for Medical Physics

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MEDICAL PHYSICS INTERNATIONAL

THE JOURNAL OF

THE INTERNATIONAL ORGANIZATION FOR MEDICAL PHYSICS

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MEDICAL PHYSICS INTERNATIONAL

The Journal of the International Organization for Medical Physics

Aims and Coverage:
Medical Physics International (MPI) is the official IOMP journal. The journal provides a new platform for medical physicists to share their experience, ideas and new information generated from their work of scientific, educational and professional nature. The e- journal is available free of charge to IOMP members.

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EDITORIAL
The Medical Physics Journals

Perry Sprawls, Co-Editor

The medical physics profession is served by a collection of outstanding journals, each distinguished by its content, method of publication, geographic coverage, and organizational affiliation. This journal, Medical Physics International, joins this distinguished group, not as a competitor for authors and readers, but as an active supporter and collaborator with the other journals. We are truly international, the official journal of the International Organization of Medical Physics (IOMP) and fully representing medical physicists in all countries of the world. Complete open access provides it with no cost to the global medical physics community.

Our mission is to publish articles that contribute to medical physics education, professional development, communication about international medical physics activities, and to preserve the history and heritage of the profession. A distinguishing feature of Medical Physics International is that it does not publish manuscripts reporting on research and development that require peer review. For these we recommend Physics in Medicine and Biology (the first journal to be designated as an official journal of IOMP in 1969), Medical Physics, Journal of Applied Clinical Medical Physics (the AAPM journals), PhysicaMedica (the European Journal of Medical Physics) and other regional and national medical physics journals that provide such publication opportunities.

EDITORIAL
Visibility of the Medical Physics Profession

Slavik Tabakov, Co-Editor

One of the main aims of the IOMP Journal Medical Physics International (MPI) is to increase the visibility of our profession. It required about 50 years after the establishment of the IOMP to gain inclusion of medical physicists in the International Standard Classification of Occupations (ISCO). During this period other smaller professions were included there mainly because of their better visibility. A number of high-profile activities, international projects and awards, collaboration with the WHO and IAEA provided excellent background for the above recognition of our profession.

We, all professionals, need to have better engagement with the general public and media to increase the positive image of our profession as an important element of contemporary healthcare. I often joke with my students that the place of medical physics and engineering in contemporary medicine is very similar to the place of the orchestra in the opera – in the pit under the scene, but without it, there is no opera. Could we be more visible? Of course we can, we only have to do it, for example by:

- at local level through short seminars explaining various new medical devices, and links with the Hospital management
- at national/regional level through links with the media explaining similar subjects and our involvement in hospital/patient safety
- at international level through increased collaboration with institutions as WHO, IAEA and others

With our current IOMP activities, such as: the update and uplift of our website; the improved design and editorship of eMPW; the launch of our unique e-Encyclopedia and Multilingual Dictionary; the new free online Journal MPI; the introduction of our International Day of Medical Physics; the active participation in various IAEA and WHO projects… we aim not only to connect our members and provide them with new information and references, but also to help with the visibility of our profession. We shall be happy if colleagues share their experience in this field through the IOMP publications.

HISTORY AND HERITAGE

A HISTORY OF THE INTERNATIONAL ORGANIZATION FOR MEDICAL PHYSICS – 50 YEARS ANNIVERSARY – PART II

Azam Niroomand-Rad[1], Colin Orton[2], Peter Smith[3], and Slavik Tabakov[4]

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[3]Aberdeen, UK, [4]Kings College, London, UK

Abstract— In celebration of 50 years Golden Anniversary of the founding of the International Organization for Medical Physics (IOMP), Part I of this article [1] described early discussions and developments that led to the formation of the International Organization for Medical Physics in 1963, followed by the early years of expansion of the Organization. This article covers the subsequent development of the Organization and reviews its major activities and links to other international organizations and how they were originated.

Keywords— IOMP, IUPESM, IFMBE, ICSU, IUPAP, ILO, ISCO, Medical Physics.

I. Introduction

This article is written by past and present members of the IOMP History Subcommittee in recognition of the Golden Anniversary of the founding of the Organization in 1963. In part I **[1]** formation of the Organization with just four National Members Organizations, representing a few hundred medical physicists, was reviewed and development of its membership was outlined.

This article highlights the major activities and accomplishments of the IOMP and recognizes the enormous time and effort donated by many of its voluntary members to promote the purposes and objectives of the Organization as outlined here:

1. Early IOMP Conferences and Initial Collaboration with Biomedical Engineers
2. Formation of the International Union of Physical and Engineering Sciences in Medicine
3. World Congresses and International Conferences on Medical Physics
4. Membership in the International Council of Scientific Unions (ICSU)
5. Formation of the Regional Federations of Medical Physics
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I. EARLY IOMP CONFERENCES AND INITIAL COLLABORATION WITH BIOMEDICAL ENGINEERS

Two years after its formation, in September 1965, IOMP held its first conference in Harrogate, UK. It was organized by the UK Hospital Physicists' Association (HPA) and over 500 people from 24 countries attended. There were 117 proffered papers in three parallel sessions and eight review papers and these review papers, together with the Presidential Address of Prof Val Mayneord, were published as a supplement to Physics in Medicine and Biology **[2]**. Thus began the sequence of the IOMP's International Conferences on Medical Physics (ICMPs).

At Harrogate, Council decided that the next conference should be held in Boston, USA, in August 1969. The third conference was held in Goteborg, Sweden and the fourth in July 1976 in Ottawa, Canada – thereby each of the founding quartet hosted one of the first four ICMPs.

Biomedical Engineers had formed the International Federation for Medical Electronics and Biological Engineering, later renamed the International Federation for Medical and Biological Engineering (IFMBE), four years prior to the formation of the IOMP **[3]**. At the International Conference of Medical and Biological Engineering held in Melbourne in 1971, R Magnusson, IOMP Vice-President, made a plea for closer association between the two organizations. It was agreed to hold further discussions to explore areas of collaboration. Subsequently in 1972 IFMBE Secretary-General attended IOMP 3rd ICMP in Gothenburg, Sweden where Council endorsed exploring closer collaboration. In 1973 the Presidents and Secretaries-General of the two organisations met when both organizations were planning conferences to be held in Ottawa, Canada (4th ICMP and 11th ICMBE). It was agreed that these meetings should be back-to-back at the same venue, with sessions of mutual interest held in the middle.

In 1976 at the Ottawa Conference it was agreed that the next joint meeting should be held in 1979 in Jerusalem, Israel. This goal was achieved in August 1979, which marks the first integrated conference (5th ICMP and 12th ICMB) by the two Organizations. John Mallard's memories of these historical events were published in an article, which is available at the History Section of Published Articles at IOMP Website (www.iomp.org).

II. FORMATION OF THE INTERNATIONAL UNION OF PHYSICS AND ENGINEERING SCIENCES IN MEDICINE

In the period 1974–1979 there were a number of meetings between officers of the IOMP and IFMBE, including the formation in 1975 of a formal committee (Prof. R. L. Clarke, representing IOMP, and Dr. J A Hopps, representing IFMBE), to prepare a paper on collaboration for discussion by both organizations at the joint meeting in 1976. Subsequently a proposal by Clarke and Hobbs for the creation of an international union tentatively designated as '*the International Union for Physics and Engineering in Medicine'* was put forward to a joint IOMP/IFMBE meeting at Ottawa. Both organizations authorized the continuation of the ad-hoc committee and requested a draft document, including draft Statutes, to be prepared for consideration by the Councils at their meetings at Jerusalem in 1979. A tentative plan was circulated for comment in early 1978 and the comments were reviewed by May of that year. Subsequently a resume was prepared for national societies because of the possible impact of a scientific union on their operation. Record of this resume is available at IOMP Archives, IOMP Headquarter, York, UK. The resume put forward the following main reasons for the formation of a union:

- Conferences. The 1976 Ottawa and the 1979 Jerusalem conferences had demonstrated a considerable overlap in the topics presented by the two organizations but more effective integration at future conferences would require closer coordination between the two organizations.
- Scientific Affiliation. Neither society had a satisfactory scientific affiliation. IOMP was an Associated Commission of the International Union for Pure and Applied Biophysics (IUPAB) but this had not provided the hoped for benefits and there were few common interests with other members. The IFMBE had withdrawn from the Council of International Organizations for Medical Science for similar reasons. If a union could be formed which met the requirements for membership of the International Council of Scientific Unions (ICSU) then two organizations would have the desired scientific affiliation and advantages accruing from membership of the world's foremost scientific body.
- Integration of programs and development of mutual interests
- Enhancement and recognition of IOMP and IFMBE in international circles.

It was thought that it was necessary to have national organizations, as well as IOMP and IFMBE, as members of the proposed union to meet requirements for membership of the ICSU. There were considerable concerns around the role of national members and this dominated discussion in 1977 and 1978. However in 1979 a simpler organizational structure was devised which did not involve national organizations. Thus a further position paper was circulated

for consideration in August 1979. The word "Sciences" was added to the name of the Union in order to enhance our chances of being approved for membership of ISCU. [4]. Statutes of the new Union were approved by Councils of both organizations at their meetings in Jerusalem in 1979 and the International Union of Physical and Engineering Sciences in Medicine (IUPESM) came into existence in January 1980.

III. WORLD CONGRESSES AND INTERNATIONAL CONFERENCES ON MEDICAL PHYSICS

The formation of IUPESM allowed IOMP and IFMBE to embark on a programme of triennial World Congresses (WCs). The WCs on Medical Physics and Biomedical Engineering were, and are, managed by IUPESM and normally jointly hosted by the medical physics and biomedical engineering national member organisations of the country where the Congress is held. Although managed by IUPESM, both IOMP and IFMBE are signatories to the contract and the WCs incorporate an ICMP of IOMP and an International Conference (IC) of IFMBE. **Table 1** is a listing of all ICMPs, WCs, years, and locations of the meetings.

In addition to the triennial World Congresses on Medical Physics and Biomedical Engineering, IOMP Officers have discussed various possibilities for further ties with the Regional Organizations. In 2003 at the WC in Sydney, Australia, Azam Niroomand-Rad, IOMP President, presented additional series of ICMPs, separate from the WCs but interleaved with them. This proposal was discussed at the Council meeting in Sydney. Additionally proposal by German Society for Medical Physics (DGMP) to organize the IOMP 14th ICMP in Nuremburg, Germany was approved. In 2004, a full discussion paper that was circulated to Council followed proposal for additional ICMPs. Council approved this proposal at a virtual meeting in October 2004 **[5]** but stipulated that the term WC should not be used for these additional series of ICMPs.

The two main objectives for introducing additional triennial ICMPs between the WCs were:

- Medical physicists worldwide, especially those from developing countries, needed more opportunities to interact with each other and be exposed to emerging technologies. Smaller and more frequent scientific meetings of high quality, would help to improve the development of medical physics, to strengthen links among regional medical physicists, and to promote the medical physics profession in countries / regions where a large WC was not an option.
- To meet the challenges of the IOMP financial resources needed to grow accordingly. It was hoped that the additional conferences would increase the income of IOMP

The conferences were to reflect the priorities and needs of the region in which they were based. A balance between various scientific, educational, training and professional elements reflecting the needs of the region along with substantial exhibition were always encouraged.

IV. MEMBERSHIP IN THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

The desire to secure membership in the International Council of Scientific Unions (ICSU) had been a key issue since the inception of IOMP, was a primary reason for the establishment of IUPESM and a key factor in determining its constitution. After the formation of IUPESM enormous efforts were made by the IUPESM Officers to secure its membership with ICSU. In summer of 1980, ICSU turned down the IUPESM application and suggested an application should first be made for Associate Membership. In 1982 this application was submitted and was accepted by ICSU.

IUPESM remained an Associate Member of ICSU for the next fifteen years but gained little from its Associate status. In 1997 ICSU reviewed the relationship between IUPESM and ICSU as part of wider review of its activities. A report was presented by IUPESM to an ICSU review panel and the opportunity was taken to push for full membership but the outcome was a continuation of associate membership. In 1999, after further discussions with ICSU, Keith Boddy, IUPESM President and IOMP Past-President, with the approval and endorsement of Council, submitted a substantive fresh application to ICSU for full membership. In September 1999 the IUPESM was unanimously admitted to ICSU as a full member [6,7]

In the years following full membership of ICSU, the IUPESM Officers have made considerable efforts to reap benefits from full membership but results have been limited. Funding was obtained to produce a brochure 'Physical and Engineering Sciences in Healthcare' and IUPESM was active in collaboration with other unions on the project 'Science for Health and Well-Being'. This eventually emerged as the current ICSU project "Health and wellbeing in the changing urban environment: a system analysis approach". IUPESM has recently been involved with a cluster of Bio Unions that have lately established new programs of international symposia and advanced summer schools.

V. FORMATION OF THE REGIONAL FEDERATIONS OF MEDICAL PHYSICS

To help develop medical physics in various regions, IOMP has supported formation of its Regional Organizations of Medical Physics in Europe, Latin America, Asia-Oceania, South-East Asia, Middle East and Africa. These Federations have developed their own Statutes and Bylaws that are consistent with IOMP Mission and Objectives. Many officers of these Regional Organizations (Federations) take part in various IOMP Committees, thus assuring the synchronized global development of the profession. The IOMP Council has representatives of both – national organizations and the respective Regional

Federations. The current Regional Federations of IOMP includes:

- European Federation of Organizations for Medical Physics (EFOMP) with 35 national members - formed in 1980
- Latin American Medical Physics Association (ALFIM) with 11 national members - formed in 1984
- Asian-Oceania Federation of Organizations for Medical Physics (AFOMP) with 16 national members - formed in 2000
- Southeast Asian Federation for Medical Physics (SEAFOMP) with 6 national members - formed in 2006
- Middle East Federation of Organizations for Medical Physics (MEFOMP) with 12 national members - formed in 2008
- Federation of African Medical Physics Organizations (FAMPO) with 15 national members - formed in 2009

VI. COLLABORATION WITH UNITED NATIONS ORGANIZATIONS

6.1 International Atomic Energy Agency (IAEA)

In the early years of formation of IOMP, several IOMP members were collaborating with IAEA – for example, in 1962 Dr. Monty Cohen from UK was a member of the Steering Group but at that time worked for the IAEA. He suggested that IOMP should apply for consultative status with IAEA. Informal contacts and communications were maintained during the early years and in 1967 IOMP Council agreed to consider affiliation with IAEA. Mr. E H Belcher, the IAEA representative at the meeting, suggested that IOMP write the Director-General requesting that the IAEA formally designate a point of contact with IOMP. However it appears little formal action was taken over the next few years but in 1976 Dr. Horst Eisenlohr was appointed liaison person to IOMP by IAEA.

In 1982 it was reported to Council that IAEA in collaboration with the World Health Organization (WHO) was planning to set up a network of Secondary Standard Dosimetry Laboratories (SSDL). IOMP was formally recognized, and continues to be recognized, as a collaborating organization associated with the IAEA/WHO Network of SSDLs. The IOMP Secretary-General, Colin Orton (1991-1994) negotiated a formal agreement for cooperation between the IAEA and the IOMP and President Udipi Madhvanath signed a Memorandum of Understanding in Vienna in June 1992. Subsequently, a list of medical physics experts willing to travel to developing countries to work with the IAEA was developed to help IAEA identify experts willing to support their programs. In 1996 IOMP signed a further Memorandum of Understanding with IAEA to help transport donated used equipment to recipients in developing countries. Collaboration has continued and IOMP contributes successfully to a number of IAEA programs and projects led by each its two relevant Divisions working in the fields of medical physics and radiation safety. Even though IOMP has never been recognized by IAEA as having formal consultative status, it is normally invited to send an observer to the Agency's annual General Conference.

6.2 World Health Organization (WHO)

In the early years IOMP collaboration with WHO was less strong than with IAEA. However at the 1972 Council meeting, Dr. Berndt Waldeskrog of WHO proposed affiliation of IOMP to WHO and Council agreed. But it appears little action was taken in the 1970s. In 1982 Alexander Kaul, IOMP President, met with Dr. Raconeanu, Chief Medical Officer at WHO to discuss formal collaboration but again it appears to have led to little action. Although the IOMP had no formal agreement with WHO there were collaborations between these two organizations and IOMP was represented in a several WHO projects and initiatives, such as the WHO's '*Global Initiative on Radiation Safety in Healthcare Settings*'.

In 2009 IOMP appointed a designated Liaison to WHO – Peter Smith (2009-2012) and Habib Zaidi (2013-Present). In the meanwhile a concerted effort was initiated to establish formal links with WHO and number of meetings were held at Geneva and at the World Congress in Munich. This finally resulted in the signing of a memorandum of understanding in 2010 and agreement on an'*IOMP/WHO Collaboration Plan for 2010-2012'*. IOMP was involved in planning and actively participated in WHO's '*First Global Forum on Medical Devices'* held in Bangkok in September 2010 and the second Forum held in Geneva in November 2013. Currently IOMP is applying for Non Government Organization (NGO) status to WHO.

6.3 International Labour Organization (ILO)

By 1995 with 55 National Members, IOMP had recognized difficulties stemming from lack of recognition of medical physicists, especially in developing countries. It was extremely important to our colleagues to be recognized par with other professionals and, therefore, be eligible for many of the benefits that were accorded to them such as status, appropriate responsibilities, decision-making, and salary negotiation. In 1995 IOMP President, Keith Boddy, initiated the first communication with the Bureau of Statistics that manages, organizes and publishes the International Standard Classification of Occupations (ISCO) of the ILO in Geneva, Switzerland. The listing of professionals in ISCO is updated infrequently. The first publication was in 1958 (ISCO-58), followed by ISCO-68, ISCO-88 and most recently in 2008 (ISCO-08).

Keith Boddy and other IOMP Presidents in particular Azam Niroomand-Rad and Colin Orton requested that Medical Physicists should be included in the listing of Health Professionals for the update of ISCO-88. However, they soon recognized that this path was long and arduous. It took them over 12 years to overcome these obstacles and have Medical Physicists be listed in ISCO-2008.

To pursue recognition of medical physicists in the revision of ISCO-88, we had to adhere to ISCO procedures. This included (but was not limited to) providing documents from governmental agencies as to the definition, task performed, and listing of medical physicists by governmental agencies. IOMP had to submit and re-submit its request along with supporting documents including list of tasks performed by medical physicists several times when Directors and/or Staffs of the Bureau of Statistics were being replaced. Two web-based consultations for update of ISCO-88 were prepared and distributed - first in 2004 **[8]** and second in 2006 **[9].**

After the first consultation ILO concluded that medical physicists were not sufficiently numerous to justify a separate unit group. The second consultation focused on where medical physics should be included in the classification and responses were equally divided between including medical physicists under "Physicists and Astronomers" or under "Health" Professionals. IOMP, and others, proposed that medical physicists should be classified under Health Professionals, because in the classification system of a number of countries medical physicists were classified under 'Health Professionals'. However, Directors of Bureau of Statistics at ILO recognized that ISCO-88 needs to be updated due to varieties of reasons including emergence of new occupations and decline of some occupations and the need for categories at the sub-major and minor groups to be more even in size than those in ISCO-88 which had 10 Major Groups, 28 Sub-Groups, 116 Minor Groups, and 390 Unit Groups. Thus ISCO-08 came to have 10 Major Groups, 36 Sub-Major Groups, 126 Minor Groups, and 446 Unit Groups.

The ILO finally decided in favor of classification under 'Physicists and Astronomers' for the following two main reasons:

- Since the basis of knowledge required for medical physics is physics, it is consistent with the ISCO conceptual model to include them in the same Unit group as other physicists.
- The view that medical physicists should be classified as health professionals because they work in the health system was not accepted as ISCO is not a classification of industrial activities.

With this conclusion it was decided to include Medical Physicists in Major Group 2 (Professionals), Sub-Major Group 21 (Science and Engineering Professionals), Minor Group 211 (Physical and Earth Science Professional), and Unit Group 2111 (Physicists and Astronomers) in ISCO-08 **[10].**

Following further discussions initiated by Fridtjof Nusslin, IOMP President and Peter Smith, IOMP Past Secretary-General, in 2010 two notes were added to ISCO-08 clarifying the position of medical physicists in relation with other health professions. The one at the end of unit group 2111 'Physicists and Astronomers' states that ***"…*** *medical physicists are considered to be an integral part of the health work force alongside those occupations classified in Sub-Major Group 22, Health Professionals and others classified in a number of other unit groups in Major Group 2, Professionals."* A similar note was added under Sub-Major Group 22. The list of tasks performed by medical physicists under "Physicists and Astronomers" was also extended and modified as indicated in ISCO-08 **[11].**

In recognition of this very important professional achievement, in 2013 IOMP launched an International Day of Medical Physics (IDMP), which will be celebrated annually on 7 November (the birthday of Marie Sklodowska-Curie). The first IDMP was coordinated by John Damilakis, ETC Chair, and was organized by many national medical physics societies on November 7, 2013.

VII. AFFILIATION WITH INTERNATIONAL UNIONS

7.1 ***International Union of Pure and Applied Biophysics (IUPAB)***

Affiliation with International Union of Pure and Applied Biophysics (IUPAB) goes back to the early days of IOMP. The IOMP affiliation with IUPAB in 1964 was not a great success and, with the formation of IUPESM, the link was broken in 1982. However it was rekindled in the last few years, largely due to the efforts of Prof. Fridtjof Nüsslin, President of IOMP, with both direct informal links and collaboration through the ICSU Biocluster.

7.2 ***International Union for Pure and Applied Physics (IUPAP)***

The International Union for Pure and Applied Physics (IUPAP) was established in 1922 as an international organization whose mission was to assist worldwide development of physics, to foster international cooperation in physics, and to help in application of physics toward solving problems of concern to humanity. IUPAP is a member of ICSU and has 20 Commissions (C.1-C20) and four Affiliated Commissions (AC.1-AC.4) on various sub-specialties in physics. [12]

As an umbrella organization for pure and applied physics, at the turn of century IUPAP decided to establish a Commission on Medical Physics with or without collaboration with IOMP. But it was important for IUPAP to cooperate with IOMP as an existing Organization for medical physics. Subsequently IUPAP and IOMP formed a joint Ad Hoc Committee and in 2003, IOMP President, Azam Niroomand-Rad, submitted a proposal to IUPAP for IOMP affiliation. One might think this was an obvious decision but it was not. In the past 30 years or so, archived documents at IOMP Headquarter, York, UK, indicate that IOMP was establishing relationship with biophysicists and biomedical engineers. Also there was some concern about jeopardizing IUPESM affiliation with ICSU. At IUPAP Council and Commission Chairs Meeting at Tata Institute for Fundamental Research, Mumbai, meeting in India, October 15-16, 2004, Azam Niroomand-Rad, IOMP President reported for IOMP. She pointed out although medical physics is an applied physics; IOMP affiliation has

been with bioengineers of IFMBE through union in IUPESM that is a member of ICSU. She indicated IOMP affiliation with IUPAP would improve relation with physics scientists. [13].

In 2005, at the IUPAP General Assembly meeting in Cape Town, South Africa, IOMP proposal was approved unanimously and an "Affiliated Commission on Medical Physics (AC.4)" was established. [14]. At this meeting IUPAP Council approved AC.4 membership; namely the positional membership of AC.4 shall consist of five IOMP elected Officers, Chairs of IOMP (SC, ETC, PRC, PC) with at most six IUPAP Liaisons including IUPAP Chairs of C6 (Commission on Biological Physics), C13 (Commission on Physics for Development), C14 (Commission on Physics Education). Subsequently this led to the formation of a new committee by IOMP known as "International Commission on Medical Physics (IComMP)" and establishment of IUPAP Young Scientist Award in Medical Physics in 2006, which is managed by IOMP but funded by IUPAP.

VIII. COLLABORATION WITH OTHER INTERNATIONAL ORGANIZATIONS

Over the years IUPESM had informal collaboration with a number of international organizations and participated in several joint projects and activities with**:**

- *International Society of Radiology (ISR)*
- *International Commission on Radiation Protection (ICRP)*
- *International Commission on Radiation Units (ICRU)*
- *Bureau International des Poids et Measures (BIPM)*
- *International Radiation Protection Association (IRPA)*
- *International Centre for Theoretical Physics (ICTP)*

In 2010 IOMP made a formal link with IRPA through a Memorandum of Understanding. This led to a '*Statement of Collaboration between IOMP and IRPA to foster Medical Physics in Developing Countries'*.

IX. IOMP PUBLICATIONS, JOURNALS, AND BOOK SERIES

9.1 ***Medical Physics World, MPW (1984) - Electronic Medical Physics World, eMPW (2010)***

In 1984 IOMP established Medical Physics World (MPW) to expand on the channels of communication among its membership. The Vice-President, Lawrence H. Lanzl, Founding Editor, announced inauguration of MPW and stated "The general content of MPW was to include a calendar of events, articles with news on national societies of medical physics, reports from the officers of IOMP, general IOMP information, editorial which will be controversial when the need arises, guest editorials, letters to the editor, and other relevant items [13]. Hard copies of MPWs were distributed through the national organizations to every medical physicist. In 25 years (1984-2010) a total of 6 Editors managed to publish 25 volumes (1064 pages) twice per year with some financial gains from advertisements. This could not have been achieved without the help of many members who served as Associate Editors, Calendar of Events Editors and Advertizing Liaison: The Editors were;

Lawrence Lanzl (1984-1986), Colin Orton (1986-1988), Richard Maughan (1998-1992), Bhudatt Paliwal (1993-1994), Azam Niroomand-Rad (1994-2000), and Ishmael Parsai (2000- 2009).

In 1997 the Electronic Medical Physics World (EMPW) was established by John Cameron to compliment MPW. Kwan Hoong Ng and Larry Deward served as Managing Editors and John Cameron, served as Editor of the "Ask Your Medical Physicist". Home Page of EMPW was maintained by the University of Wisconsin in Madison and at the time could be accessed on the Internet [16]. However, the EMPW was discontinued with the passing of John Cameron in 2005.

In 2010 MPW became electronic under leadership of Donald Frey, Editor and Ishmael Parsai, Associate Editor. The first publication of eMPW, Vol. 1(1) was in June 2010 and became available at the IOMP website. The general content of eMPW is the same as MPW with lesser restriction on cost and/or number of pages for each volume. Since 2012 under the leadership of Virginia Tsapaki, Editor and Magdalena Stoeva, Associate Editor, eMPW was further improved and continued with 2 editions per year. The Editor of eMPW were:

Donald Frey (2010-2011) and Virginia Tsapaki (2012-Present).

9.2 ***Medical Physics International (MPI)***

In 2012 a new electronic Journal with free on-line access (www.mpijournal.org), Medical Physics International (MPI), was launched under Editorship of Slavik Tabakov (UK) and Perry Sprawls (USA). The first edition was published online in March 2013 **[17]**. The purpose of this Journal is to provide the global medical physics community with articles that are not generally available in other publications. A special emphasis is to support educational activities and professional development of medical physicists and related professions and it will have links to many educational resources. Additional articles highlight recent advances in technology associated with medical physics with information on effective utilization to enhance both professional practice and education. MPI Journal also publishes proceedings from IOMP Conferences. The ICMP-2013 was the first such Conference.

9.3 ***IOMP Official Journals***

Apart from the above publications, IOMP has recognized a number of other journals as "Official Journals": **'***Physics in Medicine and Biology'* (the first journal to be designated as an official journal of IOMP in (1969), followed by **'***Physiological Measurement'* (1988) **'***Medical Physics'* (2006) and **'***Medical Physics International'* (2013**).** IOMP has also co-sponsored the '*Journal of Applied Clinical Medical Physics'* since 2003.

9.4 ***IOMP Book Series.***

In 1991 IOMP and the Institute of Physics Publishing (IOPP) entered into an agreement to publish *'The Medical Physics and Biomedical Engineering Series'*. In 2003 IOPP sold their book publishing business agreements to the Taylor and Francis Group and a new agreement was signed between them and IOMP in 2006. Since the start a total of 41 books have been published in these series.

X. IOMP COMMITTEES AND SUBCOMMITTEES

10.1 ***Developing Countries Committee (1982) and Professional Relations Committee (1997)***

Although there is no specific mention of developing countries in the Statutes of the IOMP, since the middle of the 1970s the IOMP has recognized the need to support medical physicists in developing countries. This led to the formation of the Developing Countries Committee (DCC) at the Council meeting of (6th ICMP and 1st WC) in Hamburg, Germany in 1982 [18]. The main duties were to find the needs of developing countries such as journals, spare parts and used equipment. Consequently two specific programs were established; namely – the International Libraries program and the Used Equipment program. In 1997 DCC was replaced by the Professional Relations Committee (PRC) to enhance professional activities and practices of medical physics in member societies as well. The DCC and PRC

Chairs were: Rune Walstam (1982-1989), Xie Nan-Zhu (1989-1994), M. S. S. Murthy (1994-1997), Andries Van Aswegen (1997-2000), Stelios Christofides (2003-2006), Kin Yin Cheung (2006-2009) and Raymond Wu (2009-2015).

10.1.1 Used Equipment Donation Program (1986)

The concept of providing used equipment and spare parts to developing countries was first discussed in 1986 during the meetings of DCC. Initially IOMP Vice-President Udipi Madhvanath agreed to manage this program and then M. S. Murthy, DDC Chair. Since 1998, the Used Equipment Donation Program has been successfully managed by Mohammed Zaidi and operates under PRC. This program follows the WHO Guidelines for Healthcare Equipment Donations (2000). The shipping expenses are required to be paid in advance or arranged by the recipient but financial help is available in some cases. This program has assisted delivery to and installation of 36 large equipment - including 2 Gamma Cameras and 5 Linear Accelerators in developing countries.

10.1.2. International Library Program (1987)

In 1987 the IOMP Secretary-General, Colin Orton, initiated the International Library Program to establish libraries in developing countries, some at institution level, others at departmental level, and to make arrangements for the supply of donated journals and books. The first library was situated in Guangzhou, China and, from then the program grew very rapidly under his leadership and Ms. Catherine Warmelink (later Alekhteyar), USA, took over as Curator (1990-1997). By 1994 a total of 55 libraries had been established in 36 developing countries and by 1997 there were 76 libraries in 49 countries. The subsequent Curators, all from the AAPM were: Marilyn Stovall (1997-2003) and Allan Wilkinson (2003-2015). The reason for such close ties with the AAPM was that, starting in the mid-1990s, the AAPM has sponsored the program by paying for all mailing fees for the books and journals. Since 1995 this has been a joint IOMP/AAPM program, and is currently managed by the International Affairs Committee of the AAPM and the Professional Relations Committee of the IOMP.

10.2 ***Nominating Committee (1985)***

The IOMP President, Lawrence Lanzl, established the Nominating Committee (NC) in 1985. The goal of NC was to ensure individuals or national organizations make appropriate nominations and that they are suitable for elected positions by the Council. All nominees should be known internationally for their distinction in the field, for their organizing and leadership abilities and be able to serve their respective terms of the office. The IOMP Presidents and since 2009 Vice-Presidents (with change in Bylaws) have served as the NC Chair:

Larry Lanzl (1985-1998), Jack Cunningham (1988-1991), Udipi Madhvanath (1991-1994), Keith Boddy (1994-1997), Colin Orton (1997-2000), Oskar Chomicki (2000-2003), Azam Niroomand-Rad (2003-2006), Barry Allen (2006-2009), Kin Yin Cheung (2009-2012), Slavik Tabakov (2012-2015).

10.3 ***Education and Training Committee (1985)***

In 1985, the IOMP Education and Training Committee (ETC) was established at the 7th ICMP in Espoo, near Helsinki, Finland [19]. The intent was to develop task-oriented educational and training programs and to organize short refresher courses, seminars and workshops to improve medical physics education, to advance the practice of medical physicists worldwide, to support on matters relating to education and training, and development of training materials. ETC developed a system for assessment, endorsement, and funding of such activities. Since 1994 ETC has organized 70 workshops, seminars courses with attendee from 85 countries. About half of these events have been in collaboration with the ISEP. These programs helped to develop medical physics programs in many countries especially in Eastern Europe and Asia. The ETC Chairs were:

Carlos E. de Almeida (1985-1989), Norman Baily (1990-1992), Nagalingam Suntharalingam (1993-1997), Azam Niroomand-Rad (1997-2000), Slavik Tabakov (2000-2006), Anchali Krisanachinda (2006-2009), Maria do Carmo Lopes (2009-2012l), John Damilakis (2012-2015).

10.3.1 International Scientific Exchange Program (1991)

One of the IOMP's most successful educational and training activities has been the International Scientific Exchange Program (ISEP) that was first conceived in 1989

by Azam Niroomand-Rad, when serving as Chair of ISEP Task Group in the International Affairs Committee of the American Association of Physicists in Medicine (AAPM). Since World Congress 1991 in Kyoto, Japan, these programs have been offered in collaboration with IOMP and became IOMP/AAPM ISEPs. The goals of these programs were and still are education and training of medical physicists worldwide and help to establish medical physics societies in those countries that lack such organizations. From 1992 – 2001, the ISEP was offered every year in therapeutic physics but since 2002 the diagnostic and nuclear medicine programs have been added. Two ISEP programs are now being offered on an annual basis; one in therapy and one in diagnostic and nuclear medicine. Currently 36 ISEP programs have been organized in 27 countries (www.iomp.org). This program has also helped to establish 10 national medical physics societies worldwide.

10.3.2 International Educational Projects with IOMP Participation

A number of EU e-learning materials were developed under the leadership of Slavik Tabakov. From the beginning IOMP and EFOMP were included as partners. In 2004 one of these projects, EMIT (European Medical Imaging Training) received the inaugural EU Prize for education – The Leonardo da Vinci Award. This was the first project of EFOMP and paved its way for further project funding. In 2006 IOMP was included as a full partner in the development of the first Medical Physics e-Encyclopedia and Dictionary of Terms in 29 languages – an EU project (EMITEL) which included many of the IOMP Officers and ETC members. This project (www.emitel2.eu) is a major educational reference for the profession with about 5000 users per month. [20].

In the period 2006-09 ETC developed, in collaboration with the IUPAP, a model curriculum for MSc Medical Physics courses. This project formed the basis of the recent IAEA guide for educational courses. [20]. In 2012 IOMP supported the establishment of an international MSc Medical Physics course, aiming to help colleagues from developing countries – a project of the ICTP and University of Trieste, Italy.

10.4 ***Science Committee (1994)***

The Science Committee (SC) was formed in 1994 at the WC Rio de Janeiro, Brazil [21]. The initial goal was to develop medical physics scientific programs for the triennial WCs. But from the beginning its objective was to promote research on application of physics in medicine, to create an electronic network to disseminate medical physics scientific knowledge worldwide, and to address the science needs of medical physicists especially in developing countries by organizing and funding regional scientific workshops and symposia and by having IOMP be involved on various international projects [22]. In 2012 under the leadership of William Hendee, SC Chair, a new IOMP Policy statement: "Risk of Medical Imaging" was developed, which was published in MPI Journal No.1. The SC has been instrumental in the preparation of the scientific programs of all current ICMPs and WCs and has supported many scientists from developing countries to attend these programs. The SC Chairs were:

Gary Fullerton (1994-2000), Caridad Borras (2000-2009), Harald Paganetti (2009-2012), William Hendee (2012-2014) and Geoffrey Ibbott (2014-2015).

10.5 ***Publications Committee (1998)***

In 1998, the need for establishing an IOMP Publications Committee (PC) became evident when IUPESM was being accepted for membership in ICSU (1999) and when IUPESM was organizing the WC-2000 in Chicago [23]. The goal of PC was to manage operation of MPW, to assist Regional and National Organizations of medical physics to prepare proposals for publication of new materials in traditional or new formats as necessary to extend the international medical physics knowledge base and to provide printed and electronic publications, documents and journals. The PC Chairs were:

Gino Fallone (1998-2003), Kwan Ng (2003-2006), William Hendee (2006-2012) and Tae-Suk Suh (2012-2015)

10.6 ***Awards & Honors Committee (1998)***

Since 1988, IUPESM has been presenting two IUPESM Awards of Merit at the WCs; one to biomedical engineers and one to medical physicists who have made major contributions in advancing the goals of the Union. In 1998 the need for establishing an IOMP Awards & Honors Committee (AHC) was recognized by Azam Niroomand-Rad and John Cameron. The goals of AHC were to establish awards and honors criteria, to solicit nominees, to administer awards and make recommendation to the EXCOM for approval. The intent of the awards and honors are to recognize medical physicists who have made outstanding contributions to advance medical physics knowledge and practice through research and education. The AHC Chairs were:

John Cameron (1998-2000), Fridtjof Nusslin (2000-2003), Perry Sprawls (2003-2006), Slavik Tabakov (2006-2007), Donald Frey (2007-2012) and Tomas Kron (2012-2015).

10.6.1 The Marie Sklodowska-Curie Award (2000)

The Organization's most prestigious award was inaugurated in honor of Madam Marie Sklodowska-Curie. The Marie Curie Award is presented triennially at the WCs to honor scientists who have distinguished themselves by their international reputation due to their contributions in (a) advancement of medical physics knowledge based upon independent original research, (b) education and training of medical physicists, medical students and residents, and allied health personnel and (c) advancement of the medical physics profession in adhering national and international organizations. The first award was granted to John R Cameron (2000), followed by Andree Dutreix (2003), Jack Cunningham (2006), Azam Niroomand-Rad (2009) and Charles Mistretta (2012).

10.6.2 The Harold Elford Johns Medal (2002)

The Organization's major award in teaching was established by funding received from Canada in honor of Harold Elford Johns. This award is presented triennially at the WCs to IOMP members who have made major contributions to international medical physics education. The first Medal was granted to Perry Sprawls (2003), followed by Slavik Tabakov (2006), Madan Rehani (2009), and Ahmed Meghzifene (2012).

10.6.3 The Young Scientist Award in Medical Physics (2006)

This award was introduced in 2006 following IOMP affiliation with IUPAP. This award is funded by IUPAP but selection is managed by AHC. Initially awarded triennially at the WCs but since 2012 on an annual basis, to IOMP scientists with less than eight years research experience. The first award was given to Ali Asghar Mowlavi (2006), followed by Leif Schroder (2009), Magdalena Stoeva (2012), and Ferdinand Schweser (2013)

10.6.4 Fellowship of IOMP - FIOMP (2013)

In 2007-2008, Slavik Tabakov and Donald Frey introduced the need and requirements for establishing an IOMP honor, Fellowship of IOMP (FIOMP). This honor aims to recognize IOMP members who have significantly helped to advance the goals of the Organization and its regional organizations over a significant period of time. Other achievements in medical physics are not considered as primary reasons for this honor. The Fellowship consists of a certificate and a pin and it bestows the right to use the title FIOMP after their names. The inaugural batch of 18 Fellowships were presented at IOMP 50th Anniversary at ICMP-2013 in Brighton, UK to these individuals:

Barry Allen, Carlos de Almeida, Cardid Borras, Kin Yin Cheung, Oskar Chomicki, Donald Frey, Gary Fullerton, William Hendee, Kwan Hoong Ng, George Mawko, Azam Niroomand-Rad, Fridtjof Nuesslin, Colin Orton, Madan Rehani, Peter Smith, Perry Sprawls, Slavik Tabakov, and Raymond Wu.

10.7 ***Finance Subcommittee (2000)***

By 1995, need for Treasurer was recognized. The first (honorary) Treasurer was Ann Dixon-Brown (1995-1998) followed by Interim Treasurer, Gary Fullerton, IOMP Secretary-General.

By 2000, Finance Subcommittee (FSC) was established with an elected Treasurer to serve as Chair. The goal of the FSC was to manage financial affairs of the Organization. This includes (but not limited to) preparation of annual budget reports, arrangement for account audition and allocation and dispersion of funds to Officers, Chairs of committees and subcommittees subject to duties outlined in IOMP ByLaws. The FSC Chair were:

Nisakorn Manatrakul (2000-2001), George Mawko(2001-2009), Slavik Tabakov (2009-2012) and Anchali Krisanachinda (2012-2015).

10.8 ***Rules Committee (2000)***

Up until 2000, the IOMP Statutes and Bylaws had been modified occasionally but they were becoming outdated. At WC2000, the Council decided that they needed a major overhaul. An ad hoc Governance Committee (Colin Orton, Past-President and Azam Niroomand-Rad, Vice-President) was formed to make these revisions and this led to the presentation and approval of extensively modified Statutes and Bylaws at WC-2003 and the establishment of a formal Rules Committee (RC). The goals of the RC were to advise on any matter referred to it by EXCOM or Council and to facilitate regular review of the Statutes, Bylaws and relevant policies and procedures and to make recommendations for changes to assure good governance, organization and administration of the Organization. Further modification to the Statutes and Bylaws was prepared by Fridtjof Nusslin and Peter Smith and was approved by the Council in 2009. The aims and functions of the Organization in the Statutes have remained unchanged. The RC Chairs were:

Fridtjof Nusslin (2003-2009), Kin Yin Cheung (2009-2012), Slavik Tabakov (2012-2015).

10.9 ***International Advisory Council (2000)***

An International Advisory Council (IAC) was formed in 2000 with members including representatives of IAEA, WHO, and PAHO. Membership also included two representatives from the Regional Federations and Officers. The charge was "To improve the global practice of medical physics by providing advice to the IOMP Assembly concerning international interactions, collaborations and programs that meet scientific, educational and professional needs". The name was changed from Council to Board in 2003. In 2006 EXCOM reviewed the role and effectiveness of the IAB and recommended to Council that the IAB should be dissolved due to lack of effective use of the body and existence of other more effective mechanisms for such advice. Council accepted the recommendation.

10.10. ***Committee of International Commission on Medical Physics - IComMP (2005)***

In Section 7.2, details of IOMP affiliation with IUPAP were described. This affiliation led to the formation of an IOMP committee known as International Commission on Medical Physics (IComMP) in 2005. The goals of this committee were to provide direct access to IUPAP resources including support of young scientists and women in physics and collaboration with international programs and projects of mutual interest to the two Organizations. This included but was not limited to collaboration on biological physics, physics education and physics development. The original membership of IComMP consisted of five IOMP elected Officers, Chairs of IOMP (SC, ETC, PRC, PC) with at most six IUPAP Liaisons including IUPAP Chairs of C6 (Commission on Biological Physics), C13 (Commission on Physics for Development), C14 (Commission on Physics Education). However since then the current membership of IComMP has slightly been modified. The IComMP Chairs were:

Azam Niroomand-Rad (2003-2006), Barry Allen (2006-2009), Fridtjof Nusslin (2009-2015).

10.11 ***History Subcommittee (2008)***

The IOMP History Subcommittee was established in 2008 under leadership of IOMP Past President, Azam

Niroomand-Rad with close collaboration with Colin Orton, IOMP Past President and Slavik Tabakov. The goals of the Subcommittee are to archive published articles on IOMP history and recognize contributions of IOMP members by tabulating and listing their names. These include, but are not limited to those who served as EXCOM, Chairs and members of committees, Editors of MPW and members who assisted them, and Curators of International Library Program. In addition one of major goals of HSC is to interview and video prominent medical physicists who have made major contributions to international medical physics and the Organization. Azam Niroomand-Rad has served as Chair of HSC (2008-Present).

Summary Table: International Conferences on Medical Physics (ICMPs) and World Congresses (WCs)

ICMPs	Year	Venue	World Congresses (WCs)
1st	1963	Harrogate, UK	**Inaugural ICMP**
2nd	1969	Boston, USA,	
3rd	1972	Goteborg, Sweden	
4th	1972	Ottawa, Canada,	Coordination with IFMBE
5th	1979	Jerusalem, Israel,	1st WC
6th	1982	Hamburg, Federal Republic of Germany,	2nd WC
7th	1985	Espoo, near Helsinki, Finland	3rd WC
8th	1988	San Antonio, USA	4th WC
9th	1991	Kyoto, Japan	5th WC
10th	1994	Rio de Janeiro, Brazil	6th WC
11th	1997	Nice, France, September	7th WC
12th	2000	Chicago, USA	8th WC
13th	2003	Sydney, Australia	9th WC
14th	2005	Nuremberg, Germany, September	
15th	2006	Seoul, Korea,	10th WC
16th	2008	Dubai, United Arab Republic	
17th	2009	Munich, Germany	11th WC
18th	2011	Porto Alegre, Brazil,	
19th	2012	Beijing, China	12th WC
20th	2013	Brighton, UK,	
21st	2015	Toronto, Canada,	13th WC

XI. IOMP IMPORTANT DOCUMENTS AND POLICY STATEMENTS

*11.1 **Review and Way Forward Document***

In 2003 President Azam Niroomand-Rad and Secretary-General Peter Smith prepared a comprehensive Review and Way Forward Document with input from EXCOM. This was a valuable document to review the current activities of the Organization and to set out both short and long term priorities and plans for the Organization. The goal was to provide valuable working guidelines to EXCOM, Committees and Council for future direction of the Organization. It was also of value to a variety of organizations including potential sponsors, grant awarding organizations (e.g. charitable foundations), Corporate Members, as well as those organizations with whom we had mutual interests such as IUPESM, IFMBE, IAEA, WHO and IUPAP. In February 2006 this document was circulated to Council for discussion and was approved at the WC 2006 in Seoul, Korea.

The Review and Way Forward document consisted of the following sections:

Past, Present and Membership of the Organization,
Current Activities and Proposed Developments,
External Relations,
Administrative and Financial Affairs,
Strategic Themes and Priorities, and
Specific Proposals with Assigned Priorities for the next 5 years.

It was planned that Council should review this document at regular intervals and it would evolve as IOMP evolves. A

draft of most recent update of Review and Way Forward (2006-2012) document is available at the IOMP Website (www.iomp.org).

11.2 IOMP Policy Statements

In 2003 Oskar Chomicki proposed definition for medical physics and medical physicist and after some modification Council for the first time agreed on definitions of the terms 'Medical Physics' and 'Medical Physicist'. These were later considered in the IOMP Policy Statement 1.

In 2006 Council suggested a series of Policy Statements on key topics be prepared for their consideration. To date three Policy Statements have been approved:

IOMP Policy Statement No. 1: Role and Responsibilities of Medical Physicists (2012)

IOMP Policy Statement No. 2: Basic Requirements for Education and Training of Medical Physicists (2012)

IOMP Policy Statement No. 3: Predictions of Induced Cancers and Cancer Deaths in a Population of patients exposed to low Doses (<100mSv)

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Current and Past members of IOMP ExCom, at WC2012, Beijing (from left to right):

R Wu (Current and Past Chair PRC); A Krisanachinda (Current Treasurer); V Tzapaki (Current Editor MPW), I Parsai (Past Editor MPW), J Damilakis (Current Chair ETC), T Kron (Current Chair AHC), F Nuesslin (Past President); KY Cheung (Current President); M Rehani (Current and Past Secretary General); H Paganetti (Past Chair SC); M do Carmo Lopes (Past Chair ETC); S Tabakov (Current Vice-President, Past Treasurer); W Hendee (Current Chair SC, replaced by G Ibbott in 2014); J Pemberton (Current Admin, replaced by S Hawking in 2014); missing – Tae-Suk Suh (Current Chair PC); G Frey (Past Chair AHC).

IOMP PROFESSIONAL AND EDUCATIONAL ACTIVITIES

PILOT IMPLEMENTATION OF EMERALD TRAINING MODULES IN BRAZIL

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Abstract— **A research cooperation program was established between the Institute of Physics of the University of São Paulo and the King´s College of London to conduct the translation to Portuguese language, adaptation and update of the X-Ray Diagnostic Radiology training module of the Emerald Program (www.emerald2.eu/cd/Emerald2/). The Emerald Program teaching material in X-Ray Diagnostic Radiology is divided in ten topics covering the basics of Diagnostic Radiology, Quality Control and Radiation Protection. The referred work, besides the translation of the texts into Portuguese, comprised the review of the previously produced material. During the review process, it was decided to update some of the training tasks and add more information related to current topics, such as digital X-ray imaging modalities, multi-slice computed tomography and tomosynthesis. These new additions will also be available in English. The translated or written texts have been submitted to a cross-reviewing process by the co-authors in order to standardize the language. Moreover, national radiological protection recommendations were included to assist the users of the teaching material with the Brazilian rules of radiation safety and quality control in X-ray medical applications. Part of the material was submitted to a validation and also to a practical assessment process by means of a critical analysis by experts in Medical Physics education during a workshop held in São Paulo in March 2014. Finally, a pilot implementation has been organized in order to do the last adjustments before making the material available to other users in Portuguese language. Further assessment and feedback procedures were planned in both London and São Paulo, aiming to evaluate and disseminate the final product.**

Keywords— **Emerald project, education and training, Medical Physics, Portuguese language.**

II. INTRODUCTION

The Leonardo EU project for European Medical Radiation Learning Development (EMERALD) [1], a Consortium of Universities and Hospitals from many countries, developed three training modules in medical radiation physics (X-ray Diagnostic Radiology, Nuclear Medicine and Radiotherapy). These modules were prepared in an attempt to support more widely the worldwide initiatives of education and training in Medical Physics (MP).

Each Training Module encompasses the physics and engineering of the topic, leading to competencies based on the UK IPEM Training scheme and on the recommendations of the European Federation of Organizations for Medical Physics (EFOMP) and the UK Institute of Physics and Engineering in Medicine (IPEM) Training Scheme [2]. The modules are for the training of graduated university students in MP or related disciplines, their tutors, as well as other Hospital employees.

The Emerald Program teaching material in Diagnostic radiology is divided in ten topics: General Principles of Radiation Protection, General Principles of Diagnostic Radiology Quality Control, X-ray Dosimetry and Patient Dosimetry, Radiological Image Parameters, X-ray Tube and Generator, Radiographic Equipment, X-ray Films/screen and Laboratory, Fluoroscopic Equipment, Digital Image and CT Equipment, and Basics of Shielding in Diagnostic Radiology. A very important part of Emerald are Training Timetables (syllabus) with indicative time necessary for acquiring certain professional competencies during a training period of approximately 4 months.

The present work describes a research cooperation program established between the Institute of Physics of the University of São Paulo (IFUSP) and the King´s College of London (KCL), with the participation of the Physics Department of the Catholic University of São Paulo. This research program conducted the translation, adaptation and update of the X-Ray Diagnostic Radiology training module of the Emerald Program [3]. This material written in Portuguese was named Emerald-BR.

Part of the motivation for investing in the adaptation of the original Emerald training modules to Brazilian (and Latin America) needs is based on the growing number of young physicists starting in Medical Physics area each year, and the low offer of organized training programs in the country [4,5]. This work presents the status of this project, which aims to contribute, firstly, but not only, with Brazil and Portuguese language countries, by the production of online resources for teaching and training in MP, based on the Emerald modules.

III. METHODOLOGY

The referred cooperation program between IFUSP and KCL, started by the translation of the original texts into Portuguese, after which comprised the review of the produced teaching material. The translation included the latest updates of Emerald materials including training tasks on CR, DR and Spiral CT. During the review process, it was decided to update some of the training tasks and to add more information related to current topics such as multi-slice computed tomography and digital tomosynthesis. These new additions will also be available in English in the near future.

The translated and written texts have been submitted to a cross-reviewing process by the co-authors and other contributors in order to standardize the language. National radiological protection recommendations were included to assist the users of the teaching material with the Brazilian rules of radiation safety and quality control in X-ray medical applications. At least 120 person-hour was expended for concluding these tasks in 8 months of work.

After the conclusion of the translations and previous reviewing process, the project staff organized a workshop during March 10-11, 2014, in São Paulo, for presenting the preliminary teaching material and sharing the information regarding the Emerald Project to professionals involved in education in Medical Physics (Fig.1). During this workshop, the project team presented the history and previous implementations of the Emerald program in other countries as well as the general concepts introduced by the Leonardo EU project. It was also presented the status of the translated material and the development of the Emerald-BR project. Additionally, a test-session was guided, including practical assessment by the participants of part of the material. For this purpose group of simulated experimental activities was introduced providing hands-on approach to the translated material and its application.

Fig. 1 Participants of the Workshop for diffusion of the Emerald-BR project in São Paulo.

IV. RESULTS

Most of the modules have been translated with adaptations and a grammatical and conceptual reviewing process was conducted. The translation was helped also by the Multilingual Medical Physics Dictionary EMITEL. One of the co-authors applied a language and vocabulary harmonization. In addition, the newer parts to be added to the training material are in pre-production. In the current version, the teaching material has 243 pages, 30 figures and 51 tables.

The material was submitted to a validation and to a practical assessment process by means of a critical analysis of part of the tasks by experts in Medical Physics education during the Workshop. Participants of the workshop (n=20). These included MP teachers from Universities (29%) and coordinators of training programs in hospitals (50%). The distribution of these professionals is presented in Fig 2. These participants came from the three most populated regions of the country (Fig. 3).

For the hands-on activity, the participants were distributed in six groups of 3-4 physicists pre-arranged by the organizers. The selection has taken into account the variety of professional experiences, the geographical origin, and gender. Each group received one sub-chapter of the translated material with basic informations regarding one area of diagnostic radiology.

Three groups received material, which simulated data from quality control, including images and forms for the evaluation of spatial resolution and contrast resolution of a digital and an analogic fluoroscopy equipment. The other three groups worked on the evaluation of data from Quality Control of X-ray tube and generator. Furthermore, all groups received an additional task guide to help to optimize the execution of the activities.

The opinion of the participants regarding the quality of the produced material was accessed by the use of forms including Likert scale type survey and open questions, which were filled by the participants after the last activity

(hands-on) of the workshop. The questions included in the forms were based on a previous scheme developed for the evaluation of the e-Learning material of EMERALD and EMIT [2]. These queries were designed to investigate the view of the potential trainers regarding the adequacy of the developed learning material. Table 1 presents the questions included in the forms. Questions 1 to 4 were evaluated by a score level from 1 to 4 (1 - very good; 2 – good; 3 – acceptable; and 4 – inadequate). Questions 5 and 6 were commented and reported by the participants.

Question 1 referred to the clarity of the objectives of the training task performed by the participant during the hands on section. As many of the participants are training experts, there were also questioned regarding the adequacy of the time, in days, suggested for completion of the proposed tasks. - 67% of the participants stated that the time proposed for concluding the tasks are adequate.

Question 2 focused to the appropriateness of the sequence of steps within the performed tasks evaluated by the participants, considering the material they have access during the hands on activity during the workshop and the information presented by the lecturers in the workshop. In this case, 54% of the participants considered that the sequence of training steps within the assessed tasks was "very-good", and 47% considered it as "good". Based on this result some editing will be applied to the proposed sequence of steps within the training task.

Table 1 – Questions distributed for the participants

	Questions
1	Are the objectives clear? Based on your experience, do you think that such objectives could be reached in the proposed period?
2	Do you consider the sequence of proposed tasks in the module appropriated?
3	Is the content conceptually and technically correct and in sufficient amount in the module?
4	Do you think that the trainee would be prepared in a sufficient level to:
	(a) To be familiar with the terminology and concepts regarding this task ?
	(b) To conduct the tasks WITH some assistance ?
	(c) To conduct the tasks WITHOUT assistance ?
5	How this material could be used in your institution?
6	What are your suggestions for improving this training program?

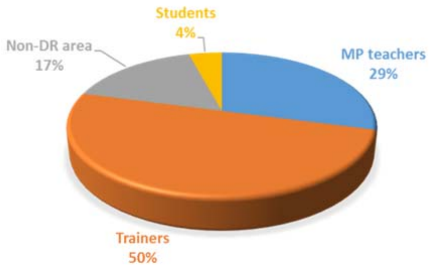

Fig 2. The four main groups of participants of the workshop were: trainers (50%), medical Physics teachers (29%), participants which main activity is not diagnostic radiology (17%), and students (4%).

The third question addressed the assessment by the participants of the conceptual and technical adequacy of the training steps within the assessed tasks during the hands on activity of the workshop. Half of the participants received the module 5.4 - Assessment of X-ray Generator kVp and Timer Parameters, and the other half the module 8.1 – Fluoroscopic Equipment. The questions in the forms they received addressed regarding the amount of information included in the modulus using the proposed Likert scale. The results showed that 67% of the participants considered it "good", and 27% considered it "very good". Thirteen percent of the evaluators considered the material only "acceptable". Consequently, the organizers of the Emerald-Br planned a specific review of these points.

Finally, question 4 reflects the opinion of the participant on how would be the level of a trainee that had used the material in two aspects: (a) familiarity with the terminology and concepts of the task; (b) and (c) ability to conduct the tasks with assistance (question 4b) or alone (question 4c). This group of tasks was intentionally proposed in order to evaluate if the participants had understood that the main use of the Emerald-BR material is as a support training reference, and that it was not intended to be a self-learning material for a pure e-Learning or distance-teaching scheme for Medical Physics. In other words, the constant support of the trainer is essential for the success of the trainee learning – what is the original objective of Emerald. The answer of the participants reflected exactly the expectations as shown in the last rows of the Table 2.

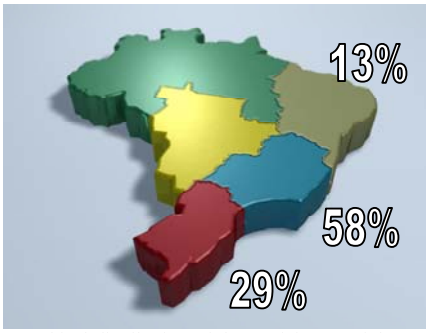

Fig 3. Geographical distribution of the participants of the workshop in the regional areas of the country. According to the distribution 58% work professionally at southeast region, 29% at south region and 13% at northeast region. There were no participants from regions north and central.

Table 2 – Evaluation of the answers from the participants of the workshop regarding the questions 1 to 4 (Table 1). The meaning of the Likert scores are: 1 - very good; 2 – good; 3 – acceptable; and 4 – inadequate

	Likert Score			
Questions	**1**	**2**	**3**	**4**
1	10 (67%)	4 (27%)	1 (7%)	0
2	8 (54%)	6 (40%)	1 (6%)	0

3		3 (20%)	10 (67%)	2 (13%)	0
4	**a**	5 (33%)	6 (40%)	4 (27%)	0
	b	10 (67%)	4 (27%)	1 (7%)	0
	c	0	0	5 (33%)	10 (67%)

The two final questions were open. The participants had a defined space for expose his or her feelings about the adequacy of the Emerald-BR material to be used in training programs in their own institutions (question 5) and to include suggestions for improving the training program (question 6).

More than 80% of the participants presented their intention in using the material in their institutions for training young graduated medical physicists. Some of them, also cited the possibility of using the material as support for last-year under-graduate students, especially in practical aspects of the Medical Physics in Diagnostic Radiology (laboratory classes), and also for helping continuous education programs of experienced Medical Physicists and as additional studying material in Residence programs.

The suggestions collected as answers to question 6 reflected a very broad range of aspects. Some of them reflected the need of reviewing the material in terms of the adequacy of the terminology in Portuguese, in particular the terms in statistics of experimental data. Other point that was cited by some participants was the need of the implementation of training programs for the trainers. The convenience of introducing hyperlinks to EMITEL e-Encyclopaedia was also commented.

V. CONCLUSIONS

Emitel has been developed as a sequence of stand-alone training tasks in order to permit its adaptation to various existing national requirements and protocols. Its original e-Learning form, facilitated by the EMITEL Multilingual Dictionary, helps its international distribution and implementation in various MP training programmes. With this on mind, the authors advise the colleagues who would implement the material to collect information from active leads of education and training in the country in order to adapt more closely Emerald to the local regulations, culture and knowledge.

The development of Emerald-BR material is still a work in progress and some adaptations are been conducted after the feedback of the participants of the workshop. A final review process and the inclusion of links with EMITEL Multilingual Dictionary will be implemented until the middle of 2014.

Additionally, a formal consultation was done to the institutions which have trainers as participants at the workshop regarding their interest in taking part of a pilot implementation of the program. Five Universities and one company and one hospital how offer training programs declared available to participating of this pilot-implementation. It will be starting in the second semester of 2014.

As a final comment to those who intend to implement the Emerald project in their regions, we advise that, as for other educational activities, to hear the educational staff involved in the task of preparing medical physicists is essential for a good assessment of the material and methods and for the adaptation to local culture and knowledge.

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EDUCATION OF MEDICAL PHYSICS AND BIOMEDICAL ENGINEERING AT GONO UNIVERSITY IN BANGLADESH

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Abstract **– Medical Physicist personnel is an integral part of cancer treatment. In Bangladesh Medical Physics and Biomedical Engineering education first started in the nineties. In 2000 a fullfledged "Department of Medical Physics and Biomedical Engineering" (MPBME) was founded at Gono Bishwabidyalay (a private university in Savar, Dhaka). Till now Gono University is one and only university offering this course in Bangladesh. In this paper achievement of quality of the education in MPBME is elaborately discussed. The department is continuously pursuing a high quality in education in all aspects like course curriculum, teaching methods, local and international collaboration, research, practical class. As a result the establishment of Medical Physics und Biomedical Engineering Education in Gono Bishwabidyalay (University) is a success story for Bangladesh. We would like to continuously develop strong and advanced Medical Physics and Biomedical Engineering Programs for education and research by incorporating the latest developments of Imaging and Radiotherapy in future.**

Keywords **– Medical Physics, Biomedical Engineering, Education, Quality, Gono Bishwabidyalay (university).**

I. INTRODUCTION

Higher education in general refers to learning that occurs at universities, academies, colleges, seminaries, or institutes of technology. In that sense, the Gono University in Bangladesh offers higher education in various disciplines. In this paper, the higher education in Medical Physics and Biomedical Engineering at Gono University is specifically addressed. It is an example how a relatively recent discipline can be implemented and developed concerning quality issues in the country of Bangladesh. This study presents a picture of the quality enhancement achieved so far at Gono Bishwabidyalay (Gono University) in Bangladesh with respect to knowledge and competence at a local, national and international level. A variety of associated developments in quality management and institutional rules are particularly illustrated.

II. HISTORY

The concept to establish higher education in Medical Physics and Biomedical Engineering in Bangladesh was started in the nineties. When Dr. Golam Abu Zakaria, Professor of Medical Physics, Germany, initiated this step by arranging several international seminaries on Medical Physics in Dhaka this subject was still quite a new subject in the country [1]. Following this, the need to implement such education in a more sustainable matter was discussed. The need was increasingly brought up by the fact that radiological techniques in diagnosis and therapy have undergone an enormous technical improvement and that an appropriate use of such techniques require a competent involvement of well educated medical physicists.

Finally the private university at Gono Bishwabidyalay headed by authorities with long-sightedness and prudence followed Dr. Zakaria's suggestion to implement academic programs with an accreditation by the University Grant Commission (UGC): a Master Program (M. Sc in 4 semesters) in 2000 and a Bachelor Program (B. Sc in 8 semesters) in 2005, both on Medical Physics and Biomedical Engineering (MPBME). Until now Gono University is still the only university in Bangladesh offering B.Sc and M.Sc courses on that subjects. The department has presently a total of 145 students in both programs.

Gono University embedded in Gonoshasthaya Kendra (People's Health Centre) at Savar near Dhaka offers a series of subjects for studying with a particular focus on aspects such as tradition, culture and creativity of the people of Bangladesh, the Liberation War of Bangladesh, Gender, Ethics and Environmental Science in order to equip students with the knowledge and skill necessary for becoming a complete human being both academically and psychologically. The University has own medical and medical related faculties. The Jahangirnagar Public University and the Bangladesh Atomic Energy Commission are located in close vicinity. Based on this environment Gono University is well able to cover the multidisciplinary aspects of Medical Physics. Thus the department can rely on the knowledge and experience of numerous teachers in medical physics and biomedical engineering as well as on access to different labor facilities.

Besides that and just from the beginning, a cooperation between the department MPBME and the University of Heidelberg, Germany including the German Cancer Research Center has been established in order to support the implementation of the department and to develop a students' educating program (in the right direction, who will have the sense of responsibility to run the department independently as well as work in hospitals according to European and international standards. Based on a grant of DAAD (German Academic Exchange Service) M. Sc students had the possibility to partly finish their practical part of thesis in Germany as part of this collaboration. In turn teachers from Germany overtook lessons in the department MPBME[2].

III. COURSE CURRICULUM

The M. Sc course (120 credit hours) comprises four semesters of six months each. The core subjects of the syllabus are taught within the department. As it is a multidisciplinary subject, teachers are recruited from different disciplines as full time and part time basis. The course subjects are conducted by the related departments associated in the university like anatomy, physiology, biochemistry, medical ethics, mathematics and computational education etc. The practical classes are carried out in the laboratories of the department as well as, in radio-diagnostic and radiotherapy departments of collaborated hospitals.

The following table- 1 shows the Syllabus of Master Course in Medical Physics and Biomedical Engineering in Gono University.

Universities under the leadership of the Chairman. Attendance, tutorial and midterm are accounted for assessment. The answer scripts are examined by the course teacher and by the external examiner. The scripts are re-examined by the 3rd examiner if they obtained marks differ more than 20% between internal and external examiner.

IV. QUALITY DEVELOPMENT

The department is continuously pursuing a high quality in education as a standard in all aspects like in collaboration, teaching methods, research, or practical class. From the beginning, the syllabuses of the bachelor and master courses are based on available relative documents issued by the DGMP, AAPM or IAEA, which have been adapted to the need of Bangladesh. The course structure is designed to enable the students to work in hospitals, health institutes and research in MPBME. The basic prerequisite for the admission to master courses is a graduation degree in one of the following subjects: MPBME, physics, and related field in physical science or in bioscience, medicine or engineering disciplines.

Table-1: Syllabus of M. Sc in MPBME

1st Semester 30 Credits	*T	**L	2nd Semester 30 Credits	T	L	3rd Semester 30 Credits	T	L	4th Semester 30 Credits
Radiological Physics and Dosimetry	3	2	Conventional Planar Imaging	2	2	Magnetic Resonance Imaging	3	2	Thesis related course-5
Anatomy and Physiology	4	2	Digital X-Ray Imaging and CT	2	2	Nuclear Medicine	3	2	Thesis presentation-5
Biostatistics	2	2	Ultrasound Imaging	2	2	Radiation Oncology	3	2	Thesis work-20
Mathematics and Computational Skills	4	2	Brachytherapy	4	3	Radiation Treatment planning	3	3	
Professional Ethics-1	1	-	External Beam Radiotherapy	3	2	Techniques in Radiotherapy	3	2	
Radiation Biology	3	1	Radiation Therapy Devices	3	2	Radiation Protection	2	1	
Biomedical Electronics	2	1							
Semester viva voce	1	Semester viva voce	1	Semester viva voce	1				

*T indicates the credit hours for theory course; one credit hour course is of minimum one hour lecture per week and **L indicates the credit hours for Lab work; one credit hour is equal to 3 hours per week.

The Department has three individual laboratories in spacious areas; Physics, Medical physics, Biomedical (lab) (Fig: 1). Within the country, the department has collaboration with National Institute of Cancer and Research Hospital (NICRH), Institute of Nuclear Medicine and Ultrasound, Dhaka Medical College Hospital (DMCH), Secondary Standard Dosimetry laboratory of Bangladesh Atomic Energy Commission (BAEC), Bangladesh Council Scientific and Industrial Research (BCSIR), where practical classes are taken. Outside the country it collaborates with the Saroj Gupta Cancer Center and the Research Institute (formerly known CCWHRI), Thakurpukur, Kolkata, School of Biomedical Engineering, Jadovpur University, Kolkata, India, North Bengal Oncology Center, Siliguri, India, Mannheim Medical Center, Heidelberg University, Germany. The cooperation agreement includes knowledge transfer by exchange of faculty members, the Teachers Fellowship Program to provide a supportive professional experience for fresh recruits, up gradation of the Department of medical Physics of Gono Bishwabidyalay, joint research for M. Sc and Ph. D students.

Fig.1: Students working in a Biomedical engineering lab.

Up to 2013, after the establishment of the MPBME department, many students were awarded M. Sc degree and B. Sc. degree in MPBME. At present these graduates are working in the radiotherapy department of the public hospitals; National Institute of Cancer and Research Hospital (NICRH), in the radiotherapy departments of Dhaka Medical College Hospital, Bangabandhu Sheikh Mujib Medical University (BSMMU) and Combined Military Hospital (CMH) and in the radiotherapy departments of different private hospitals; the United Hospital, Square Hospital, Khwaja Yunus Ali Medical College and Hospital, Ahsania Cancer Mission and Hospital or are teaching Medical Physics and Biomedical Engineering in Gono University.

Selected students perform their project work in India and also in different local radiotherapy hospitals. Both bachelor and master students, teachers are attending national and international conferences every year, publishing journals, papers and abstracts. The syllabuses of both courses are based on international standards which have already been published in the book 'Medical Physics and Engineering education and training 2011 of IOMP and discussed on many international conferences. The latest books and publications are available in the department; most of the books and equipment are directly sent from Germany. The international conference at Gono University in spring 2011 with participation of more than 250 delegates with 11 countries considered as a further highlight of the efforts to align the quality level to international standards.

V. Conclusion

In summary, the quality of Medical Physics education was improved such that the number of students is continuously increasing. At present the need to provide qualified Medical Physicists in the country can be served only partially by these physicists, however, we are sure that in the near future Gono University will produce a greater number of Medical Physicists and thus contributes for an appointment of them in all government radiotherapy hospitals after creation of medical physicist positions.

The establishment of Medical Physics und Biomedical Engineering Education in Gono Bishwabidyalay (University) is a success story for Bangladesh. We would like to continuously develop strong and advanced Medical Physics and Biomedical Engineering Programs for education and research by incorporating the latest developments of Imaging and Radiotherapy. For the future we would like to establish a further close collaboration with other foreign universities and research institutes. We would be glad to participate in international scientific conferences in order to enhance our potential for a better treatment of the cancer patients in our country.

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MEDICAL PHYSICS ORGANISATIONS

IOMP PROJECT SUPPORTING THE DEVELOPMENT OF MEDICAL PHYSICS IN AFRICA IN COLLABORATION WITH IAEA & WHO

On behalf of the IOMP Working Group for MP development in Africa: S. Tabakov [1]

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***Abstract*— IOMP begins a large new project, together with its Regional Organisation FAMPO, aiming support for the professional development of Medical Physics in the African continent. The paper presents a brief status of the initial stages of the project and the activities of its Working Group: Prof. Fridtjof Nuesslin, Dr K Y Cheung, Dr Madan Rehani, Dr Raymond Wu, Dr John Damilakis, Ms Rebecca Nakatudde, Dr Taofeeq Ige, Dr Ahmed Ibn Seddick and Dr Slavik Tabakov (Chair).**

One of the recent priorities of the International Organization for Medical Physics (IOMP) is the development of medical physics in Africa. This is in connection with the increased need of specialists dealing with various aspects of medical technology in healthcare in Africa – ranging from radiation safety of patients to effective and safe use of medical equipment.

IOMP assisted the formation in 2009 of the Federation of African Medical Physics Organizations (FAMPO) – an IOMP Regional Organisation - which currently includes the National Societies of: Algeria, Cameroon, Egypt, Ghana, Morocco, Nigeria, South Africa, Sudan, Tanzania, Uganda, Zambia and Zimbabwe. FAMPO has about 350 medical physicists (2/3 of these being in Radiotherapy). In parallel, the International Atomic Energy Agency (IAEA), the World Health Organization (WHO) and other Institutions, as the American Association of Physicists in Medicine (AAPM), the UK Institute of Physics and Engineering in Medicine (IPEM), the German Society for Medical Physics (DGMP) and others, also assist various regional projects in Africa.

During 2012 IOMP started a large project for medical physics development in Africa, which aims to develop and implement various types of training, educational & qualification measures, professional infrastructure and partnerships, and also to sync existing activities in the field. The first step was to secure financial support for the organisation of a dedicated Workshop "Medical Physics in Africa – status and way forward", satellite to the International Conference on Medical Physics ICMP2013 (Brighton, UK). Support was kindly provided by the International Union for Pure and Applied Physics (IUPPAP). Additionally IAEA and WHO funded some participants from Africa to attend this Workshop. The Workshop on 1/09/2013 was co-organised by IOMP and FAMPO officers and attracted about 100 colleagues from various countries (including colleagues from 11 African countries). The Workshop included presentations from Nigeria, Morocco, Uganda, Egypt, Ghana, South Africa, FAMPO, IOMP, IAEA and WHO. The presentations included also survey of medical physics in various African countries (see the next paper in this Journal) and triggered a number of discussions. The materials from the Workshop are now being collected for inclusion in the part II of e-book *Medical Physics & Engineering Education and Training.*

At the following Round Table "Medical Physics Development in Africa" (3/09/2013), another event satellite to ICMP, Brighton, the discussions were transferred into decisions for the way forward. Twenty senior officers of IOMP, FAMPO, IAEA, WHO, AAPM and IPEM took part in the open discussion, observed by a number of colleagues from other countries. An initial plan for action was agreed including the following parts and tasks:

1. Immediate tasks

- Increasing the visibility of medical physicists in Africa through publishing articles in the local and international press. The articles aim to inform the authorities of the countries about the inclusion of medical physicists as a unique professional group in the International Labour Organisation (ILO, Geneva) official list of professions in the world – the International Standard of Classification Occupations (ICSO 08), approved by the United Nations and published in Geneva during 2012;
- Facilitate the celebration in various countries of Africa of the International Day of Medical Physics on 7 November (the birthday of Marie Curie).

2. Short term tasks

- Collect all presentations from the Workshop as full papers for inclusion in the new e-book and plan its dissemination;

- Present the status and tasks from the Workshop in Brighton at the WHO 2nd Global Forum on Medical Devices, Geneva;
- Identify possible hosts and sponsors for a further activity/workshop on Medical Physics Professional Development in Africa;
- Organise a Tele-conference in Spring 2014 between IOMP, FAMPO and other interested parties to draft a Long-term Plan for Medical Physics Development in Africa.

3. Long term Goals

- Create Specific Working Groups to assist this large long-term project
- Organise a large Workshop on Medical Physics Professional Development in Africa, including sessions related to training for the most urgent areas of Equipment Quality Control and Radiation Safety
- Organise a system for Sync between the activities of all parties interested in assisting the development of medical physics in Africa;
- Assist the development of more educational and training courses on Medical Physics in Africa;
- Plan and execute further tasks for rapid increase of the number of medical physicists and engineers in Africa.

The IOMP/FAMPO Work Group organising the Workshop in Brighton included: Prof. Fridtjof Nuesslin, Dr K Y Cheung, Dr Madan Rehani, Dr Raymond Wu, Dr John Damilakis, Ms Rebecca Nakatudde, Dr Taofeeq Ige, Dr Ahmed Ibn Seddick and Dr Slavik Tabakov (Chair).

The initial steps of this long-term large project included forming networks of interested colleagues and Institutions. Colleagues from King's College Hospital, London were active in this area by organising trips and short courses related to medical equipment management and safety in Uganda and Zimbabve. A meeting of FAMPO officers and IOMP is planned during the meeting of the African Radiation Oncology Group (AFROG) in Accra, Ghana (April 2014). To sync these activities with the other existing activities, the meeting in Accra also handles the IAEA RAF6044 & 045 Project Coordinators Meeting. Similar FAMPO – IOMP meeting is planned also as a satellite to the WHO-supported African Regional IRPA Congress in Rabat, Morocco (September 2014).

These activities will continue during the World Congress on Medical Physics and Biomedical Engineering in Toronto, Canada (June 2015) with a large IOMP-WHO-IAEA Workshop, aiming to engage all key players in the field and provide a solid background for the project.

We invite all institutions and colleagues planning to take part in this huge IOMP project to get in touch with the IOMP Working Group in order to sync our plans and increase the effectiveness of the help for the development of medical physics in Africa. In Particular we would appreciate receiving information about various current projects in Africa (aims, partners, stage of development).

The further steps of this project will be presented in the next issues of Medical Physics International.

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The IOMP Officers and the Working Group for Medical Physics Development in Africa, including FAMPO Officers, expresses its gratitude to the colleagues and institutions supporting this project – in particular: WHO, IAEA, IUPAP and our large member organisations, such as AAPM, IPEM, DGMP and others.

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Some of the attendees of the 'African Workshop' and the following Round Table discussion at ICMP 2013, Brighton, UK

THE ROLE OF HEALTH MANAGERS IN PROMOTING MEDICAL PHYSICISTS IN AFRICA

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3. Medical Physicist, Department of Radiotherapy, Mulago Hospital, Kampala Uganda.

Abstract **- Background: The International Atomic Energy Agency (IAEA) has greatly improved the training of Medical Physicists and radiation scientists in African. It is mandatory for each member state to have a regulatory body. In hospitals, with the support of the Health managers, it is the work of the Medical physicist to ensure safety and protection. However, the regulators should over see as a national body. Collaboration among the Medical Physicists, hospital managers and the regulators is critical. This research aimed at analysing the current scenario and collaboration among regulators, Medical Physicists and hospital managers in the safe use of ionizing radiation in medicine in Africa.**

Objectives: To assess the current levels of participation and collaboration among regulators, Medical Physicists and hospital managers in the safe use of ionizing radiation in medical Practices in Africa.

Methods: The study was conducted by Federation of African Medical Physics Organisations (FAMPO) during two independent foras. Two questionnaires were designed and used. One to 25 participants from the regulatory bodies during the Regional (AFRA) Training course held between 20th -24th February, 2012 in Gaborone Botswana . The second was to 11 medical Physicists during the Africa Radiation Oncology Group (AFROG) conference held between 20th -24th February, 2012 in Kampala Uganda.

Results: Several gaps exist among the regulators, medical physicists and hospital managers. Training of medical physicists and regulators has been done by the IAEA with little support from the Health managers. Few member states have medical physics and radiation protection associations' responsible for their recognition.

Conclusion: To bridge the gaps, existing qualified Medical Physicists should inform the health managers and policy makers about the role of the Medical Physicists. Through these medical physicists, associations like FAMPO should bridge the gaps using different foras. More training centres for medical Physicists and other radiation scientists should be established.

Keywords: **FAMPO, Medical physics, regulators, Africa, Training**

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I. INTRODUCTION

FAMPO is the "Federation of African Medical Physics Organisations that was established on 7th October 2008 with the aims and purposes of promoting improved quality service to patients and the community in the Africa, promoting the co-operation and communication between Medical Physics Organisations in the region, and where such Organisations do not exist between Individual Medical Physicists, promoting the profession and practice of medical physics and related activities in Africa, promoting the advancement in status and standard of practice of the medical physics profession, promoting and improving the training of Medical Physicists, promoting research and developing in the field of Medical Physics, promoting appropriate use of technology to the benefit of rural populations, organizing and/or sponsor international conferences, regional and other meetings or courses and collaborating or affiliate with other Scientific Organisations. The Federation extends its activities throughout Africa and local Islands in the Region [4]. FAMPO's activities can be got on the website *http://www.federatio-fampo.org.*

During the Third African IRPA Regional Congress (AFRIRPA 2010) that was held from 13th -17th September, 2010 in Nairobi Kenya, several issues were discussed between FAMPO and other parties [7]. These included IOMP, IRPA, WHO, participating medical Physicists and other radiation protection stakeholders. Among the Issues discussed activities In line with FAMPO's objectives were to be carried out according to FAMPO's work plan.

Although there has been growth in the number of radiological and therapeutic facilities in Africa, with an increase in the training of other relevant personnel like radiologists, oncologists and radiographers, these centres still have very few academically and clinically trained medical physicists. This growth has not been matched by growth in manpower in the medical physics speciality[1,2]. What is the current situation?

In all matters of FAMPO's activities, stake holders should be involved. This will be a quicker, easier and transparent procedure to drive the systems especially with our governments to include hospital managers and regulators. IOMP is in position to support most of the activities. However, the initiative is in our FAMPO's hands[1,2]. What is the level of collaboration?

It is very difficult to work with whoever is not known to you. Thus FAMPO should create a data base to improve their functioning. This should involve: Identification of all medical physicists and their addresses in Africa, identification of all centres of radiotherapy, Nuclear Medicine and Diagnostic Radiology in Africa, identification of the type of equipments and sources used in these centres [5,6]. This information can be used as a base line for training by assessing demand and deployment of medical physicists in individual African countries.

Countries to carry out local training of Medical Physicists in Africa should be identified and put in place measures to allow retention of the trained personnel in their respective countries. FAMPO should take an initiative to incorporate the governments through its council representatives [7].

Through IOMP, manufacturers should be contacted to participate in local training of medical physicists. It is FAMPO's responsibility to identify countries where such short and long term training should be done in Africa. To cut on costs of training, countries should share training resources. Where are the trained and qualified MP and other radiation Scientists in Africa and which countries should take up the training? [7]

Young medical physicists have been ignored and left un attended to by qualified senior ones in their countries. Very little or no information is given to them about training opportunities, congress attendance and whatever is happening in the field of medical physicists. Can FAMPO act as a disseminating desk?[9].

The regulatory bodies/ NLO / project coordinators have nominated wrong people to always attend medical physicist's foras. These include relatives and friends. Can FAMPO have a way of dealing with this through the council members from individual countries to support in training and put in place measures for retention?

Could there be collaboration between FAMPO and IRPA to train medical physicists in Africa in radiation protection? Can an alliance be formed to solve the problem of man power especially in handling the work of Radiation Protection Officers (RPO) in hospitals?

Could there be a link between FAMPO and other Medical Physics Organisation from other continents? .This can be an opportunity to compare notes and also learn from how other association execute their activities to success [7].

Could FAMPO have a link in establishing radiation protection units in hospitals through their Council members. This will improve on communication and ALARA network with other associations in individual countries and among countries.

Haven't MP and radiation scientists in Africa conducted research? FAMPO to encourage research and encourage posting all data collected regarding ionizing radiation on the UNSCEAR website through the correct government channels. This should be a collective effort with other related fields. Dissemination of conferences should be the role of every one.

MP being part of the medical profession, has there been a link with WHO? WHO is in position to support FAMPO in local training of medical physicists to increase on the qualified radiation experts to manage and participate in patient care. With collaborations between FAMPO and WHO, IRPA, IOMP, IAEA and machine vendors, well qualified expertise in MP and other related radiation sciences will be achieved. It is very difficult to equip centres with equipments without having well qualified man power [3,8,9]

II. AIM OF THE STUDY

This research aimed at assessing the current levels of participation and collaboration among regulators, Medical Physicists and hospital managers in the safe use of ionizing radiation in medical Practices in IAEA member states in Africa.

Objectives of the study

1. To identify the training gaps of MPE/QE/ RPO in radiation protection and safety in IAEA African member states.
2. To identify countries with recognised professional bodies governing medical physicists and other radiation protection personnels in IAEA African member states.
3. To establish the current situational analysis of the communication links among Medical Physicists, facility manager and Regulators during management of radiation protection aspects in Medical Practices.
4. To assess the level of involvement of medical physicists, regulators and hospital managers in safety of Medical Practices.
5. To identify the challenges faced by Medical Physicists and regulators when conducting their

work in medical practices in IAEA African member states.

III. Methods and materials

The study was conducted by the Federation of African Medical Physics Organisations (FAMPO) Executive members during two independent foras. Two questionnaires tailored among regulators, Medical Physicists and hospital managers in the safe use of ionizing radiation in medical Practices were designed. One was addressed to 11 medical Physicists that participated during the African Radiation Oncology Group (AFROG) conference held from 20th -24th February, 2012 in Kampala Uganda from eleven countries ie Morocco, Egypt, Kenya, Zimbabwe, Ghana, South Africa, Uganda, Zambia, Cameroon, Tunisia and Mauritius. The second was used to 25 participants from the regulatory bodies of 15 different IAEA African member states that represented their countries during the Regional (AFRA) Training course for trainers in the use of ICT teaching materials in radiation protection held between 20th -24th February, 2012 in Gaborone Botswana and participating countries included; Tanzania, Morocco, Ghana, Niger, Kenya, Botswana, Mali, Nigeria, Egypt, Zambia, South Africa, Sierra Leone, Mauritius, DR. Congo and Uganda.

The questionnaire was used to obtain data on: identifying the training gaps of MPE/QE/ RPO in radiation protection and safety in IAEA African member states, identifying countries with recognised professional bodies governing medical physicists and other radiation protection personnels in IAEA African member states, establishing the current situational analysis of the communication links among Medical Physicists, facility manager and Regulators during management of radiation protection aspects in Medical Practices, assessing the level of involvement of medical physicists and regulators in Medical Practices and identifying the challenges faced by Medical Physicists and regulators when conducting their work in medical practices in IAEA African member states. The data collected was analysed and to be used to improve on the functionality of FAMPO in achieving its objectives.

IV. Results and discussion

A. Training gaps of MPE/QE/ RPO in radiation protection and safety in IAEA African member states.

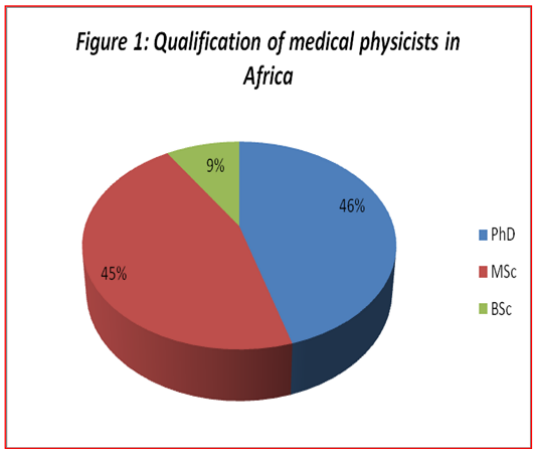
To assess the training gaps of MPE/QE/ RPO in Africa, the qualifications, working experience and centres of training of medical physicists and regulators were analysed.

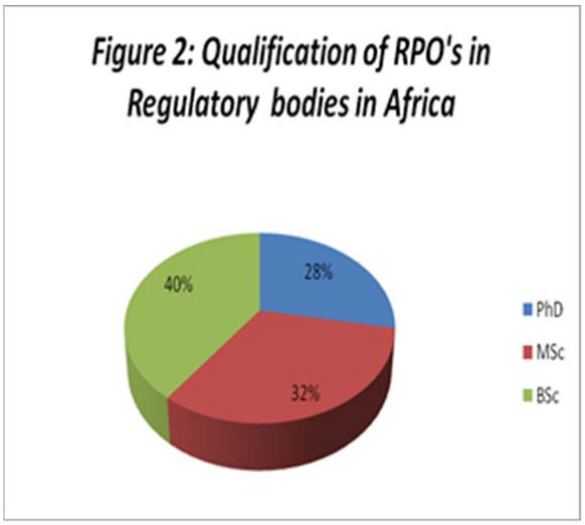
A.1 Qualification of Medical Physicists and Regulators in IAEA African member states

Figure1 and 2 show the percentage distribution of the current qualifications possessed by medical physicists and regulators working in African hospitals respectively. 9% of the medical physicists have a Bachelor of Science degree in physics, 45% have a Masters degree in Medical Physics and 46% have a PhD in Medical physics.

There is a big divergence among the highly and least qualified Medical physicists in Africa. Identification of the 46% PhD holders and 45 Masters Holder in the area of MP is a key aspect for FAMPO to increase local training of lower but competent carders in MP. This is a cheaper and efficient way once we have well equipped training centres in all areas of Medical practices. It is very difficult to equip centres with equipments without having well qualified man power. This will increase on machine down time, loss of funds by governments, more accidents and incidents. Therefore, training of medical physicists in Africa should be supported by all stake holders.

On the other hand, 40% of the Regulators have a Bachelor of Science degree in physics, engineering or chemistry, 32% have a Masters degree in Physics, engineering or chemistry and 28% have a PhD in similar areas. This shows a uniform distribution of carders at all levels of qualification which is not reflected in the MP Field. However, the diversion of the employed RPO's in different subject matter has presented a problem especially when inspecting Radiotherapy Medical Practices due to lack of training and expertise.





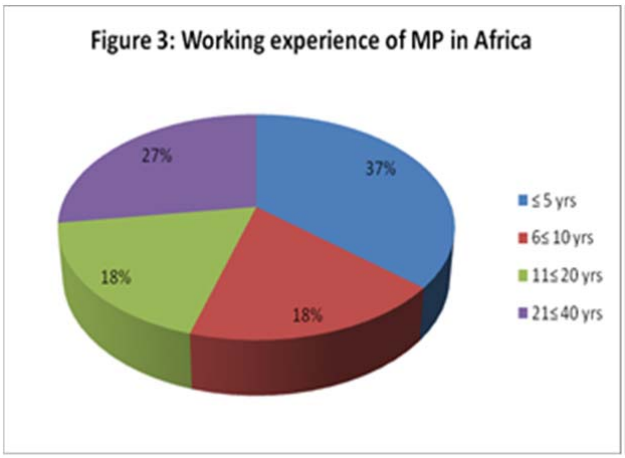
A.2 working experience of Medical Physicists and Regulators in IAEA African member states

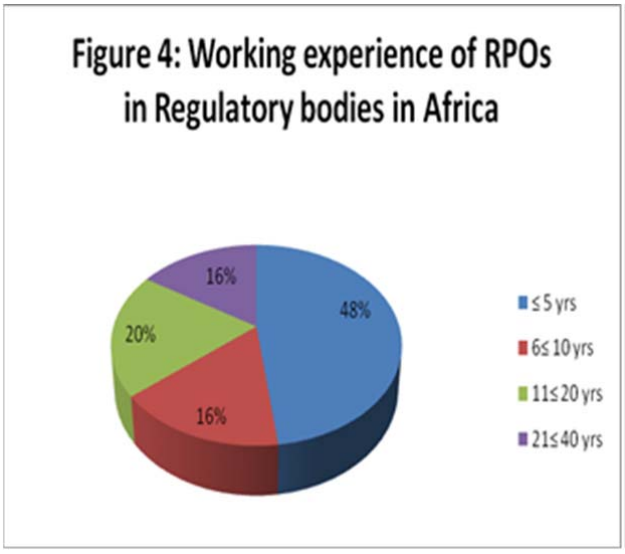
Figure 3 and 4 shows the percentage distribution of the years of working experience in the field of medical physics and regulatory bodies of the current medical physicists and regulators in Africa respectively. 37% of the medical physicists have worked for less or equal to 5 years, 18% for more than 6 years but less than 10 years, 18% for more than 11 years but less than 20 years and 27% for more than 21 years but less than 40 years.

A big divergence in the working experience of above 21 years corresponding to 27% for the senior MP staffs and below 5 years totalling to only 37% indicate a big gap in the training capability of MP. Continuous training to achieve a uniform distribution of all cadres is a key issue for FAMPO and all stakeholders.

In many centres, although there has been growth in the number of radiological and therapeutic facilities in Africa, with an increase in the training of other relevant personnel like radiologists, oncologists and radiographers, these centres still have very few academically and clinically trained medical physicists. Most of the training has been sponsored by the International Atomic Energy Agency (IAEA). Through different bodies governing MP, member states should take on 100% or cost share in training of MP at higher degrees as it is for other Health professions.

On the other hand 48% of the regulators have worked for less or equal to 5 years, 16% for more than 6 years but less than 10 years, 20% for more than 11 years but less than 20 years and 16% for more than 21 years but less than 40 years. Continuity is possible in RPO field as compared to MP. A good number of young carders is being trained. This is not reflected in the MP Field. FAMPO has established that training of MP is very expensive and very few training centres in Africa exist.

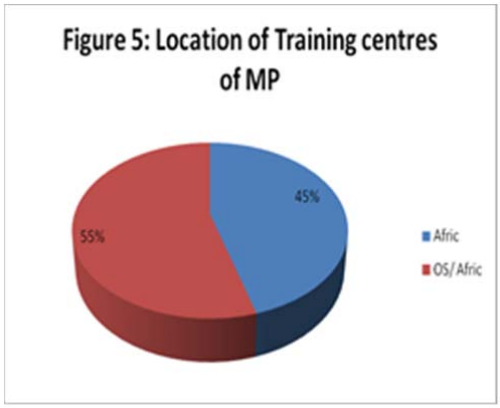


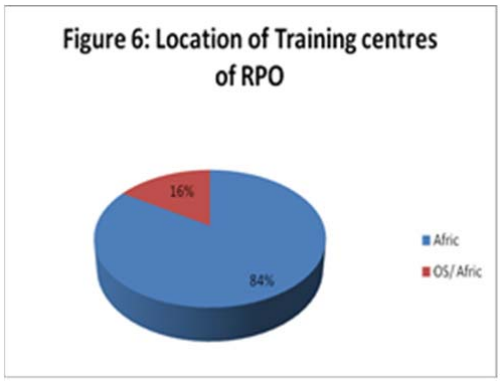


A.3 Centres of training of Medical Physicists and Regulators in IAEA African member states

Figure 5 and 6 indicate the centres where the existing medical physicists and regulators in Africa have trained respectively. 55% of the MP have trained in centres outside Africa and only 45% have trained in African centres. The 45% that have trained in African centres indicate only training centres in South Africa and North Africa. No training centre for Medical Physics exists in East Africa and West Africa. Due to the great demand of Radiation Scientists, it is proved that MP can work as MPE, QE or RPO and have been the backbone of the existing Regulatory bodies in most African Countries. With support of the IOMP, IAEA, WHO, machine vendors, local governments, identification of a training centres for MP in of East and West Africa is key to FAMPO's activities and work plan.

On the other hand, only 16% of the regulators have trained in centres outside Africa and 84% have trained in African centres. Training has been done in their own countries. This indicates that many centres exist in Africa for training RPO's as compared to MP's. However, the incompetence especially in inspecting Radiotherapy centres could be resulting from non comprehensive curricula used for training. Employing personnel with MP background in the regulatory authority can be a quick solution. A review and unifying the training curricula could be a solution. This is an action point for FAMPO, respective Radiation Protection Associations in Africa and other stakeholders.





B. Countries with recognised professional bodies governing medical physicists and other radiation protection personnels in IAEA African member states.

Assessment was done to ascertain IAEA African member states with the Law regulating use of ionising radiation, bodies governing radiation use and recognised professional bodies governing and registering medical physicists and RPOs in African countries

B.1 Existence of Law regulating use of ionising radiation in IAEA African member states

All the 11 participating medical Physicists and 25 regulators indicated that they have approved Laws and bodies governing the use of radiation in their respective countries. However, no concrete answers were given to bodies registering regulators as a profession.

B.2 Recognised professional bodies governing and registering medical physicists and RPOs in African countries

Figure 7 and 8 indicate the percentage existence of bodies governing and registering medical physicists in IAEA African member states as indicated by the responses obtained from the MP and regulators respectively. 36% participating MP indicated to have recognised bodies governing and registering medical physicists and 64% of African countries do not have.

On the other hand, the responses of the regulators indicated that only 45% do have recognised bodies governing and registering medical physicists. 52% of African countries do not have this body. The figures indicated are comparable to those reported by the MP. Recognition of MP in Africa is one of FAMPOs objective. This is backed up by the International Labour Organisation that currently recognises MP as a profession.

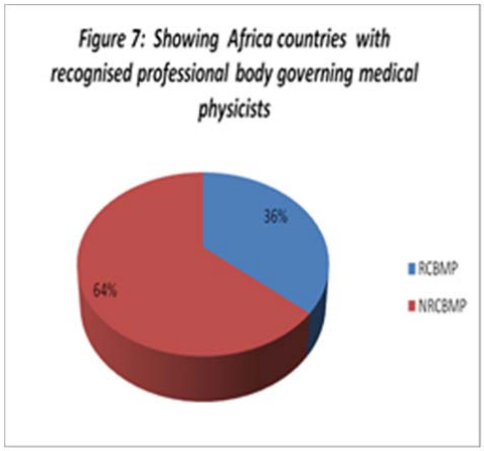


FIGURE 7: (Response from the medical physicists perceptions in the questionnaire used for AFROG- Uganda)

RCBMP: % age African Countries with recognized bodies governing and registering medical physicists

NRCBMP: % age African Countries with NO recognized bodies governing and registering medical physicists

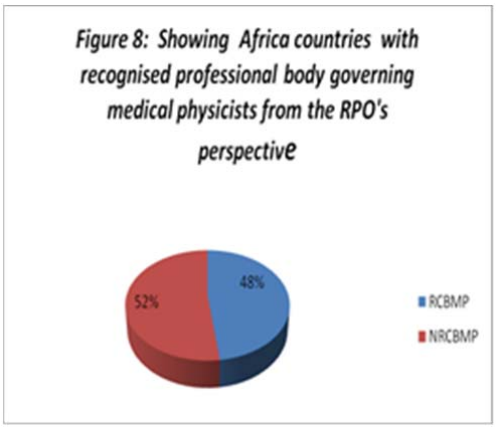


FIGURE 8: (Response from the RPO's perceptions in the questionnaire used in Botswana)

RCBMP: % age African Countries with recognized bodies governing and registering medical physicists

NRCBMP: %age African Countries with NO recognized bodies governing and registering medical physicists

Non recognition by some states has presented a challenge of ineffective communication among individual physicists and related fields. This has also led to non-representation on hospital and government boards which has led to minimal financial support to the field of MP. Through FAMPO, mass collaboration and recognition of MP in Africa should be done and sensitization of their roles done through networking with the existing MP or related bodies.

C. Communication links among Medical Physicists, facility manager and Regulators during management of radiation protection aspects in Medical Practices.

Figure 9 and 10 indicate the existence of collaboration between medical physicists and Regulators in management of safety in Medical Practices as collected from the MP and regulators respectively

From the perspective of MP, 55% of African Countries have collaboration between MP and RPO when managing safety issues in Medical practices. Among the areas of collaboration include; consultancy, conference participation and individual dosimetry. However, the 45% that work in isolation pose a challenge on how safety issues are managed. Whereas both parties can work as Qualified experts (QE) especially in settings with low personnel in both fields. FAMPO should work with the different Radiation Protection Associations in Africa to achieve positive results with minimal accidents and incidents.

On the other hand, 80% of RPOs of African Countries have collaboration with the existing MP when managing safety issues in Medical practices. However, some countries with no MP at the medical facility or regulatory body face a challenge when inspecting Radiotherapy centres. Some countries use the same RPO as QE and MPE. There is also a mix of duties and roles among MP and RPO.

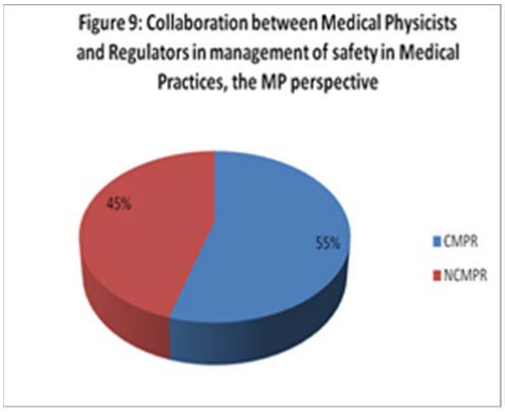


Figure 9 : Existence of collaboration between medical physicists and Regulators in management of safety in Medical Practices as collected from the MP during AFROG

CMPR: % age African Countries that have collaboration between MP and RPO when managing safety issues in Medical practices

NCMPR: % age African Countries that have NO collaboration between MP and RPO when managing safety issues in Medical practices

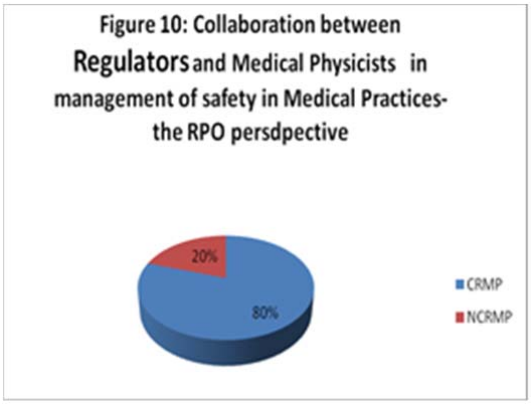


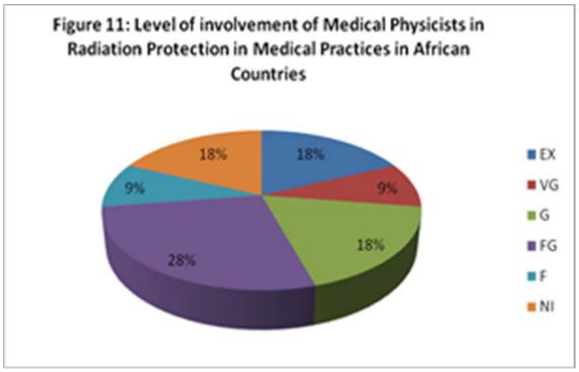
Figure 10: Existence of collaboration between medical physicists and Regulators in management of safety in Medical Practices as collected from the regulators (RPO's in Botswana)

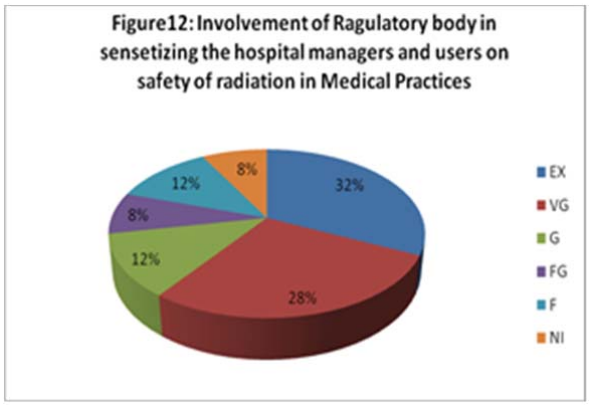
CMPR: % age African Countries that have collaboration between MP and RPO when managing safety issues in Medical practices

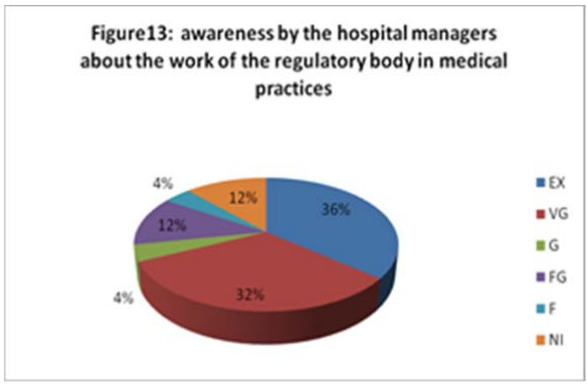
NCMPR: % age African Countries that have NO collaboration between MP and RPO when managing safety issues in Medical practices

D. Level of involvement of Medical Physicists, regulators and hospital managers in Radiation Protection in Medical Practices in IAEA African member countries

Scores of the level of involvement of medical physicists, regulators and hospital managers in radiation protection of medical practices were made according to the scoring criteria; Excellent (EX) 90%-100%, very good (VG) 80%-90%, good (G) 70%-80%, fairly good (FG) 60%-70%, fair(F) 50%-60% and not involved at all (NI) bellow 50%. Figure 11, 12 and 13 show the levels of involvement of; MP in radiation protection in medical practices, Regulatory body in sensitizing the hospital managers and users on safety of radiation in Medical Practices and awareness by the hospital managers about the work of the regulatory body in medical practices







Results as indicated in figure 11, indicated a non uniform level of involvement of MP in handling radiation protection in medical Practices. 18% for excellent involvement, 9% for very good, 18% for good, 28% for fairly good, 9% for fair and 18% are not involved at all. The 55% that indicate below 70% involvement causes a challenge and FAMPO should investigate for the causes of this less involvement of MP in manning radiation protection in medical practices.

Results as indicated in figure 12, for the Involvement of Regulatory body in sensitizing the hospital managers and users on safety of radiation in Medical Practices. 32% for excellent involvement, 28% for very good, 12% for good, 8% for fairly good, 12% for fair and 8% are not involved at all. For the Law to be strong, effectiveness of the regulatory bodies should be felt by all radiation users in every country. Un effectiveness causes loopholes in the implementation of the Law.

Results as indicated in figure 13, indicated, 36% for excellent awareness by the hospital managers of the work of the regulatory bodies in medical practices, 32% for very good, 4% for good, 12% for fairly good, 4% for fair and 12% are not aware at all. Since the hospital managers play a big role in policy, training and funding. Through sensitizing workshops organized by the regulatory bodies to create awareness and have a vote for support in terms of operational funds, training and employment of MP and RPOs.

E. Challenges faced by Medical Physicists and regulators when conducting their work in medical practices in IAEA African member states

Several challenges were noted from the respondents and these included.

- Untimely release of funds from the government for the regulatory bodies to carry out their work.

- Inadequate number of Medical Physicists in the country. Most regulators/ RPOs play the roles of the Medical Physicists.
- Lack of commitment to radiation safety by some hospital managers in some hospital or clinics
- Confusion on the roles and responsibilities of the Regulators and Medical Physicists.
- Some hospital administrators do not appreciate the need for radiation safety in their settings
- Unjustified increase of licence fees brings lack of cooperation with users
- In adequate collaboration and communication among regulators, existing MP and hospital mangers
- Some countries with no MP employed in the regulatory body, find it very difficult to inspect Radiotherapy centre.
- Some countries do not have any MP existing so no collaboration can be done.
- Unauthorised radiology centres
- Some countries share same body for radiation protection and MP.
- Most regulatory bodies and MP have not established the radiation sources used in medical practices. A data base is missing. So inspection and licensing of all sources is very hard
- MP play the role of RPO in some countries. This presents a big overload.
- Due to limited personnel, time is not enough to carry out safety assessment in some hospitals
- Lack of developed procedure and training of MP and RPOs.
- Lack of inadequate commitment to safety culture at policy level, managerial level and individual level.
- Some countries have newly recruited MP and regulators. So no link at all.
- Some counties have unqualified experts who try to work as MP and regulators. This presents a brain drain.
- Unwillingness to work in remote/rural centres leaves safety issues in medical practices unattended too.
- Lack of tools to use and expertise to use them

V. CONCLUSION

The gaps identified in the study should be an indicator for FAMPO to carry out close collaboration through the FAMPO Council representatives, radiation protection associations, WHO, IRPA, IOMP, machine vendors and policy makers when executing its functions.

Currently, about 48 individual medical physicists in Africa have expressed interest in FAMPO and registered. In addition GAMP, NAMP, SAAMPS, SAMP and MPST of Ghana, Nigeria, South Africa and Tanzania have also expressed interest. The Federation extends its activities throughout Africa and local Islands in the region and the activities of the federation are not aimed at profit.

ACKNOWLEDGMENT

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EDUCATIONAL RESOURCES

VISUAL DEMONSTRATIONS OF MEDICAL PHYSICS CONCEPTS FOR DIAGNOSTIC RADIOLOGY RESIDENT EDUCATION

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Abstract— **Diagnostic radiologists need to have a good understanding of radiologic physics to practice in a safe and effective manner. However, many physical phenomena relevant to medical imaging are challenging to teach in a method amenable for physicians. The need to avoid extensive use of mathematical formulas and other more traditional explanations of these concepts, like those commonly used in the education of physics and engineering students, presents a challenge for the communication of complex concepts. However, many of these medical physics concepts can be demonstrated visually using typical equipment found in a modern classroom. Therefore, a series of demonstrations using a projector and screen and several printed transparencies and other simple objects, representing a source of x-rays, an imaging detector and the patient or other imaged objects, respectively, has been developed and used during lectures for diagnostic radiology residents. More than a dozen different physical phenomena common in diagnostic imaging can be demonstrated in this way. These demonstrations have been well received by the residents, have resulted in more interactive didactic sessions, and, have enhanced their comprehension and recollection of these topics.**

Keywords— **Education, medical physics, radiology, residency, transmission imaging.**

I. Introduction

Radiologists need to have a good understanding of several aspects of medical physics and imaging technology [1-6]. Typically this education takes place during their residency, and, ideally, a large portion of it is provided via interaction with a medical physicist. However, the teaching of medical physics concepts by a physicist to diagnostic radiology residents can sometimes be challenging. The use of extensive mathematical derivations and formulas is in general not a successful approach, although many topics are easier to explain in this manner. In an attempt to convey information in a more graphical manner, it is tempting to also depend solely on the use of electronic slides. However, this can result in a monotonous lecture.

With the use of standard classroom equipment and a few simple objects, it is possible to provide visual demonstrations of many physical phenomena relevant to diagnostic imaging, especially in the realm of transmission imaging. By experiencing these phenomena, rather than just being told about them, the residents' grasp of the concepts is enhanced, resulting in a better understanding and recollection of them. In addition, these demonstrations provide for more interaction between the residents and the lecturer, resulting in a more interesting experience for both.

II. Materials and methods

A. Methods

Although the concepts presented here are in general used to perform demonstrations of transmission imaging phenomena, some of them cover basic aspects of image quality relevant to all imaging modalities. In a few cases the underlying physical phenomena during the demonstration are different than those in the imaging situation (e.g. x-ray scatter vs. light refraction), however the concepts are still better understood with these demonstrations.

To perform most of these demonstrations, a typical classroom projector connected to a computer with presentation software (e.g. PowerPoint, Microsoft Corp, Redmond, Washington, USA) is used to represent an x-ray tube. The characteristics of the "x-ray beam" emitted by this "source" are defined using appropriate PowerPoint slides. The screen projected to by the projector is used to represent both the "x-ray detector" and/or the "monitor" where images are displayed, depending on the demonstration. Finally, transparencies and some acrylic objects are used to represent the patient or other imaged

objects. These are simply held up in the path of the "x rays" by the lecturer. The position where these need to be held varies depending on the demonstration.

The concepts covered by these demonstrations currently are, in no particular order:

- Straight-line travel of electromagnetic radiation
- Object, subject, image and display contrast
- Point spread functions
- Linear systems
- Frequency domain
- Contrast and modulation transfer functions
- Quantum and image noise
- Noise frequency and noise power spectrum
- Anatomical noise
- Magnification
- Geometric unsharpness
- Inverse square distance relationship
- Sampling and aliasing
- X-ray scatter

The following are descriptions of how some of these concepts are demonstrated.

Point Spread Functions: To demonstrate the concept of a point spread function, a simple transparency with a single small black circle printed on it is held up in front of the projection of a blank white electronic slide. This is sufficient to demonstrate how the manner in which a single point object is imaged by the system characterizes the system response. By varying the distance between the transparency and the projector, the size and sharpness of the projected "point" is varied. A larger blurrier point reflects the image obtained with a system of poor spatial resolution, while a sharper point reflects improved spatial resolution.

System Linearity: The introduction onto the x-ray beam of a second transparency with another equal small black circle is used to demonstrate the concept of linearity. It is apparent to the residents that although another object is introduced into the field of view, the system response to the first object does not change. This therefore provides a demonstration of why, due to system linearity, the point spread function is a useful metric. This is perhaps the best example of how some concepts are simplified by these methods; this demonstration is almost obvious, while explaining the concept of system linearity using traditional methods is typically very counterintuitive to the residents.

Object, subject, image and display contrast: To explain these four concepts, a homogeneous "x-ray field" is used by displaying a blank PowerPoint slide. Three or four disks of varying darkness are printed on a transparency, cut out, and placed in between two slabs of polymethyl methacrylate (PMMA) (Fig. 1(left)). In this case the PMMA slabs are semi-circular representing a breast undergoing mammography, but they can be of any shape. This "breast" is held up in the "x-ray beam," and the "lesions" are shown to have different object contrast, which modify the "x-ray beam" after the breast, resulting in subject contrast. The fact that how this subject contrast is captured by the "detector", i.e. the system response, can vary is demonstrated by having a volunteer hold a black paper in front of the screen, representing a different detector (Fig. 1(right)). The resulting image contrast is shown to be different if the detector is a white screen or a black screen.

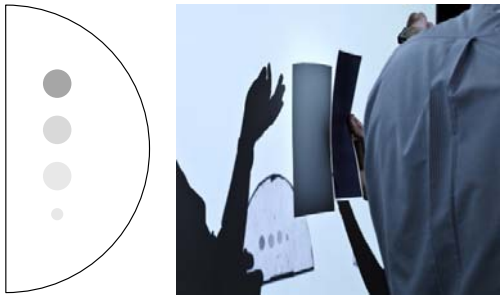


Fig. 1 (left) Semi-circular PMMA phantom with a number of disks of different graylevel representing a breast with lesions with different object contrasts. (right) The phantom is held up in front of two different "detectors" to show the difference in resulting image contrast.

Frequency domain, contrast and modulation transfer function: Without the use of formulas, explaining the concept of the frequency domain (or k-space) is very challenging. A transparency with printed line pairs or sine waves of varying spatial frequency (Fig. 2(left)) can be used to explain this concept and how it is relevant to spatial resolution. Depending on the position of the sine wave transparency, the higher frequency waves are blurred by the "imaging system", resulting in loss of contrast. It is explained that the ratio between the darker and brighter areas of the sine waves vs. their spatial frequency are plotted, creating the modulation transfer function (MTF) (Fig. 2(right)). By varying the distance between the transparency and the projector, the spatial resolution of the "imaging system" is varied, and the contrast loss at different frequencies varies, yielding a different MTF. With this demonstration, both the concept of the MTF and the relationship between spatial resolution and signal transfer properties are understood. A second transparency with line pairs instead of sine waves is briefly shown, explaining the difference between the contrast transfer function and the MTF.

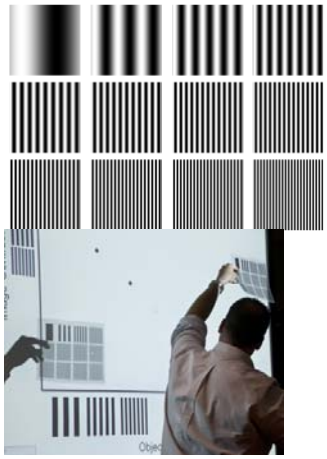
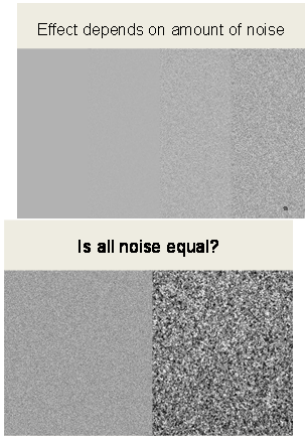


Fig. 2 (left) Transparency with sine waves used to demonstrate the concept of frequency domain and (right) the construction of the MTF.

Quantum and image noise, noise frequency and noise power spectrum: Using image processing software, images of white and colored noise of varying levels are created and included in PowerPoint slides (Fig. 3(top)). When displayed using the projector, placing a transparency with disks of varying graylevel in the path of the different areas of the noisy "x-ray beam" shows how image noise affects detectability of lesions (Fig. 3(bottom)). Then showing the disks in the "x-ray beam" with white vs. colored noise shows how noise frequency also affects detectability. This demonstration, along with the previous explanation of the frequency domain described above, also helps introduce the concept of noise power spectrum.



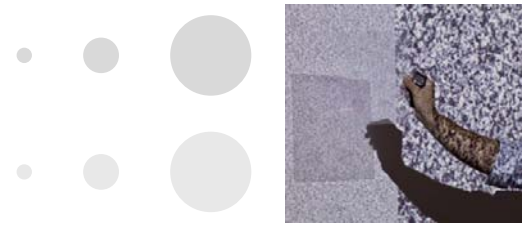


Fig. 3 (top) Electronic slides containing image noise of varying levels and frequency characteristics. (bottom) A transparency with disks of varying gray level is held in front of the different noisy "x-ray fields" to demonstrate the change in detectability of "lesions" with noise of different characteristics.

To explain the issue of anatomical noise (or tissue superposition), the electronic slide consisting of noise is replaced with one that includes a region of interest of normal mammographic background, and the transparency with "lesions" is again held up in the beam of "x rays." Again, the impact of the anatomic noise on the detectability of the lesions becomes apparent.

Magnification: Two transparencies with squares are printed; one with a single square and another one with four adjacent squares each of the same size as that of the other transparency, arranged so as to form one larger square. After comparing the two transparencies to show that the smaller square is exactly four times smaller than the larger one, a resident volunteer holds up the transparency with the larger square against the screen. The transparency with the smaller square is held up half-way between the screen and the projector (purposefully, this distance is measured during the demonstration). The perfect alignment of the small square with the larger square is shown (Fig. 4). In addition, this setup, plus the previously discussed concept that x-rays travel in straight lines between interactions, is used to explain the inverse square distance relationship. This concept is made apparent since it is explained that the same number of x-rays that went through the first small square go through the four squares in the second transparency. Therefore, the x-ray fluence is decreased by a factor of four, or the square of the increase in distance traveled.

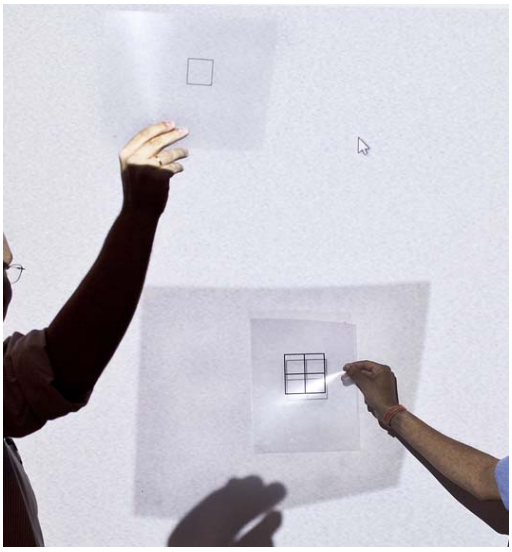


Fig. 4 Two transparencies with printed squares of different sizes are used to demonstrate magnification and the inverse square distance relationship.

Sampling and aliasing: To introduce the concept of sampling, a chest radiograph is printed on a transparency and shown in front of a projected grid representing the array of pixels of a detector (Fig. 5 (top)). It is discussed that the entire signal incident on a whole pixel is averaged to represent the signal at that pixel, and the resulting image is shown in a projected slide (Fig. 5(bottom)).

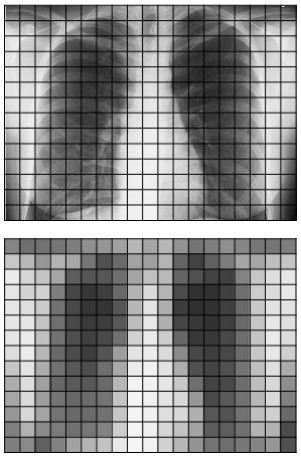
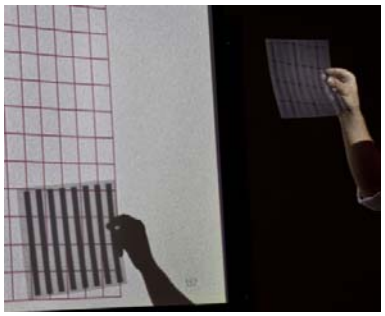


Fig. 5 (top) A chest radiograph on a transparency is shown in front of a projected grid pattern representing the pixels of a digital detector. (bottom) The continuous "x-ray beam" containing the information of the chest x-ray is then projected using a transparency with the array of "pixels" overlaid, followed by the result of the coarsely sampled image.

This demonstration serves as an introduction to the concept of aliasing, since the same setup is used but this time with a transparency with a single sine wave pattern (Fig. 6(top)). The spatial frequency aliasing that takes place when this sine wave is sampled by the "detector" is shown with two electronic slides (Fig. 6(bottom)).



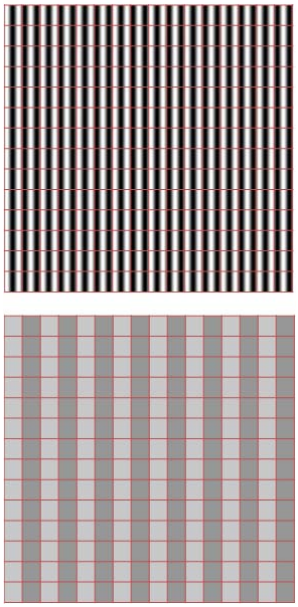


Fig. 6 (top) A sine wave pattern on a transparency is shown in front of a projected grid pattern representing the pixels of a digital detector. (bottom) Two separate electronic slides show how the high frequency sine wave pattern is aliased by the course sampling into a lower frequency pattern.

This is another example of how this type of demonstration aids immensely in the understanding of a complex topic. Using a simple transparency and the projection of a grid of "pixels," the concept of frequency aliasing can be visualized by the residents, with no need for mathematical formulas.

X-ray scatter: A blank white electronic slide is displayed representing a noise-free "x-ray beam." A 10 cm pediatric head CT phantom is held up in the path of the light beam with its long axis close to horizontal (Fig. 7). By adjusting the position of the phantom, it is possible to show how the shadow of the phantom is impacted by light refraction. The change in visibility of the 1 cm diameter holes in the phantom due to the refracted light falling on the projections of these holes is used as an example of how contrast is reduced by the presence of x-ray scatter. This is an example of a demonstration that does not rely on the same physical phenomenon that is being demonstrated, but it still useful to explain a key concept in radiographic imaging.

Fig. 7 A CT phantom is used to demonstrate the phenomenon of x-ray scatter and its impact on image contrast.

Other demonstrations, not all of which involve the use of the projector and screen, are used to explain other imaging concepts. For example, to demonstrate the benefit of a rotating anode in the x-ray tube, a resident volunteer is asked to direct the beam of a presenter's laser pointer at a point close to the outer edge of a Frisbee or plastic plate. The Frisbee has an axis through its center that allows for its easy rotation. When the Frisbee is rotated while the laser is held in place, the residents can easily see how the heat deposited by the "electron beam" is distributed along a circle, therefore increasing the heat capacity of the focal spot.

B. Evaluation

At the end of each lecture, the residents are asked to complete a survey form, in which one of the questions asks specifically about the usefulness of these demonstrations, to be graded with a score from 1 to 5, with 5 being the highest score. In addition, the survey includes separate questions for free-form comments on the strengths and weaknesses of the instructor's teaching. The residents' responses to these surveys over the three years that these visual demonstrations were used were analyzed.

III. Results

The feedback from the residents attending these sessions has reflected a very positive opinion of these demonstrations. From a total of 51 completed survey forms, the average score on the usefulness of the visual demonstrations was 4.76 (std. dev. = 0.47), with a range of 3 to 5 (although a single score of 3 was received, all others being 4s and 5s). Of the 51 surveys, only 32 included any comment on the instructor's teaching strengths. Of these 32 positive comments, 18 mentioned the visual demonstrations as a strength. The

demonstrations were not mentioned in any of the surveys as a weakness.

Very positive feedback has also been received both directly during informal one-to-one conversations with residents that attended these lectures and indirectly through comments to other faculty.

IV. Discussion

This innovative method of communicating medical physics concepts relevant to transmission imaging has been very well received by the residents. It appears to have also substantially improved the residents' understanding of the concepts and their impact on image quality and patient dose, their ability to explain and recollect them. In addition, these types of demonstrations help promote interaction with the medical physicist during class and throughout their residency.

V. Conclusions

The use of demonstrations that show physical phenomena relevant to diagnostic imaging, rather than just describing them using electronic slides and/or blackboard diagrams, let alone mathematical formulas, can enhance the learning experience for diagnostic radiology residents. In addition, the didactic sessions become more interactive and promote a two-way discussion of concepts that is challenging to obtain during traditional didactic lectures.

Although the list of demonstrations is already extensive, additional concepts that can be shown using this methodology are always being sought. Finally, although the electronic slides needed to project and to print the transparencies are easy to prepare, these are available by request via e-mail to the author.

Acknowledgment

The author would like to thank Kevin Makowski for the photographs and Jessica Paulishen for assistance with editing.

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OPTIMIZING MEDICAL IMAGE CONTRAST, DETAIL AND NOISE IN THE DIGITAL ERA

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Abstract— **Use of digital imaging within all of the medical imaging modalities and methods provides many advantages and values to the practice of clinical medicine. However, the use of digital technology, digital image structure, and the ability to process digital image data in many ways add additional complexity to many imaging procedures. All medical imaging professionals, including radiologists, technologists, and medical physicists must be knowable and experienced with digital imaging in order to obtain maximum values from modern imaging technology and procedures. A common characteristic of all procedures that produce digital images is that the human body is divided into many discrete samples or voxels which are then represented by pixels in the image. The structure of the digital image, especially the voxel/pixel size, has a significant effect on image quality and visibility of structures and objects within the body. The optimization of medical imaging procedure protocols and selection of technique factors requires a comprehensive knowledge of digital image structure, impact on image quality, and the concept and practice of optimization.**

Keywords— **Digital Images, image quality, protocol optimization.**

I. INTRODUCTION

With increasing digital technology in almost all areas of our lives, medical imaging is no exception. The majority of medical images from all modalities are either directly produced or converted into a digital format. This offers many advantages but also challenges in the process of adjusting imaging quality and optimizing imaging procedures for maximum clinical benefit. Medical imaging professionals including radiologists, technologists, physicists, and engineers can be more effective in providing optimized images if they have good knowledge of the structure of digital images and the relationship of that structure to image quality and visibility of anatomy and signs of pathology.

The objective of this article is to review the structure and characteristics of digital images and the impact on three image quality characteristics: contrast, image detail (spatial resolution) and visual noise. These are image characteristics that must be considered together and "balanced" in the process of procedure optimization.

II. THE DIGITAL ADVANTAGE

There are many advantages to having medical images in digital form and it is helpful to review some as illustrated in Figure 1.

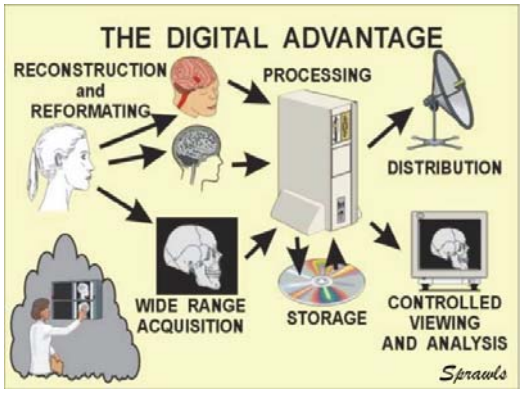

Figure 1. The advantages of medical images in digital form.

Image Reconstruction: The formation (reconstruction) of images with tomographic and 3D modalities--CT, MRI, SPECT, and PET--requires digital computations which result in images in a digital format. Typically the quality characteristics of the digital images can be adjusted when setting up the image acquisition protocols and the image reconstruction that follows.

Wide Dynamic Range or Latitude Acquisition: This applies to all modalities but is especially significant in radiography and CT. When a radiograph is recorded on film there is a very limited range of exposure to the receptor that will produce adequate image contrast and not over- or under- exposed films, This is because of the limited exposure latitude of film relating to the chemical process that records the image. Digital radiographic receptors of all types do not have this limitation and have the advantage of a wide exposure range (dynamic range) in which good image contrast can be captured. This is one of the significant advantages of digital compared to film radiography.

Image Processing: Images in digital format can be processed to alter or enhance specific characteristics. This

can be during the image reconstruction function or later as post processing.

Image Storage and Retrieval: With the advances in digital storage and memory technology and especially the increased capacity, the storage and rapid retrieval of digitized medical images is both possible and practical. This contributes to increased efficiency of clinic operations and improved patient care with the rapid access to images from both current and previous procedures.

Image Transmission and Distribution: The ability to transmit images over networks, from local to global, adds a new dimension to the practice of radiology. It makes images available for viewing and interpretation by qualified medical professionals regardless of where they are located. This is especially significant in acute and emergency cases where a correct diagnosis and guidance can mean the difference between life and death.

Education, Training, and Consultation: Radiology education and training is much more effective and efficient because of the extensive digital resources that are now available. These include teaching files with expanded content and accessibility and extensive online publications, courses, and reference materials. A very valuable feature is the ability of medical professionals to go online and access reference images and information at the time they are viewing images from specific cases. This is providing education at "the point and time of need".

The full advantage of digital imaging will be realized only when the quality of the images provides the required visualization for the purposes of the procedures being performed. That depends on the knowledge and experience of the medical imaging professionals.

III. Digital Image Structure

Sampling: A first step in producing a digital medical image is to divide the human body into many individual and discrete samples. Within the body these samples are the *voxels* (volume elements) which are then represented in the image by corresponding *pixels* (picture elements). Generally each tissue voxel is represented by a specific pixel in the image unless some different form of image formatting is used.

Sample (Voxel and Pixel) Size: The size of the individual voxels and pixels is a critical factor in determining image quality and visibility. In most imaging procedures the size is adjustable through a combination of imaging protocol or technique factors that must be considered by the staff conducting the procedure.

Tomographic Imaging and Voxels: For modalities that produce tomographic images of slices (CT, MRI, SPECT, PET) the voxel size is the critical factor. It is determined by the combination of three adjustable parameters as shown in Figure 2.

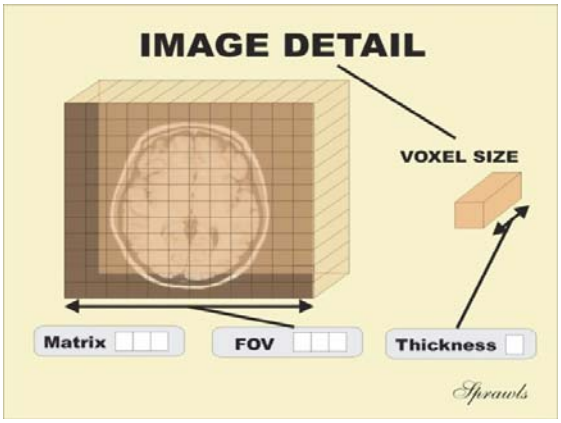

Figure 2. The factors that determine voxel size and related image detail.

The face dimension of the voxel, which closely relates to the corresponding pixel, is determined by the ratio of two factors, the physical size of the imaged area, the field of view (FOV) and matrix size which is the number of voxels/pixels across each dimension of the image.

Field Of View (FOV): First, the distinction must be made between the FOV and image size. The FOV is the physical dimension of the area being imaged at the location within the body. That is significant because two of the image quality characteristics depend on the actual size of the individual tissue voxels and not the size of the pixels in the displayed images.

In most imaging procedures the FOV is adjustable and is set based on the anatomical region to be imaged but with the recognition that reducing FOV does produce smaller voxels and pixels.

Image Matrix Size: The matrix size is the number of voxels and pixels across each direction in the image. Most images are square matrixes with equal dimensions in each direction with sizes that are binary multiples such as 512X512, 1024X1024, etc. There are some applications, especially in MRI, where there are advantages in using rectangular matrixes.

Matrix size is a design characteristic of each of the imaging modalities and within a modality an adjustable protocol or technique factor and is used to control the quality of the images as we will describe in detail later.

Slice Thickness: The thickness of tomographic slices is usually the largest dimension of a voxel and can be adjusted to control image quality.

Projection Imaging and Pixels: The projection imaging modalities--radiography, fluoroscopy, and the gamma camera-- do not form small tissue voxels. The critical factor in determining image quality is the size of the pixel within the body at the location of objects being viewed. It is not the size of the pixel in the displayed image.

Because of the geometric magnification associated with radiographic and fluoroscopic imaging the effective pixel size varies with location within the space between the focal

spot and image receptor. This must be taken into account when considering image quality as illustrated in Figure 3.

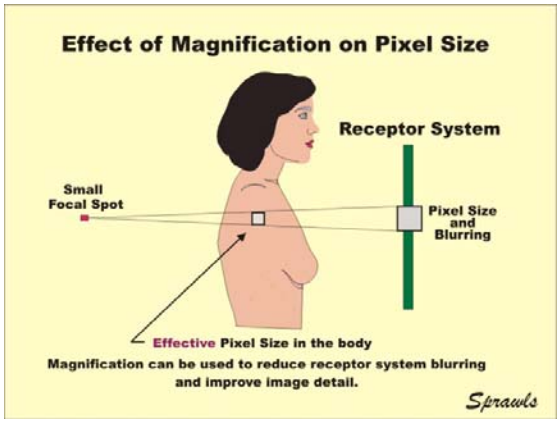

Figure 3. The relationship of image pixel size at the receptor to the sample size within the body.

The ratio of receptor pixel size to the pixel size within the body increases with the geometric magnification. One important factor associated with this is that magnification actually reduces the effective pixel size (tissue sample size) in relation to the fixed pixel size within the receptor. Later we will be seeing that a pixel is actually a source of blurring added to the image. When there is significant geometric magnification the blurring from the receptor is actually reduced at the location that is being imaged within the body. One of the common applications of this principle is *magnification mammography*. It is used to produce images with the least possible blurring and maximum detail especially for visualizing the small micro-calcifications that can be valuable signs of early stage breast cancer. This procedure requires the use of a small focal spot so that the focal spot blurring does not counteract the reduction in receptor system blurring produced with the magnification.

IV. Image Quality Characteristics

The overall quality characteristic of a medical image is *visibility* of anatomical structures, objects, or signs of pathology that are required for diagnosis and guiding treatment procedures. Visibility of the various objects within the body is determined by a combination of factors as illustrated in Figure 4.

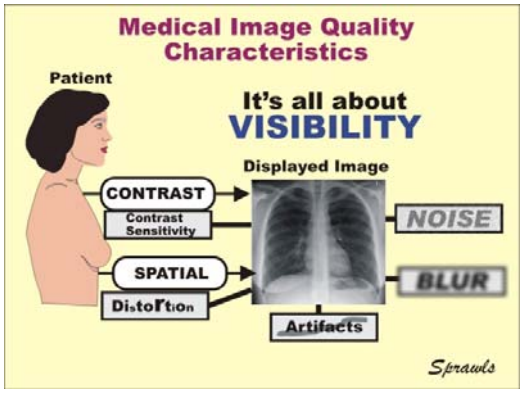

Figure 4. The individual image quality characteristics that affect visibility of structures and objects within the body.

The relationship of visibility to these individual characteristics is somewhat complex and depends on the physical characteristics of the objects within the body. Our objective here is to observe how digitizing an image affects specific characteristics and overall visibility. We will confine the consideration to three characteristics: contrast, detail, and noise, all of which are dependent on the digital structure of images.

Image Contrast and Procedure Contrast Sensitivity: Contrast is the foundation image quality characteristic because without contrast there is no visible image. Contrast originates within the human body as some form of physical contrast, depending on the image modality. The imaging process transforms the physical contrast into visible contrast displayed in the image. Contrast sensitivity (contrast resolution) is the characteristic of the imaging process that determines its ability to "see" the physical contrast within the body. When images are in a digital form processing can be used to enhance and optimize the contrast characteristics.

Image Detail: There is some blurring that occurs in all imaging procedures, including our human vision. The effect of blurring is to reduce the visibility of small objects and structures, anatomical detail. Detail might be referred to as image sharpness and is related to the characteristic spatial resolution that is often measured or calculated to evaluate imaging system performance. Detail is the clinically important characteristic because it determines the smallest objects that can be visualized. It is determined by the physical and design characteristics of each imaging modality and also depends on the adjustment of the protocol or technique factors, including those that affect the digital voxel and pixel size.

Image Noise: Visual noise, a generally undesirable image characteristic, reduces the visibility of low contrast objects and structures. In x-ray and radionuclide imaging it is determined by the concentration of photons captured in the individual digital voxels and pixels. In MRI it depends on the RF signal strength from the individual digital voxels.

Spatial and Geometric Characteristics: Most medical images are produced either by the projection method in

which an x-ray beam is passed through the body projecting an image onto the receptor (radiography and fluoroscopy) or by reconstruction of tomographic images (CT, MRI, SPECT, PET). The major quality issues are the relationship of the areas visible in images to the anatomical regions of interest for specific clinical purposes.

Artifacts: Artifacts, often in the form of streaks, images of things that are not true anatomical structures, "ghosts", and areas of reduced visibility generally are characteristics of each imaging modality. Some artifacts might be related to the digital structure of images but will not be discussed in this article.

V. DIGITAL CONTRAST ENHANCEMENT

One of the major advantages of digital images is the ability to adjust and optimize the contrast for maximum visibility within the various anatomical regions and tissue compositions and characteristics. This is possible because digital image processing can be performed between the acquired and recorded image and the displayed image. This is a distinct advantage over images recorded on film in radiography where the acquired or recorded image is also the displayed image.

Receptor Dynamic Range and Latitude: This is the characteristic of all imaging systems that determines the range of exposure values to the receptor that will result in the recording of the image contrast coming from the human body. Radiographic film has a limited range of exposure over which it can record an image with adequate contrast. This is the film latitude which corresponds to dynamic range for digital receptors. If the exposure to a film is outside the latitude range, that is either under- or over-exposed, contrast will be diminished or completely absent. Digital imaging methods generally have a wide dynamic range over which full image contrast is recorded.

Pixel Bit Depth: Each pixel in an image is recorded as a binary number which is a multiple of the number two such as 4, 8, 16, ……..256, 512, 1024, 2048,4096. This is known as the bit depth of a pixel. It represents the possible number of different values a pixel can have which determined how many brightness levels or shades of gray will be displayed in an image. A high-quality halftone might have as many as 4096 values..

Pixels with an 8-bit depth can have 256 different values or brightness levels. This can be adequate for an image after processing and ready for viewing but does not provide a wide dynamic range for the image receptors or detectors.

A desirable feature is to have a wide dynamic range for the initial images recorded by the receptor in radiography or for the data captured by the detectors as in CT. This is to ensure that the receptors or detector systems capture the full range of exposures that represents contrast coming from the human body. This reduces the possibility of under- or over-exposed images with respect to contrast that can often happen with radiographic film.

Image Processing and Windowing: If an image recorded with a wide-dynamic range receptor is viewed directly it would usually appear with very low contrast, a dull gray image. This is because the range of exposure representing the image contrast is small in respect to the total dynamic range that is being displayed. However, an image for display with optimum contrast for specific clinical procedures can be produced by including one or more forms of digital image processing between the recorded or reconstructed image and the image displayed for viewing as illustrated in Figure 5.

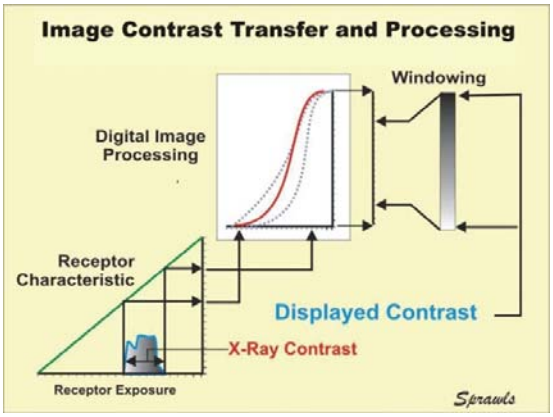

Figure 5. The contrast processing that occurs between the image recorded by the receptor and the displayed image.

In the example shown here the contrast in the x-ray image delivered to the receptor extends over a relatively small segment of the full dynamic range. The important point is that the wide dynamic range does not cut off the contrast, as can happen with film. This provides good image data for processing.

There are usually two things to be achieved with processing.

Look Up Table (LUT) Processing: This gives an image general contrast characteristics that resemble radiographic film. These characteristics are appropriate for specific clinical procedures. This often uses look-up-table (LUT) processing in which pixel values are changed to other values that have been programed in the tables. Different tables are selected to give an image a specific contrast characteristic.

Windowing: The other action is to select a smaller range from within the wide dynamic range to be the displayed in the image. This has the effect of increasing the image contrast. The range that is selected is designated as the *window* and can be adjusted by the person viewing the image. The window level control places the window within the larger dynamic range and the window width control determines the range of pixel values that will be displayed in the image. The width is very much an image contrast

control. Decreasing the window width increases visible contrast in the displayed image.

VI. DIGITAL IMAGE BLURRING AND DETAIL

Visibility of anatomical detail and small objects within a body is limited by the blurring that occurs during the production of an image. There are several sources of blurring within each imaging modality and some of these are adjustable when setting up an imaging procedure. Focal spot size is an example. In radionuclide imaging there is blurring associated with the design of the collimators.

Digitizing an image is a blurring process because all details within a pixel area are blurred together and displayed as one pixel. When viewing a digitized image we see an array or matrix of pixels but cannot see any detail within the individual pixels. In the tomographic imaging modalities the voxels are three-dimensional (3D) blurs. While the digitizing process of dividing the body and imaged area into discrete samples, as previously described, does introduce an additional source of blurring it does not significantly reduce image quality and visibility if the imaging factors are adjusted appropriately and optimized. With respect to selecting voxel and pixel sizes to adjust the blurring there are two relationships that should be considered. One is the relationship of the voxel/pixel blurring compared to the other sources of blur within the imaging process and the other is the effect of voxel/pixel size on image noise. Both of those relationships will now be considered.

Other Sources of Blurring: Within each medical imaging modality and procedure there are several sources of blurring, usually associated with the image acquisition phase, which generally comes before the digitizing process. Those sources are characteristics of each imaging modality (radiography, CT, MRI, etc.) and associated with the equipment design and operating factors. This might be referred to as the pre-sampled blurring or spatial resolution. Here we will not go into the detail for each modality but will consider a representative imaging system illustrated in Figure 6.

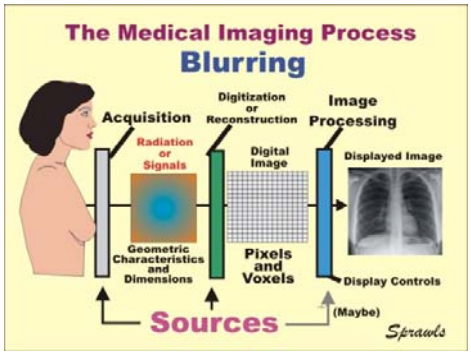

Figure 6. Sources of blurring common to all imaging systems.

Our specific interest here is the blurring introduced by the digitizing process in which the body is divided into individual samples, the voxels and pixels, each one is a blur. The size of the voxels and pixels, and the resulting blurring, can usually be adjusted when setting up the imaging procedure protocol or technique factors. This is by selecting values for the FOV, matrix size, and slice thickness. The question, what is the most appropriate and the optimum voxel and pixel size for a specific procedure?

Comparing Blur for the Imaging Modalities: There is a general range of blur values associated with each imaging method as illustrated in Figure 7.

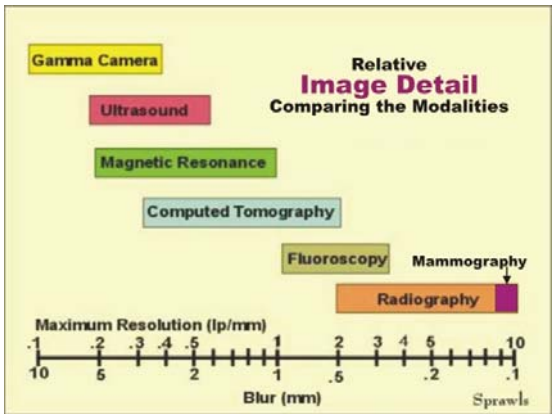

Figure 7. The general range of blur values for each of the imaging modalities.

Each imaging modality is characterized by the limits to the visibility of detail that can be achieved because of the blurring associated with the imaging process. This characteristic is related to and sometimes measured or evaluated in terms of spatial resolution. The general values shown here represent the total or composite blur produced by both the physical design of the equipment (focal spot, detectors, collimators, etc.) and the digitizing process.

Optimum Voxel/Pixel Size: A fundamental question is how should voxel/pixel size be adjusted and matched to the other sources of blur within the imaging process? Should the voxel/pixel size be set to the smallest possible value in order to minimize blurring and give the best visibility of detail? The relationship is illustrated in Figure 8 for radiography but the principle applies to all modalities.

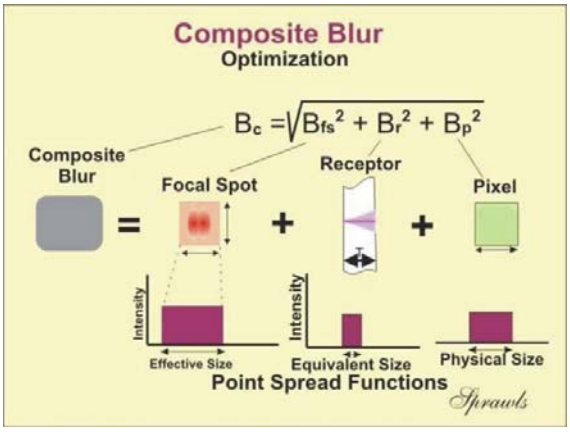

Figure 8. The combining of blur values.

The total blur that occurs during an imaging procedure is the composite, or sum, from all sources. Radiography is illustrated here but the principle applies to all modalities; only the sources of blurring are different. The physical dimensions of a blur are often expressed as point spread functions. Because of the complexity of the shape and intensity distributions blur dimensions are often expressed as "effective" or "equivalent" sizes, which relate to their ultimate image quality characteristics. This corresponds to the actual physical dimensions of voxels and pixels. This approach to analysis in the spatial domain rather than in the frequency domain, which uses modulation transfer functions (MTF), is very helpful for comparing the sources of blur and understanding the process of optimization. A reasonable estimate of the composite or total blur can be calculated using the root mean square as shown rather than the more complex mathematical process of convolution integration.

Our interest here is considering pixel size in relation to other blur values and what an appropriate or optimum pixel size is.

The Smallest Possible Pixels? An initial thought might be that pixels should always be made as small as possible because they are additional sources of blurring in an imaging procedure. As we are about to consider, that is not the best approach. There are several reasons for adjusting pixel and voxel sizes to larger values than what is physically possible with the specific imaging technology.

A major factor is that when pixel size is set to significantly smaller values than the blur from other sources there is diminished improvement in image detail. The blurring from the other sources becomes the controlling factor.

However, with most of the imaging modality the factor that is contradictory to reducing voxel/pixel size is image noise.

VII. DIGITAL IMAGE NOISE

Producing an image in digital form and dividing the body into voxel and pixel samples does not introduce or add noise but is a major factor in controlling the noise coming from other sources within the imaging process. This relationship is illustrated in Figure 9.

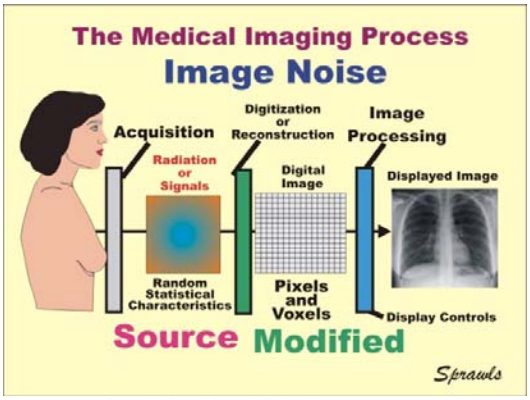

Figure 9. The relationship of digital image structure to the sources of image noise.

Quantum Noise: For both the x-ray and radionuclide imaging modalities the major source of image noise is the random distribution of photons that is captured in each sample (voxel or pixel) to form the images. The noise value, sometimes expressed as the standard deviation of the concentration of captured photons, is inversely related to the photon concentration or receptor exposure. For the digital imaging methods the "critical number" with respect to noise is the number of photons captured in each voxel or pixel as illustrated in Figure 10.

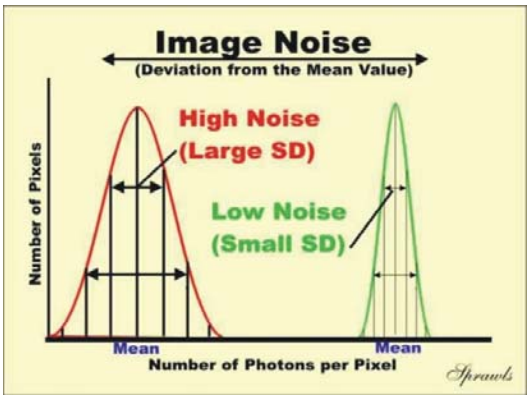

Figure 10. The relationship of image noise to the number of photons per pixel, or receptor exposure.

There are two approaches to decreasing noise by increasing the number of photons per pixel. One is to increase the exposure delivered by the x-ray beam or radionuclide and the other is to increase the size of the

voxels and pixels. Both of these have adverse effects on other factors. The first generally leads to increased radiation dose to the patient and the second contributes to decreased image detail. These are the major factors that require consideration in the process of *optimizing* imaging procedure protocols.

MRI Signal to Noise: Noise is also a limiting factor with MR imaging. Although the source of noise is very different from that with photon imaging, voxel size is also a controlling factor. Since MRI uses RF signals the intensity of the signals, or signal strength, plays a major role in the amount of noise that appears in an image. Noise in an image is decreased by reducing RF noise radiation from the body and by having a stronger RF signal coming from the tissue being imaged, or increasing the signal-to-noise (S/R) ratio. There are several approaches to decreasing the noise component including RF coil design and selection, signal averaging, and the receiver bandwidth adjustment. However, it is the signal strength, not the noise radiation, which is related to voxel size.

Every Voxel is a Signal Source: During the MR imaging process the body is divided into individual voxels. During the acquisition phase of the procedure the combined actions of the slice selection, phase encoding, and frequency encoding gradients give the signals from each voxel unique values so that during the reconstruction phase the signal from a specific voxel is displayed in the corresponding image pixel. The brightness of a pixel relates to the strength of the RF signal from the voxel. Image contrast is produced by the differences in RF signal strengths between the various tissues and anatomical areas. Image noise, however, is determined by the overall or average signal strength throughout the imaged area.

The signal strength is determined by the level of tissue magnetization within each voxel which ultimately depends on the quantity of magnetic nuclei (typically protons) within a voxel. For a specific tissue this is directly determined by voxel size.

When setting up an MR imaging protocol and selecting voxel size, it is a direct control on RF signal strength and the noise that will appear in the image.

Conflicting Requirements: Now we see a problem! Increasing voxel size for the purpose of decreasing image noise can have the adverse effect of increasing image blurring and reducing visibility of detail. That conflict is present in all modalities and methods that produce digital images and is one of the major issues to be considered in optimizing imaging procedures.

VIII. OPTIMIZING DIGITAL IMAGING PROCEDURES

In the process of setting up an imaging procedure protocol and selecting technique factors there are always conflicting requirements. With x-ray and radionuclide procedures there is the need to balance image quality with radiation dose to the patient. With MRI this compares to the general conflict between image quality and the desire for faster image acquisition which has significant clinical advantages.

While setting up an optimized protocol usually begins with the non-digital factors such as adjusting the x-ray spectrum, control of scattered radiation, selecting RF coils in MRI, etc., it often includes the selection and adjustment of voxel and pixel sizes. That is the focus of our attention in this discussion. To help us in visualizing the relationships and communicating with others we will use the analogy of a football game as illustrated in Figure 11.

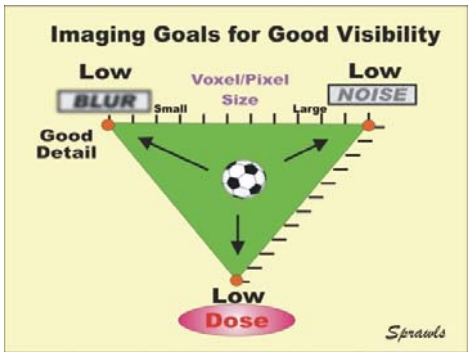

Figure 11. The Conflicting Goals in an Imaging Procedure.

In a football game our team has only one goal to move the ball toward. That makes it simple; just requires skill and much physical effort! In medical imaging it is complex because "our team" has several competing goals as illustrated. Each imaging protocol or set of technique factors is represented by a position of the ball somewhere on the field. By changing factors the ball can be moved closer to one of the desirable goals. The challenge is that as we move closer to one goal we are moving away from the other goals. That is the problem we face in optimizing imaging procedures.

What is Optimum Image Quality? That is a universal question throughout medical imaging. The answer for the most part comes from the combined and shared experiences of medical imaging professionals, especially radiologists, who have determined the image characteristics necessary to provide adequate visibility for the various clinical applications. Physicists contribute by providing knowledge about the specific image quality factors and their relationships to imaging methods and technology.

General image quality requirements along with imaging protocols and techniques for various clinical procedures are part of the "common knowledge" within the practice of radiology and supported by a variety of educational resources and references. While this provides a foundation for imaging there is still the opportunity to more fully optimize imaging procedures for variations in clinical requirements and patient characteristics. That requires an

understanding of the effect of the digitizing process on image quality.

Evaluating Clinical Image Quality: A first step in optimizing digital image quality is to evaluate images that are being produced. This requires consideration of at least the three characteristics, contrast, detail, and noise. The contrast can usually be adjusted as the image is being viewed (by windowing) but detail and noise are typically established during the acquisition and reconstruction of images. Consultation among the radiologists, technologists, and medical physicists can determine if the detail and noise is appropriate or needs to be changed.

Digital Imaging Procedure Optimization: With knowledge of image quality requirements for specific imaging procedures and the evaluation of images that are being produced, the imaging team can engage in the process of "continuing quality improvement" and the balance of image quality with other requirements such as managing radiation dose and image acquisition time.

IX. CONCLUSIONS

The incorporation of digital imaging within the medical imaging modalities provides many advantages and values but also major challenges. The digitizing process has a significant effect on image quality in several respects. Because of the opposing effects, especially between detail and noise, imaging procedures must be optimized for maximum clinical benefit.

The ultimate value of digital imaging in medicine will be obtained only when these concepts and practices are included in education and training programs for radiologists, technologists, medical physicists, and engineers.

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PRACTICAL AND APPLIED MEDICAL PHYSICS

CLINICAL COMPARISON OF DENSITY CORRECTION METHODS ASSOCIATED WITH PENCIL BEAM CONVOLUTION ALGORITHM FOR CLINICAL SITUATIONS

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Abstract- **Purpose: the aim of this work was to quantify and assess the differences in dose computed using density correction methods integrated into the Pencil Beam Convolution (PBC) algorithm for planning target volumes and organs at risk. Methods and materials: 12 patients including 7 chest cancers, 2 head and neck cancers, 2 brain cancers and 1 prostate cancer were analysed. For each patient, 3 treatment plans were generated using exactly the same beam configurations. For plans 1, 2 and 3 the dose was calculated using Modified Batho method (PBC-MB), Batho Power Law method (PBC-BPL) and Equivalent Tissue Air Ratio method (PBC-ETAR), respectively. To evaluate the treatment plans, the monitor units, isodose curves, dose volume histograms, quality indexes and gamma indexes were compared. A statistical analysis was performed using the Wilcoxon signed rank test. Results: the difference in monitor units using PBC-BPL was 1.6% (SD : 2.5) for lung and less than 1% for head and neck, brain and prostate. This difference was less than 1% for all sites using PBC-ETAR. The Wilcoxon test showed a statistically significant difference between PBC-MB and PBC-BPL only for chest ($p < 0.01$). There was a statistically significant difference between PBC-MB and PBC-ETAR for chest ($p = 0.02$), head and neck ($p = 0.02$) and brain ($p = 0.02$). For dose volume histograms the difference between density correction methods was less than 1.1%. Wilcoxon test showed only a significant difference for minimum dose using PBC-BPL. The three density correction methods showed similar quality ($p > 0.05$). 2D gamma analysis showed all pixels with gamma ≤ 1. Conclusion: the density correction methods based on 1D using PBC-BPL and PBC-MB produced a dose distribution close to PBC-ETAR which calculates the density correction in 3D. Therefore, we propose the use of the Modified Batho method to calculate the delivered dose.**

Key words: **density correction, PBC, Modified Batho, Batho Power Law, Equivalent TAR**

I. INTRODUCTION

The aim of radiotherapy is to deliver the prescribed dose to the tumour with a minimum dose to the surrounding healthy tissues. The International Commission on Radiation Units and Measurements (ICRU report No. 50, 1993 and report No. 62, 1999) recommends the dose to be delivered should be within ± 5% of the prescribed dose [1,2]. The dose calculation can be performed using different algorithms. These algorithms play a key role in treatment planning systems (TPS). The TPS Eclipse® (Version 8.1; Varian Medical Systems, Palo Alto, CA) incorporates the Pencil Beam Convolution (PBC) algorithm. The PBC algorithm includes three density correction methods for dose calculation in order to take into account the heterogeneity of tissues. The objective of this study was to compare the different density correction methods implemented in the PBC algorithm in terms of their ability to calculate the delivered dose in Monitor Units (MUs) and the dose distribution under a variety of clinical situations.

II. MATERIAL AND METHODS

A. Dose calculation algorithm

In this study, the dose calculation was performed using the PBC algorithm incorporated in the Eclipse® TPS. The PBC algorithm is based on a pencil beam kernel convolution and computes the dose to the patient as the superposition of the total energy released per mass unit within an energy deposition kernel. The kernel represents the spread of energy from the primary photon interaction site throughout the volume. To model the heterogeneity, the kernels vary with electron density based on the electron

density scaling theorem. Heterogeneity corrections are always based on relative electron densities obtained from a CT-Scan. Calculations with density correction were performed using three density correction methods: Batho Power Law (PBC-BPL), Modified Batho (PBC-MB) and Equivalent Tissue Air Ratio (PBC-ETAR). This process involved two stages: first, a relative dose distribution was calculated within a medium of homogeneous water–equivalent composition, and then an Inhomogeneity Correction Factor (ICF) was added. This factor makes adjustments to the uncorrected distribution to account for variations in tissue density [3,4,5,6,7,8]. The ICF is thus defined as:

ICF= Dose in heterogeneous medium divided by Dose at the same point in homogenous medium (1)

Batho Power Law method: this method was proposed by Batho in 1964 and then generalized by Sontag and Cunningham. It calculates the density distribution in one dimension 1D. The correction factor is given by:

$$ICF = \prod_{m=1}^{m=N} TAR(X_m)^{(\rho_m-\rho_{m-1})/\rho_0 (\mu_{en}/\rho)_N/(\mu_{en}/\rho)_W} \quad (2)$$

Where: N is the number of layers of different densities above the point of calculation, m: layer number, X_m: distance from point of interest to the surface of the m^{th} layer. ρ_m and ρ_0 are the electron densities of the m^{th} layer and that of water, respectively. $(\mu_{en}/\rho)_N$ and $(\mu_{en}/\rho)_w$ are the mass energy absorption coefficients of the material in layer N and that of water, respectively.

Modified Batho method: this method is based on the Tissue Maximum Ratio (TMR) and calculates the density distribution in 1D. The correction factor is given by:

$$ICF = (\mu_{en}/\rho)_N/(\mu_{en}/\rho)_W \prod_{m=1}^{N} (TMR(z-z_m+z_{bu}))^{(\mu_m-\mu_{m-1})/\mu_w} \quad (3)$$

where μ_m and μ_w are the linear attenuation coefficients of the material in layer m and water respectively; Z_{bu} is the build-up depth and Z_m is the distance along the beam from the surface to the layer m in the phantom.

Equivalent Tissue Air Ratio method: this method calculates the density distribution in 3D and uses full CT information to account for scattered radiation. It uses the Tissue Air Ratio **(**TAR) dependent on the effective beam radius ($\tilde{r}$) to take account of scattered radiation and effective depth (d') for primary beam correction. The correction factor is given by:

$$ICF = \frac{TAR\ (d', \tilde{r})}{TAR\ (d, r)} \quad (4)$$

where $d', \tilde{r}$: are the effective values of depth (d) and beam radius (r) respectively.

B. Treatment plan design

For each patient, 3 treatment plans were generated using exactly the same configuration of beams, collimator and accessories. The doses in plans 1, 2 and 3 were calculated using PBC-MB, PBC-BPL and PBC-ETAR, respectively. In all plans, the dose was prescribed at a single reference point, as recommended by ICRU. The dose using PBC-MB was taken as the reference plan and was the one used to treat the patients. The reference treatment plans were designed according to the clinical experience of the department and ICRU recommendations. For the Planning Target Volume (PTV), 95% of the prescribed dose encompassed the volume and the maximum dose within the PTV was under 107% of the prescribed dose. For organs at risk (OAR), the recommended dose constraints were respected.

C. Clinical cases

This study included 12 patients presenting a wide range of tumor types and cancer sites: 7 chests, 2 head and neck, 2 brains and 1 prostate. These patients were irradiated using 3D- Conformal Radiation Therapy. Table 1 shows the tumor location, the number of PTV, the total prescribed dose (Gy), and the number of fields and energies (MV) for each patient.

Table 1 The tumor location, PTV number, total prescribed dose, number of treatment fields and energies for each patient.

Patient	Site	PTV	Dose (Gy)	Fields	Energy MV
1	Chest	2	66	6	18
2	Chest	3	66	14	18
3	Chest	3	70	10	18
4	Chest	2	60	9	18
5	Chest	2	60	12	18
6	Chest	2	54	8	18
7	Chest	2	90	6	6
8	Head and neck	3	60.7	12	6
9	Head and neck	3	72	12	6
10	Brain	1	36	5	6
11	Brain	1	40.5	4	18 and 9
12	Prostate	2	70	10	18

D. Treatment plan evaluation

Dosimetric analysis: in order to evaluate the treatment plans, the following dosimetric parameters were used and compared:

MUs: for each patient and each field the MUs calculated using PBC-MB, PBC-BPL and PBC-ETAR in plan 1, 2 and 3 were compared.

Isodose curves: the 95% and 100% isodose curves inside the PTVs were compared.

Dose volume histogram (DVH): for each PTV, minimum dose, mean dose and maximum dose as well as the

calculated dose delivered to 95% of the PTV (D95) were compared.

Quality index: we used the Conformity Index (CI) defined as the ratio of the minimum dose encompassing the PTV to the prescribed dose, to compare the plan conformity. We used the Homogeneity Index (HI), defined as the ratio of the maximum dose to the PTV to the prescribed dose, to compare the homogeneity dose for PTV. The PTV Conformity Index (CI_{PTV}), defined as the PTV volume receiving more than 95% of the prescribed dose divided by the PTV volume, was used to compare the degree of conformity of the prescribed dose. We used the geometrical index (g) to compare the geometric conformity to PTV and normal tissues, where $g = (V_{PTV} + V_{NT}) / PTV$ volumes. V_{PTV} designates the PTV volumes receiving a dose less than 100% of the prescribed dose. V_{NT} are the normal tissue volumes receiving 100% of the prescribed dose [9,10].

Global analysis: the gamma index was introduced by Low et al [11]. In this study, a 2D gamma index was used to compare the dose distribution using the CT-Scan image including PTV and the OAR. The DICOM image for each patient was exported from TPS Eclipse® to RIT-113® (Radiation Dosimetry Systems, Version 5.2). The matrix center was aligned with the isocenter. The dimensions used were 20x20cm². For this study, the gamma criterion was set at 3% for the dose and 3mm for the "Distance to Agreement". The 2D gamma analysis was displayed using a gamma plot and gamma pixel histogram indicating the fraction of pixels with a gamma index equal or below a specific value. A mean value of gamma ≤ 1 indicates agreement between dose distributions. We considered that the dose distribution using PBC-MB agreed with the dose distribution calculated with PBC-BPL or PBC-ETAR if 95% of pixels had gamma ≤ 1.

Statistical analysis: Wilcoxon signed rank test was used to assess the statistical significance of differences. Language R® (version 2.15.2/2012-10-26) was employed to calculate *p*-values with an alpha error equal to 5%. A *p*-value < 0.05 was considered as statistically significant. Data are presented as Mean ± Standard Deviation (SD).

III. Results

MUs: Table 2 summarizes the dosimetric and statistical results for the MUs. It can be seen that the Wilcoxon test showed a statistically significant difference between PBC-MB and PBC-BPL only for the chest. The comparison between PBC-MB and PBC-ETAR showed that the difference was statistically significant for chest, head and neck, and brain. Figure 1 shows the beams distribution as a function of difference in MUs (%) for all fields.

Table 2 Dose difference in MUs between PBC-MB and PBC-BPL or PBC-ETAR for plans 1, 2 and 3; *p*-value: using Wilcoxon signed rank test; SD: Standard Deviation.

Patient	MB *vs* BPL		MB *vs* ETAR	
	Mean ±SD	*p*-value	Mean ±SD	*p*-value
Chest	1.6±2.5	< 0.01	0.2±2.1	0.03
Head and neck	0.1±1.1	0.5	0.7±1.4	0.02
Brain	0.4±0.6	0.2	0.6±1.2	0.02
Prostate	0.2±1.1	0.7	0.1±0.7	1

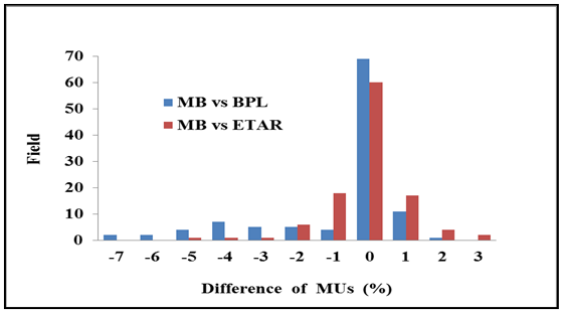

Fig. 1 Beam distribution as a function of difference in MU for all fields.

Isodose curves: there was no hot spot either in normal tissues or within the PTV in any treatment plan. In the transverse plan, we found that the 95% line calculated by the three density correction methods included the whole PTV whatever its location. There was no difference in the 100% isodose curves. Figure 2 shows the transverse views of isodose distribution curves for plan 1, 2 and 3 with heterogeneity correction.

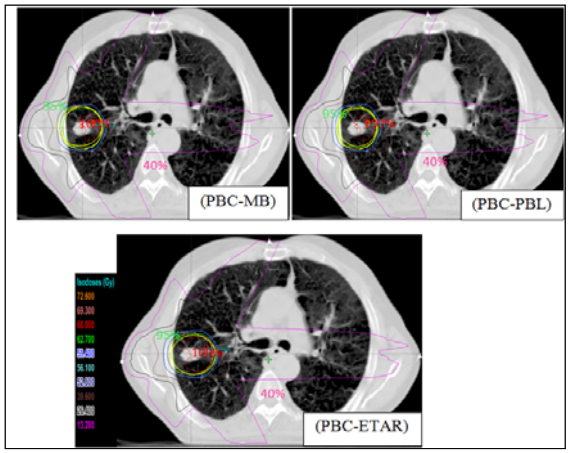

Fig. 2 Transverse views of isodose distribution curves for plan 1, 2 and 3 using density correction methods: PBC-MB, PBC-BPL and PBC-ETAR, respectively. A dose of 66Gy was prescribed at isocenter for lung in plans 1, 2 and 3. Yellow colouring shows the PTV. Red, green and orange colouring show100%, 95% and 40% isodose curves, respectively.

DVH: Table 3 summarizes the dosimetric and statistical results for PTV. It can be seen that the difference between PBC-MB and PBC-BPL was less than 1.1%, but the

difference between PBC-MB and PBC-ETAR was less than 0.6% for all sites. Figure 3 shows the DVH for lung using the three density correction methods.

Table 3 Dose volume parameters for planning target volume for all patients. D95: the calculated dose delivered to 95% of the PTV volume; *p*-value: Wilcoxon signed rank test; SD: Standard Deviation.

Plans	Dose	Minimum dose	Mean dose	D95	Maximum dose
BPL	Mean ±SD	1.1±1.2	0.1±0.7	0.9±2.3	0.6±1.1
	p-value	0.001	0.4	0.06	0.05
ETAR	Mean ±SD	0±2.6	0.2±1.1	0.5±1.7	0.6±1.2
	p-value	0.43	0.1	0.6	0.1

Quality indexes: Table 4 summarizes the quality indexes for all patients using the three density correction methods. A Wilcoxon test showed that there was no statistically significant difference between all indexes, ($p > 0.05$).

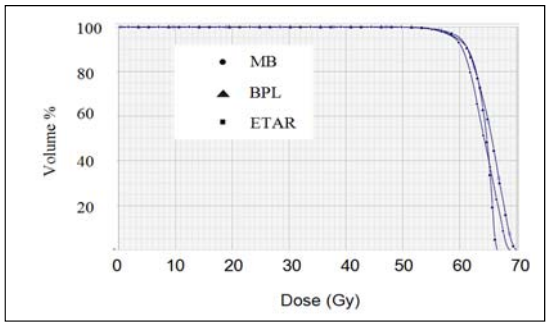

Fig. 3 Cumulative dose volume histograms for PTV located in lung. The histograms were calculated by PBC- MB, PBC-BPL and PBC-ETAR for plans 1, 2 and 3 respectively.

Table 4 Quality index for all patients using PBC-MB, PBC-BPL and PBC-ETAR for plans 1, 2 and 3 respectively. CI: Conformity Index; HI: Homogeneity Index; CI_{PTV}: Conformity Index for planning target volume and g: geometrical index; *p*-value: Wilcoxon signed rank test; SD: Standard Deviation.

	Index	CI	HI	CI_{PTV}	g
MB	Mean ±SD	0.8±0.2	1.1±0.04	0.8±0.2	0.2±0.2
BPL	Mean ±SD	0.8±0.2	1.1±0.04	0.8±0.2	0.2±0.2
	p-value	1	0.3	0.2	0.2
ETAR	Mean ±SD	0.8±0.2	1.1±0.04	0.8±0.2	0.2±0.2
	p-value	1	0.09	0.6	0.05

Global analysis: 2D gamma analysis showed that the mean values of gamma were less than unity using PBC-BPL and PBC-ETAR, compared to PBC-MB. The results for the gamma pixel histograms showed that the 95% of pixels had gamma ≤ 1 using the set criteria (3%, 3mm). Figure 4 shows 2D gamma plots in the traverse plane, comparing PBC-MB with PBC-BPL and PBC-ETAR for chest cancer. The gamma plot was calculated in 2D using DICOM images including the PTV and OAR. The rectangles in figure 4 show the PTV and the red shading indicates that gamma values were unity (outside tolerance limits). We note a small area with gamma >1 using PBC-BPL, but using PBC-ETAR all pixels had gamma <1. Figure 5 shows the 2D gamma pixel histograms obtained from the comparison between PBC-MB and PBC-BPL and PBC-ETAR for chest cancer. In this case we note that the condition of 95% of pixels with gamma ≤ 1 is satisfied.

IV. Discussion

There is a wide variety in the algorithms used to apply density corrections. The report of Task Group No.65 of the Radiation Therapy Committee of the American Association of Physicists in Medicine has classified the density correction methods into two general categories according to:

- the description of the density correction (1D or 3D)
- the inclusion or exclusion of electron transport

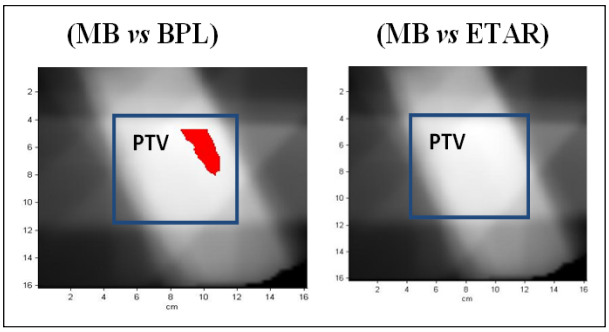

Fig. 4 gamma plot in 2D comparing PBC-MB with PBC-BPL, and with PBC-ETAR for chest cancer. The gamma plot was calculated in 2D using DICOM images including the PTV and OAR. We note that there was a small area with gamma >1 in the PTV using PBC-BPL, but all pixels had gamma <1 using PBC-ETAR.

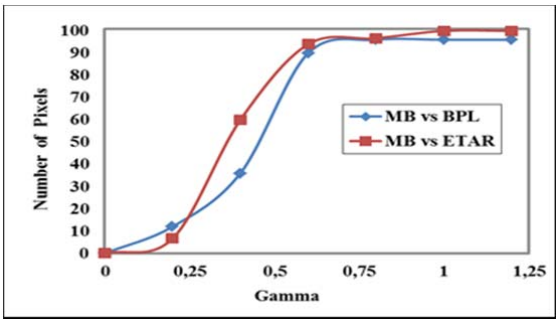

Fig.5 Gamma pixels histograms in 2D obtained from the comparison between PBC-MB with PBC-BPL and PBC-ETAR for chest cancer. In this case we note that the condition of 95% of pixels with gamma ≤ 1 is satisfied.

In this study three density correction methods that are frequently integrated into the PBC algorithm were used. None of these methods take into account the changes in lateral electron transport. The modified Batho method is based on an empirical correction factor that uses TMR and calculates the dose in 1D. The Batho Power Law method applies a correction factor using TAR and calculates the dose in 1D. The ETAR method calculates the dose in 3D. In this study for simple heterogeneous tissues such as head and neck, brain and prostate, there was no statistically significant difference between MU results for PBC-MB and PBC-BPL, but the difference was highly significant for chest ($p < 0.01$). This suggests that the low density nature of lung tissue influences the dose distribution. Using the PBC-ETAR method the difference was statistically significant for chest, head and neck and brain. For tumors located in high density tissues such as the prostate the three density correction methods calculated the same MUs, ($p = 1$). The inaccuracy between the density correction methods is due to the nature of the correction factor, which influences the dose calculation. However, all three methods showed the same quality indexes for all clinical cases, as shown in Table 4. The global analysis, based on 2D gamma, showed that the three density correction methods calculated the same dose distribution for each patient including PTV and OAR. In all cases the mean values of gamma were less than unity and 95% of pixels had gamma ≤ 1. We observed that the PBC-MB method currently offers the best compromise between under dosage and over dosage for PTV. Therefore, in our department we propose this method to calculate the dose for all cancers whatever the site.

V. Conclusion

In this study we compared the density correction method PBC-MB with PBC-BPL and with PBC-ETAR. We generated 3 treatment plans for 12 patients presenting a wide range of tumor types and sites. The inaccuracy between density correction methods was 1.6% for MUs and 1% for DVH. However, the methods showed similar quality indexes ($p > 0.05$). We propose that the Modified Batho method PBC-MB is used to calculate the delivered dose.

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Conflict of Interest : None

DESIGN AND IMPLEMENTATION OF A NEW DEVICE FOR THE INTEGRAL MEASUREMENT OF TOTAL SOURCE-ON TIME FOR A HIGH DOSE RATE (HDR) REMOTE AFTER LOADING TREATMENT UNIT

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Abstract— **Most treatment units that utilize a radioactive source are equipped with a timer that measures the source-on interval; however, independent verification of the accuracy of this internal timer for each treatment is part of a comprehensive QA program. Design and implementation of a new device used to automatically measure the total integral time that a radioactive source spends outside the safe will be presented. Most radiation therapy rooms have installed a radiation detector unit operating independent of the radiation producing device. One wall mounted sample of such device is a simple Geiger Muller (GM) counter known as the "PrimAlert-35" made by Nuclear AssociatesTM that will illuminate when placed in radiation field. Using a digital timer known as "Veeder Root TimerTM" connected to the auxiliary output of a PrimAlert-35, we were able to visualize the signal on an oscilloscope screen and determine that is was a step function. We also found that auxiliary output is a 200 millisecond pulse when in alarm condition, and the timer could not track the pulse because of the oscillation of the signal. A circuit was then designed and added to the PrimAlert-35 unit to stretch the 200 ms pulse so that it appears to be a non-pulsing signal at a constant DC level. This allowed us to measure the time interval for as long as the PrimAlert-35 was active. This is an equivalent time for the source being out of the safe. Our timer can be utilized to enhance the quality assurance program necessary for the safe implementation of an HDR brachytherapy or Co-60 teletherapy program.**

Keywords— **Quality Assurance, Teletherapy, Brachytherapy, Radioactive Sources.**

I. INTRODUCTION

In the past few decades high dose rate (HDR) brachytherapy has become a significant modality in the treatment of cancer. HDR sources are capable of delivering high doses of radiation in very short time and hence, from the radiation safety point of view, are a cause of concern for radiation oncologists, physicists and staff. The high activity of the source requires a very precise timing system for accurate dose delivery.

Dose is delivered to the patient by dwelling the source at set locations for specific amounts of time. Dwell times are calculated by complex radiation treatment planning systems (TPS) for a set number of dwell positions determined from 3-dimensional imaging. For the accurate delivery of treatment, the HDR is equipped with a redundant set of timers that measure and monitor the total time that the radiation source sits in each of the dwell positions, as well as the total treatment time. The HDR room is also equipped with a Gamma area monitor, which alerts staff if radiation level exceeds a certain limit. This function is very important since it assists in identifying the status of source position: whether the source is in or out of the safe. A comprehensive HDR quality assurance program necessarily must establish and follow proper definitions of clinical and machine parameters [1,2], one of the most important being the accuracy of the total treatment time. Yet most clinics will verify the timer accuracy by hand with a stopwatch, a method prone to subjective error. In this article, we present the design and implementation of a timer device that gives the integral "source-on-time" and its implementation as part of our HDR QA program. This device when added to the Gamma monitor "PrimAlert-35", measures the time for which the source of radiation is outside the shielded area, hence providing an independent method to monitor the active "source-on-time". This additional measurement will also serves as a double check on the total treatment time given by the HDR planning system. Such a timing system can also be used to verify the source-on-time for Co-60 teletherapy systems in developing countries or utilized in new emerging technologies, such as MR-RT machines.

II. METHODS AND MATERIALS

Measurements were made using our Varian HDR unit (iX) and a commercial simple Geiger Muller (GM) counter (Figure 1) known as the "PrimAlert-35" manufactured by Fluke BiomedicalTM. The PrimAlert-35 is a compact G-M counter monitor that responds to scatter radiation and can be mounted anywhere inside of the treatment vault. It is implemented in high radiation areas as an independent monitor of ambient radiation levels. A visual indicator light illuminates when the measured radiation level reaches a certain threshold. It has a range indicator at 1, 2, 4, 8, 16, and 32 mR/hr that allows an immediate assessment of the radiation risk. The light for each level goes on when the radiation intensity reaches that level, and goes out when the rate drops below the level. If the alarm threshold is set to the highest sensitivity, it will trigger the indicators at radiation levels

of about 5 times the background level, approximately 0.02 mR/hr.

The circuit diagram of the PrimAlert-35 is relatively simple and operates using a 12VDC power supply. The timer's input signal can easily be taken from the output of this detector unit.

Figure 1. Sample image of a PrimAlert-35 G-M Radiation Detector

For the purpose of this project, we designed a circuit diagram depicted in Figure 2 with simple plug-in at the output of the PrimAlert-35 device, to start a timer exactly concurrent with the triggering of the PrimAlert-35. Of all radiation detector types, the G-M counter produces signals of the same amplitude as soon as finds radiation present, regardless of strength of radiation source in the area. At the instant the detector is activated via presence of a source, the timer turns on and remains on as long as the detector remains active. Because of the high activity of the source, this means that the timer activates almost immediately after it has been deployed from the safe, and measures the time it takes for the source to return.

The total time the source was out of the safe was measured manually with a stopwatch and with the automated timer circuit. The stopwatch was activated as close as possible to when the PrimeAlert alarm was activated. The dwell position was set to 100 cm from the afterloader and the dwell times were set to span the range of clinically relevant treatment dwell times.

III. Results

A series of measurements (Table 1) were made using the new PrimAlert-35 device with the additional timer circuit attached. These measurements were checked against the internal timer of the HDR unit, a manual stop watch used to measure the radiation on-time from the control console, and the auto timer from the circuit diagram shown in figure 2 located in the patient treatment room. The dwell location was 100 cm from the afterloader. The contribution from transit time has been subtracted from both measurements

IV. Discussion

As shown in Table 1, the ability of the timer circuit to accurately measure the dwell time is comparable to manual timing. The timing circuit averages a higher deviation by approximately 0.2 seconds, which may be caused by the configuration of the pulsed circuit as it operates on a 0.2 s period step-function. The anticipated transit time effect does not appear to have a large influence on the timing results. The manufacturer cites the transit speed of the source between 50-60 cm/s, with an average of 55 cm/s [3]. This should introduce ~3.8 – 4 s worth of transit time exposure over the course of 100 cm from the safe to target and back to safe. The timing circuit is also accurate over the relevant clinical ranges and shows a high degree of reproducibility

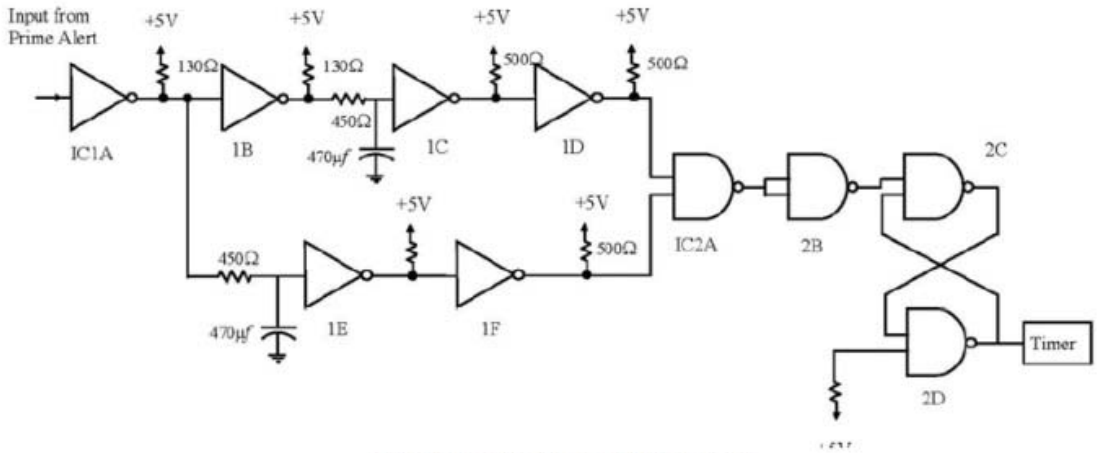

Figure 2. Diagram of automated timing circuit

The timer can also be used as an independent verification of the total source exposure time for patients treated with HDR brachytherapy or Co-60 teletherapy. The transit time for each patient's HDR plan can be quickly subtracted off with minimal effort. Obviously, teletherapy treatments will not have the added complexity of incorporating transit time.

The automated timer can also be used for efficient and objective daily and monthly timer tests, simplifying the process of these QA tests.

V. Conclusions

We developed a method to obtain automatically the period of radiation on-time for the HDR I-192 source using a specially designed timer circuit. By this method, we could quantitatively measure the total time the source is out of the safe. This timer can be implemented as part of a rigorous QA program for HDR brachytherapy or Co-60 teletherapy units in an effort to reduce the susceptibility of measurement bias introduced by human involvement. The timer results can also be utilized as an independent validation of each patient treatment. This circuit can be integrated into the in-room radiation monitor. Our timer circuit is a simple and cost-effective method to provide independent verification of timer systems utilized in modern radiation therapy.

Table 1 Comparison of manually measured and automatically measured time of source exposure. Manual measurements were performed using a stopwatch for total source-out time. Automated timer measurements were generated by the PrimAlert timer circuit. Transit time was subtracted assuming 50 cm/s transit speed to a dwell position at 100 cm. All units are in seconds.

Computed Dwell Time	Manual Timer	Automated Timer with Transit Time	Automated Timer without Transit Time
10	11.5	13.3	9.6
30	31.6	36.0	32
50	52.4	55.5	51.5
70	71.2	76.1	72.1
90	90.6	95.8	91.8
120	120.2	125.1	121.1
150	151.0	155.9	150.9
200	201.1	204.8	200.8

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TUTORIALS

A REVIEW OF DIGITAL BREAST TOMOSYNTHESIS

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Abstract— **While the principle of tomosynthesis has been known for almost a century, digital breast tomosynthesis (DBT) is a novel technology that owes its rapid development to the introduction of full-field digital mammography (FFDM). This review article covers the principles and design considerations of DBT, including system geometry. Further, the article provides an in-depth introduction to DBT dosimetry, and discusses recent studies on several breast imaging applications, which highlight the potential for clinical performance improvements due to DBT.**

Keywords— **Tomosynthesis, breast imaging, mammography, breast cancer**

I. Introduction

For the past decades, x-ray projection imaging of the breast, also known as mammography, has been the workhorse of the breast-imaging suite. Mammography is the recommended breast-cancer screening tool for most women. Breast cancer screening with mammography is estimated to account for about half of the 24% reduction in breast cancer mortality achieved between 1975 and 2000 [1]. A screening mammography exam consists of two anatomic projections along the cranio-caudal (CC) and mediolateral-oblique (MLO) directions for each breast.

Diagnostic mammography is the primary problem-solving tool for breast abnormalities. Its uses include the work-up of screen-detected findings, or the short-term follow-up of probably benign lesions, with a 31.4% positive predictive value for biopsy recommendations [2].

Despite these successes, mammography is limited by tissue superimposition. Overlaying dense tissues can mask tumors, potentially leading to a missed cancer. Furthermore, overlapping structures can mimic the appearance of a tumor and thereby cause a false-positive recall or biopsy. Tomosynthesis imaging has the potential to overcome these limitations by adding depth resolution to a mammogram [3–6]. In tomosynthesis, a sequence of projection views is acquired while the x-ray source travels along an arc. The projections are then reconstructed into a quasi-three-dimensional image volume. Conceptually, tomosynthesis could be considered a limited-angle CT scan.

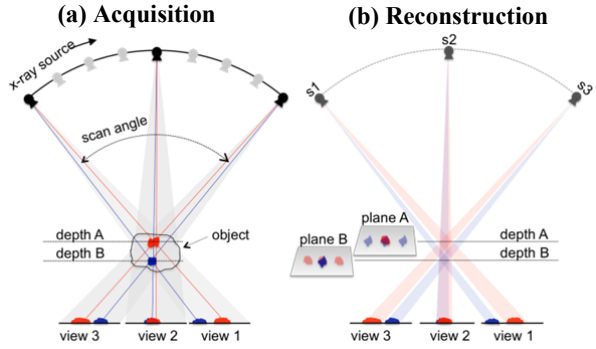

Fig. 1 (a) Tomosynthesis data acquisition and (b) shift-and-add image reconstruction. In this schematic, three source positions (s1-s3) are shown, while in an actual DBT unit, the number of projection views ranges between ~10 and 30 (see Table 1).

Tomosynthesis data acquisition and image reconstruction are shown schematically in Fig. 1. Within the object to be imaged, two structures are located at different depths, indicated by depth A and depth B (Fig. 1a). In each projection view, the x-ray source angle is different and therefore structures at different depths are projected onto different locations. Figure 1b shows an example of shift-and-add reconstruction: A reconstructed plane at a given depth in the object is obtained by adding all projection views. Depending on the imaging geometry, the projections are shifted and minified prior to summation. As seen in the reconstructed (i.e., tomosynthesis) planes A and B, the structure that is actually located at the corresponding depth is in-focus,

whereas the structure above or below is blurred. Thus, each reconstructed tomosynthesis plane contains image information from the entire object. This is different from a CT image, where structures outside the reconstructed image plane are removed entirely.

The principle of tomosynthesis was demonstrated as early as 1932 by Ziedses des Plantes [7]. Film-based clinical prototypes were built in the 1970s-1980s [8,9]. Digital breast tomosynthesis (DBT) was pioneered in the 1990s by Niklason, Kopans and colleagues [10,11], owing to advances in large-area flat-panel detector technologies [12]. Originally, these detectors were developed for use in full-field digital mammography (FFDM), which received approval by the Food and Drug Administration of the United States (FDA) in 2000. Piggybacking on these technological advances, digital breast tomosynthesis received FDA approval for use in breast cancer screening and diagnosis merely a decade later.

II. Image characteristics

The overall image appearance of a DBT image is similar to that of a conventional mammogram. Figures 2 and 3 show examples of benign and malignant breast masses imaged with mammography and tomosynthesis.

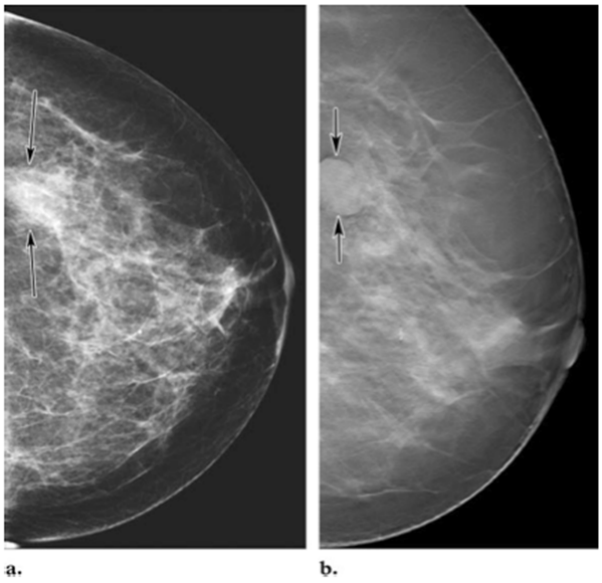

Fig. 2 (a) Mammogram and (b) tomosynthesis image of a benign breast mass (arrows) demonstrating enhanced visibility in the latter. Reproduced, with permission, from Park JM, Franken EA, Garg M, Fajardo, LL, Niklason, LT. Breast tomosynthesis: Present considerations and future applications. Radiographics, 2007, vol 27 Suppl. 1, pages S231–40.

The smooth margin of the benign mass in Fig. 2 is difficult to perceive in the mammogram because of overlaying densities that are projected onto the same location in the image. In the tomosynthesis image, the sharp lesion margin is clearly visualized, as confounding out-of-plane structures are removed (i.e., blurred).

In Figure 3, the tomosynthesis image reveals ductal infiltration by the cancer, which is not seen in the mammogram due to masking by overlapping fibroglandular tissue.

Thus, tomosynthesis potentially depicts benign lesions more clearly, decreasing recall rates, and reveals breast lesions that are not seen in a mammogram, thereby increasing breast cancer detection rates.

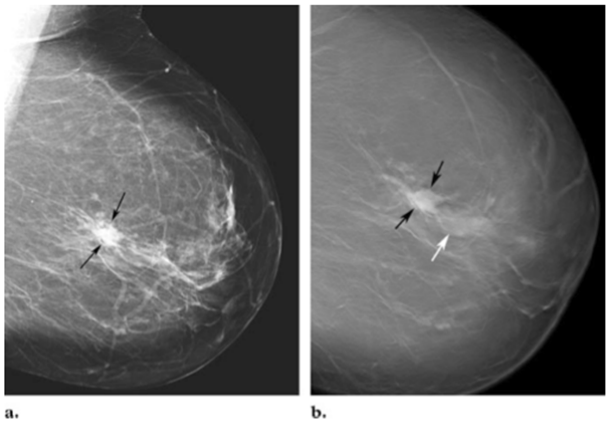

Fig. 3 (a) Mammogram and (b) tomosynthesis image of a malignant breast tumor (DCIS). Note the ductal extension of the cancer, seen only on tomosynthesis (white arrow). Reproduced, with permission, from Park JM, Franken EA, Garg M, Fajardo, LL, Niklason, LT. Breast tomosynthesis: Present considerations and future applications. Radiographics, 2007, vol 27 Suppl. 1, pages S231–40.

The spatial resolution of a tomosynthesis image volume is highly anisotropic. In planes parallel to the detector surface, resolution approximates that obtained by mammography, while depth resolution is poor. Due to the limited angle scan, depth resolution depends both on the scan angle (α) and the extent of an object along the scan direction. As a rule of thumb, an object of extent (x) persist across a depth (d) of about

$$d = x/\tan(\alpha/2) \quad (1)$$

Thus, depth resolution is better for small structures, i.e., microcalcifications typically only persist across a few tomosynthesis planes. Due to the highly anisotropic image volume, typical voxel dimensions in tomosynthesis are 100 μm x100 μm in-plane, and 1mm in-depth.

III. System design considerations

A large number of factors need to be considered when designing a DBT system. The basic components are

similar to those of a mammography system, such as the x-ray source and, for most systems, the flat-panel digital detector. Therefore, a DBT system can typically also be used for the acquisition of a conventional projection mammogram. In fact, the standard imaging protocol of the Hologic Selenia Dimensions system is to first acquire a FFDM, and then to retract the anti-scatter grid to perform a tomosynthesis scan, all while the breast is under compression. The total dose of this combined 2D + 3D imaging protocol is below the MQSA limit of 3 mGy per view when imaging the mammographic accreditation phantom.

However, actual requirements for tomosynthesis differ from those of a mammography system, and many represent trade-offs:

X-ray beam quality and gantry motion DBT systems tend to use higher x-ray tube potentials than what is used in FFDM, but with a relatively low-Z filter. Overall this produces x-ray beams with a lower effective energy, but allows for more efficient x-ray tube operation. [13]. The x-ray gantry for most tomosynthesis systems travels along an arc (for an in-depth discussion, see [3,14]). While the gantry moves, the x-ray beam can be continuously "on", or pulsed. Other systems employ a step-and-shoot operation (Table 1). The advantage of step-and-shoot over a continuous beam is the elimination of focal spot motion blur in the projection image. On the other hand, the overall acquisition time in a step-and-shoot system tends to be longer, making the system more susceptible to patient motion.

In most DBT systems, no anti-scatter grid is used because the source-detector geometry is different in each projection view. In some systems, the source-detector configuration remains constant during the scan [15]. This particular system has minimal scatter because it employs a slit-scanning photon counting detector. The GE SenoClaire is advertised to use an anti-scatter grid, but the actual implementation is proprietary.

X-ray detector The dose-dependence of the detector DQE is important in tomosynthesis systems, as the exposure to the detector per projection is at least an order of magnitude lower than that in FFDM [16]. Since electronic noise is independent of the detector entrance exposure, it can exceed quantum noise levels and reduce detection efficiency. In addition, temporal detector performance, such as lag and ghosting, needs to be considered. Electronic readout time should be below that of the overall scan time, and is sometimes reduced by pixel binning. In principle, photon-counting detectors are well suited for tomosynthesis because they do not exhibit electronic noise and have excellent temporal performance. Additionally, photon-counting detectors perform well in low count-rate applications, such as tomosynthesis [17,18]. Therefore, the Philips (Sectra) prototype DBT system uses a photon counting detector. Detectors for tomosynthesis are discussed in detail in [19].

Scan parameters The choice of the scan angle, and to a lesser amount the choice of number of views, greatly affect image quality of the tomosynthesis image. A number of investigators have studied the impact of these parameters on the detection performance over a range of signal sizes [20–24]. Consensus was found that increasing the scan angle increases the detectability of tumor-sized objects (~1cm diameter), while small scan angles improve detection of small-scale signals, such as microcalcifications and spiculations (Fig. 4). Current commercial DBT systems and prototypes utilize a wide variety of scan parameters (Table 1). The optimal parameter choice for DBT will likely depend on the physical factors of the system components, as well as the image reconstruction algorithm used. The clinical application may play a role as well.

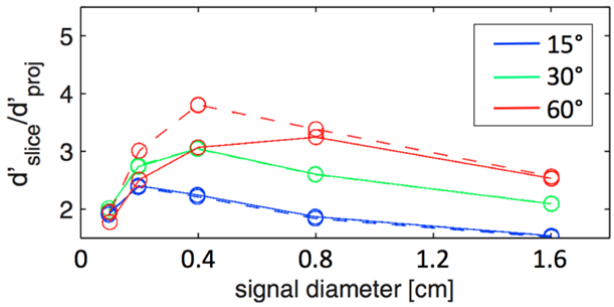

Fig. 4 Ratio of detectability index for a spherical signal in a DBT slice to that in a single projection, when an equal number of photons is used to acquire the tomosynthesis scan or the single projection, for scan angles of 15, 30 and 60, and 11 views (solid line) and 21 views (dashed line). These data are the result of a tomosynthesis simulation that assumed an ideal system, without degradation due to physical factors such as limited x-ray detection efficiency or detector blur. Details of the simulation can be found in [25] .

Image reconstruction The image reconstruction algorithm strongly affects the image quality in tomosynthesis imaging [26–28]. Early systems made use of modified filtered-back projection algorithms.

Table 1 Design parameters of commercial tomosynthesis units.

Model	scan angle (deg)	# of views	x-ray operation	scan time (sec)	Reconstruction algorithm
Hologic Selenia Dimensions*	15	15	continuous (pulsed)	4.5	FBP-based
Siemens MAMMOMAT Inspiration**	50	25	continuous (pulsed)	20	FBP-based
Giotto**	40	13	step-and-shoot with variable dose/view		iterative
GE SenoClaire**	24	9	step-and-shoot	7-10	iterative (ASIR)

* Approved for breast cancer screening and diagnosis by the Food and Drug Administration of the United States (US)

** CE mark

The appeal of this algorithm lies in its simplicity and short reconstruction time, but it can produce artifacts when the view sampling is sparse. Additional filtering is typically used to improve its performance in tomosynthesis [29,30]. Some DBT systems employ iterative reconstruction algorithms, which are better suited to reconstructions from limited angle, few-view projections (see Table 1) [28,31–33].

IV. Radiation dosimetry

In gross terms, the breast is composed of three types of tissue: glandular, adipose and skin. Since the risk of development of breast cancer in adipose tissue is minimal, breast radiation dosimetry is concerned only with the dose deposited in the glandular tissue of the breast. Therefore, since it was proposed by Hammerstein et al in 1979 [34], the metric of choice to estimate dose in x-ray breast imaging is the *mean glandular dose* (MGD, sometimes also referred to as the *average glandular dose* [AGD]), which means the absorbed dose to all the glandular tissue of the breast in the field of view. It is important to note that in breast imaging, due to the use of x rays of relatively low energy, the variation in the glandular dose deposited in different regions of the same breast during one acquisition can vary considerably with tissue depth [34–36].

One complicating factor for estimating the MGD is that although glandular tissue tends to be concentrated towards the center of the breast, the amount and spatial distribution of glandular and adipose tissue in a breast is random, and can vary widely among women. To avoid this complication, Hammerstein et al proposed that, for comparison purposes among techniques, the MGD be estimated assuming that the breast is composed of a homogeneous mixture of adipose and glandular tissue surrounded by a layer of skin [34]. Of course, since this definition of the breast tissue is not representative of any patient breast, Hammerstein et al stated that risk estimates should not be made from MGD. Recent studies have shown that using MGD to a homogeneous breast as an estimate of absorbed dose to the glandular tissue portion of an actual patient's breast can result in large errors [37,38]. For two reasons, however, the use of the MGD with the homogeneous breast assumption has become the *de facto* standard in breast dosimetry. In the first place, it is very challenging to estimate the actual MGD to an actual patient breast considering its real tissue distribution. In addition, for most applications having a relative, rather than an absolute, dose estimate is sufficient. Specifically, for quality control and assurance, technique optimization and comparison of imaging technologies, having a metric that correlates with risk and is relatively easy to estimate is not only sufficient, but desirable. Therefore, the MGD and how it varies with patient and imaging system characteristics has been studied extensively in mammography [39–44].

Of course, these studies do not actually provide and analyze values for MGD, but rather for its normalized version, the *normalized glandular dose* (D_gN). This metric is simply the MGD normalized by the air kerma (or exposure) at the top surface of the breast (on the side where the x rays are incident). The D_gN can be thought of as the conversion factor from entrance air kerma to MGD. From the studies of D_gN in mammography it is known that this conversion factor is a function of breast thickness, glandular density and x-ray spectrum [39–44]. In DBT, the impact on D_gN of a new acquisition parameter, the projection angle, was studied by Sechopoulos et al [45,46]. In those studies, the authors found that the impact of the projection angle on D_gN varies only with breast thickness and size, and is mostly independent of glandular density and x-ray spectrum. Therefore, Sechopoulos et al proposed that for calculation of MGD in DBT imaging, the D_gN data for mammography could be used with the addition of a new factor, the *relative glandular dose* (RGD), which introduces the variation in D_gN due to the variation in position of the x-ray tube during tomosynthesis acquisition. Therefore, the RGD was defined as:

$$RGD(\alpha) = \frac{\mathrm{D}_g\mathrm{N}(\alpha)}{\mathrm{D}_g\mathrm{N}(0°)} \quad (2)$$

where α is the tomosynthesis projection angle. As is apparent, $D_gN(0°)$ is equivalent to the mammographic D_gN for the equivalent acquisition parameters (breast characteristics and x-ray spectrum). With this definition of RGD, the MGD for a complete tomosynthesis acquisition can be estimated using:

$$MGD = ESAK_0 \cdot DgN_0 \cdot \sum_N RGD(\alpha) \quad (3)$$

where $ESAK_0$ is the entrance surface air kerma for the zero-degree projection (equivalent to the mammography acquisition geometry), D_gN_0 is the mammographic D_gN conversion factor, and the sum of RGD is over all N projection angles included in the tomosynthesis acquisition. This equation can be re-written as:

$$MGD = ESAK_0 \cdot DgN_0 \cdot N \cdot \overline{RGD} \quad (4)$$

where, as before, N is the number of projections included in the tomosynthesis acquisition and $\overline{\mathrm{RGD}}$ is the mean of all N RGDs for the projection angles involved in the tomosynthesis acquisition. Since, as mentioned, RGD is independent of breast density and x-ray spectrum, for a specific tomosynthesis system, and therefore for a known distribution of projection angles, $\overline{\mathrm{RGD}}$ for each specific breast thickness can be

calculated beforehand and provided in a table. Sechopoulos et al [45,46] provided tables for D_gN_0 and fit equations for RGD for breast tomosynthesis imaging in the CC and MLO views. The upcoming Report of Task Group 223 of the American Association of Physicists in Medicine (in print) will provide RGD values for a generic tomosynthesis system and the $\overline{RGD}$ values for a number of commercial and advanced prototype tomosynthesis systems using as a basis the Wu et al model for mammography breast dosimetry commonly used in the US [40,41].

Similar modifications to the mammography breast dosimetry model developed by Dance et al and used in the United Kingdom, Europe and by the International Atomic Energy Agency [39,43,47] were made for DBT, as described by Dance et al [48]. In that nomenclature, RGD is replaced by t, while $\overline{RGD}$ is replaced by T, but their definition is equivalent. In this work, Dance et al provide values for t and T for generic systems and values for T for three currently commercial and advanced prototype DBT systems [48]. Additional tabular values for normalized glandular dose for x-ray tubes with tungsten targets were provided by Ma et al [49]. Ma et al also studied how these values vary with varying positioning of the breast on the detector, finding that this can cause a variation in dose of up to 13%.

All the above publications that studied and provided values for D_gN and RGD (or t and T) allow for the calculation of MGD for breast tomosynthesis for a given acquisition condition. They do not, however, provide information on the radiation dose involved in tomosynthesis acquisition in absolute terms, and therefore do not provide the information necessary to compare the actual glandular dose used in DBT to that used in other modalities, such as conventional mammography. To obtain dose values in absolute terms and be able to compare the dose involved in DBT with other breast imaging modalities, it is necessary to characterize the ESAK used by the imaging system to acquire an image. Of course, in a clinical system this value will depend on the settings of the automatic exposure control (AEC), which will vary the tube voltage and the tube current-exposure time product (and in some systems the additional filter) depending on the imaged breast characteristics. Typically, the compressed breast thickness is used to set the tube voltage, while the breast glandular density is probed with a low-dose scout image to set the tube current-exposure time product. Depending on the AEC system, it may also vary the tube voltage based on the results of the scout image. Given this variation in acquisition parameters with breast characteristics, to be able to study the MGD in tomosynthesis it is necessary to characterize the AEC system behavior. For this, Feng and Sechopoulos used custom-made homogeneous breast phantoms of varying thickness and equivalent breast density to probe the acquisition settings used by a commercial DBT system to acquire both tomosynthesis and mammography images [50]. Using an ion chamber and a dosimeter they were able to obtain ESAK values for the range of equivalent breasts investigated, and, in combination with these values, Monte Carlo-based D_gN_0 and RGD values were used to estimate MGD for these breasts. The authors found that in the majority of cases the MGD from tomosynthesis was higher than that for mammographic acquisition, and that for an average breast defined as 5 cm thick with 50% glandular density the increase was minimal (8%). However, for a newer definition of an average breast (6 cm thick and ~15% glandular density), the difference was larger (83%). It was also found that given the advances in system technology, the overall MGD for a combined mammography/tomosynthesis study is similar to that used for digital mammography alone just a few years earlier on previous generation systems [51]. The Feng and Sechopoulos study was exclusively breast phantom-based, and, as the authors suggested, it is of interest to compare MGD estimates for mammography and DBT based on acquisition parameters used for a large number of actual patients, data that was not available at the time. In the same year, Strudley et al reported on quality control procedures used during the TOMMY trial, a multi-site patient trial performed in the United Kingdom [52]. These tests included estimation of the MGD used by the Hologic Selenia Dimensions systems used in this trial for different breast equivalent phantoms, and they found similar relationships between mammography and tomosynthesis MGD as those reported by Feng and Sechopoulos [50].

In the first study using patient data to characterize MGD in tomosynthesis, Dance et al tested the appropriateness of the tomosynthesis dosimetry model proposed for the European guidelines discussed above by comparing the MGD estimates following the proposed protocol with polymethyl methacrylate (PMMA) phantoms to those obtained when imaging a total of 541 patients with two different commercial DBT systems [53]. The authors found that the use of the phantoms resulted in a reasonable estimate of MGD for patients (of course, still assuming the homogeneous tissue mixture approximation). In addition, they found a relationship between mammography and tomosynthesis MGD similar to that previously reported by Feng and Sechopoulos and Strudley et al.

Cavagnetto et al also studied the entrance surface air kerma and MGD from mammography and tomosynthesis, using the UK/IAEA breast dosimetry model and data on the image acquisition parameters selected by the AEC system during acquisition of 300 patient mammography and tomosynthesis combined exams with a commercial system [54]. The authors found similar increases in MGD when comparing the tomosynthesis to the mammography acquisitions as those reported by Feng and Sechopoulos

and Strudley et al using phantoms and Dance et al using patient data. In addition to this comparison, in the same study, Cavagnetto et al investigated the feasibility of using metal oxide semiconductor field effect transistor (MOSFET) dosimeters to measure ESAK in real time during combined acquisition of a mammography and tomosynthesis exam for each patient. The authors found that the use of such detectors is feasible, but that for low tube current-exposure time products, such as those used for compressed breast thicknesses below 30 mm, the measurement noise results in higher-than-desirable uncertainties in the measurement. However, the authors point out that this would typically affect only about 2% of the population of compressed breasts.

In the initial commercial implementation of DBT in the United States, the acquisition of a complete breast screening exam included the acquisition of both a standard 2D mammogram and the tomosynthesis projections. This resulted in an increase in the glandular dose from screening as reflected in the works discussed above. More recently, the introduction of a "synthetic" mammogram, as discussed below [55], eliminates the need to acquire the mammogram in addition to the tomosynthesis projections, substantially reducing the dose involved in screening with DBT.

To aid in the estimation of MGD for DBT acquisitions, especially during testing for quality assurance and/or control in the clinical realm, Li et al compiled the data presented in tabular form from the various studies discussed above [37,39,43,45–47,50] and from the quality control manual of a commercial DBT system [56] and performed various parameterizations of the different models [57]. This allowed the authors to provide easy-to-use electronic spreadsheets that permit the user to enter the appropriate inputs (e.g. breast thickness, tube voltage), with the spreadsheet providing the value of the corresponding factor (e.g. D_gN in the case of the US-based data or g, c, s, and t factors for the UK/IAEA data). This avoids the need for the user to perform any interpolation of results from tabular data.

Finally, the introduction of non-normal incidence of x-rays during tomosynthesis acquisition can necessitate modifications to the AEC behavior testing during dosimetry quality assurance and control procedures. To address this, Bouwman et al [58,59] have introduced a new set of phantoms, based on PMMA and polyethylene (PE) slabs of varying thicknesses. These are equivalent to the set of "standard breasts" [43] used in the European Guidelines for quality assurance in breast cancer screening and diagnosis [60] but resolve the possible issues encountered in tomosynthesis with the previous methodology.

V. Clinical studies

In 2007, initial studies by Poplack et al. and Rafferty et al. found breast lesions to be more conspicuous on DBT than on conventional mammograms [61,62]. Subsequently, several reader studies used enriched datasets (i.e., a mix of patient cases in which the cancer prevalence is higher than in a screening population) to investigate the diagnostic performance of DBT. Based on 125 patient cases, 35 of which had verified breast cancer, Gur et al. found a 30% reduction in recall rate when combining mammography with DBT, compared to mammography alone [63]. In this early study, no benefit in sensitivity was found. Gennaro et al compared single-view DBT (MLO) to two-view mammography. Based on images from 200 patients with at least one breast lesion, she concluded that DBT performance was not inferior to mammography [64]. Svahn et al. found higher sensitivity for single-view DBT, compared to two-view FFDM, without significant changes in specificity [65].

Breast cancer screening with DBT Subsequent larger studies on screening populations corroborated the findings of increased sensitivity and reduced recall rate. After introducing routine screening with DBT to their practice, Rose et al report a reduction of recall rate from 8.7% to 5.5%, based on 13856 women screened with mammography and 9499 women screened with mammography plus tomosynthesis [66]. In a retrospective study that reviewed screening mammograms from 13158 women and screening mammography plus tomosynthesis from 6100 women, Haas and colleagues found a 30% decrease in recall rate in women screened with mammography alone (12.0%), compared to women screened with mammography plus tomosynthesis (8.4%) [67]. The cancer detection rate was greater for mammography plus tomosynthesis than for mammography alone, but the difference was not statistically significant. A decrease in recall rate was observed for all breast densities, with statistical significance for all densities except for predominantly fatty, which is the breast density for which mammography sensitivity is highest [68]. Likely, the difference in cancer detection rate failed to reach significance because of the relatively smaller number of cancers compared to the number of recalls, which requires a larger number of women participating in a study.

Skaane et al. reported interim results of a prospective screening study (i.e., the Oslo tomosynthesis screening trial), which included 12631 women that were screened within a timeframe of roughly one year. A 31% increase in cancer detection rate for mammography plus tomosynthesis (8.0/1000) was found, compared to mammography alone (6.1/1000) [69]. The false positive rate for mammography plus tomosynthesis was 5.31%, a 13% reduction compared to that for mammography alone (6.11%). This more modest reduction in recall rate in

comparison to the study by Rose et al and Haas et al may be due to differences in cancer screening strategies in Europe and the United States [70]. However, this interim analysis also found that the mean interpretation time doubled, from an average of 45 sec for mammography alone to about 90 sec for mammography plus DBT.

Diagnostic imaging with DBT Hakim et al. performed a preference study comparing DBT with additional mammographic views [71]. In 81% of the cases, combined FFDM and DBT was perceived to be equal or better for diagnosis. This study did not include cases with microcalcifications alone. The workup of screening recalls with DBT was investigated by Brandt et al., who found that assessment with DBT was highly correlated with that of clinical work-up with additional mammographic views, in a cohort of 146 women with abnormalities (excluding calcifications) [72]. Zuley et al. found that diagnostic performance in terms of area under the ROC curve (AUC) improved significantly when DBT was used instead of additional mammographic views, based on 182 cases that included 217 noncalcified lesions [73].

Comparing DBT alone with FFDM and FFDM plus DBT, Thibault et al. and Gennaro et al. were able to show non-inferiority of DBT alone, using patient data from a GE prototype [64,74]. Foernvik and colleagues found DBT alone to be more accurate for the assessment of lesion size than FFDM, significantly improving the accuracy of tumor staging [75]. Actual lesion sizes were verified by ultrasound imaging, and DBT imaging was performed with a Siemens system. Mun et al. found similar improvements with a GE DBT prototype [76].

Visualization of microcalcifications with DBT Spangler and colleagues performed an investigation of microcalcification imaging with DBT [77]. Their study included 100 cases with 60 microcalcification clusters (40 benign, 20 malignant). The remaining 40 cases were normal. The four standard mammographic views, i.e., CC and MLO images of both breasts, were available for both FFDM and DBT. Patient cases were acquired using the Hologic Selenia Dimensions DBT system. Microcalcification detection sensitivity was higher with FFDM. This finding held for all microcalcifications, as well as for both benign and malignant clusters individually. For calcification clusters that were detected on both modalities, the difference in AUC in the task of distinguishing benign from malignant clusters was not statistically significant. Note that the tomosynthesis display did allow for "slab-viewing".

On the other hand, Kopans et al report that conspicuity of microcalcifications was equal to or better than FFDM in 92% of 119 sequential cases with calcifications [78]. The patient images used in this study were acquired on a GE prototype unit, at a dose equivalent to that of two screen-film mammograms.

These apparently inconsistent findings could be due to differences in study design – the first study being an ROC study, whereas the latter study was a subjective preference study. Furthermore, patient data for the studies was collected on different DBT units, operated at different dose levels, and, perhaps importantly, with different scanning modes (i.e. continuous pulsed vs. step-and-shoot). Further research is needed to clarify whether DBT image quality is sufficient for microcalcification imaging.

VI. Practical considerations

One view or two view DBT? Since DBT is a tomographic modality, presumably a single DBT view might provide sufficient depth information, so that a second DBT view might not be needed.

Anderson et al. investigated the detection of subtle breast masses with DBT in a small study that included 44 cancers in 37 breasts, using a Siemens prototype DBT system [79]. For each breast, a single-view DBT scan as well as two-view mammograms were available. 22 masses were more visible on DBT than single-view mammography, and the BIRADS score of 21 masses was upgraded. In comparison with two-view mammography, 11 masses were more visible on DBT, and BIRADS scores of 12 masses were upgraded. Wallis et al. compared two-view mammography with one or two-view DBT, using the SECTRA microdose DBT system [80]. Improvement was found for two-view DBT, but not for single-view DBT. In two studies using patient data acquired on a GE prototype, both Gennaro et al. and Thibault et al. found that single-view DBT was not inferior to two-view FFDM [74,81].

Synthetic 2D The original FDA-approved imaging sequence of the Hologic Selenia Dimensions unit consisted of the acquisition of a conventional FFDM image, followed by the DBT scan. In order to reduce patient dose, Hologic introduced the use of a *synthetic 2D* image to replace the FFDM acquisition. This synthetic *2D* image is generated from the tomosynthesis dataset, making the acquisition of the conventional mammogram obsolete, and thereby reducing radiation dose substantially. The "synthetic 2D" image is processed to emphasize suspicious structures in individual DBT slices, rather than to approximate a mammographic projection. In 2013, the FDA approved the replacement of the FFDM image from the combined FFDM-tomosynthesis exam with a synthetic 2D.

Two recent studies by Skaane et al. and Zuley et al. report similar performance when readers used FFDM or synthetic 2D [82,83]. With an earlier version of the synthetic 2D, Gur et al. found a slight decrease in cancer detection sensitivity, but no change in recall rate [55].

A method to generate synthetic 2D images that enhance lesion characteristics is described by Schie et al [84]. Note that this is not the algorithm used by Hologic. The use of synthetic 2D may also prove useful for comparison with prior mammograms or DBT images.

Reading time Several studies report significant increases in reading time with DBT [63,85,86]. Given the low prevalence of breast cancer in screening populations with about 5 cancers per 1000 screening exams, longer reading times will reduce the cost-effectiveness of breast cancer screening. Computer-aided detection schemes may potentially help offset the reduction in productivity [87–90].

VII. CONCLUSIONS

DBT is an emerging tomographic modality for breast imaging that may potentially replace conventional projection mammography both for breast cancer screening and diagnosis. Current clinical studies are promising and indicate the potential for increased cancer detection sensitivity and reduced recall rates. However, several issues need to be addressed to better integrate DBT into the clinical environment, such as the development of efficient viewing strategies. Further, if DBT is to replace FFDM, its clinical performance in lesions with microcalcifications needs to be ascertained and possibly improved.

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ANNOUNCEMENTS

PUBLICATION OF DOCTORAL THESIS AND DISSERTATION ABSTRACTS

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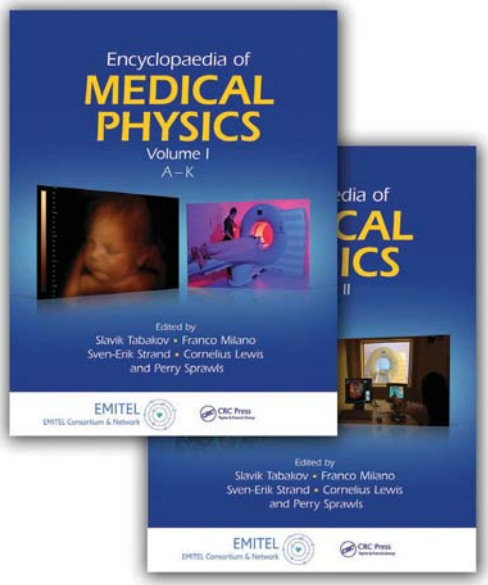

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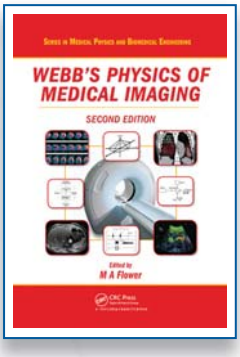

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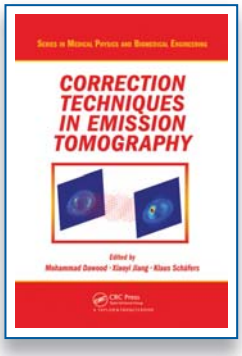

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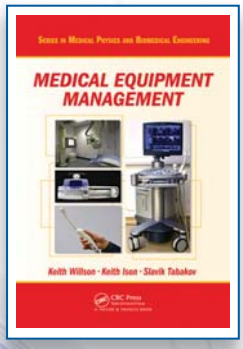

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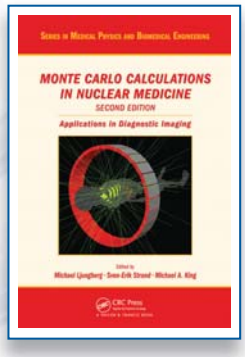

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WELCOME

Dear colleagues,

Welcome to this issue of the journal that contains abstracts of papers and invited talks presented in the International Conference on Radiation Protection in Medicine organized by the Roentgen Foundation-Bulgaria, in partnership with the National Centre of Radiobiology and Radiation Protection at the Ministry of Health, Bulgarian Society of Biomedical Physics and Engineering, Bulgarian Association of Radiology, Bulgarian Nuclear Regulatory Authority and Medical University in Varna. The conference is supported by a number of international and professional organizations.

The conference has 46 invited presentations, 82 oral papers and 246 posters. This issue contains abstracts of these presentations.

In view of controversies surrounding the radiation effects at level of couple of CT scans, it was deemed appropriate to have a plenary session on this topic with eminent speakers from the field of radiation biology and epidemiology besides those involved in radiation risks assessment as a result of exposure of children through CT scan. Another plenary session has been devoted to communication of risks where those on fore-front like referring physicians have been invited along with patients organization representatives and those communicating risks through website.

Will newer technologies lead to safer imaging and what developments are needed and are on horizon is another issue that is going to be debated by experts and manufacturers.

Clinical decision support systems that have potential to reduce unnecessary examinations and increase level of appropriateness is going to be deliberated actively. Tracking of examinations and radiation dose is an issue that hold great potential for improving patient protection. A session with experts who have worked for many years on this topic and have experience in day-to-day practice of tracking shall shed light on this emerging topic.

International organizations and professional bodies have important role in improving patient protection and two sessions are allocated to representatives of these organization to inform participants about on-going actions besides highlighting their accomplishments.

Protection issues for patients and staff in interventional procedures are drawing interest and they have been provided important slots with many papers showing result of work in many countries.

A number of educational sessions are going to deal with topics like facility design and shielding, how to use CT equipment for appropriate image quality and lowest dose, regulatory inspections and patient dosimetry.

The motto of the conference is “Facing increasing challenges”, and the conference program deals with areas that highlights issues and throws challenges to professional community to meet them.

The serene surroundings of Black Sea coast provide unique opportunity to develop ideas and strategies to deal with challenges.

We hope that this issue of the journal will provide food for thought in this very important area of radiation protection.

Madan Rehani
Chair of the Scientific Program Committee

Jenia Vassileva
Chair of the Organising Committee


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	epidemiological studies?	
S2B.O3	On the estimations of radiation induced cancer risks from very low doses of radiation and how to communicate about these risks	S. Mattsson, M. Nilsson
S2B.O4	Knowledge on radiation exposure for commonly prescribed tests amongst junior doctors in a north Indian referral hospital	R. Guleria, J. Kumar, N. Agarwal, et al.
S2B.O5	The WHO-IRQN referral guidelines project-preliminary results of a pilot exercise	L. Lau, M. Kawooya, M. Reed, et al.
S2B.O6	Russian guidance on radiological support for justification of radiodiagnostic examinations	M. Balonov, V. Golikov, S. Sarycheva, et al.
S2B.O7	Justification of CT scans using referral guidelines for imaging	G. Stanescu, G. Rosca-Fartat, D. Stanescu
S2B.O8	Dose tracking and radiology department management	G.Kirova, E. Georgiev, C. Zasheva
S2B.O9	Cost-risk-benefit analysis in diagnostic radiology and its relevance to radiation protection	B. M. Moores
Posters		
S2B.P1	Study for ionizing radiation safety awareness among patients in Erbil hospitals	Runak ali, Qasim ali, Safa Hamed
S2B.P2	Comparison of the radiation protection activity, by examine the prevention of radiation induced micronucleus formation of N-acetyl–L-cysteine, trimethylglycine and their combined action in human lymphocytes	G. Racheva, M. Alyakov
S2B.P3	Risk of cancer associated with multiple CT scans	A. N. Menyaylo, V. V. Kashcheev, S. Yu. Chekin, et al.

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S3A.I2	Dose surveys and DRLs: critical look and way forward	M. Rehani
S3A.I3	Collective effective dose in Europe from x-ray and nuclear medicine procedures	R. Bly, A. Jahnen, H. Järvinen, H. Olerud, J. Vassileva, S. Vogiatzi
S3A.O1	Analysis of the factors correlating with medical radiological examination frequencies	A. Jahnen, H. Järvinen, H. Olerud, et al.
S3A.O2	Indication based national diagnostic reference levels (DRL) for paediatric CT: a new approach with proposed values	H. Järvinen, R. Seuri, M. Kortesniemi, et al.
S3A.O3	Comparison between diagnostic reference levels by anatomy and clinical indication	P. Charnock, AF. Dunn, K. Flintham, et al.
S3A.O4	Entrance surface air kerma in X-ray systems for paediatric interventional cardiology. A national survey	C. Ubeda, E. Vano, P. Miranda, et al.
S3A.O5	Pediatric doses in Russia and the possibility of DRL application	I. Shatskiy, V. Golikov
S3A.O6	Establishment of national diagnostic reference levels in diagnostic radiology in the Czech	L. Novák, J. Uhlíř, P. Papírník, et al.

	Republic	
S3A.O7	Establishment of diagnostic reference levels in CT: First experience in Algeria	A. Merad, N. Khelassi-Toutaoui, A. Toutaoui et al.
Posters		
S3A.P1	Diagnostic reference levels in interventional radiology. a spanish programme (ERRAPRI)	R. Ruiz-Cruces, E. Vano, M. Perez-Martinez, et al.
S3A.P2	Indication-based diagnostic reference levels for adult CT-examinations in Finland	A. Lajunen
S3A.P3	Diagnostic reference levels for dental panoramic radiography	G. Manousaridis, C. Koukorava, C. J. Hourdakis, et al.
S3A.P4	Local typical doses as a tool for optimization of x-ray procedures	M. Kaneva, Sv.Iankova
S3A.P5	Local diagnostic reference level for brain computed tomography scan in Nigeria	I. Garba, P. Engel-hills, F. Davidson, AM. Tabari
S3A.P6	Contribution to the estimation of population doses from CT and mammography examinations in Slovakia	D. Salat, D. Nikodemova, A. Salatova
S3A.P7	Romanian medical exposure to ionizing radiation in 2012	O. Girjoaba, A. Cucu
S3A.P8	Trends in examination frequency and population dose from medical X-ray examinations in Sudan, 2010	I.I. Suliman, S.B. Ibraheem, B.E.Youssif, et al.
S3A.P9	Evaluation of collective effective dose of Ukrainian population due to X-Ray diagnostic examinations	L. Stadnyk, O. Nosyk, O. Shalopa
S3A.P10	Establishing Reference Levels for Computed Tomography Procedures in Kenya	G.K. Korir, J.S. Wambani, A.M. Tries
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S3A.P14	Monitoring medical radiation exposure in the Netherlands	D. Valk, I. R. de Waard - Schalkx
S3A.P15	Establishment of dose reference level for pediatric patients in computed tomography in Sudan	A. Sulieman

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S3B.O2	Clinical implementation of a protocol for 3D IMRT quality assurance	GR. Gueorguiev, C. Cotter, JC. Turcotte, et al.
S3B.O3	New method for estimation of fluence complexity in IMRT fields	T. Hanušová, V. Vondráček, K. Badraoui-Čuprová
S3B.O4	Photoneutron shielding in a medical accelerator room	Y. N. Kim, G .H. Kim, S. K. Kim, et al.

S3B.O5	Be aware of neutrons outside short mazes for 10 MV facilities	S. Brockstedt, H. Holstein, L. Jakobsson, et al.
S3B.O6	Protecting a CT simulation room to accommodate a cyberknife facility	M E. Sheridan, M. Martin, S. Khalil, et al.
S3B.O7	An assessment of dose fractionation effect on the level of radiation induced bystander effect in normal cell line	M.T. Bahreyni Toossi, SH. Solimanifard, R. Kamran Samani, SH. Mohebbi
Posters		
S3B.P1	The place of postoperative radiotherapy in the complex treatment approach of advanced paranasal melanoma. Is local tumor control achievable without radiation – induced demyelinising syndrome?	L. Marinova, I. Mihaylova, I. Tzenev, et al.
S3B.P2	Protective, elective lung irradiation in non-metastatic Ewing's sarcoma	L. Marinova, I. Hristozova, I. Mihaylova, P. Perenovska
S3B.P3	Demonstrate occupational radiation protection at radiation therapy of B.P.Koirala memorial cancer hospital (BPKMCH) in Bharatpur, Nepal	P.P.Chaurasia, S.B. Chand Bharatpur
S3B.P4	Optimizing delineation accuracy of tumours in PET for radiotherapy planning using blind deconvolution	A. Guvenis, A. Koc
S3B.P5	Evaluation of excess dose to the skin due to using thermoplastic mask in radiotherapy patients	Mohamad Bagher. Tavakoli H., Kyvan. Jabari, Hosein. Saberi
S3B.P6	The effect of energy spectrum change on DNA damage in and out of field in 6MV photon beams	Ahad Ollah. Ezzati
S3B.P7	Investigation of dose variation with minor displacement in high dose rate brachytherapy	MH. Hyvarinen, SP. Pella, ND. Dumitru, et al.
S3B.P8	A comparison study on optimization results Eclipse versus Branlab on SBRT lung plans	BD. Doozan, SP. Pella, M. Stephens, TC. Constantino
S3B.P9	Development of dose evaluation program for 4-dimensional radiotherapy	YN. Kim, SK. Kim, KK. Jeong, SH. Park
S3B.P10	Risks of lung fibrosis and pneumonitis using electron beams for postmastectomy radiotherapy	H. B. Omer, A. Sulieman, K. Alzimami
S3B.P11	Optimization treatment of anal canal cancer using high dose rate(HDR) brachytherapy	YH. Herrassi, SJ. Jebbari

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PLENARY SESSION 1.

RADIATION EFFECTS AND RISKS


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PL1.1

RADIATION EFFECTS AND RISK: DEFINING ISSUES

M. Rehani

Consultant, International Atomic Energy Agency, Vienna, Austria

How much, if any, are carcinogenic risks of a CT scan is a debatable issue. There may be better understanding when exposure through several CT scans is involved. But in backdrop of reports estimating number of cancers likely to occur as a result of CT examination of children, there is responsibility on our part to provide clear picture and guidance to professional colleagues and to public. There are clear-cut issues that need to be debated and these are:1. To provide clarification of level of radiation exposure to human where carcinogenic effects are certain and where they are not, at what level extrapolation is the only way and at what level there is weak but agreeable acceptance. 2. Despite agreement, what is the basis for controversy as observed in recent years. 3. To understand the results and limitations from 3 major pediatric CT scientific studies on childhood exposures published recently 4. How to deal with accumulated doses from CT exposures over a period of time? 5. Linear no threshold (LNT) theory may be scientifically agreeable, but is it appropriate to use it for estimation of number of cancers from CT scans. Is it appropriate to use it for communication of risks with patients? 6. How to deal with issues where we partially know? 7. To understand successful strategies used in risk communication. 8. How to communicate and how to be an effective communicator with patients, parents, and media about ionizing radiation. The presentation shall deal with issues that are of contemporary interest.

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PL1.2

RESULTS FROM EPIDEMIOLOGY ABOUT CANCER RISKS AT LOW DOSES

D. Laurier

Institute for Radiological Protection and Nuclear Safety (IRSN), Fontenay-aux-Rose, France

The quantification of risks associated to low levels of exposure to ionizing radiation is one of the main issues for radiation protection. Improving the characterization of the shape of the dose response relationship for low doses and low dose rates has been identified as a major challenge for radiation research in the next decades. The presentation will review the current results from epidemiology at low dose and low dose rate (less than a few hundred mSv). Studies conducted among populations with either occupational, medical or environmental exposures will be considered, with a specific focus on children. Expected impact of ongoing researches will be discussed.

PL1.3

RADIATION EFFECTS AT LEVEL OF FEW CTS

A. Berrington

National Cancer Institute, USA

Computed tomography (CT) imaging is a valuable diagnostic tool, and new clinical applications continue to be identified. As a result the rates of CT scan use have increased rapidly in the US and elsewhere, particularly in the last ten years. Whilst the immediate benefit to the individual patient can be substantial, the relatively high radiation doses associated with CT, compared to conventional radiography, have raised potential health concerns. Children are known to be more radiosensitive than adults and in the past they received higher doses of radiation from CT scans than necessary because technical settings were not adjusted for patient size. Based on usage data and projection models from the Japanese atomic bomb survivors we estimated that approximately 29,000 future cancers could be related to the number of CT scans performed in the US in 2007, including about 4000 from CT scans performed in children. Until recently, however, no studies had assessed the potential cancer risks from CT scans directly. In the UK pediatric CT scans study, a retrospective cohort of about 180,000 children we reported the first direct evidence of significantly increased risks of leukemia and brain tumors. The dose-response estimates were statistically compatible with those from the Life Span Study (LSS) of the Japanese atomic bomb survivors following childhood exposure and similar follow-up periods. The absolute risk estimates were small nevertheless: about 1 excess cancer per 10,000 CT scans by 10 years after exposure. Although clinical benefits should outweigh these small absolute risks, radiation doses from CT scans ought to be kept as low as possible and alternative procedures, which do not involve ionizing radiation, should be considered if appropriate.

PL1.5

OVERVIEW OF THE EPI-CT STUDY

A. Kesminiene*[1], S. Baatout [2], E. Cardis [3], M. Hauptmann[4], A. Jahnen[5], M.Kaijser[6], C.Maccia[7], M. Pearce[8] and I. Thierry-Chef[1], on behalf of the EPI-CT Consortium members

1 International Agency for Research on cancer (IARC), Lyon, France
2 Studiecentrum voor Kernergie - Centre d'Etude de l'Energie Nucléaire (SCK.CEN), Brussels, Belgium
3 Centre for Research in Environmental Epidemiology (CREAL), Barcelona, Spain
4 Netherlands Cancer Institute, Amsterdam, the Netherlands
5 Research Centre Henri Tudor (Tudor), Luxembourg
6 Karolinska Institute (KI), Stockholm, Sweden
7 Centre d'Assurance de qualité des Applications Technologiques dans le domaine de la Santé (CAATS), Bourg-La-Reine, France
8 Institute of Health & Society, Newcastle University, Newcastle upon Tyne, the United Kingdom

The European collaborative epidemiological study to quantify risks for paediatric computerised tomography and to optimise doses (EPI-CT), funded by the European Union, was designed as a multinational cohort study of children and young adults who have received substantial doses of ionising radiation from CT scanning. It compromises 3 main parts: the epidemiological cohort study is assessing the cancer effects of radiation exposure from CT; the dosimetry package is developing sophisticated methodology for individual CT dosimetry and related uncertainty and furthering dose reduction and optimisation strategies; the biological part is exploring potential biomarkers of exposure and sensitivity to study biological mechanisms underlying hypersensitivity observed in paediatric patients exposed to CT radiation. The study is built-upon and expands existing cohort studies in France, UK and Germany and sets-up similar cohorts in 7 European countries (Belgium, Denmark, Germany, the Netherlands, Norway, Spain and Sweden) based on a common protocol. It is coordinated by IARC and has recruited around 1,000,000 patients. In some of the participating countries, efforts to evaluate impact of potential confounders, such as socio-economic status, congenital disorders and confounding by indication, on the radiation risk estimates have been made and taken into account while designing the study. In the context of EPI-CT, an approach for dose reconstruction that can accommodate two different dosimetric strategies was implemented, depending on the availability of information and the possibility to automatically extract that information from the Digital Imaging and Communications in Medicine (DICOM) headers. For the distant past, only sparse information about scanner settings and technical parameters can be obtained. A patchwork approach is therefore used to retrieve information from a specially developed questionnaire, surveys, scientific publications, expert interviews and interpolations. For the recent years, scanner settings are being directly extracted from DICOM headers. Individual organ doses will be estimated for each child. Uncertainty analyses will be conducted and probability density functions will be derived from available data to provide distributions of doses. EPI-CT, the first large-scale international collaborative study, will contribute not only to estimating effects of low level radiation in children, but to consolidate a European paediatric cohort for long-term follow-up.

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PANEL DISCUSSION

RISK COMMUNICATION


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PD1

RISK COMMUNICATION IN MEDICAL IMAGING: WHAT IS THE RESPONSIBILITY OF THE MEDICAL PROFESSIONAL AND THE MEDIA TO PARENTS AND THE PUBLIC?

M. Goske

Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio, USA

Risk communication is "the way in which decision-makers communicate with various interested parties about the nature and level of risk, and about the risk reduction strategies to reduce the risk.[1]" The risk from medical imaging that uses ionizing radiation may be difficult to quantify but it is the professional responsibility of the radiologists to inform patients and parents as part of the process of informed decision making. This talk will discuss the hypothetical risks associated with medical imaging, how to communicate those risks to parents, patients and caregivers and optimal communication tools to share this information. The talk will also discuss the media and the role it plays in risk communication regarding radiation used in medical imaging.

S3A.P41. Risk communication United States Environmental Protection Agency Last accessed 3/25/2014. http://www.epa.gov/ttn/fera/data/risk/vol_1/chapter_29.pdf

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PD3

IAEA EXPERIENCE IN COMMUNICATING RADIATION RISKS THROUGH THE RPOP WEBSITE

O. Holmberg, M. Rehani

International Atomic Energy Agency, Vienna, Austria

The radiation protection of patients (RPOP) website of the IAEA (http://rpop.iaea.org) has been communicating information about patient and staff risks and protection since late 2006. The website has become an important source of information with over 20 million hits per year through more than 0.3 million visits. As a result, it appears on first page of Google search and on top of first page when search is made using commonly used terms, like radiation protection in…computed tomography, fluoroscopy, radiology, nuclear medicine, radiotherapy, PET/CT, dental radiography etc. The approach used has been catchy and relevant questions with short answers. The answers are such that in first line itself one get an impression of text in paragraph and that helps busy professionals. There is specific information for patients and public. For patients, the information is classified under x-rays, computed tomography, interventional procedures, nuclear medicine, radiotherapy and pregnancy and children. The philosophy adopted is not scaring patients on one side and avoiding negligence where the need for caution or alarming about potential effects is desirable. Further, the purpose is to provide information about wide areas on use of ionizing radiation at one place. The factors contributing to success shall be presented.

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PD4

SAFETY IN CT: PATIENT PERSPECTIVES ON RADIATION DOSE

J.W. Graff*

Powerful Patient Inc., Brookline, MA, USA

People with genetic cancer syndromes have a special interest in imaging. They also have special risk factors with respect to radiation. They need to utilize the potential of imaging while keeping in mind concerns about cumulative radiation exposure. Before imaging, early detection of problems was limited. With imaging, issues can be identified when they are small and a good plan of action can be developed early. Operations can be planned and metastatic cancer avoided. The positive contribution of imaging to the care of these patients can be profound. However, this additional surveillance is not without cost. An average patient with one of these syndromes will undergo 100 or more scans in their lifetime. Imaging professionals should be able to describe the risks and benefits of each scan in terms that the patient and the ordering physician can understand to make smart decisions about the ordering of scans. Why CT versus MRI? When are x-ray or ultrasound appropriate, and when are they not? What are the costs and the medical risks for the patient? What value does this picture add for the physician? Is there a way to answer the medical question with a test other than a scan? Medicine is a team sport, and the patient is an integral member of the team. The presentation will include the results of a 2014 survey of patients with rare and chronic conditions requiring imaging to track disease progress. References: Graff, Safety in CT, JACR, March 2014, in press.

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PLENARY SESSION 2

RADIATION PROTECTION IN NEWER AND UPCOMING TECHNOLOGIES


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PL2.1

TECHNOLOGICAL ADVANCES IN COMPUTED TOMOGRAPHY: FEASIBILITY OF SUB-MSV IMAGING

R. Gupta*

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X-ray Computed Tomography (CT) represents a mature technology that is widely used in routine clinical practice. While the clinical utility of CT imaging is undeniable, its radiation dose remains a concern. Having overtaken the background radiation, at the population level radiation from medical imaging represents the largest component of per capita exposure, with CT accounting for the single largest modality with in this count. With increasing utilization of CT, this problem is expected to become even more pressing in future. Therefore, ways to reduce CT dose are highly desirable. This presentation will review the imaging chain of a 3rd generation CT scanner and identify opportunities for reducing radiation exposure. A typical 3rd generation CT scanner consists of an X-ray source and a detector assembly, both of which are mounted on a rotating gantry. As the gantry rotates, a set of projection images are acquired and converted into a tomographic image. In this presentation, we will cover advances in X-ray source design, contrast mechanism, detector design, and reconstruction algorithms and describe how these advances can reduce radiation dose.

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PL2.2

ITERATIVE RECONSTRUCTION ALGORITHMS AND DOSE REDUCTION IN CT

S. Singh*

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Radiation dose associated with Computed Tomography (CT) is considered as one of the top patient safety concerns in healthcare. Technical advancements in multidetector-row CT scanner technology offer several benefits for imaging utilization of the disease process. These advancements have resulted in expanding clinical applications of CT and hence over 85 million CT examinations annually in United States alone. Therefore, several technologies have been developed to reduce radiation dose with more efficient use of scanning parameters as well as enhance diagnostic information in low radiation dose CT. Recently “newer” image reconstruction techniques have been introduced to optimize CT radiation dose. Although iterative reconstruction (IR) algorithms were introduced back in 1960’s for single photon emission CT, filtered back projection technique was chosen as the conventional image reconstruction technique due to its simplicity and faster reconstruction times. In early 1970s, IR was also used in the first transmission CT efforts and was successfully used in the first clinical CT products. However, initial efforts of IR were done on relatively small amounts of measured data, such as smaller matrix size. With advances in computational speed and power (better central processing units [CPU] and graphics processing units [GPU]), iterative reconstruction techniques have re-emerged and have shown the potential of radiation dose optimization without affecting on diagnostic image quality. With this talk, I will review the basics of iterative reconstruction algorithms, different type’s commercial IR algorithms available, IR’s implementation for various clinical applications in CT examinations and finally optimizing various settings of these algorithms for reducing radiation dose.

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PL2.3

PATH TO SUB-MSV CARDIAC IMAGING: TECHNOLOGY ENABLERS AND THE STATE-OF-THE-ART

V. Sinitsyn

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CT coronary angiography (cCTA) has in the past years been used more and more widely in diagnostic work-up of cardiac patients. Indications to cCTA recently has been substantially expanded. CTA is performed with large variety of scanners but still almost 2/3 of examinations are done with 64-row scanners. Traditional retrospectively gated 64-slice cCTA is associated with relatively high radiation doses of approximately 12-18 mSv. Research in cardiac radiology and technical innovations in technology of CT have resulted in substantial decrease of radiation exposure to patients. There are several approaches to decrease radiation doses related with cCTA. Major ones are prospective gating, lower tube voltage and tube current modulation, iterative reconstruction, high-pitch scanning.Use of prospective cardiac gating results in 2-3-fold decrease of the radiation exposure to patient. Application of iterative reconstruction allows to decrease tube voltage and tube current without loss of image quality and diagnostic information. As a result of that one see a general trend to use 80-100 kV tube voltage for cCTA instead of the «standard» 120 kV. Body mass index (BMI) remains a string predictor of image quality and low-dose CTA sometimes could bring unsatisfactory results in patients with increased BMI. Sub-millisivert cCTA has became a reality in most of patients with low or normal BMA even for 64-row scanners. Further decrease of dose could be achieved with help of new generations of CT like wide-detector and dual-source scanners. High-pitch flash scanning is possible with dual-source CT in patients with low heart rate. In that case one can reach radiation exposure to patient in submillisivert range in most of cases. Issue of further decrease of radiation exposure has become even more important with inclusion of myocardial perfusion CT into protocols of cCTA. But sub-millisivert cCTA alone should not be a primary goal to radiologist. Patients are referred to cCTA for obtaining vital diagnostic information which is based on good image quality combined with low (ALARA) dose. Today usage of dose-saving strategies in cCTA has been accepted as a new standard in cardiac radiology and it demonstrates high awareness of both radiologists and referring doctors of risks associated with radiation exposure to cardiac patients.

PL2.4

TECHNOLOGICAL ADVANCES IN HYBRID IMAGING AND IMPACT ON DOSE

S. Mattsson*, M. Andersson, M. Söderberg

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To give an overview of the latest developments related to imaging technologies utilizing radiopharmaceuticals (RP) in combination with CT (PET/CT, SPECT/CT) as well as RP in combination with MR (PET/MR), a technique now moving through feasibility studies to clinical investigations. The radiation exposure from CT has been of concern for several years and the relatively high radiation doses from PET and SPECT investigations are now also under discussion. The combination of two high-dose investigations in PET/CT and SPECT/CT is of special concern. The aim is to provide information on radiation doses to patients and staff - critical parameters for justification and optimisation. Tools for dose management related to patients, staff and the public will be discussed. For CT, automatic exposure control systems are available from all manufactures and offer major dose reduction potential. More efficient x-ray detectors are developed and extensive research on energy-resolved photon-counting detectors is ongoing. Estimation of patient-specific doses is of particular concern. Today several tools are available to monitor patient radiation doses, which make benchmarking possible. Utilization of new gamma cameras based on solid state detectors offers the ability to minimize radiation exposure to patients and staff. For RP, a number of patient dose estimates have been updated. The implementation of simple protocol adjustments, including discharge procedures, can reduce the radiation exposure to the investigated patient as well as to other patients and the public. There are new data about staff doses to fingers, hands and eye lenses. Various investigations indicate a wide variability in CT techniques and administered activity of various RP among clinical facilities. Use of improved reconstruction methods has the possibility to significantly decrease the effective dose to patients both for CT, SPECT and PET. For SPECT the introduction of new solid state detectors contributes to lowering the effective dose to the patient and/or reducing the acquisition time. The RP used are also of concern for the irradiation from patients to other patients, staff and the public. For staff members, there are now dosimetry systems that give real-time information about their radiation exposure, as well as access to time stamped dose data. Improvements in the collection of patient (and staff) dose data are needed.

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PLENARY SESSION 3

TRACKING OF EXAMINATIONS AND DOSE


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PL3.1

TRACKING EXAMINATION AND DOSE: OVERVIEW

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Capability to know how many and what type of radiological examination that an individual patient has undergone implies tracking of examination or exposure and when dose involved in these examinations is accounted for, then it is tracking of dose. While exposure and dose tracking, both have been documented to be useful for strengthening the process of justification and optimization, there is still work to be done on utility of cumulative dose. Somehow many people associate tracking with cumulative dose, which should not be the case. Tracking exposure and dose is a reality in many countries. A large number of papers by the author have dealt with different aspects of tracking namely; use of permanent patient identifier as a digital signature through smart cards, results of global survey on existing program and gauging of interest in future development, development of templates for implementation of tracking at the practice (hospital) level, multi-practice level, national level and international level, suggestions for implementation in less-resourced countries, dose quantities that should be covered and how to make sense from dose figures and views of referring physicians in many countries. It is clear that picture archiving and communication systems (PACS) of today have possibility to allow tracking and technology overall seems geared. There are examples of regional (sub-national) and national PACS. Tracking can be a reality through PACS without eHealth system in place. With vision of cross boarder PACS, it seems a reachable goal in coming years. There is need to develop Aps for referring physicians and algorithms that can support process of appropriateness.

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PL3.2

INDIVIDUAL DOSE TRACKING

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Tracking the radiation exposure to medically exposed populations can promote adoption of best practices among medical facilities that use ionizing radiation. In May, 2011, the American College of Radiology (ACR) launched a Dose Index Registry that allows imaging facilities to submit patient-specific dose data for comparison of average dose indices among similar practices across the country. The Dose Index Registry provides an important tool for practices to benchmark their radiation exposures for medical imaging and highlight areas where improvements may be made. While some U.S. states have passed legislation to require the reporting of individual patient doses and potentially tracking those doses over time, individual patient dose tracking has many confounding variables to consider. First, it is not clear which dose measures should be tracked. Second, the variation among these dose measures must be understood relative to the variations in body habitus that are encountered in clinical practice, both for constant levels of image noise and for various levels of image noise that can be accommodated with different clinical indications. Estimation of stochastic risk is the primary driver behind cumulative radiation exposure tracking on an individual basis. However, there are many uncertainties associated with risk estimation from low-dose radiation that relate to the age, gender and life expectancy of the affected individual.

PL3.3

TRACKING OF EXAMINATIONS AND DOSE-EXPERIENCE FROM FINLAND

R. Seuri

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Tracking of patients examinations and dose are often discussed separately, and sometimes one or the other may be more important for the user. But they are parts of the same procedure and thus inseparable. Justification starts with the referring physician, who has to know the patients previous examinations to decide if the patient needs further imaging, and which would be the right modality and procedure. The physicians concern is the information gained from imaging, and their awareness of radiation safety issues might be limited. However, if the dose indicators are stored to pacs together with the images, also the referring physician is able to see the dose difference in e.g. abdominal plain film and CT, or routine head CT compared to limited CT examination for ventricular dilatation. The same information is important for both the radiographer and the radiologist when judging the justification of a procedure. Even more important the dose information is for the optimization process. In digital radiography the only way to really know the dose is if it is numerically available, too high dose is not obvious in the image as it was in the film era. In ct we can use the dose information in optimization the same way: comparing dose indicators, imaging parameters and image quality. Image quality is part of optimization. The ALARA principle must always be considered together with the indication; different indication requires different image quality. Renal stones are perfectly well diagnosed with much lower image quality, and thus lower dose. Procedures with dose information can also be compared to examinations performed with different scanners or even in different hospitals. This way it serves both optimization and quality control purposes. For quality control the dose information is priceless. Doses for certain procedures are easily collected to be compared to DRLs. Especially if there seems to be need of dose reduction, it should be evaluated together with all the imaging professionals: the radiographers, radiologists, and medical physicist, also especially with new equipment also the vendor´s application specialists. The dose information is very practical in everyday work when you get the idea how to use it, but it has to be easily available together with the images.


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SPECIAL FOSUS SESSION 2

CLINICAL DECISION SUPPORT


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SF2.1

THE ROLE OF RADIATION PROTECTION AND CLINICAL DECISION SUPPORT IN THE CONTEXT OF PATIENT-CENTRED CARE

P. Vock*

University of Bern, Spiegel, Switzerland / European Society of Radiology, Vienna, AT

In its position statement, the European Society of Radiology (ESR) proposes a GPS approach to radiation protection where G means global or holistic, P personal or patient-centric, and S safe. Patient-centricity increasingly is a prerequisite in radiology. This presentation will evaluate the role of imaging methods in patient-centred medicine: as other biomarkers (e.g. “omics”) imaging data can serve to give the individual patient an individualised instead of standardised treatment giving all patients the same type and dose of therapy. Imaging biomarkers have a prominent role in screening for and detecting disease, they serve to stage a recognized disease, to predict and to evaluate the response to treatment, and they allow for guided local tissue sampling as well as targeted interventional therapy. These prominent roles of imaging procedures in patient-centred care ask for patient-centred radiation protection. Optimisation in patient-centred imaging adapts protocols to the very needs of the individual patient, respecting body size, age and gender, in order to answer the clinical question using minimal radiation exposure. This includes local shielding and dose-saving tools. Justification in patient-centred imaging gives ICRP level 3 of justification a key role. While evidence-based referral guidelines at level 2 may suggest one preferred imaging technique to clarify one clinical situation, patient-centred justification for the very same situation may choose different techniques depending on the patient, e.g. by preferring ultrasound or MRI to radiography or CT in children, pregnant patients, young females, and in some recently found situations of individually increased radiosensitivity. Furthermore, at level 3 co-morbidity – such as renal failure - will often influence justification. An ESR project team is working to fill the gap of harmonised European imaging referral guidelines. Unfortunately, even the existence of evidence-based referral guidelines cannot guarantee their sometimes time-consuming use. To improve justification clinical decision support systems (CDS) are currently introduced: they combine interactive digital referral guidelines with electronic patient data, respecting levels 2 and 3, and they can include incentives to the referrer for following the guidelines. The presentation will illustrate optimization, justification and the use of CDS.

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SF2.2

PRACTICAL USE OF DECISION SUPPORT

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While substantial variation is expected in the medical radiation exposures and their estimated risks, other sources of variation in the use of ionizing radiation for medical imaging are concerning. Specifically, deviation from best practice in the use of medical imaging should be reduced, if not eliminated. The over-utilization of chest CT examinations both with and without IV contrast material is a good example of wasted radiation. A recent report in the lay press noted that more than 200 U.S. hospitals administered these “double scans” more than 30% of the time when best practice is less than 5%. Moreover, failure to adopt best practice tends to cluster geographically suggesting that local influences may drive resistance to adoption. Several tools exist to help reduce variation among practices when it comes to rational exam selection. The American College of Radiology has developed Appropriateness Criteria that provide a mechanism for guiding practitioners to the appropriate imaging examination. The Appropriateness Criteria return a numeric score for any given combination of medical topic, variant, and imaging examination, and multidisciplinary diagnostic algorithms are needed that go beyond the Appropriateness Criteria to guide practitioners to the appropriate diagnostic pathway for a given clinical scenario. Work is under way in this regard, however, the pressure for rapid throughput, particularly in the Emergency Room, confounds our ability to implement such tools on a wide scale. Computerized order entry with decision support offers the promise to introduce these tools at the point of care, which should increase their use and adoption in the medical community at large.

SF2.3

EUROPEAN PERSPECTIVE OF CDS

L. Donoso

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European Society of Radiology, 1st Vice-President

The ESR considers European referral guidelines for medical imaging essential and that the improvement of guideline use is urgently needed. This can only be achieved through IT based solutions, i.e. embedding them in a Clinical Decision Support (CDS) environment. A CDS format would create the flexibility to adapt the guidelines to national, local, institutional or organisational needs. This view is based on the results of a European Commission (EC) Tender Project, the findings of which show that only two EU countries – France and the UK – develop their guidelines autonomously. More importantly, the study revealed a significant lack of imaging referral guidelines use, partly because they are only available in text formats. To remedy this problem, the ESR began to develop European imaging referral guidelines and a CDS system to achieve appropriate use of radiation and to avoid unnecessary radiation exposure of patients. Several stakeholders, including the European Commission (EC), the Heads of European Radiological Protection Competent Authorities (HERCA), the UK Royal College of Radiologists (RCR), the French Radiology Society (SFR), the American College of Radiology (ACR) as well as the International Atomic Energy Agency (IAEA), have acknowledged the need for a CDS system and signalled their support. In the pilot phase of the project carried out during 2013, a group of experts from the ESR, RCR and SFR worked on comparing and merging the UK and French guidelines, which revealed considerable discrepancies between the two national guidelines. Both the outcome of the EC Tender Project and the comparison work demonstrated that an approach based on different national guidelines does not appear feasible as they are not generalisable. A global approach seems better suited to the requirements of flexibility and customisation. The ESR therefore intends to develop a global set of guidelines in an algorithmic CDS format, designed to be adapted for national or local use according to specific circumstances and requirements.

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F1.2

INTERNATIONAL BASIC SAFETY STANDARDS

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The International Atomic Energy Agency first published basic safety standards (BSS) in 1962. Revised editions have been published in 1967, 1982, 1996 and an interim edition in 2011. The interim 2011 edition, “Radiation protection and safety of radiation sources: International Basic Safety Standards” will be cosponsored by the following international organizations: the European Commission (EC), the Food and Agriculture Organization of the United Nations (FAO), the International Labour Organization (ILO), the OECD Nuclear Energy Agency (OECD/NEA), the Pan American Health Organization (PAHO), the United Nations Environment Programme (UNEP) and the World Health Organization (WHO), and the cosponsored edition will be published in 2014. The text of the interim edition of 2011 takes into account the findings of UNSCEAR, the 2007 recommendations of the ICRP, the increasing use of radiation in medical technologies world-wide, and the experience of Member States in applying the 1996 edition of the BSS. This paper will summarize the changes between the 1996 edition and the interim 2011 edition of the BSS in the area of medical exposures, including changes to definitions, the assignment of responsibilities, the justification of medical exposures, and for optimization of protection and safety in medical exposures. A Safety Guide “Radiation Safety in Medical Uses of Ionizing Radiation” to provide guidance on implementing the requirements is being developed and is expected to be completed in 2015, for publication in 2016.

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F1.3

EUROPEAN ACTIVITIES IN RADIATION PROTECTION IN MEDICINE

G. Simeonov*

European Commission, Directorate General for Energy, Luxembourg

The recently published Council Directive 2013/59/Euratom ("new European Basic Safety Standards", EU BSS) modernises and consolidates the European radiation protection legislation by taking into account the latest scientific knowledge, technological progress and experience with implementing the current legislation and by merging five existing Directives into a single piece of legislation. The new European BSS repeals previous European legislation on which the national systems for radiation protection in medicine of the 28 EU Member States are based, including the 96/29/Euratom "Basic Safety Standards" and the 97/43/Euratom "Medical Exposure" Directives. While most of the elements of the previous legislation have been kept, there are several legal changes which will have important influence over the regulation and practice in the field all over Europe – these include, among others, (i) strengthening the implementation of the justification principle and expanding it to medically exposed asymptomatic individuals, (ii) more attention to interventional radiology, (iii) new requirements for dose recording and reporting, (iv) increased role of the medical physics expert in imaging, (v) new set of requirements for preventing and following up on accidents and (vi) new set of requirements for procedures where radiological equipment is used on people for non-medical purposes ("non-medical imaging exposure", NMIE). The EU Member States have to enforce the new EU BSS before January 2018 and bring into force the laws, regulations and administrative provisions necessary to comply with it. The European Commission has certain legal obligations and powers to verify the compliance of the national measures with the EU laws and, wherever necessary, issue recommendations to, or open infringement cases against, national governments. In order to ensure timely and co-ordinated implementation of the new European legal requirements for radiation protection, the Commission is launching several actions including promotion and dissemination activities, exchange and discussion fora and provision of guidance. These actions will be based on previous experiences and will rely on the results of recent and ongoing EU-funded projects. Important stakeholders including the Euratom Article 31 Group, HERCA and different European professional and specialty organisations will be involved.

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F1.4

WHO ACTIVITIES ON IMPLEMENTATION OF BONN CALL FOR ACTION

M. Pérez

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The wide use of radiation in medicine calls for a public health approach to control and minimize health risks, while maximizing the benefits. The World Health Organization (WHO) is conducting a Global Initiative on Radiation Safety in Health Care Settings to mobilize the health sector in the safe use of radiation in medicine. This initiative brings together key stakeholders (e.g. health authorities, international organizations, professional and scientific societies) in concerted action. The Global Initiative takes into account the priorities identified in the ”Bonn Call for Action”, main outcome of the International Conference on Radiation Protection (RP) in Medicine (Bonn, December 2012), by including:

1. Assessment of risks and trends
    i. Improve global data collection on medical exposures
    ii. Shape and promote a RP research agenda
2. Prevention of unnecessary medical radiation exposures
    i. Support implementation of imaging referral guidelines
    ii. Produce RP education tools for dental practice
    iii. Develop criteria for justification of imaging og asymptomatic people
3. Implementation of standards and regulations
    i. Support BSS implementation in member states (MS)
    ii. Foster co-operation between health authorities and regulatory bodies
4. Quality and safety improvement
    i. Disseminate existing guidance on clinical audit
    ii. Harmonize criteria for reporting and learning
    iii. Promote use of prospective risk profile analysis tools
    iv. Promote radiation safety culture.
5. Occupational health promotion
    i. Identifying radiation risk profiles for healthcare workplaces.
    ii. Provide guidance on RP to occupational health physicians
6. Education, training, staffing
    i. Scaling-up the role of medical physicists, radiographers
    ii. Disseminate guidance on RP education and training of health workforce
    iii. Advocate for the inclusion of RP in the curriculum of medical and dental schools
7. Communication
    i. Develop a toolkit for radiation risk communication to support risk/benefit dialogue in health care
    ii. Produce advocacy tools targeting messages for specific audiences
    iii. Host a web portal & newsletter to facilitate information exchange

As one of the eight co-sponsoring organizations of the updated international radiation basics safety standards (BSS), WHO is committed to support BSS implementation at country level. This requires a multi-sectoral approach and partnerships at global, regional and national levels, including a strong involvement of public health authorities.


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ROLE OF REGULATION AND CURRENT CHALLENGES


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SF3.1

HERCA ACTIONS ON STRENGTHENING RADIATION PROTECTION IN MEDICINE

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6 The French Safety Authority, ASN, Paris, France

HERCA (Heads of the European Radiological protection Competent Authorities) is a voluntary association. The HERCA Working Group on Medical Applications (later called WG MA) will cover all radiation protection issues concerning medical applications of ionizing radiation for diagnosis and therapy. The WG MA conducts its work mainly through work packages that are currently on justification, inspection competence of authorities and stakeholder involvement with CT-manufacturers). The work of the WG MA concords well with the Bonn Call-for-Action. The work packages outlined above address elements of the first three Actions. •The WG MA is producing a position paper with regard to justification. This is being developed with due regard to the “triple A” approach (Awareness, Appropriateness, Audit). The position paper mainly deals with how radiation protection competent authorities themselves can contribute to improve justification, although the roles and responsibilities of others are acknowledged. The WG MA intends to invite comments from: professional organizations, patient representatives, health authorities and other key international bodies. The WG MA recognized that the regulatory bodies have an important role in promoting and ensuring that optimisation is a part of every medical exposure. To do so effectively as part of the major regulatory activities, regulatory bodies will need to be aware of developments in the fields they are regulating and inspectors will need an up to date working knowledge of current radiological practices. To improve that knowledge and practical skills the WG MA had a first inspection training course in UK in 2013 and that will be repeated in 2014. The first Inspector Workshop is under preparation. Following HERCA initiative, CT manufacturers have accepted their responsibilities with regard to the reduction of patient dose and formalized this in 2011 within a voluntary self-commitment, through COCIR. This has been developed further as part of annual liaison with the WG MA. A further important result of this process was the insight that international cooperation is increasingly important for success, and that this cannot be limited to a European level. HERCA has intensified its cooperation with other international regulatory and scientific bodies such as FDA and NCRP. In the presentation more examples will be given of the achieved results against the actions of the Bonn Call-for -Actions.

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SF3.5

SURVEY ABOUT THE SITUATION IN EUROPE REGARDING AUTHORISATION AND USE OF HAND HELD DENTAL X-RAY SYSTEMS

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The paper presents the summary of the results from the survey initiated by the Working group on Medical Application (WG MA) of Heads of European Radiological protection Competent Authorities (HERCA). Questionnaire of 11 questions was sent to all members of the WG MA, and 21 countries responded. In 15 out of the 21 countries, license or permit is required for dental intraoral x-ray systems, in 4 registration, and in 2 notification only. In only 5 countries, authorisation for import of x-ray systems, including hand held, is required. Acceptability criteria for dental intraoral equipment are in place in 16 countries. Handheld intraoral dental x-ray units are in use in 15 countries, but in most countries only few units are licensed mostly for forensic medicine, nursing homes, dental care for elderly and disabled persons, or used by police. Variety of portable devices is available, produced in USA, Korea and China. Most countries require the license applicant to justify the use of a hand held unit. In 9 countries commercials of hand held dental systems are available. Position statement or guidelines for use of hand held dental x-ray equipment are available in only 8 countries; in 2 countries they are issued by the professional societies, and in others by the radiation protection authority.

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EC1

HOW TO USE THE EQUIPMENT YOU HAVE FOR APPROPRIATE QUALITY AT LOW RADIATION DOSE

E. Castellano*

The Royal Marsden NHS Foundation Trust, London, UK

A CT department's ability to image with low radiation doses is determined primarily by the CT scan protocols and the radiologists' image quality expectations, and to a lesser extent by the dose reduction features available. The multi-slice CT technology level has a smaller influence than might be expected: it is feasible to scan with similar doses using 16, 64 and 128 slice CT scanners. An exception is cardiac CT where dose is directly related to the scanner's technical specification. The key to appropriate image quality with low radiation dose is therefore scan protocols optimised by a multi-disciplinary team that includes radiologists, technologists and medical physics experts. To optimise effectively, an in-depth understanding of the technical performance of the scanner is required. This educational course revises the principal technical features that influence dose and image quality. It presents strategies for reviewing and optimising scan protocols, and suggests means of influencing radiologists' expectations about CT image quality. Finally, the special case of cardiac CT is considered.

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EC2A

RADIATION SHIELDING AND FACILITY DESIGN: PART 1 PRINCIPLES OF DIAGNOSTIC RADIOLOGY SHIELDING

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Shielding for diagnostic radiology must offer protection against primary and secondary X-rays. The largest contribution is from scattered X-rays. In the UK, calculations of scattered radiation levels are based on patient dose data, which are now readily available and relate to the amount of radiation used. A report setting out the UK methodologies was published in 2012 by the British Institute of Radiology, which developed techniques established in an earlier report from 2000. This lecture will outline the basic principles of the techniques described in the report. It aims to equip the attendee with an understanding of the principles and their practical application. It will start with discussion of the selection of dose constraints for the design and estimation of the potential workload for different types of facility. The measure used for evaluating dose is the air kerma and the link between this and effective dose will be discussed. Kerma-area product is the measure used for recording patient dose which includes all the radiation incident on the patient. Factors have been established based on experiments and computer simulations linking kerma-area product to the levels of scattered radiation for radiography and fluoroscopy. Transmission requirements can then be determined from comparisons between calculated radiation levels and the dose criteria, taking into account the occupancy of the area. There are a variety of materials that can be used for shielding and the protection they provide can be calculated from simple equations using coefficients relating to tube potential. Account will be taken of the many developments in radiology in recent years. For fluoroscopy units in which the image receptor intercepts the entire primary X-ray beam, the only radiation of significance when considering staff exposure is scatter. Therefore, the application of the methodology will be illustrated through an example based on an interventional radiology room. Similar principles for shielding apply to cone beam CT techniques using interventional equipment and other fluoroscopy procedures. Interestingly the thickness of shielding required does not increase as rapidly as workload rises, so designs will often allow a significant increase in workload before further protection is required. The application of the method to radiography, including dealing with primary radiation, and computed tomography using the dose-length product will be described in part 2 on the following day.

EC2B

RADIATION SHIELDING AND FACILITY DESIGN: PART 2 PRACTICAL METHODOLOGIES FOR RADIOGRAPHY AND CT

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The second lecture on shielding methods in radiology will build on the basic principles outlined in part 1. In radiography unlike fluoroscopy the primary beam my not be fully intercepted. Therefore potential requirements for shielding against primary radiation will be described, which can use either the detector air kerma or the entrance surface air kerma. Appropriate factors are given to allow for attenuation of the image receptor. Although the main discussion will relate to general radiography, mammography rooms and dental facilities which require rather less shielding and for which plasterboard is often sufficient, will also be considered. This lecture will cover protection for CT facilities in which shielding requirements have increased substantially in the last decade with the moves to multi-slice and helical scanners. These changes have served to both increase the patient throughput and the incident radiation levels. Major changes have been made in the approach to the design of shielding for CT. Scatter dose has been quantified in terms of dose-length product to provide a link similar to that between kerma-area product and scatter kerma for radiography and fluoroscopy. This approach allows the shielding designer to make a direct link between scatter kerma and patient dose, and removes the need to depend on manufacturer-supplied isodose curves. However, techniques are included that allow protection provided by the gantry to be taken into account, if this is appropriate. Because of the higher CT workloads, exposure to tertiary scatter from ceilings and around open doorways has become an issue, and a method for quantification of this scatter will be described. All the methods and the factors used in the calculations are included in the British Institute of Radiology Report. This is a guide and is not intended to be overly prescriptive or to necessarily supplant pragmatic or alternative approaches to shielding design. But it provides all the information required to shield different types of X-ray facility, based on data relating to patient dose. All the factor included have been carefully researched through practical experiments and Monte Carlo simulations. Sutton, D G, Martin, C J, Williams, J R and Peet, D J (2012) Radiation shielding for diagnostic radiology. (British Institute of Radiology: London), www.bir.org.uk.

EC3

PATIENT DOSIMETRY IN DIAGNOSTIC AND INTERVENTIONAL RADIOLOGY- HOW I DO IT?

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There is growing concern the last few years about the risks associated with patients' exposure to radiation from various X-ray procedures. Inadvertent exposure to elevated amount of radiation doses can also lead to injuries in the short term. A number of these accidents have been reported such as burns, hair loss or even exposure of the eyes that can results in a large increase risk of developing cataracts. Some of these incidents are investigated. However, it seems that most of these accidental exposures, patients were exposed to a much higher dose of radiation than is typical for such scans. For all the above reasons patient doses need to be measured or calculated. This becomes extremely important due to the immense expansion of high dose procedures such as multidetector computed tomography, contrast enhanced digital mammography or complex interventional procedures. Furthermore patient dosimetry is also required in order to check the practice of a facility and to determine a set of standards for the particular department. Concerns have been raised about how imaging facilities administer medical imaging exams that use radiation: wide variations have been observed among radiation doses associated with particular types of medical imaging exams. Studies in the literature that report even a 13-fold variation between the highest and lowest dose. Differences in equipment performance, competence, skills, working habits and examination procedures are important factors which influence the patient dose. The particular paper will demonstrate the various ways of measuring patient dose with emphasis to the high dose and most recent practices. Furthermore, focus in new imaging techniques such as contrast enhanced digital mammography, breast tomosynthesis, cone-beam computed tomography and biplanar radiographs that recently claim to replace CT which currently is considered the gold standard for the evaluation of femoral and tibial torsion for children or adult with legs deformity will be made. Measuring methodology, dosimetric approaches and a description of the relevant information that are reported until today are going to be presented.

RPM 2014

SCIENTIFIC SESSION 1

AUTOMATIC DOSE DATA COLLECTION


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S1.I1

AUTOMATED RADIATION DOSE COLLECTION AND INITIATIVE FOR A NATIONAL DOSE REGISTRY IN CANADA

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Supported by major international organizations on radiation protection, the Bonn Call-for-Action advocates for a registry to: "(1) support accountability for patient safety, (2) strengthen the process of justification (e.g. information available at the point-of-care for the referring practitioner), (3) support optimization (e.g. use of diagnostic reference levels (DRLs)), (4) provide information for assessment of radiation risks, and (5) establish a tool for use in research and epidemiology". Currently, there is no dose tracking program or infrastructure at the provincial or national level in Canada. With the expanding implementation of state-of-the-art digital modalities and the increasing adoption of dose tracking software solutions, it is now possible to build a national dose registry leveraging on the standard-based digital imaging infrastructure already in place in Canada, in accordance with Canada Health Infoway's eHealth strategies. The role of our new Canadian Coalition for Radiation Safety is to bring together all expertise required to create such a tool. In order to build this registry, we need to: (1) Research and develop a standard-based, extensible data model for a national dose tracking platform, (2) Research and develop generic data submission tools that can be customized/adapted for major modality and vendor solutions, (3) Develop algorithm to extract data from reports and text in DICOM headers, (4) Research innovative ways for real-time, dynamic data visualization, benchmarking and practice optimization, (5) Develop intelligent terminology mapping and quality assurance mechanism to ensure data quality, and (6) Research and develop a feedback mechanism for decision support at the point of care. In conclusion, our platform will allow for implementing the best practices in radiation protection and understanding the long term effects of low dose radiation exposure on populations.

S1.O1

UNSCEAR'S PLATFORM FOR ONLINE DATA COLLECTION ON MEDICAL RADIATION USAGE AND EXPOSURE

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The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), established by the United Nations General Assembly in 1955 to assess and report levels and effects of all sources of ionizing radiation conducts regular Global Surveys on Medical Radiation Usage and Exposure. Its systematic reviews and evaluations aim to determine trends in frequencies and doses of medical examinations. UNSCEAR uses an online software platform and other adequate software tools to facilitate the data collection process which will be presented here. After a short registration and validation process to ensure that only recognized person who are nominated as (National Focal Person) by their countries to submit data officially, users can access the UNSCEAR web portal platform at http://survey.unscear.org. Other users are allowed to register to be able to support their NFP. Users of the same country can access their own country area on the platform, where dedicated Excel templates (questionnaires) are available. Users and NFPs are requested to download the detailed questionnaires (diagnostic radiology, nuclear medicine, interventional radiology, radiation therapy) and to upload them after completing the required data collection. An expert panel validates the submissions to ensure the data quality before the data will be imported to the UNSCEAR database for further processing and analysis. Users can follow the data processing status on their country specific page. Information on the frequency and doses per radiological procedure (including treatments) are collected. Information on age and sex distribution per procedure can be provided in a separate rubric of each questionnaire but are not obligatory. Additional information on the health care system as radiological workforce or devices are also collected for a better analysis of the data. The UNSCEAR Survey platform is composed of three major components: (a) a portal to manage users and the submitted data, (b) the dedicated Excel spreadsheets (questionnaires) that are used to collect the data and (c) the UNSCEAR database that is used for the evaluation. This system provides useful features to simplify the data collection and evaluation process and it keeps track of the submitted data. Therefore, it is expected that the number of countries participating in UNSCEAR's Medical Survey on Medical Radiation Usage and Exposure will increase in the future. * Presenting author: Ferid.Shannoun@unscear.org

S1.O2

DATA COLLECTED FROM PACS FOR A LARGE MULTI-NATIONAL EPIDEMIOLOGICAL STUDY ON CANCER RISK ASSOCIATED TO CT EXAMINATIONS IN CHILDHOOD: THE EPI-CT PROJECT

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The European EPI-CT study was set-up to quantify the radiation-related risk of cancer in a large multi-national cohort of pediatric patients receiving CT scans. In addition, the study aims to pilot test biological markers of CT-irradiation and to inform on dose reduction. Recent studies conducted in the UK and Australia reported statistically significant increased risks of cancer associated with paediatric CT scans. In these studies, relatively crude exposure assessment was used to quantify doses. In EPI-CT, we intend to improve the dosimetric approach by collecting technical examination parameters of each individual scan available in the hospital Picture Archiving and Communication System (PACS). This paper describes the data obtained for dose reconstruction from PACS. In each participating hospital data collection begins with generating a list of eligible patients from the Radiological Information System (RIS) This list is then provided to dedicated software: the Performance and Monitoring Server for Medical Data (PerMoS). The PerMoS Data Collector, installed locally in the hospital, establishes a connection to the hospital's PACS. The image data is then queried and processed, leaving the image aside and taking only pseudonymized DICOM metadata containing detailed technical parameters. These are then uploaded from the hospital to the PerMoS data centre trough a secure connection. Reconstruction of organ dose cannot be performed accurately without knowing the area of the body exposed during the CT examination with sufficient detail. Different approaches to define the exact scan position are being developed. Additional parameters, such as the scan length, also need to be calculated. Once all parameters are available, the NCICT package, a Monte Carlo based dosimetry tool, will be used to estimate organ doses for every individual. Currently, data is collected from 58 hospitals in 8 countries, representing a total of 123 615 patients with 190 953 studies and 952 837 series. Distribution of the examinations by different age groups, calendar periods, scan types, etc. will be presented. Updated values will be analyzed to provide detailed information beneficial for optimization. We faced several problems during the data collection at organizational and technical level, but we are confident that the data collected that will improve dose reconstructions and will be useful for our optimization work.

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S1.O3

BENEFITS OF AN AUTOMATIC PATIENT DOSE REGISTRY SYSTEM FOR INTERVENTIONAL RADIOLOGY AND CARDIOLOGY AT FIVE HOSPITALS OF THE MADRID AREA

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To present the results of connecting the interventional radiology and cardiology laboratories of 5 university hospitals to a unique server using an automatic patient dose registry system developed in-house, and to evaluate its feasibility more than a year after its introduction. The system named DOLIR (Dose On Line for Interventional Radiology) consists in in-house developed software compiled with Microsoft™ .NET Visual Studio as a basic tool. It receives and stores the demographic and dosimetric parameters included in the MPPS DICOM objects sent by the modalities (Philips Allura XPer FD10 and FD20) in a database and creates a graphical interface to analyze the information received. The database was created and powered with Microsoft™ SQL Server Express. A corporative network was used for the transmission of the DICOM MPPS messages. The medical physics department of each hospital periodically upgrades the calibration factors necessary to correct the dose values sent by the modalities. The graphical interface allows the evaluation of: fluoroscopy time, number of exposures, number of frames, kerma area product (KAP) and cumulative air kerma (CAK) (both for fluoroscopy and exposure). The system accumulates the values of all the procedures performed to the same patient in the different centers and creates two additional parameters: Life KAP and Life CAK. Since October 2012, a total of 14 catheterization laboratories (9 cardiac and 5 interventional) has been connected to the system. In 2013, the system processed 10,775 procedures (6877 cardiac and 3898 interventional). The graphical interface provides a quick overview of the patients' individual data and a basic statistical tool to analyze each parameter registered (range, mean, median, and standard deviation, together with frequency histograms). The calculation and presentation of Life KAP and Life CAK in the graphical interface resulted especially useful immediately after clinical procedures to identify whether patients had reached skin doses likely to potentially initiate tissue reactions. In these cases, a clinical follow-up protocol was applied. A year after its introduction, the system has led to an efficient management of patient data recorded during interventional cardiology and radiology procedures performed at the participating centers and made it possible to immediately identify patients needing clinical follow-up for potential skin injuries.

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S1.O3

DESIGNING AND TESTING A TEACHING MODULE ON AUTOMATIC PATIENT DOSE REGISTRY IN RADIOLOGY

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To develop a teaching module on automatic patient dose registry in diagnostic radiology addressed to medical physicists with free software, without the need of previous programming knowledge and to evaluate its feasibility by having it tested by several medical physicists with no previous experience of these tools. This teaching module is composed of two parts: first, an introduction to the functionalities of automatic patient dose registry systems, an introduction to DICOM and a revision of some existing in-house developments and commercial tools; secondly, a step-by-step tutorial aiming at developing a system based on free software. The system uses Microsoft™ SQL Server Express to create and manage the database, and Mirth™ Connect as the basic tool to receive, filter, transform, route, process and store into a database the information received from DICOM modalities or from a PACS. The functional tool receives DICOM objects and extracts the related dosimetric parameters of the header in a database for ulterior processing. A set of training material has been prepared including presentations (introduction and step-by-step tutorial), the free software necessary to implement the trial and some sample of anonymized images to test the behavior of the system. The training material was used by three medical physicists with no previous experience in managing DICOM tools: its feasibility was evaluated, the time necessary to complete each module was measured, the information provided was assessed as to its adequacy to reach the objectives, and procedures on how to use this material as an e-learning activity were identified. A teaching module on automatic patient dose registry in diagnostic radiology addressed to medical physicists using free software and with no previous programming knowledge is feasible. It is possible to use this training functional tool as an e-learning activity. The medical physicists participating in the trial were able to develop the functional tool. The time necessary to reach the proposed objective varied from 30 to 50 hours.

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S1.O4

RADIATION EXPOSURE MONITORING IN LUXEMBOURG

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Medical patient radiation exposure is a popular and controversial topic, it is the primary source of artificial exposure of the population in industrialized countries. However, the radiation protection of persons exposed for medical purposes is of relatively recent concern (Euratom 84/466 & 97/43). The concept of regulatory dose limit is inappropriate in the context of medical examinations. For medical radiation exposures the dose to the patient should be as low as reasonably achievable (ALARA principle) and this can be achieved through the justification and optimization of the radiological examination. Dose should be as low as reasonably achievable but consistent with an image quality allowing a correct medical diagnosis, as a result, the tracking of patient radiation dose is very important and very useful. It should also be noted that many regulations and guidelines express the need for facilities to monitor radiation dose estimations during medical examinations using radiation. Different hospital sites of the Grand Duchy of Luxembourg have opted for a DACS (Dose Archiving and Communication System) solution. DACS uses dose information stored together with the clinical images in the PACS (Picture Archive and Communications Software) in the form of dedicated and sometimes private DICOM header values, printed as an image in SC (Secondary Capture) images, as SR objects (Structured Reports) or in log files stored on the console of the X-Ray device. DACS allows to: (i) view the dose received for a certain exam or hospital stay, (ii) view the patients cumulative dose history (patient dosimetric history), this will implement the principle of justification and answer the following question: in light of this history, is the examination justified?, (iii) determine if a given patient dose exceeds the DRL (Diagnostic Reference Level) established for the given examination or whether the patient required a supplementary examination, (iv) send Dose information (anonymized) to registries for follow up at population level (i.e. DRL following Euratom), (v) compare ‘dose profiles’ with other sites/regions, with local policy targets or with standards of practice and (vi) compute the population ‘dose profile’ for a certain hospital, region or pathology. In this presentation we will show the potential that a DACS can offer with examples of dose optimisation in mammography, conventional radiology and computed tomography conducted at our hospital sites.

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S1.O5

IVEU: IT-BASED COLLECTION AND REPORTING OF RADIOLOGICAL EXAMINATION PARAMETERS.

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In Germany, each single site using ionizing radiation in human medicine is assigned to a competent medical authority (CMA). Duties of these CMAs are e.g. the inspection of medical aspects of the use of X-rays at the sites as well as technical quality assurance of X-ray devices. The CMAs themselves have to report the results of their work to the ministries and the Federal Office for Radiation Protection (BfS). This reporting currently has weaknesses due to incompleteness and complexity of data collection and interpretation. In this paper we present the IVEU software framework that supports the data collection, analysis and reporting of x-ray examination parameters at the sites, in CMAs and for the BfS. A questionnaire was used to capture the IT-situation at the different CMAs and to define the requirements for the IVEU framework. Most CMAs already deploy systems with information about the X-ray operators and their devices. The new software had to be able to collect DICOM meta-information and to link these information with the data already available in the existing systems. The combined data needed to be stored for further processing, viewing and exporting. External interfaces to existing systems and data mining tools had to be defined. The IVEU framework was implemented as a Java desktop application with a Postgresql database. Actual usage scenarios range from single computer installations up to mid-size environments using a central database. The software framework provides functions to import images from several sources (CD, file system, PACS query/retrieve) and to extract their metadata. For the calculation of custom values like mean mAs or scan length in CT - an integrated JavaScript engine is used. Integrated filtering, viewing and export to CVS allow an easy access and analysis of the data. The generation of reports and exchange of data between IVEU installations complete the list of features. Interfaces allow the use of additional modules. Today, modules for classification, reporting, dose calculation and statistics are available. The software role out is starting in February 2014, including user training. A cross sectional study with the aim to prove the usefulness of the new IT-optimized methods is planned in the course of the project within 2014. This project is supported by the BMU/BfS under tender 3611S40008 (IVEU)

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S1.O6

ONLINE DATA COLLECTION PLATFORM FOR NATIONAL DOSE SURVEYS IN DIAGNOSTIC AND INTERVENTIONAL RADIOLOGY

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According to the Bulgarian regulation for radiation protection at medical exposure, the National Centre of Radiobiology and Radiation Protection (NCRRP) is responsible for performing national dose surveys in diagnostic and interventional radiology and nuclear medicine and for establishing of national Diagnostic Reference Levels (DRLs). Two national dose surveys were completed since 2002 in which data collection was performed manualy with filling paper forms by each facility and sending them to the NCRRP. The next national dose survey is under preparation to be performed in the period 2014-2015, with the ambitious aim to include conventional radiography, mammography, conventional fluoroscopy, interventional and fluoroscopy guided procedures and CT, and to cover most of the facilities in the country. New survey will be performed electronically using centralised online data collection platform established by the NCRRP. The aim is to shorten the survey and to improve the accuracy by reducing human errors and increasing the number of responding facilities. This is facilitated by the fact that after the enforcement of the Medical exposure regulation in 2005 all fluoroscopy and stationary radiography equipment was equipped with dose-area product meters and patient dose records keeping in electronic or paper format was required. All newly installed CT scanners have dose displays and records of patient doses should be kept. Online dose data collection platform was developed, in which hierarchical scheme was implemented, by data registering in few steps: entry to the system by authorized hospital representative; facility data registering, then equipment parameters entering, and at the last step – patient dose data entering for a number of pre-selected x-ray procedures. Short but clear instructions are also included to guide users, and to minimize errors. For each type of procedure electronic data collection forms were elaborated and integrated in the platform. After entering patient data the software suggests local typical dose to be used by the facility for comparison with the national DRLs and optimization. The system provides also tools for further data analysis by the NCRRP staff. Since many of the X-ray systems in Bulgaria are still analog, the online system at this stage allows the user to manually enter patient data. A module is under development for automatic harvesting of dose data from PACS systems of digital equipment.

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RPM 2014

SCIENTIFIC SESSION 2A

INTERVENTIONAL PROCEDURES


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S2A.O1

A SET OF PATIENT AND STAFF DOSE DATA FOR VALIDATION OF MONTE CARLO CALCULATIONS IN INTERVENTIONAL CARDIOLOGY

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To obtain a set of experimental values of patient and staff doses in a cardiac catheterization laboratory using the range of radiographic and geometric parameters typical in clinical practice. The data obtained will be available for validation of Monte Carlo calculations and for training purposes and help optimize radiation protection for patients and staff. Experimental measurements were made with an anthropomorphic phantom and a monoplane flat detector based x-ray system used for interventional cardiology procedures. Operational protocols were the three standard fluoroscopy modes (low, medium and high) and a cine acquisition mode. Patient dose values were measured with a transmission ionization chamber: Kerma area product (KAP) and cumulative air kerma (CAK) at the entrance reference point. Occupational doses were measured with active solid state dosemeters at the typical position of the operators (for femoral and radial accesses) and at the position of the circulating nurse. All the dosemeters used during the experiments had previously been verified with traceable calibrated dosemeters. Values of KAP and CAK rates were measured for fluoroscopy and cine modes and Hp(10) for three operator's positions (with and without protection tools). The set of experimental results were obtained for different operational conditions: 1) Lateral angulations (LA) from -90º to +90º at intervals of 20º; 2) Cranio caudal (CC) angulations from -30º to +30º at intervals of 15º; 3) Combined LA and CC angulations (4 positions); 4) Table height (isocenter and ± 10 cm); 5) Distance image detector to patient (from 95 to 115 at 10 cm intervals); 6) Collimation and wedge filter (2 collimation sizes and 2 wedge filter positions); 7) Magnification (using 25, 20 and 15 cm); 8) Patient thicknesses (with a standard Rando phantom and increasing the kV and mAs with 2 additional copper absorbers). Uncertainties were also estimated. A set of around 500 dose rate values for patient and staff were obtained using the most common radiographic and geometric parameters used in clinical interventional cardiology practice. This set will allow detailed validation of Monte Carlo calculations and also relative comparisons of patient and staff doses in different operational conditions for training and optimization purposes.

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S2A.O2

IMPLEMENTING ALERT LEVELS FOR MAXIMUM SKIN DOSE ASSESSMENT IN INTERVENTIONAL PROCEDURES. USE OF DIFFERENT DOSIMETRIC METHODS.

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Interventional procedures in radiology and cardiology are associated with potentially high local skin doses. Knowledge of dose distribution to the patient skin is therefore of outmost importance and can be assessed using different dosimetric methods, as thermoluminescent detectors (TLD) or radiochromic films. EURADOS WG-12 focuses on characterizing these detectors, while comparing their practicality and accuracy. Six dosimetry laboratories participated in the study, each using its own method for skin dose measurement: radiochromic films, TLD arrays or TLD foils. The study included 155 patients and three interventional procedures: neuroembolization (NE), chemoembolization (CE) and percutaneous coronary interventions (PCI). The investigation also focused on correlating measured maximum skin doses to the different dose indicators. Thus, fluoroscopy time and available dose indicators including air kerma area product (KAP) and air kerma at reference point (Ka,r) were recorded. The work finally compared the different dosemetric methods when jointly used for skin dose measurement on the same patient. Measured skin dose values ranged from few mGy up to 7.7 Gy, 3.9 Gy and 3.0 Gy, respectively for NE, CA and PCI. Skin dose values higher than 3 Gy (ICRP threshold for skin injuries) were recorded in 32%, 19% and 7% of the cases for NE, CA and PCI, respectively. Despite the known assumption that Ka,r is merely a conservative estimator of skin dose, this online indicator had a reasonably good correlation with the measured maximum skin dose for NE procedures. As such, the study indicates that displayed quantities can be used to predict maximum skin dose and alert operating staff of possible tissue reactions. Meanwhile, when radiochromic films and TLDs were jointly used on the patient, the ratio of measured skin doses recorded with films and TLD ranged from 1.2 to 3.9. This shows on the one hand, that both radiochromic films and TLD are good dosimetric methods for measuring skin doses in interventional procedures and on the other hand, dose mapping with TLDs is proven to be difficult and such detectors are not practical and cost-effective to be used routinely. Finally, TLD foils have shown to combine both film and TLD advantages, namely 2D mapping and high dose accuracy, but remain unavailable in clinical routine.

The presented results are a valuable input for increasing awareness related to the importance of dose management in interventional procedures.

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S2A.O3

DEFINITION OF LOCAL TRIGGER DOSE VALUES FOR COMPLEX INTERVENTIONAL CARDIOLOGY PROCEDURES: A FEED BACK EXPERIENCE OF A HIGH VOLUME CATHETERIZATION CENTRE IN FRANCE.

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International bodies and radiation safety regulators consider patient skin dose in interventional cardiology as an important issue and recommend clear actions to be undertaken as to prevent deterministic skin effects and carefully comply with the ALARA principle. In order to establish guidelines for both dosimetry specialists and practitioners, trigger values for Air Kerma at the IRP and for DAP were recently updated and published by international professional bodies for patient undergoing complex and lengthy or repeated interventional procedures. Practical implementation of recommended trigger dose values in the routine daily work is however not easy since it requires organization and collaboration of multidisciplinary teams. This paper will discuss patient dosimetry results obtained in one of the major interventional cardiology centres in France where about 4,500 IC procedures were performed between October 2012 and October 2013 on 3,220 patients in three different catheterization laboratories. Discrepancies between Air Kerma values displayed by equipment and assessed peak skin dose will be presented for all the procedures having exceeded the recommended trigger dose value of 5000 mGy i.e. about 1.3% of the total number of procedures. Data analysis and methodology applied to determine the most relevant local trigger dose values within the considered centre will be discussed and compared to recommended ones.

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S2A.O4

EVALUATION OF A REAL TIME DISPLAY FOR SKIN DOSE MAP IN CARDIAC CATHETERIZATION PROCEDURES

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During interventional cardiology (IC) procedures, patients with different degrees of complex pathologies may occasionally require interventional procedures with large fluoroscopy times or high number of cine series, likely to cause radiation skin injury. European regulation requires patient doses to be recorded: the most common radiation quantities used are kerma area product (KAP) and cumulative reference air kerma (CAK), but these indicators are not directly related to peak skin dose, and optimization to reduce high doses in certain regions of the skin results difficult. Some systems based on external computers used to offer skin dose maps in real time, but they are no longer available. Several radiation protection organizations call for the re-introduction of such tools. A prototype designed to monitor the patient skin dose distribution in real time for interventional cardiology and available as a new display inside the catheterization laboratory has been tested. Different experimental conditions were simulated using copper absorbers. Dose measurements were performed with reference dosimetry systems (solid state multimeter, optically stimulated luminescence dosemeters (OSLD) and radiochromic films). The incident air kerma (Ki) values were compared with the results displayed and archived by the real time prototype. Radiochromic films were used to verify the geometry accuracy in the size and position of the irradiated areas. The real time skin dose map system presented values 32% and 40% higher than the Ki measured in the range of 0.1-2.3 Gy. Taking into account the couch and mattress absorption and the backscatter, the prototype dose indicator would be numerically equivalent to the entrance surface air kerma in patient skin within a range of ±20%. Concerning the geometry accuracy, the prototype, which has a spatial resolution of 0.5 cm, and the analysis of the dose maps with radiochromic film showed differences of 1,5 cm. The prototype tested performs acceptable estimations of the patient skin dose maps and peak skin dose in cardiac catheterization procedures. This tool gives interventional cardiologists the opportunity to optimize in real time the skin dose distribution during complex procedures and reduce the risk of skin injuries.

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S2A.O5

ACCURACY OF A DOSE MAP METHOD ASSESSED IN CLINICAL AND ANTHROPOMORPHIC PHANTOMS SITUATIONS USING GAFCHROMIC FILMS

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A dose map method has been integrated on GE X-Ray angiographic systems to provide an indication of the local dose distributed on a patient envelope representative of individual patient shapes. Several tests have been performed to assess the accuracy of the method by using Gafchromic XR-RV3 films in anthropomorphic phantom situations and in clinical situations. The dose map method computes local doses for each frame, depending on the estimated air kerma, the exposure area, the image chain and table relative position and system settings, including table and mattress estimated attenuations and backscatter correction. The local dose is displayed as a 2D map during the procedure on a screen allowing the operator to visualize where the local dose has been distributed on the patient envelope. To evaluate the accuracy of the local doses, values inside different level of irradiated areas have been compared between the film and the dose map method. Since not available post exam, exposed areas for clinical situations have been determined from the Gafchromic films. The dose map results show a good visual agreement for the anthropomorphic phantom situations and the local doses agreed with less than 40% accuracy compared to the Gafchromic films in both situations.

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S2A.O6

COMPARISON OF TWO ANGIOGRAPHIC SYSTEMS IN PAEDIATRIC INTERVENTIONAL CARDIOLOGY

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The purpose of this study was to analyse the levels of radiation exposure for patients and staff of a new biplane X-ray system based on flat detector (FD) technology in a paediatric cardiac catheterization laboratory. A comparison with the results obtained with the previous existing conventional system equipped with image intensifiers (II) was made. The X-ray system which had been in routine use for about 12 years was a Toshiba 'rebuilt' (using parts from other old X-ray systems) equipped with II. The new system is a Philips Allura Xper FD20/20. Patient entrance dose rates (i.e. entrance surface air kerma (ESAK)) and scatter dose rates (i.e. Hp(10)) to the eyes and the ankle position of the cardiologists have been measured for the typical paediatric patient thicknesses (i.e. 4-16 cm of PMMA), using the most common exam protocols and operation modes. All measurements were made in the same geometrical conditions and with only the frontal C-arm. The ESAK values for the different PMMA thicknesses and fluoroscopy modes with the II-system resulted from 1.41 to 15.4 mGy per min and 0.62 to 5.46 mGy per min for the FD-system. For cine mode these values were 49.70 to 323.22 μGy per frame (with the old II system) and 2.42 to 59.80 μGy per frame (for the new FD system). For the II-system, the scatter dose rates (frontal C-arm without angulation and without protection) ranged from 0.67 to 12.2 mSv h-1 at the eye position of the cardiologist during fluoroscopy and cine modes. At the lower extremities, these values were 1.11 and 24.24 mSv h-1. In the case of the FD system, these values ranged from 0.24 to 0.67 mSv h-1 for eye lens and from 0.73 to 2.01 mSv h-1 for position of cardiologist's ankle. The newly installed X-ray system showed lower dose values for patients (an average reduction factor of 1.6 times and 9.7 times in dose for fluoroscopy and cine modes, respectively) and staff with an average reduction factor of 15.9 times at the eye position during fluoroscopy and cine modes, if no protective tools are used. At the lower extremities, this value was 7.6 times.

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S2A.O7

INSPECTION WITH CARDIOLOGY DEPARTMENTS IN NORWAY – ARE THEY MAKING IT GREAT IN RADIATION PROTECTION?

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Staff involved in interventional cardiology receives the highest occupational doses in Norway and skin burns of patients have been reported. Focus and awareness on radiation protection (RP) in cardiology is therefore crucial to reduce the associated radiation risks. To identify the level of RP for patients and staff, and compliance with the RP regulation, the Norwegian Radiation Protection Authority (NRPA) carried out inspections with cardiology departments in Norway. Totally eight hospitals (seven public, one private) were inspected by NRPA during 2013-2014. The inspections were carried out as quality system audits; based on documents reviews, interviews, on-site inspections and observation of interventional procedures. Focus topics for the inspections were: organization of RP, role and involvement of the RP officer and medical physicists, education and training in RP, justification and optimization, protection of staff and patients, personal dosimetry, diagnostic reference levels, monitoring and follow-up of patient doses and performance of quality control of X-ray equipment. The inspections revealed that most of the inspected hospitals had non-conformities with the RP regulation. Most deviations were associated with education in RP and follow-up of patients who had received high radiation doses. Lack of estimation of eye lens doses to evaluate the risk of exceeding the new dose limit for cardiologists with high personal dosimeter readings (worn outside the apron) was common. Other common non-conformities dealt with establishment of local diagnostic reference levels and their systematic use in optimization of cardiology practice. Notification of unintended incidence, especially patient doses much higher than intended, was not systematically reported in the hospitals quality system. The inspections revealed a need for increased awareness of RP in cardiology practice. Level of compliance with some of the requirements given in the RP regulation was poor. Finally, inspections turned out to increase the awareness of RP in cardiology and are identified as an effective tool for improving RP at the hospitals.

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S2A.O8

RADIATION PROTECTION OF PATIENTS AND ITS IMPACT ON STAFF IN INTERVENTIONAL PROCEDURES IN ALGERIAN HOSPITALS

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Increasing numbers of procedures are being performed worldwide using X-rays to guide interventions in the body. X-rays are used to continuously monitor the process resulting in prolonged exposure and high patient radiation doses. In Algeria, an important increase of the number of X-ray equipment was observed after 1980 with a spike in 1995 and 2000. According to the International Action Plan on Radiological Protection of the Patients, patients have the right to expect and be assured that radiation used in diagnostic and/or treatment procedures will be administered in a safe and effective manner. To ensure patient dosimetry and helping in raising awareness of the needs and building capacity for developing radiation protection of patient and staff in Interventional Cardiology (IC) and Radiology (IR). Three major Algerian hospitals were selected: CHU Bab el Oued, EHS Maouche and CHU-Parnet. The data collection included information on radiation protection tools used in interventional rooms for the staff (such as use of personnel monitoring badge by the operator and assistants, lead apron or lead glass eye wear etc) and on patient radiation dose. The dosimetric quantities used to investigate patients doses were Kerma-Area Product (KAP) and maximum skin dose (MSD). To evaluate MSD, gafchromic films were used. The calibration of films was done by using a standardized procedure provided by the IAEA. The results of staff radiation protection investigation showed that lead aprons are used by the radiologist or the cardiologist performing the procedure, as well as the radiographers. Lead eye glasses are not systematically used. Only, one personnel monitoring badge is used by radiation workers due to the regulations of the country which is worn below the lead apron. For patients, the results revealed large variations in MSD and KAP values. The large discrepancies in MSD values for all procedures are due to the variations in the field size and the focus to skin distance, the projections and angulations used, experience of the operator, complexity of the procedure. The large variations in MSD values stress the need to continuously monitor patient dose in interventional procedures with special emphasis to interventional cardiology procedures. Common strategies must be undertaken to reduce radiation doses to both medical staff and patients. Staff training on radiation protection is highlighted.

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S2A.P1

PATIENT RADIATION DOSES IN VARIOUS FLUOROSCOPICALLY GUIDED ORTHOPAEDIC PROCEDURES

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The increasing use of fluoroscopy in orthopedic trauma practice requires the investigation of patient radiation doses in the orthopedic operating theatre. During a period of 1 year, all orthopedic procedures performed under fluoroscopic guidance using a mobile C-arm unit, were monitored and the type of the procedure, the fluoroscopy time (T), the kerma-area product (KAP) values and the number of radiographic acquisitions (films or digital) were recorded. The two most often performed techniques were: intramedullary nailing (IMN) of intertrochanteric/peritrochanteric fractures (101 cases, 49.3%) and antergrade IMN of femur or tibia shaft fractures (28 cases, 13.7%). For the rest of the recorded procedures, none accounted for more than 5% of the studied sample; so they all categorized as “various” (76 cases, 37%). Large variations in T, KAP and number of radiographs were observed among the same procedure type among different patients. For IMN of intertrochanteric/peritrochanteric fractures, antergrade IMN of femur/ tibia shaft fractures and for various procedures, respectively, median values were 2.1, 2.2 and 0.6 min for T, 6.3, 6.3 and 0.6 mGy.cm2 for KAP and 21, 2.2 and 6.7 for radiographs. Patient doses during fluoroscopically guided procedures measured in our orthopedic theater are relatively low compared to other interventional procedures (e.g. DSA angiography). However, since the patient dose is largely dependent on the proper use of fluoroscopy, all orthopedic departments need to investigate their practices and the resulting patient exposures during such procedures.

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S2A.P3

CALCULATION OF PATIENT AND PHYSICIAN RADIATION ABSORBED DOSES IN CORONARY ANGIOGRAPHY USING MONTE CARLO SIMULATION

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Coronary angiography is the most common test to show inside of the coronary arteries. In this procedure, patient and physician receives high amounts of radiation absorbed doses because of long fluoroscopy time. Awareness of patient and physician radiation absorbed doses in coronary angiography is an important issue in radiation protection dosimetry. Because, this knowledge can help the physicians to adjust the tube parameters and use suitable lead protection for high radiosensitive tissues to reduce the absorbed doses of patient and themselves. In addition, following the ALARA rule is not possible without having information about radiation absorbed doses of patient and physician. In this research, radiation absorbed doses of some high radiosensitive tissues in patient and physician during coronary angiography have been calculated by using Monte Carlo simulation. To reach this goal, ORNL phantom and MCNPX code have been used. Three normal projections in coronary angiography have been chosen for this research (PA, RAO, and LAO). X-ray source has been simulated as a disk which was located at a distance of 65 cm from the patient. Tube voltage has regulated to 84, 89, and 86 kV in three mentioned projections respectively. Patient has been exposed by X-ray for 175 s and during the exposure; field size has been adjusted to 95, 79, and 95 cm2 for PA, RAO, and LAO projections respectively. Physician has considered in the standing position close to the patient's right leg (for femoral access) that is a common position for physician in coronary angiography. The calculated results showed that the absorbed doses of patient's lungs and physician's spleen with amounts of 4.149 and 0.31 mSv, respectively, are the highest values in comparison to the other studied tissues. In case of patient's lungs, the deviation between the calculated absorbed dose in this research and the experimental result in literature was found to be around 9.2%. Furthermore, since, recently cases of cataract among angiography physicians have been observed, calculation of absorbed doses in physician's eye lens were done in this research. Considering the result of this research, physician's eyes have absorbed 0.022 mSv in a coronary angiography. So, using lead glasses could be useful to reduce eyes absorbed doses. According to the calculated results of this research, lead glasses have decreased physician's absorbed doses 83.33 and 30% respectively in left and right eyes.

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S2A.P4

RADIATION DOSES ABSORBED BY THE PATIENT DURING CORONARY INTERVENTIONS IN FOUR CROATIAN HOSPITALS

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The number of coronary interventions increased substantially in recent years. Although of great benefit to patients, the procedures impart high patient doses. Though there is legal framework for patient dose measurements in Croatia during radiological procedures, in practice it applies only occasionally. Quality control manual introduced in University Hospital Osijek and expanded to other big cardiac centres in Croatia, besides for checking the technical characteristics of the device, provides constant measurement and analysis of patient doses in interventional cardiology. It also includes patient examination for radiation skin injuries when possibility of dose larger than 2 Gy exists. Aim of the study was to determine and compare patient radiation doses absorbed in cardiac interventions measured in 4 years in four big cardiac centres with the values proposed by the European Commission and other professional bodies. The local reference dose levels are also set. In accordance with the IAEA action plan it will serve to initiate regular quality control on all fluoroscopic devices in Croatia. In case of high skin doses, patients would be examined for skin injuries. The radiation dose absorbed by the patient was measured as the product of air kerma and area (KAP), fluoroscopy time and number of cine images. Skin doses were measured by radiochromic films when complicated procedure was expected. Clinical practice, personal protection and wearing of dosimeters were observed. We also compared doses of the same cardiologists at an interval of three years. The study showed large dose ranges. The proposed national DRL are as follows: 32 Gy cm2, 6.6 min and 610 images for coronary angiography, and 72 Gy cm2, 19 min and 1270 images for coronary interventions. The measured values are within the proposed EU DRLs, but there is a room for optimization. Moderate correlation between peak skin doses and KAP measurements were observed in all rooms but revealing a large difference in way of working between different hospitals. Deterministic skin effects were not observed in this study. A moderate reduction in doses was found in follow-up of the doses of the same cardiologists at an interval of four years. It was interpreted as the effect of education and rise of the experience of the interventional team. The study can contribute to the assessment of overall health risks caused by medical radiation procedures in Croatia.

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S2A.P5

AN AUDIT OF PATIENT RADIATION DOSES IN INTERVENTIONAL CARDIOLOGY

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Many interventional cardiology procedures result in substantial radiation doses to the patient. It is difficult to conclude from the literature what the optimal Diagnostic Reference Levels (DRL) are for common procedures such as coronary angiograms, PTCA and pacemaker insertions. Values for Dose Area Products (DAP) ranging from 29 Gy.cm2 to 57 Gy.cm2 have been quoted (IAEA, Vano et al. (2012)). Similarly, values of 58 and 94 Gy.cm2 have been quoted for PTCA exams respectively. In this study, a patient dose audit was performed in Galway University Hospitals for 2012 and 2013 for the six most common cardiac angiographic procedures (a total of 2436 procedures). These were coronary angiograms (1945), PTCA procedures (172), Coronary angiogram + PTCA (218), pacemaker insertions (27), box/lead changes (36) and defibrillator implants (38). The average DAP as well as 75th percentile DAP (DRLGUH) were determined. DRLGUH for each of these procedures was compared to the DRLV quoted in the Vano study. For some procedures (Angiograms, PTCA, and Angiogram +PTCA) the DRLGUH exceeded the DRLV by significant amounts (28.8%, 49.7% and 16%) and (34.4%, 86% and 58%) in 2012 and 2013 respectively. Other procedures such as the pacemaker insertion, box/lead change, and defibrillator implant showed DRLGUH much lower than the quoted DRLV (44.1%, 83.24% and 23.6%) and (0.14%, 17% and 22%) for 2012 and 2013 respectively. This study indicates a clear need for local DRLs to be developed specifically for each procedure and perhaps the implementation of new strategies to reduce actual DAPs to bring them closer to the quoted DRLs.

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S2A.P6

RADIATION EXPOSURE TO PATIENTS AND MEDICAL STAFF IN HEPATIC CHEMOEMBOLIZATION INTERVENTIONAL PROCEDURES

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The purpose of this study is to evaluate patient and medical staff doses received from transarterial chemoembolization of hepatocellular carcinoma which is the most common primary liver tumor worldwide, and its incidence is rising. The study was performed in three hospitals in Recife, capital of the state of Pernambuco, located in the Northeast of Brazil. Two are public hospitals (A and B) and one is private (C). The x-ray imaging systems used in this study were a Siemens Artis Zee unit with a flat panel detector (hospital A); a Thosiba angiography system, model DRX-T7345GDS, equipped with image intensifier (hospital B) and a Phillips Allura FD20 (hospital C). The maximum skin dose (MSD) of the patient was estimated using radiochromic films and the air kerma area-product (PKA) was measured by a transmission chamber. For each procedure the number of images, irradiation parameters (kV, mA and fluoroscopy time) and the cumulative air kerma (Ka,r) at the reference point were also registered. For the medical staff dosimetry, thermoluminescent dosimeters (TLD-100) were used attached next to the eyes, close to the thyroid (above the shielding), on the thorax under the apron, next to the hands in the region of the pulse, and next to the feet. The effective dose to the staff was estimated using the algorithm of von Boetticher. The mean value of the total air kerma - area product was 23,555 µGy.m2, 59,113 µGy.m2 and 49,869.9 µGy.m2 for hospitals A, B and C, respectively. The total acquired images in the procedures performed in the three hospitals ranged from 75 to 475 frames, with a mean value of 233. With regard to the physicians, the average effective dose was 37µSv, and the Sy, respectively.□minimum and maximum values recorded were 10 µSv and 43 The results showed that the feet received the highest doses followed by the hands and lenses of the eyes, since the physicians didn't use lead glasses and the equipment had no lead curtain.

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S2A.P7

PATIENT DOSES IN INTERVENTIONAL PROCEDURES IN GASTROENTEROLOGY

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The purpose of present work is to study doses to patients undergoing interventional procedures in gastroenterology. The study was conducted in a interventional radiology room equipped with C-arm fluoroscopy system used for different interventional procedures. During a period of May to December 2013 a total of 80 patients were registered undergoing diagnostic invasive or therapeutical interventional procedure. The data collected comprise type and complexity of the procedure (evaluated by radiologist), patient dose in total air kerma-area product, PKA, per procedure, PKA in cine and fluoroscopy mode separately, fluoroscopy time, number of images acquired, as well as clinical patient data (age, weight, height). Four types of most commonly used procedures were included: Endoscopic retrograde cholangiopancreatography (ERCP), Percutaneous transhepatic cholangiography (PTC), Arteriography (A), Pleural drainage (PD) and Placement of esophageal stent (ES). From the collected sample of patients the min, max, average and median values were calculated. The mean values of total PKA varied between 0.8 Gy cm2 and 73.3 Gy cm2, while the highest individual patient doses were found to be for PTC. The mean values of PKA for ERCP and arteriography were commensurable: 17.4 Gy cm2 and 18.2 Gy cm2, respectively. The analysis of the results indicates that the number of images acquired is the main contributor to the total dose, averaged 118 and 61 for arteriography and ERCP, respectively. For all procedures the mean values of fluoroscopy time varied between 0.8 min and 5.1 min. This is the first study of patient doses in interventional gastroenterology in the country. Further studies in other department will aim at proposing national reference levels for most common gastroenterology procedures.

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S2B.O1

FOLLOW UP OF CHILDREN EXPOSED TO IONISING RADIATION FROM CARDIAC CATHETERIZATION: THE COCCINELLE STUDY.

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Cardiac catheterization has become an essential tool in the diagnosis and treatment of children with a wide variety of congenital and acquired forms of cardiovascular disease. Despite the clear clinical benefit to the patient, radiation exposure from paediatric cardiac catheterization may be substantial. Given children's greater sensitivity to radiation and the longer life span during which radiation health effects can develop, an epidemiological cohort study, named Coccinelle, is carried out in France to evaluate the risks of leukaemia and solid cancers in this population. A total number of 8000 included children is expected. All children who have undergone at least one cardiac catheterization procedure since 2000 and were under 10 years old are included. Electronically stored patient records from the departments of paediatric cardiology of the French national network for complex congenital heart diseases are being searched to identify the children to be included. The main procedures investigated are: Diagnostic, Patent Ductus Arterious closure, Atrial Septal Defects closure, balloon valvuloplasty, balloon angioplasty and electrophysiology procedures. For each procedure, dosimetric parameters (dose area product, fluoroscopy time and total number of cine frames) are retrieved retrospectively. Organ doses, especially to the lung, the oesophagus, and the thyroid are calculated with PCXMC software. Up to age 15, the cohort will be followed up through linkage with French paediatric cancer registries. Up to now, 4500 children have been already included in the cohort but recruitment is still ongoing. On average, each child has undergone 1.3 cardiac catheterization procedure, for a total of over 5,000 procedures. Nearly half of these were performed during the first year of life. Dosimetric data were analysed for 801 procedures performed between 2010 and 2011. For diagnostic procedures, the mean effective dose value was 4.8 mSv (min: 0.3 mSv: max: 23 mSv). For therapeutic procedures, the mean effective dose value was 7.3 mSv (min: 0.1 mSv; max: 48.4 mSv). Highest organ doses were found for the lungs and oesophagus. These preliminary results revealed that therapeutic procedures can lead to important exposure levels. This reinforces the need to conduct epidemiologic studies such as the Coccinelle study in order to evaluate the radiation-induced cancer risk in this specific paediatric population.

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S2B.O2

CAN ST2 PROTEIN REPRESENT A NOVEL IONIZING RADIATION BIOMARKER FOR POTENTIAL USE IN EPIDEMIOLOGICAL STUDIES?

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Application of ionizing radiation (IR) in imaging diagnostic studies including radiography, fluoroscopy, angiography and computed tomography scanning is justified by the assumption that the magnitude of the risk of radiation-induced health effects at low doses and dose-rates, applied in medical diagnostic settings, is far less than the likely benefit to the patient for indicated examinations. However, evidence suggests that low radiation doses can be associated with increased risk of cancer and non-cancer diseases including cardiovascular disease (CVD). Therefore, the development of appropriate biomarkers for use in molecular epidemiological studies is crucial for improving our understanding of the complex relationship between dose and risk in the low-dose range, typical for diagnostic or occupational exposure. The current study is designed as a pilot investigation on whether the ST2 protein, an Interleukin-1 receptor family member, can represent a novel molecular marker for low-dose radiation cardiovascular effects. Since the soluble form of ST2 plays an important role in vascular remodeling, i.e. in the pathology of CVD, ST2 has emerged as a prognostic marker in patients with myocardial infarction and heart failure. In order to evaluate the potential use of ST2 in epidemiological studies, we have collected blood plasma samples from 45 occupationally exposed individuals from the “Kozloduy” Nuclear Power Plant in Bulgaria (cumulative doses from 0.11 mSv to 190 mSv) and 25 healthy individuals representing the external control group. Results suggest a higher number of occupationally exposed individuals with elevated levels of ST2 above the clinical threshold of 35 ng/ml, and statistically significant elevation in the median levels of the marker in the exposed group, in comparison to non-exposed individuals. A slight increase of ST2 values with dose can be suggested. The marker appears to be age-independent. In conclusion, we believe that the present results might represent an important initial step towards an easy and reliable method for identifying individuals who are at risk from developing radiation induced CVD.

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S2B.O3

ON THE ESTIMATIONS OF RADIATION INDUCED CANCER RISKS FROM VERY LOW DOSES OF RADIATION AND HOW TO COMMUNICATE ABOUT THESE RISKS

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The paper is intended to give a short overview of the epidemiological and experimental data on cancer risks associated with very low absorbed doses of ionizing radiation. It will also discuss methods to present these data in an understandable way to those who are exposed. The linear no-threshold (LNT) approach to estimating cancer risks involves the use of epidemiological data at higher doses (>100 mSv), but is supported by data from exposure of more sensitive population groups like foetuses and children and the presence of rare types of cancer, establishing an “anchor point” for the linear model, at around 10 mSv. Results from radiobiology however suggest that there are processes not necessarily explained by the current single-cell hit/LNT model of radiation effects. Some biophysical arguments support a linearity down to very low doses, others do not. The mechanisms of action of radiation may be different at low doses from those observed at high doses. The ICRP concludes that the linear non-threshold (LNT) model combined with an uncertain dose and dose-rate effectiveness (reduction) factor (DDREF) of 2 for extrapolation from high doses is a deliberate basis for radiation protection at low doses and low dose rates. Even if there are significant deviations from linearity in the relevant dose range, we know almost nothing quantitatively about these effects. We do not know the magnitude or even the direction of any such deviations from linearity - the risks could be lower than those predicted by a linear extrapolation, but they could also be higher. Until more results concerning the effects of low-dose exposure are available, a reasonable radiation protection approach is to consider the effect proportional to the dose. To balance the often exaggerated fear of radiation among the public with the fact that the radiation in other contexts is neglected requires good knowledge of radiation and radiation protection, and an understanding of the psychology of risk communication. With respect to the medical use of radiation for diagnosis, assistance in medical interventional procedures and therapy, the benefits of justified and optimized procedures need to be weighed relative to the potential risks. The risk of radiation-induced effects is not well understood at the levels of radiation used for most diagnostic procedures. But there are clearly risks associated with not performing an examination that should also be considered.

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S2B.O4

KNOWLEDGE ON RADIATION EXPOSURE FOR COMMONLY PRESCRIBED TESTS AMONGST JUNIOR DOCTORS IN A NORTH INDIAN REFERRAL HOSPITAL

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There has been a tremendous increase in the use of ionizing radiation in medicine. Considering the number of tests being done daily where ionizing radiation is being used one would expect physicians to be well versed with the knowledge, the risks, costs and legal restriction associated with the use of these tests. Studies suggest that most doctors grossly underestimate or are not aware of the dose of radiation patients are being exposed to for common investigations perform in day to day practice. Also, the potential hazard of the test such as the risk of cancer is almost never discussed with the patients. We evaluated the knowledge amongst junior clinical doctors in our hospital on the radiation exposure that occurs when common radiological tests are prescribed. The study was done during the period of November 2012 – December 2013 amongst junior doctors in our hospital. A structured questionnaire was designed and sent to 200 doctors. One hundred and fifty three doctors including senior residents, junior residents, research officers, interns and medical students completed the questionnaire. Doctors were asked to identify the average dose of radiation received when a person underwent a chest X-ray. Also, taking an X-ray to represent 1 unit they were asked to estimated the equivalent doses of radiation for various radiological investigations i.e. X- rays spine, CT scans, PET scan, mammography, ultra sound, etc. A 20% derivation above or below the accepted correct values was taken as a correct answer. About 18% doctors were correctly able to state the radiation exposure that occurs with the chest X-ray. For the other questions the correct answer ranged from 6 – 30 % for various tests where ionizing radiation was used. 17% of the respondent did not know that an ultrasound was not associated with ionizing radiation. Only 27% were aware of the radiation exposure that occurs with computerized tomography (CT). Interestingly, none of the doctors felt the need to provide patients any information or the need for consent about the risk patient may have from ionizing radiation. Despite increasing effort to increase awareness, knowledge amongst junior doctors regarding the risk from ionizing radiation is grossly inadequate. There needs to be an ongoing effort at all levels including undergraduate training program to make young doctors aware of the risks of ionizing radiation in medicine.

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S2B.O5

THE WHO-IRQN REFERRAL GUIDELINES PROJECT-PRELIMINARY RESULTS OF A PILOT EXERCISE

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In collaboration with 30+ other international organizations, health authorities, regulatory bodies, professional societies, and healthcare organizations, a worldwide radiation protection project was jointly conducted by the World Health Organization (WHO) and the International Radiology Quality Network (IRQN) to promote clinical justification of medical imaging. The project team reviewed existing referral guidelines for medical imaging, identified the common recommendations(1) and compiled a set of consensus guidelines. “Referral Guidelines for Diagnostic Imaging” was produced in 2013, consisting of 44 imaging guidelines together with the basic principles of medical imaging and radiation protection. To improve the development and implementation of referral guidelines, a pilot exercise was conducted to collect feedback from the end-users. The publication was distributed to pilot sites along with questionnaires designed to identify the: availability, awareness, and use of referral guidelines; internet access; preferred presentation format (e.g. tabulated or algorithms), media and implementation strategy (e.g. print, CD, mobile devices, CPOE, web-based, etc.); gaps; future topics and performance indicators. It was tested at 40 sites representing a diverse spectrum of settings in 16 countries from the 6 WHO regions. Of the 155 participating practitioners, 80 were imaging practitioners and 75 were other health practitioners (e.g. family doctors, paediatricians, radiographers, etc.). The findings are presented, with intent to inform future related actions and to support the adoption and sustainable update of evidence-based referral guidelines. Referral guidelines and procedure justification projects improve quality of care, patient safety and appropriate use of medical imaging. By working together as a multi-disciplinary team under an inclusive global platform, the stakeholders and their actions support the implementation of the new International Radiation Basic Safety Standards (BSS) and the Bonn Call for Action. (1)Based on the American College of Radiology ACR Appropriateness Criteria, Western Australian Department of Health Diagnostic Imaging Pathways and The Royal College of Radiologists “Making the Best Use of Clinical Radiology Services” recommendations.

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S2B.O6

RUSSIAN GUIDANCE ON RADIOLOGICAL SUPPORT FOR JUSTIFICATION OF RADIODIAGNOSTIC EXAMINATIONS

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The mandatory condition for radiation protection of patients is justification of diagnostic examinations associated with the use of ionizing radiation, both X-ray and nuclear medicine examinations. An important part of the justification process is assessment of radiation risks caused by exposure of a patient during examination. Both the referral physicians and medical radiologists in Russia usually lack knowledge of radiation risks associated with diagnostic examinations. Institute of Radiation Hygiene, St. Petersburg, in collaboration with Medical Radiological Research Center, Obninsk, recently developed draft methodology both for medical doctors and sanitary inspectors called “Assessment of radiation risks of patients undergoing diagnostic examinations with the use of ionizing radiation”. The document addresses patients of various age groups and wide spectrum of modern X-ray and nuclear medicine examinations. The methodology is mostly based on the Russian national survey of patient effective doses in radiology, including CT, mammography, intervention radiology and nuclear medicine, including SPECT and PET, for patients of various age groups. Risk categorization was implemented with the use of effective doses with account for age dependence of radiation risk. International scale of risk categorization was applied in order to simplify risk perception by medical doctors and sanitary inspectors. The output of the methodology is the series of tables for each diagnostic technology with lists of examinations for three age groups (children/adolescents, adults, and senior people) corresponding to various radiation risk categories. For readers interested in more precise risk assessment, specific methodology based on organ doses is also presented. The paper will present both scientific justification of the draft methodology and main output tables with narrative guidance of their application in justification process.

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S2B.O7

JUSTIFICATION OF CT SCANS USING REFERRAL GUIDELINES FOR IMAGING

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The new ICRP Recommendations, Publications 103 and 105, maintain the three fundamental principles of radiation protection. The ICRP 105 - Radiation Protection in Medicine, referring to their appropriate application in case of medical exposures, highlights that the justification and the optimization of the medical procedures are the applicable principles in order to minimize unnecessary radiation exposure. The computed tomography (CT) scanning is the most important contributor to the population dose arising from diagnostic medical exposure. In the last decade the new CT scanners became more efficient from imagistic point of view, but also an increasing source of radiation exposure. This study analyzes the efficiency of the justification of individual CT procedures using the good practice guide and represents also a self assessment in relation to justification principle implementation. The conformity of the CT scans with guide's recommendations was retrospectively analyzed in a pediatric emergency hospital in Romania. Also, the involved patient doses were estimated. The results show that around one third of the examinations were not prescribed in conformity with the guide's recommendations, but these results are affected by unclear guide provisions, discussed here. Around a quarter of total collective dose is due to the examinations not prescribed according to the guide's recommendations. The implications of the provisions of the revised IAEA's Basic Safety Standards and of the Council Directive 2013/59/EURATOM were analyzed. The use of referral guideline for imaging is an appropriate mechanism to document the implementation of the justification principle for the individual medical exposure (ICRP's third level of justification). The education and training courses for medical doctors (especially for referrers) disseminating the provisions of the good practice guide should be considered as the main support for the justification of the CT scans at the individual level.

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S2B.O8

DOSE TRACKING AND RADIOLOGY DEPARTMENT MANAGEMENT

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Public concern regarding health risks from ionizing radiation peaked in the last 20 years with the enormous increasing of the use of computer tomography. The widespread of MDCT as a basic imaging study and diversity of CT protocols and radiation exposure requires a new management approach in promoting, performing and controlling the imaging diagnostic process. The purpose of the presentation is to review the reasonable measures that can be implemented as a routine practice in the process of management of a general radiology department regarding CT radiation risk. Based on the 6 years experience in management a general radiology department and the newly implemented supportive software for dose tracking, analyzing and reporting, we present our approach concerning radiation risk reduction. Thanks to it some problems have been solved and some reasonable measures have been implemented into a daily practice.

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S2B.O9

COST-RISK-BENEFIT ANALYSIS IN DIAGNOSTIC RADIOLOGY AND ITS RELEVANCE TO RADIATION PROTECTION

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In 1973 ICRP Publication 22 recommended that the acceptability of radiation exposure levels for a given activity should be determined by a process of cost-benefit analysis. It was felt that this approach could be used to underpin both the principle of ALARA as well for justification purposes. The net benefit, B, of an operation involving irradiation was regarded as equal to the difference between its gross benefit, V, and the sum of three components; the basic production cost associated with the operation, P, the cost of achieving the selected level of protection, X, and the cost Y of the detriment involved in the operation: B = V - (P + X + Y). This approach was applied to processes where a practice employing radiation could be separated from the irradiation of the population, when V and P could be considered to be independent of exposure.However, for medical practices patients are exposed directly to achieve a total benefit so that V and P cannot necessarily be considered to be independent of exposure. Purely risk based radiation protection strategies have not prevented significant growth in both population and individual patient doses arising from radiological practices and the appropriateness of x-ray examinations is now a major consideration. Consequently, it is worthwhile reconsidering the ICRP cost-benefit analysis concept as a basis for ALARA and justification in medical radiation protection. This paper presents a theoretical cost-risk-benefit analysis that is applicable to the diagnostic accuracy (level 2), of the hierarchical efficacy model presented by NCRP. This level is concerned with the sensitivity and specificity of an x-ray technique in a defined clinical problem setting. The approach adopted will consider two distinct patient populations within an overall population referred for x-ray examinations. Those for whom an examination is deemed to be appropriate (justified) and those for whom an examination is inappropriate (unjustified). The analysis enables the total costs of an examination to be expressed in terms of the sensitivity and specificity arising from any practice as a function of the relative numbers of appropriate/inappropriate examinations. The relevance of economic factors to medical radiation protection will be discussed for a variety of patient referral criteria and healthcare models.

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S2B.P1

STUDY FOR IONIZING RADIATION SAFETY AWARENESS AMONG PATIENTS IN ERBIL HOSPITALS.

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Medical x-ray exposures have the largest man made source of population exposure to ionizing radiation in different countries. Recent developments in medical imaging have led to rapid increases in a number of high dose x-ray examinations performed with significant consequences for individual patient doses and for collective dose to the population as a whole. Although the quantity is low in diagnostic examinations, special attention should be given to this fact in order to minimize unnecessary exposure for patients. The main objective of the study was to evaluate the level of radiation safety awareness among patients. The study was carried out by using questionnaires tailored to the patients at selected hospitals in Erbil administrated to 260 patients. 239 (91.9%) were responded. The data was analyzed using SSPS 17 package. Equally proportion of female 111(46.4%) and male 128 (53.6%) was found. Of these 84(35.1%) of patients done X-Ray without asking physician, while 142 (59.4%) of patients known that radiation causing damage. Large majority of patients 187 (78.2%) wish knowing about radiation advantage. A few patients 78 (32.6%) knowing radiation warning sign and more than 146 (61.1%) patients repeated X-Ray more than once. The study shows lesser awareness about ionizing radiation. There is need for educations of the public on radiation safety and to allay their fears about radiation. Determine the level of radiation safety awareness among patients.

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S2B.P2

COMPARISON OF THE RADIATION PROTECTION ACTIVITY, BY EXAMINE THE PREVENTION OF RADIATION INDUCED MICRONUCLEUS FORMATION OF N-ACETYL–L-CYSTEINE, TRIMETHYLGLYCINE AND THEIR COMBINED ACTION IN HUMAN LYMPHOCYTES.

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One of the biggest challenges in front of the radiologists is the radiation protection of the human population and determining of newer radiation protectors that should have minimal negative effects to the organism used in efficient concentration. Our current work targets to research and compare the specific radiation protection activity of two native metabolites N-acetyl–L-cysteine (NAC) and trimethylglycine (betaine, TMG) and their combined action. NAC is acetylated amino acid C5H9NO3S that is metabolized to cysteine and glutathione. Conversion of cysteine to glutathione is a part of homocysteine metabolism. TMG is an N-trimethylated amino acid (CH3)3N+CH2CO2- that is biosynthesized by oxidation of choline (trimethylaminoethanol) and is a component of another branch of homocysteine metabolic pathway. It participates in the transformation of homocysteine to methionine. As a normal component in the cell and information received by previous research studies, we assumed that NAC and TMG could have radiation protection effect separate and together to irradiation of model systems (human lymphocytes of peripheral blood). Defined eight groups of samples: 1. Control group of non-treated and non-irradiated lymphocytes 2. Control group of non-treated, irradiated lymphocytes. 3. Lymphocytes treated with TMG two hours before irradiation 4. Lymphocytes treated with TMG two hours after irradiation 5. Lymphocytes treated with NAC two hours before irradiation 6. Lymphocytes treated with NAC two hours after irradiation. 7. Lymphocytes treated with combined metabolites two hours before irradiation. 8. Treated with combined metabolites two hours after irradiation. The samples have been irradiated with dose 3 Gy by using of 137 Cs-source. To determine the existence of any possible radiation protective effect of TMG and NAC has been performed micronucleus formation analysis. The results showed significant protection against DNA damage and formation of micronucleus that correlated with their ability to decrease the intracellular ROS. The radiation protection activity of both metabolites increases in the following order: combined > NAC > TMG. The present study indicated that both of the examined amino acids derivatives have therapeutic and preventative activity against gamma irradiation and development of acute radiation syndrome.

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S2B.P3

RISK OF CANCER ASSOCIATED WITH MULTIPLE CT SCANS

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With widespread use of CT examinations there is concern that patients repeatedly undergoing CT examinations may accrue high cumulative dose. Multiple CT scans are often done on the same patient resulting in an increased risk of cancer. There are prior existing publications estimating cancer risks from CT scanning however they typically use effective doses or cover a general population and are not specific individuals who have multiple CT scans that may be done over a period of years. Simply adding the risks from single scans does not correctly account for the survival function. Methodology for estimating personal radiation risks attributed to multiple CT imaging using organ doses is presented in presentation. The estimated magnitude of attributable risk fraction (ARF) for possible development of radiation-induced cancer points to the necessity for strong clinical justification when ordering multiple CT scans. The presented risk estimates of possible radiation induced cancer as a result of multiple CT imaging demonstrate the ARF magnitude of 0.6% for Russian population and 0.8% for Euro-American and Asian populations. These ARF values can be 3-5 times higher, because in practical work a patient can undergo repeat CT scans on the same day. ARF value can be increased by uncertainty factors in radiation-induced risk estimating.

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RPM 2014

SCIENTIFIC SESSION 3A

DOSE SURVEYS AND DRLS


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S3A.I1

HOW TO OPTIMIZE YOUR CT PRACTICE: THE ROLE OF DIAGNOSTIC REFERENCE RANGES IN PEDIATRIC CT SCANS

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"The diagnostic reference range (DRR) provides a minimum estimated patient dose, below which accurate interpretation of the image may be compromised, as well as an upper estimated patient dose, above which the patient dose may be in excess".[1] Diagnostic reference levels (DRL), a similar concept, are based on third quartile values of mean radiation doses within hospitals and are advisory dose levels that can be used as guidance as part of a robust practice quality improvement program. This talk will review the history of DRL, the current status of DRL and their use throughout the world. The talk will emphasize how DRL and DRR can be used to guide practice such that if DRL are exceeded, local review for improvement purposes can be performed.

[1]. Goske MJ et al. Diagnostic Reference Ranges for Pediatric Abdominal CT. Radiology 2013 268(1).

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S3A.I2

DOSE SURVEYS AND DRLS: CRITICAL LOOK AND WAY FORWARD

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Radiation dose surveys as indices to reflect dose to a phantom or representative patient have been conducted widely in many countries and have been used to compare doses with established diagnostic reference levels (DRLs). Invariably, the observation is that doses are within DRLs with rare exception. It is taken as a measure of optimization in place. Is this truly optimization? Optimization requires as low dose to patient as possible while maintaining the image quality to meet clinical purpose. Firstly, DRLs are not applicable for comparison of individual patient dose indices; secondly, one needs to have either an approach like as low as reasonably achievable or some reference like 50% of DRL value or still lesser to further optimize; thirdly, there has to be accountability for patient size or cross section; fourth, there needs to be consideration for technology versus technology at which DRLs were established; fifth, there needs to be comparison with facility's own doses in earlier years which is rarely done; and sixth, one has to avoid use of DRL as de facto dose limit and the same is applicable to 50% value if chosen as achievable dose. The author questions the utility of DRL as a tool now, not withstanding its utility in earlier years when detecting outliers, that is, 25% of cases outside 75 percentile was useful. When one is hardly able to trigger investigation through surveys and comparison of mean doses with DRLs, it tends to indicate that DRLs have become almost redundant, at least for vast majority of cases. Now, with so much interest in optimization, the emphasis has to be on optimization within DRLs.

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S3A.I3

COLLECTIVE EFFECTIVE DOSE IN EUROPE FROM X-RAY AND NUCLEAR MEDICINE PROCEDURES

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Population doses from radiodiagnostic (x-ray and nuclear medicine) procedures in Europe were estimated for the first time in the recent DOSE DATAMED 2 (DDM2) project (www.ddmed.eu) launched by the European Commission. Data of 36 countries was collected to an established database. The results of the data collection and analysis lead to the following conclusions of the overall total collective effective doses in European countries: For x-ray procedures in EU-countries and EFTA countires (Norway, Iceland and Switzerland) the collective effective dose is 636000 manSv, resulting in a mean effective dose of 1,1 mSv per caput. For all European countries included in the DDM2 survey the collective effective dose was 636000 manSv, resulting in a mean effective dose of 1,1 mSv per caput. For NM procedures in EU-countries and EFTA countries the collective effective dose is 30700 manSv, resulting in a mean effective dose of 0,06 mSv per caput. For all European countries included in the DDM2 survey the collective effective dose is 31100 manSv, resulting in a mean effective dose of 0,05 mSv per caput. The contribution of NM procedures to the total population dose is about 5 %. The overall per caput effective dose for all medical imaging (X-rays + NM procedures) is therefore 1,12 mSv for EU and EFTA countries and 1,10 mSv for all European countries. These values are about half of the recent value of collective effective dose estimated in Australia and about one third of the corresponding value in the USA. However, comparing the results with an earlier estimation of population dose in Europe, in the DDM1 countries, there seems to be a trend upwards. The contribution to the total population dose of CT, plain radiography, fluoroscopy, interventional radiology and NM procedures is respectively about 57 %, 17%, 12 %, 9 %, 5 % (Group 1) and 52 %, 22 %, 13 %, 8 %, 5 %. The overall per caput effective doses are about half the recent value of per caput effective doses estimated in Australia (Wallace 2012) and about one-third of the corresponding value in the USA (NCRP 2009). Comparing the results with an earlier estimation of population dose in Europe, in the DDM1 countries, there seems to be a trend upwards; however, because for part of the DDM1 countries the new data are based on Top 20 estimations only, no strict conclusion about the percentage increase can be made. While the average dose in Europe turned out to be relatively low, there are high variations of the results between countries.

S3A.O1

ANALYSIS OF THE FACTORS CORRELATING WITH MEDICAL RADIOLOGICAL EXAMINATION FREQUENCIES

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The European Commission (EC) project Dose Datamed II (DDM2) had two objectives: to collect available data on patient doses from the radio-diagnostic procedures (X-ray and nuclear medicine) in the European Union (EU), and to facilitate the implementation of Radiation Protection 154 Guidelines (RP154). Besides the collection of frequency and dose data, two questionnaires were issued to gather information about medical radiological imaging and the different health care systems in Europe. This paper analyses a possible correlation between the collected frequency data, national economic data and selected variables from the results of the detailed questionnaire. All European countries were invited to answer two successive online questionnaires. One questionnaire was a query on general questions about the respective country and the second questionnaire a more detailed query related to the healthcare system, medical examination practice and diagnostic reference levels. The collection of the frequency and dose values, which was categorized according to RP154 (TOP 20, 74, 225), was included in the detailed questionnaire. In addition, more general information was collected from different online sources, namely the EUROSTAT database, OECD and other public data sources for non-EU member states. The data analysis was performed using the R software package, a free software for statistical computing and graphics. Only countries that provided at least TOP 20 frequency data and answered the detailed questionnaire were included in the analysis. Finally, variables of country data that might correlate with the examination frequency were tested using linear regression models. Based on a 35 countries data set, there is a significant relationship between the gross domestic product (GDP) and the overall CT examination frequency. High income countries perform more CT examinations. However, there is no correlation between the GDP and the total number of X-ray examinations in a country. A possible correlation between the frequency data and the number of CT devices, the number of general practitioners and the number of radiologist in a country could not be proved. However, further analysis of the DDM2 dataset will be a useful source to improve UNSCEAR's extrapolation model which is applied to estimate the global level of medical exposure.

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S3A.O2

INDICATION BASED NATIONAL DIAGNOSTIC REFERENCE LEVELS (DRL) FOR PAEDIATRIC CT: A NEW APPROACH WITH PROPOSED VALUES

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Indication based national Diagnostic Reference Levels (DRLs) for a few most common paediatric CT examinations are proposed. Patient dose data (CTDIvol and DPL values) have been collected for over 750 patients in 4 university hospitals. Two indications for head CT, four for thorax, two for abdomen and two for whole body CT were considered. The basic DRLs are proposed according to the third quartile (75 %) approach. For head CT, the DRLs are proposed in terms of patient age with four age groups (<1 y, 1-5 y, 5-10 y and 10-15 y). For the other CT examinations, the DRLs are proposed in terms of patient weight using a DRL curve instead of discrete values, i.e. by expressing CTDIvol and DLP values as an exponential function of patient weight. To ensure proper application of the DRLs, information is provided on the main factors (scanner types, dose reduction techniques) associated with the patient dose data forming the basis of the DRLs. Further, dose levels (curves) corresponding to the 50 % and 25 % levels of the dose distribution are provided with the DRL curve, to provide wider opportunity for optimization with different level of techniques and practices. To assess the feasibility of the results and the approach, the results are compared with patient dose data from a recent, wider study between several hospitals from a few Nordic and Baltic countries. The DRL values proposed are comparable with the data from a few other Nordic hospitals and generally lower than the values published in other countries. For all four indications selected for thorax CT (angiography, infection, trauma, tumour), the same DRL is proposed, while for head CT two different DRLs are proposed (“head routine” with higher DRLs and “ventricular size” with lower DRLs).

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S3A.O3

COMPARISON BETWEEN DIAGNOSTIC REFERENCE LEVELS BY ANATOMY AND CLINICAL INDICATION

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Currently accepted DRLs for plain film in the UK lists 16 common examinations by body part and projection. CT reference doses are also published by body part with reference to clinical indication, however in the most recent publication there are only 6 adult examinations listed. It has been shown that methodologies exist to obtain mass data exports from local hospital radiology information systems or via the DICOM header. This allows local DRLs to be established for more examination types, however these methodologies obtain examination names that are usually given with reference to the body part being examined. During a recent routine dose audit at a major Trust hospital, it was noted that some examinations appeared to consist of a bi- or multi- modal distribution of doses, indicating that the examination name was being used for two or more types of examination. This study looks at two of these examinations and compares the results of a dose audit based on the examination name or body part versus the results of an audit against an examination based on clinical indication. The two examinations chosen are: Chest AP as a body part separated into lung nodule detection and nasogastric tube placement (NG Tube); CT Head separated into stroke detection and trauma. Data extracted from RIS is used to establish a local DRL based on body part. This method follows the process recommended in IPEM 88 by comparison with national data as a first step and then with previous audits from the same. In addition to this, data has been marked to show which clinical indication and in the case of the NG tube data set, whether the image quality was sufficient for the required purpose. It has been shown that although reference doses by body part are useful, they are more relevant and have less of a spread of values if clinical indication is used as opposed to body part. A higher dose is required for CT trauma head so having local DRLs for trauma and stroke detection is desirable. Likewise, chest examinations performed for detection of nasogastric tubes appear to be slightly overexposed by radiographers, possibly subconsciously, in order to better visualise the nasogastric tube. However further work is required to ascertain whether this is justifiable. A national list of examinations by clinical indication would be ideal and would improve mass dose data extraction techniques and establishment of a better range of examinations.

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S3A.O4

ENTRANCE SURFACE AIR KERMA IN X-RAY SYSTEMS FOR PAEDIATRIC INTERVENTIONAL CARDIOLOGY. A NATIONAL SURVEY

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The aim of this work is to report the results of a national survey on entrance surface air kerma (ESAK) values in paediatric interventional cardiology systems for different phantom thicknesses and operation modes. Six X-ray systems (three with image intensifiers (II) and three with flat planel (FP) detectors) were evaluated. They represent the 100% of the cardiac laboratories that perform paediatric interventional procedures in Chile. The systems were evaluated using the methodology agreed during the DIMOND European programme, adapted in our case, to paediatric procedures. Solid state detectors have been used to measure incident air kerma (IAK) values for 4, 8, 12 and 16 cm of PMMA for fluoroscopy and cine modes. To facilitate comparison of our results with other measurements, a backscatter factor of 1.3 was used to calculate ESAK. The attenuation of the table and mattress were considered. The 3rd quartile values obtained during the survey for the different PMMA thicknesses and fluoroscopy modes (low, medium and high dose) were: 0.62 mGy/min; 1.59 mGy/min and 3.43 mGy/min, respectively, for 4 cm of PMMA; 1.41 mGy/min; 3.08 mGy/min and 6.01 mGy/min, repectively, for 8 cm PMMA; 2.82 mGy/min; 5.96 mGy/min and 11.93 mGy/min, respectively, for 12 cm of PMMA; 6.72 mGy/min; 14.27 mGy/min; and 18.10 mGy/min, repectively for 16 cm PMMA. For cine mode, the values for the different PMMA thicknesses (4, 8, 12 and 16 cm) were: 3.00; 9.37; 27.14; and 67.74 µGy per frame, respectively. As an outcome of this survey, a preliminary set of reference levels for ESAK in paediatric interventional cardiology has been obtained. Values can be used by medical physicists and maintenance engineers to help in setting cardiac equipment and paediatric protocols and suggesting further potential optimization actions when appropriate. Results of this survey could also be considered by Health and Regulatory Authorities to update national Chilean legislation on radiation protection requiring quality assurance programs, especially in paediatric medical exposures. This survey is also a first step to launch a national programme on diagnostic reference levels in paediatric interventional cardiology allowing to know the impact of the X-ray systems setting and the impact of the used clinical protocols (values of fluoroscopy time and number of cine frames).

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S3A.O5

PEDIATRIC DOSES IN RUSSIA AND THE POSSIBILITY OF DRL APPLICATION

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For children, the radiation risk is higher than for the whole population, so it is vital that exposure with ionizing radiation to pediatric patients be justified and optimized as much as possible. For all radiography examinations, the radiation dose of the exposed children should be quantified and used for protection purpose. This can be achieved by calculation the patient effective dose (ED) and the subsequent establishment and use of DRL. In the survey eight most often performed in Russia X-ray examinations (skull, cervical spine, thorax spine, lumbar spine, chest, abdomen, pelvis, hip) were included. The children were divided into five age groups: newborn (<0.5), 0.5-2, 3-7, 8-12 and 13-18. Typical parameters for the selected examination types of the “standard patient” were obtained for each of 15 investigated X-ray units from the data collected in nine hospitals in St. Petersburg. Effective dose was estimated using software ‘EDEREX’. Range of X-ray examinations varies in the each hospital according to its specialization. In total, 631 typical parameter sets for the selected examination types were collected. For each of examination and parameter set, effective dose of pediatric patients was assessed. For some examinations the doses significantly depend on age, and the for the others average doses are relatively independent on the age. Average effective dose per same kind of projection can vary up to 80 times in different hospitals, but typically vary within factor of 20. Comparison of average effective dose per projection in St. Petersburg clinics with the similar data from Italian clinics showed that ones in St. Petersburg is higher than in Italy up to factor of four but in absolute terms the dose does not exceed tenths of mSv. The significant spread of average effective doses between different X-ray rooms and the presence of X-ray units with anomalously high values of effective dose indicate a lack of standardization in the number of cases of radiological examination methods, lack of quality control of the equipment and the procedures. High exposure levels in St. Petersburg pediatric hospitals in comparison with Italian ones indicate to real possibility to reduce the levels of exposure of children in routine radiology. One of the first steps in this direction could be the introduction into the Russian practice of diagnostic examinations of the concept of children's diagnostic reference levels.

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S3A.O6

ESTABLISHMENT OF NATIONAL DIAGNOSTIC REFERENCE LEVELS IN DIAGNOSTIC RADIOLOGY IN THE CZECH REPUBLIC

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Currently valid diagnostic reference levels in the Czech Republic are not established on a basis of national dose survey. The values are adopted for some general radiography, fluoroscopy, dental, CT and mammography examinations from older British and European dose surveys. Therefore the values do not reflect the current situation in patient doses in the country. Thus a national dose survey in diagnostic radiology was carried out in the years 2012 and 2014. The group of "TOP 20" examinations identified in the European Dose Datamed project was chosen for the national dose survey. Typical patient doses for a standard sized patient (local diagnostic reference levels) and a description of standard procedures of the examinations were collected from a sample of university hospitals, public regional hospitals and private practices. From a national registry of frequency of the X-ray examinations it was estimated that about 50 % of all examinations is carried out in the hospitals/practices in the sample. However it was a common case, that the hospital provided data only for some of the examinations from the TOP 20 list. Up to now, the number of values obtained for particular examination from the TOP 20 group varies between 10 for some of the fluoroscopy examinations with low frequency and more than 100 for the most frequent examination of the chest. The values of typical patient doses were expressed in terms of entrance surface air kerma and kerma – area product for general radiography procedures, volumetric computed tomography index and kerma – length product for CT examinations, mean glandular dose for mammography examinations and kerma – area product for fluoroscopy and interventional examinations. The typical doses from the hospitals were provided by a medical physicist responsible for the patient dose assessment in the hospital. Third quartiles of the dose distributions were used to propose new national diagnostic reference levels. The collection of the data will be finished in spring 2014, when the final values of national diagnostic reference levels will be determined and proposed to Czech Regulatory Body for formal adoption and incorporation in the national regulations. The national dose survey is financed by the Technology Agency of the Czech Republic.

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S3A.O7

ESTABLISHMENT OF DIAGNOSTIC REFERENCE LEVELS IN CT: FIRST EXPERIENCE IN ALGERIA

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CT is a powerful clinical tool for the diagnosis and management of patients. Therefore, judicious use of the modality requires strict adherence to the principles of radiation protection: justification and optimisation and to ensure that the risk to patients does not outweigh the benefit gained from the technique. At the core of optimisation is the establishment of diagnostic reference levels (DRLs), first proposed by the International Commission on Radiation Protection (ICRP) in 1996. To propose CT Diagnostic Reference Levels (DRLs) by collecting radiation doses for the most commonly performed CT examinations in one site. Examination-specific DRLs for various patients groups can provide the stimulus for monitoring practice to promote improvements in patient protection. Such DRLs can be set not only at a national level (as investigation levels for unusually high typical doses), but also locally by each CT centre. In order to establish a national reference levels for CT in Algeria, a pilot study has investigated the most frequent CT examinations at the National Centre of Medical Imaging in the university hospital CHU Bab-El-Oued. Data were collected for 4 CT scanners and about 500 patients. All equipment had multislice capability (4, 16 and 320 slices). The survey includes the recording of CT parameters for each of CT examinations. Dose data [CT volume index (CTDIvol) and dose length product (DLP)] on a 20 average-sized patients in each category were recorded to calculate CTDIvol and DLP value. The rounded 75th percentile was used to calculate a local DRL for the Centre. Locals DRLs are proposed using CTDIvol (mGy) and DLP (mGy. cm) for CT head, thorax, abdomen, pelvis, thorax-abdomen, abdomen-pelvis and thorax-abdomen-pelvis, CT Coronary angiography and angio CT. Wide variations in mean doses are noted between CT scanners. These values are comparable to other international studies. The survey of dose estimates from CT highlights the substantial variations in practice in the same centre for similar types of examination and similar patient group. Such observations indicate the need for improvement through implementation of measures to keep all doses within acceptable ranges for the clinical purpose of each examination. This work must be nationally generalized.

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S3A.P1

DIAGNOSTIC REFERENCE LEVELS IN INTERVENTIONAL RADIOLOGY. A SPANISH PROGRAMME (ERRAPRI).

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According to ICRP, management of patient doses in diagnostic and interventional radiology may be facilitated by using diagnostic reference levels (DRLs), which is a tool for evaluating whether the patient dose is unusually high or low for a particular medical imaging procedure. Following these recommendations, a survey to set DRLs for interventional radiology was carried out in cooperation with the Spanish Society of Vascular and Interventional Radiology (SERVEI) with especial emphasis on the evaluation of the complexity indices. A common basic quality control protocol including calibration of the patient dosimetry systems in the X-ray systems involved, based on previous European research programmes has been applied together with the evaluation of image quality parameters using test objects. Kerma area product (KAP), fluoroscopy time (FT) and number of digital subtraction angiography (DSA) images were collected from 2009-2013 in eight different Spanish hospitals using a sample of 1,469 procedures (nine different types). A previous consensus document was agreed between the radiologists and the medical physicists involved in the survey, including the quality criteria to be used and the exclusion criteria for the different type of procedures. KAP (median and 3th quartile values) in Gy cm2, for the nine procedures included in the survey (with all the complexity together) were: Lower extremity arteriography (n=784) 44,1 /77,5; Renal Arteriography (n=37) 45,8 / 107,1; Transjugular Hepatic Biopsies (n=30) 19,7 / 45; Biliary Drainage (n=314) 16,4 /29,9; Uterine fibroid Embolization (n=56) 134,6 / 214,1; Colon endoprostheses (n=31) 104 /169,4; Hepatic chemoembolization (n=269) 178,8 / 303; Femoropopliteal revascularization (n=62) 50,7 /118,5; Iliac Stent (n=66) 72,6 /170,2. The obtained values represent an initial set of national DRLs to be used by interventional radiologists to help in optimization. Results of the quality control of the X-ray systems and the complexity indices for the different procedures will help to decide if correcting actions could be necessary for some of the catheterization laboratories. The Spanish Nuclear Safety Council funded this work.

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S3A.P2

INDICATION-BASED DIAGNOSTIC REFERENCE LEVELS FOR ADULT CT-EXAMINATIONS IN FINLAND

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A diagnostic reference level (DRL) is a predefined dose level, which should not be exceeded in an examination that is conducted appropriately on an average-sized patient. In Finland, the DRLs for most common examinations are given by Radiation and Nuclear Safety Authority (STUK). The previous DRLs for CT-examinations for adults were issued in 2007 and they covered only examinations conducted on a particular body region. Since the image quality requirements, and thus the dose needed, vary between different indications, there has been a call for indication-based DRLs for CT. The new partially indication-based DRLs for CT came into effect on June 2013 and are given as CTDIvol and DLP values. They are based on a dose survey done in 2012. Doses for different examinations were reported from 57 different CT units out of the approximately 100 units that are in use in Finland. Doses were collected from examinations conducted on a particular body region, based on some indication and from some special examination types. The DRLs were set on a third quartile of the doses reported from examinations, where the patient's weight was between 60 and 90 kg (except for examinations on the head, for which no weight limit was used). The DRLs for a particular body region are for head, paranasal sinuses, thorax, abdomen, whole body and aorta examinations. The indication-based DRLs are for lung tumor, urinary stones and lymphoma. The special examination types are HRCT-examination of the lungs, trauma-CT (body) and CT colonography. On average, the DRLs for a particular body region dropped approximately 20 % from the previous DRLs. The analysis of the survey data revealed also additional information. For example, in scanners where iterative reconstruction was used, the dose was, on average, approximately 35 % lower than in scanners without iterative reconstruction. (Because, on average, scanners where iterative reconstruction is available are quite new, the dose reduction due to iterative reconstruction is not that straightforward.) And according to the survey, the average doses between different manufacturers vary substantially (even fivefold) in some examinations. Also the average doses in the same examination from one scanner model can vary between different hospitals and even between two identical scanners in the same hospital.

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S3A.P3

DIAGNOSTIC REFERENCE LEVELS FOR DENTAL PANORAMIC RADIOGRAPHY

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The purpose of the present study is to present the national Diagnostic Reference Levels (DRL) established for panoramic dental examinations in Greece. The establishment of DRL is a useful tool for the optimization of radiological procedures and patient dose and it is addressed by the BSS, European directives and the national regulations. Measurements performed by the Greek Atomic Energy Commission on 90 panoramic systems countrywide, corresponding to 15 % of the total operating in Greece. The DRL values, expressed in terms of incident air kerma (Ki,air) at 1m from focus, were determined from the 3rd quartile of the respective frequency distribution. DRL values have been proposed for four different patient groups (child, small adult, standard adult and large adult). The DRL values for these groups were 2.2 mGy (children), 3.3 mGy (small adults), 4.1 mGy (standard adults) and 4.6 mGy (large adults). Further investigation is necessary in order to correlate patient dose and imaging system modality and therefore, different DRL may be established for different imaging system modalities (e.g. film, digital, etc)

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S3A.P4

LOCAL TYPICAL DOSES AS A TOOL FOR OPTIMIZATION OF X-RAY PROCEDURES

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Determination of the typical diagnostic dose (TDD) is part of optimizing medical radiation exposure. It is specific for any X-ray imaging device and examination. Patient dose measurements are collated with National reference diagnostic level (NRDL). This paper presents the results from the work of the medical physicists from Medigray Ltd. related with the development and application of the Bulgarian legal requirements for determination of local typical doses in hospital X-ray departments throughout the country and their collation with the national reference diagnostic level database.

Our initial results for determination of TDD can be summarized as follows:

30 X-ray imaging devices; Determination of TDD for three types of examination

- 10% - typical diagnostic doses comparable with NRDL with deviation up to 5%
- 60% - typical diagnostic doses higher than NRDL with deviation exceeding 5%
- 30% - typical diagnostic doses lower than NRDL with deviation exceeding 5%

After identifying and eliminating the reasons for higher TDD measurements and after consulting physicians specialized in Diagnostic Imaging in relation to the diagnostic informativeness of the image at lower TDD values, the results of the same X-ray imaging devices and examinations after 2 years are:

30 X-ray imaging devices; Determination of TDD for three types of examination

- 60% - typical diagnostic doses comparable with NRDL with deviation up to 5%
- 20% - typical diagnostic doses higher than NRDL with deviation exceeding 5%
- 20% - typical diagnostic doses lower than NRDL with deviation exceeding 5%

After the initiation of this activity and in view of its future development and acknowledgement, our team of specialists in Medigray Ltd is looking for the active support of every specialist in the field of Diagnostic Imaging in achieving the goal of “higher diagnostic informativeness at lower radiation exposure”.

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S3A.P5

LOCAL DIAGNOSTIC REFERENCE LEVEL FOR BRAIN COMPUTED TOMOGRAPHY SCAN IN NIGERIA

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The aim of this study was to measure the dose delivered to patients undergoing Computed Tomography (CT) examinations of the head for the purpose of developing DRL for dose optimisation in Northern Nigeria. Background: A brain CT scan is the most common CT examination performed and contributes significantly to the total collective effective dose to the population. Elimination of unnecessary or unproductive radiation exposure is necessary. To achieve this, practitioners must adhere to the principles of the justification of practices, and optimisation of radiation protection. Furthermore, the development of DRLs for the local context is advised. The study was conducted in three radiology departments with CT centres in Northern Nigeria. Data was collected from 60 consenting adult participants (weighing 70 kg ± 3) that had brain CT scans on seventh generations 4&16-slice GE and 16-slice Philips CT scanners. For each brain scan, patient information, exposure factors, weighted computed tomography dose index (CTDIw), volume computed tomography dose index (CTDIvol) and dose length product (DLP) values were recorded. The data was analysed using SPSS version (16) statistical software. The mean, standard deviation and third quartile values of the doses were determined at the 95% confidence interval. An inter-comparison of the measured doses from the three research sites was conducted. A combined dose for the three centres was calculated, and compared with the reported data from the international communities where there are established DRLs. Results: The mean CTDIw and DLP values were: centre A (88.21 mGy and 713.34 mGy.cm), centre B (67.89 mGy and 1098.18 mGy.cm), and centre C (70.47 mGy and 597.00 mGy.cm). Comparison of CTDIw and DLP both showed statistically significant differences, (p=0.003) and (p=0.03) respectively, for the scanners of the same manufacturers. In the case of the scanners of a different model but the same number of slices, the comparison of DLP was statistically significant (p=0.005) while no significant difference was noted in the measured CTDIw. Conclusion: The study has established LDRLs of CTDIw and DLP as 76.94 mGy and 985.47 mGy.cm respectively which are significantly higher than most of the reported data in the literature. Also dose variation between centres was noted. Keywords: Head Imaging, Radiation Dose, Dose optimization, CT, LDRLs, Radiation Protection

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S3A.P6

CONTRIBUTION TO THE ESTIMATION OF POPULATION DOSES FROM CT AND MAMMOGRAPHY EXAMINATIONS IN SLOVAKIA

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In the last 10 years the medical use of radiation increased rapidly world -wide and consequently higher contribution to the population doses have been observed. In the same time the number of CT and mammo examinations in Slovakia grow up about 3 -4 times. For the evaluation of the radiation load of CT examinations the quantity DLP has been used as a good indicator of the effective dose. AGD values together with the new tissue- weighting factors,published in ICRP 103(2007) represented the effective dose of the slovak population from mammography examinations. In the presentation there will be discussed the results of collecting the data of CT examinations of head, neck, chest, abdomen, pelvis and trunk, and the dependence of AGD on the breast thickness for mammo examinations. Using the DQC system (Dose Quality Control) for the archivation of the exposure parameters of examinations, as well as, the individual patient´s doses at 20 CT and 40 mammography departments in Slovakia, covering more than 50% of all realized CT and mammo examinations. The results are a part of our participation in the DDM 2 European Project, and create the base for the setting of national diagnostic reference levels and evaluation of the collective doses of the slovak population.

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S3A.P7

ROMANIAN MEDICAL EXPOSURE TO IONIZING RADIATION IN 2012

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Medical exposure, the main source of artificial exposure, shows an increasing trend in the last years, manifested both by increasing the number of examinations with ionizing radiation and by increasing the dose level received by patients. Annual results obtained for medical exposure to ionizing radiation based on the data collected from Romanian hospitals are useful for the update of the national database and optimization of radiological procedures for diagnostic and treatment. National legal framework harmonized with the Community provisions stipulate the obligation and responsibility of the public health network to ensure the radiological protection of the patient during the medical exposures to ionizing radiation. Medical exposure level is expressed in terms of annual collective dose and is evaluated from annual frequencies and the average effective dose per procedure for different types of radiological and nuclear medicine procedures. The Romanian hospitals reported during 2012 a number of 5.505.792 radiological examinations and 19.199 diagnostic and treatment examinations of nuclear medicine. Based on the data reported, the average effective doses and their contributions to the collective dose were evaluated. The main contributions to the collective dose of the radiological procedures are registered for CT abdomen and pelvis region, followed by chest CT and head CT examinations. The next positions are x-ray examinations of the chest and gastrointestinal disease and radiographic examination of the lumbar spine and chest, which in spite of their low effective dose have an important contribution to the collective dose due to the large number of examinations. For nuclear medicine procedures, major contributions to collective dose are given by bone scintigraphy, followed by PET-CT and thyroid scintigraphy.

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S3A.P8

TRENDS IN EXAMINATION FREQUENCY AND POPULATION DOSE FROM MEDICAL X-RAY EXAMINATIONS IN SUDAN, 2010

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A nationwide survey was conducted to estimate examination frequency and collective and per caput effective doses arising from medical X-ray procedures in Sudan, 2010. Information was collected from 30 hospitals performing radiography, computed tomography (CT) and interventional radiology (IR) procedures. The results were compared with the global dose pattern given in UNSCEAR report. The estimated annual number of examinations was 33 million radiographic X-ray procedures (99 %), 0.34 milion CT exams per year (14 % Paediatric CT), 0.02 million fluoroscopy and interventional radiology procedures. The annual collective and per caput effective doses from medical X-ray procedures (excluding mammography and dental radiology), respectively mount 7197 man Sv and 0.18 mSv. In Sudan, less than 1 % of diagnostic radiology procedures are CT examinations, but their contribution to the collective dose was approximately 16 % . The study offered the first projection of frequency and population dose from medical X-ray examinations in Sudan and provide estimates of the impact of the medical X-ray procedures at the national level. Keywords: Population dose; Medical X-ray examinations; Examination frequency; Annual collective effective dose; Annual effective dose per caput

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S3A.P9

EVALUATION OF COLLECTIVE EFFECTIVE DOSE OF UKRAINIAN POPULATION DUE TO X-RAY DIAGNOSTIC EXAMINATIONS

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X-Ray diagnostic examinations give the main contribution (80%) to the collective effective dose of the Ukrainian population. Annually about 40 million X-ray examinations is performed for 46 million people of Ukraine. For optimization of radiation risk from medical diagnostic exposure it is necessary to know which type of X-ray diagnostic examinations give the main contribution to total population collective dose. The purpose of this investigation were the estimation of frequency and collective effective doses for different X-ray diagnostic examinations, and their contribution to the total collective dose of Ukrainian population. The determination of population collective doses in diagnostic radiology were assessed in according to the methodology proposed in EC Project "The Study on European Population Doses from Medical Exposure (Dose Datamed 2)". The frequency of 45 most common types of X-ray diagnostic examinations including chest fluorography (film and digital), radiography, fluoroscopy, CT, mammography, dental, intervention procedures and other were collected due to questionnaire survey in 2009-2012. The data about the frequency of X-ray examinations were analyzed for 24 Ukrainian Regions. The average effective dose for each type of radiography has been estimated by Program ODS-60 (Finland) using the data of measured radiation output. For three types of X-ray diagnostic examinations: fluorography, chest radiography (PA) and lumbar spine (AP), the effective doses has been estimated from the results of phantom simulation using the average values of entrance surface doses (ESDs) and the conversion factors from ESDs to effective doses. Total frequency of X-ray diagnostic procedures were 1218 examinations per 1000 population in Ukraine. It was determined that the most widespread types of X-ray examinations are the chest film fluorography and the chest X-ray examinations - 43.3% and 16.4%, respectively. The radiography of the bones and joints system contributes 25%, radiography of the digestive tract - 2.3 %. Total collective effective dose for all type of X-ray diagnostic procedures was 1060 man-mSv per 1000 population. The collective effective dose from the chest fluorography gave the main contribution to total population effective dose– 450 mSv (42%). For optimization of medical exposure in diagnostic radiology and decreasing of radiation risk it is necessary to replace the chest film fluorography on the digital screening radiography.

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S3A.P10

ESTABLISHING REFERENCE LEVELS FOR COMPUTED TOMOGRAPHY PROCEDURES IN KENYA

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To estimate the typical radiation dose and associated effective doses during computed tomography examinations of patients in clinical practice in Kenya. A structured questionnaire-type form was developed for recording examination scanning protocols and patient dose from ten representative hospitals and clinics across the country. The annual number of computed tomography examinations per 1000 people was estimated to be 3 procedures. Volume CT dose index, dose length product, effective dose and national diagnostic reference levels were determined for 20 types of computed tomography examination procedures. Radiation doses during computed tomography examinations were higher and varying between facilities, emphasizing the need to develop local diagnostic reference levels as a standardization tool and optimization of radiological protection of patients at facility levels.

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S3A.P11

MEASUREMENTS OF PATIENT DOSES IN CHEST, ABDOMEN AND PELVIS CT PROCEDURES

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Medical exposure is the largest source of man-made exposure to ionizing radiation that accounts for nearly 96% of all man-made radiation exposure to human and continues to grow substantially. CT scanning is recognized as a high radiation dose modality, and estimated to be 17 % of the radiological procedure and responsible of 70% medical radiation exposure. However, although diagnostic X-rays provide great benefits that their use involves some risk of developing cancer is generally accepted. The objectives of this study are to measure patient doses during chest, abdomen and pelvis CT chest X rays with contrast medium. A total of 51 patients (53% females and 47% males) were examined for evaluation of metastasis of the diagnosed primary tumor during four months. A CT machine from Siemens 64 slice were used. All quality control parameters were checked prior data collection. Patient demographic data were collected using standard data collection sheet. The mean age was 46±2 years and 49.85±16.2 for males and females, respectively. The mean patient weight was 74.9±16.7and 72.9±15.9 for males and females in that order. The mean and range of male patients' doses in terms of dose length product (DLP) was 1502±416.3 (587-2502) mGy.cm2 and CTDI vol (mGy) was 21.6±5.6 (9.4-35.8) mGy while the females' doses were 1486.5±381.1 (803-2508) mGy.cm2 and CTDI vol (mGy) was 24.1±5.5 (14.2-39.4) consequently. The majority of patients were undergone the procedures for evaluation of metastasis. This justifies the large field of view per procedures. Consequently, the radiation dose per procedure is higher compared to previous studies. Therefore, optimization of patient doses is required in order to reduce the probability of radiation risk. Special concern is required for these patients group to reduce their probability of radiation induced cancer.

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S3A.P12

RADIATION DOSE LEVELS FOR CONVENTIONAL CHEST AND ABDOMINAL X RAY PROCEDURES IN ELECTED HOSPITALS IN SUDAN

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Medical x-rays are the largest man-made source of public exposure to ionizing radiation. Chest and abdominal X rays are the most common procedures in radiology departments worldwide. Therefore, measurement of patient doses is recommended. The objectives of this study are to: (i) measure and compare patient radiation dose during chest and abdominal X rays in screen film radiography (SFR) and Computed radiography (CR) ii) assess the utilized equipment performance and (iii) delineate a dose reference level for these procedures in Sudan. Patients' doses were measured in five hospitals in Khartoum, Sudan. Hospital A (state hospital (SFR), B and C (Teaching hospitals (SFR)), D (University hospital (SFR)) and E (private hospital (CR)). Patient demographic data (age, and body mass index (BMI, kg/m2) and radiation exposure factors (tube voltage (kVp, tube current- time product (mAs) and image receptors were evaluated. A total of 196 patients were examined. 74.5% of the patients undergone chest X ray procedures and the rest of patients for abdominal X rays. Entrance surface air kerma (ESAK) were calculated from patient exposure parameters using DosCal software. The X-ray tube outputs (mGy/mAs), exposure factors(kVp, mAs and time) accuracy, linearity and reproducibility were measured using Unfors Xi dosimeter. Results: The mean and range of the patients ESAK doses (mGy) during chest X ray procedures were 0.07(0.02-0.16), 0.05(0.01-0.07), 0.04(0.01-0.08), 0.05-0.010.10) and 0.08 (0.02-0.13) for hospital A, B, C.D and E, respectively. While the mean and the range of the ESAK doses (mGy) for abdominal X rays were 0.24(0.14-0.56), 0.36(0.19-2.72), 0.20 (0.13-0.25), 0.37(0.25-0.56) and 0.62 (0.26-0.92) for hospital A, B, C.D and E, in that order. Dose reference levels were proposed for both procedures based on the international standards. The entire quality control tests were within the acceptable limits. In agreement with previous studies, patient doses in hospital E are higher than other hospitals due to CR system. Patients' doses showed wide variations. The wide variations of patient dose can be attributed to the variation in the patient related demographic data, equipment related factors and the processor quality. The results of this study were comparable with previous published studies with few outliers.

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S3A.P13

SURVEY OF THE APPLICATION OF DIAGNOSTIC REFERENCE LEVELS FOR X-RAYS IN THE NETHERLANDS

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In 2012 the Dutch Commission on Radiation Dosimetry (NCS) published reference levels for the use of X-rays for a number of radiologic tasks. These are meant to indicate acceptable doses that lead to good X-ray imaging and radiology departments are not obliged to adhere to these levels. These values should not be used at an individual level, but compared to radiation doses given to a group of patients given the same treatment. The departments appear to be well informed about these so-called Diagnostic Reference Levels (DRLs). They are either well underway in implementing them or have already done so. The levels have usually not yet been incorporated in the QA system of the department nor in the treatment protocols. This is shown in an RIVM study that was conducted by order of the Dutch Healthcare Inspectorate (IGZ). For this purpose a survey was held among 20 Dutch hospitals. It was shown that the amount of radiation used, as far as it was indicated by the hospitals, remains below the DRLs. Where this was structurally not the case, it was caused by either the weights of the patients (a higher weight requires a higher dose) or the complexity of the procedures. In addition, large differences emerge in the way hospitals compare doses to the DRLs. The DRLs have been formulated for a theoretical standard patient for each radiologic task. Before doses can be compared to the DRLs, these need to be derived for this standard patient. A procedure for this has been prescribed, but it is not always followed in practice. This is especially difficult in the case of children, as most general hospitals diagnose only few children. This leads to insufficient data to pursue the prescribed procedure. To improve the implementation process radiology departments are recommendend to look at eachother's experiences and learn from these. Apart from that, it needs to be investigated whether the methodology for checking the DRLs for children can be adjusted. This is important because children are more sensitive to radiation from X-rays.

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S3A.P14

MONITORING MEDICAL RADIATION EXPOSURE IN THE NETHERLANDS

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All European Union member states are obliged to collect data on patient radiation dose from medical diagnostic imaging. The use of ionizing radiation for this imaging results in a slightly increased cancer risk for the patient. This cancer risk increases with dose. Apart from that, in the Netherlands medical radiation applications contribute most to the mean effective dose to the population of all artificial radiation sources. Therefore, the National Institute for Public Health and the Environment has been commissioned by the Ministry of Health, Welfare and Sport, to collect and analyse information on medical radiation applications. This information is published and updated yearly at the Dutch website: www.rivm.nl/ims. The website contributes to making conscious choices in medical imaging, taking into account the risks and benefits of the use of radiation. This information shows the development in medical radiation exposure from 1991 until the most recently collected information of 2012. The data shown on the website are collected in a yearly survey. For this purpose a questionnaire is sent to all Dutch hospitals and institutions that use radiation applications (N=132). This questionnaire retrieves information about the amount of specific examinations. The numbers of examinations are then combined with the dose per examination. The average doses per examination that are used date from 2002, but have recently partly been updated. In the coming years, all doses should be updated. The response rate of the questionnaire was 99% in 2012. The diagnostic use of radiation has been divided in four categories. Together these add up to a mean effective dose per caput of 0.93 mSv in 2012. CT-examinations contribute 0.45 mSv, other radiology examinations 0.37 mSv. Nuclear medicine adds 0.09 mSv and diagnostic imaging outside the hospital (as in dental clinics) 0.02 mSv. The mean radiation dose per caput due to medical radiation exposure has increased per year since 2002 (from 0.52 to 0.93 mSv). However, a diminishing increase is seen since 2010.The main cause of the increase in dose is the increasing numbers of CT examinations. Among the other radiology examinations, the largest contribution to the mean effective dose comes from angiography. This is due to the high dose per examination.

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S3A.P15

ESTABLISHMENT OF DOSE REFERENCE LEVEL FOR PEDIATRIC PATIENTS IN COMPUTED TOMOGRAPHY IN SUDAN

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The use of pediatric CT that had recently emerged as a valuable imaging tool has increased rapidly with an annual growth estimated at about 10% per year. Worldwide, there is a remarkable increase in the number of CT examinations performed. The purposes of this study are to: (i) to measure the radiation dose and estimate the effective doses to pediatric patients during CT for chest, abdomen and brain and (ii) propose a local diagnostic reference level for CT procedures. A total of 182 patients were investigated. CT scanners that participated in this study are helical CT scanners (64 slices, 16 slices and dual slices). Organ and surface dose to specific radiosensitive organs were estimated by using software from National Radiological Protection Board (NRPB). For all patients, the age was ranged between 0-10 years while the weight was ranged between 5.0 kg to 29.0 kg. The DLP was 320.58 mGy.cm, 79.93 mGy.cm, 66.63 mGy.cm for brain, abdomen and chest respectively. The effective dose was, 2.05, 1.8, 1.08 mSv for brain, abdomen and chest respectively. The patient dose is independent of CT modality and depends on operator experience and CT protocol. The study has shown a great need for referring criteria, continuous training of staff in radiation protection concepts. Further studies are required in order to establish a reference level in Sudan.

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S3B.I1

AVOIDANCE OF RADIATION ACCIDENTS AND INCIDENTS

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Radiotherapy has long been an effective way of treating cancer and it is estimated that 50-60% of patients with cancer would benefit from radiotherapy. More than five million patients undergo radiotherapy each year around the world, with a substantial percentage having successful outcomes. In many developing countries there is, however, no access at all to this treatment modality. Expanding radiotherapy into countries and areas without current access has the potential to save a great number of lives, but it is mandatory that the expansion is done with safety in mind, considering the complexity of this high-technology treatment modality and the potential for serious consequences when something goes wrong. It is worth considering that radiation accidents involving medical uses have accounted for more deaths and early acute health effects than any other source, including accidents at nuclear facilities. Accidents involving radiotherapy might cause harm or death to patients, but can also undermine the public's confidence in the treatment, which is serious in its own right. The International Atomic Energy Agency (IAEA), which is a member of the United Nations family, has the mandate through its statute to work for the safe, secure and peaceful uses of nuclear science and technology, which includes the safe use of medical radiation technology for health purposes. Safe radiotherapy requires basic capacities built in terms of safety infrastructure and relevant health professionals' availability and training. IAEA is supporting national strategies for strengthening of regulatory infrastructure, through development of international standards and assistance to implement these including the establishment of a legal and regulatory framework, support of cradle-to-grave management of radioactive sources, and support of relevant technical services in radiation safety. IAEA is also supporting national capacity building through providing health professionals with education, training and guidance, facilitating information exchange, including voluntary reporting of safety related events, giving direct technical assistance and building awareness. These elements are essential when aiming to make good use of radiotherapy in fighting cancer in all regions of the world.

S3B.I2

RISK MANAGEMENT REQUIRES GOOD SAFETY CULTURE - FORTHCOMING EUROPEAN GUIDELINES PROMOTE PROACTIVE RISK ASSESSMENT AND ANALYSIS OF EVENTS IN RADIOTHERAPY

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The new Euratom BSS (Council Directive 2013/59/EURATOM) introduces, among other things, new specific requirements for quality assurance and events reporting. For example, the regulations stipulates that Member States shall ensure that for radiotherapeutic practices the quality assurance programme includes a study of the risk of accidental or unintended exposures. In addition, it is specified that any undertaking acquiring medical radiological equipment is provided with adequate information on the risk assessment for patients. Within a European Commission (EC) project, to provide help in the implementation of the new BSS requirements, European guidelines have been prepared on risk assessment and analysis of adverse error-events (adverse events caused by errors) and near misses in external beam radiotherapy. The Guidelines discusses the major concepts and principles for risk management, introduces briefly the methods for both proactive risk assessment and reactive analysis of events, and provides basic information also on the classification and reporting of adverse error-events and near misses. A number of recommendations are given to institutions providing radiotherapy services and to national authorities. Successful quality and risk management requires development of a safety culture in the institution. A feature of a good safety culture is that there is a high awareness of risks, and that error reporting is considered positive, constructive and responsive—a culture that seeks solutions not culprits. At national level, therefore, the Guidelines recommend a development or updating of a national strategy on quality and risk management, which will promote the safety culture in radiotherapy. A strong collaboration between national authorities (authorities for healthcare and radiation protection but also for control of medical devices) and professional societies is deemed necessary, including improved dialogue with manufacturers. At the institutional level, the importance of a dedicated quality management system and safety culture is stressed for the basis of risk management. For proactive risk assessment, the Guidelines then recommends a minimum approach to start with and in-depth approach to continue after having feedback from the initial efforts. Acknowledgements: This study is funded by the European Commission (Contract ENER/11/NUCL/ S12.612180.).

S3B.O1

RISK ANALYSIS OF THE EXTERNAL RADIOTHERAPY PROCESS WITH FOCUS ON HUMAN FACTORS AND THE TECHNICAL PART OF QUALITY ASSURANCE

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The Swedish Radiation Safety Authority has financially supported two projects on risk analysis of the radiotherapy process. The purpose of the work was to promote the use of risk management for improving patient safety within radiotherapy. One study was focused on human factors and the other was focused on the technical part of quality assurance. The studies embraced three hospitals in Sweden, performing both conventional and virtual (i.e. computed tomography) simulations. One hospital used equipment (treatment planning system, oncology information system and linear accelerators) from the same vendor and the other two used equipment from different vendors. The techniques used for risk analysis were failure mode effects analysis (FMEA), failure mode effects and criticality analysis (FMECA) and fault tree analysis (FTA). The work has given the authority an increased knowledge of the various sources of risks and the nature of them. The highest risks were identified in the following areas: target definition, dose prescription, manual data input and patient positioning. This has also been confirmed by incidents reported to the authority. The authority will use the information from the work to prioritize inspections as well as for reviewing the legislation. For the hospitals involved, the work has contributed to a better understanding of the radiotherapy process and an awareness of typical existing risks. It can be concluded that risk management is a powerful tool to identify weaknesses in the radiotherapy process and to develop and to improve a quality assurance program. Regarding the technical part of the program, it might be possible to develop a standard fault tree, which can be used by any clinic independently of the equipment and local procedures used.

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S3B.O2

THE RADIOTHERAPY IN BULGARIA – NEW CHALLENGES

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Radiation therapy (RT) is a key treatment modality for cancer patients. In recent years, there have major developments in the technology of radiation oncology with advances moving from simple 2-dimentional (2-D) treatments to 3- D, image based, conformal treatments to intensity-modulated radiation therapy (IMRT), to daily image-guided radiation therapy (IGRT) and respiratory correlated 4-D treatments. The Volume modulated arc therapy (VMAT) with its advantages is more and more put in practice nowadays. The underlined principle of these advances is to improve patient outcome while maintaining normal tissue complications at acceptably low levels. This year more than 10 new accelerators will be introduced into practice in our country. The implementing of the new techniques is a great challenge and a big step forward in radiotherapy. It is obvious that well trained personnel is required so that the team can deliver accurate the prescribed radiotherapy course. On national level the RT program has to be actualized to take into account all clinical, medical physics, radiation protection and safety considerations. A further step will be the establishing of an audit group with the aim to review the RT process on site, including the organization, infrastructure, clinical and medical physics aspects of the RT practice with a view to quality improvement.

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S3B.O3

DOSIMETRY AUDIT OF RADIOTHERAPY TREATMENT PLANNING SYSTEMS

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In the radiotherapy Treatment Planning Systems (TPS) various calculation algorithms are used. The accuracy of dose calculations has to be verified. A heterogeneous cubic-shape phantom has been designed within a Coordinated Research Project of the IAEA. The heterogeneous phantom was developed in the frame of IAEA Coordinated Research Project. The phantom consists of frame made with polystyrene and bone or lung inhomogeneity slabs. Special inserts allow to position TLD capsules within the polystyrene below the bone or lung material and also within the lung equivalent material. There are also inserts for positioning ionization chamber and films. These enable comparisons of the doses calculated by TPSs for specific treatment. The comparisons were performed for a number of various TPS and for a number of various linear accelerators in radiotherapy departments in Poland. Seven Polish radiotherapy centers (of 28 in total) were audited. Six different TPSs and eleven calculation algorithms were examined. Generally most of the results from TLD and ionizing chamber were within 5% tolerance. Differences between doses calculated in TPSs and measured with TLD did not exceed 4% for bone and polystyrene equivalent materials. Under the lung equivalent material, on the beam axis the differences were lower than 5% whereas inside off the beam axis – in some cases were around 7%. The measurements allow to the detect limitations of TPS calculation algorithms. The audits performed with the use of heterogeneous phantom seem to be an effective tool for detecting errors in radiotherapy procedures.

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S3B.O4

IN VIVO TLD DOSE MEASUREMENTS IN CATHETER BASED HIGH DOSE RATE BRACHYTHERAPY

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Specific patient treatment procedure, high-gradient dose distribution and the large range of dose and dose rate makes in vivo dosimetry in high dose rate (HDR) afterloading brachytherapy to one of the most challenging procedures in the praxis of experimental patient dosimetry. Delivered dose quantities in HDR brachytherapy usually relay on the data provided by dose planning system without any independent verification of treatment delivery. The aim of this work was to perform in vivo and in situ patient dose measurements in catheter based HDR brachytherapy, to evaluate results of dose measurements and to propose method for the independent treatment delivery verification. Brachytherapy unit „GammaMed iX“ (Varian Medical Systems) was used for head and neck cancer patient treatment. 192Ir source was inserted and transported via catheters surgically preimplanted into the cancerous tissues or otherwise arranged close to the irradiation target. Additional 1-3 empty catheters for in vivo dose measurements were incorporated into treatment geometry. Dose measurements were performed using individually calibrated TLD micro rods arranged in train sequences and inserted into empty 6 Fr catheters. Theoretical dose values were evaluated after reconstruction of catheter positions. Standard algorithm “Acuros” (Varian Medical Systems) of treatment planning system Eclipse was used for dose calculations. Brachytherapy doses to patients delivered according to the prescribed dose plans were investigated and the results of the conducted investigation are presented in this paper. Comparison of calculated and measured in vivo dose values at the certain positions corresponding to the placement of TLD mini roads within the patient’s body indicated good agreement between dose variation tendencies. Obtained dose comparison results allowed the approval of the traceability of the proposed in vivo dose measurement method for the treatment delivery verification in catheter based HDR brachytherapy. However it was found that measured dose values differed by 10-15 % from those obtained using a standard dose calculation algorithm of brachytherapy dose planning system. Possible measurement uncertainties were discussed on the basis of the obtained results.

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S3B.O5

A DOSIMETRIC STUDY OF PROSTATE BRACHYTHERAPY USING MONTE CARLO SIMULATIONS WITH A VOXEL PHANTOM, MEASUREMENTS AND A COMPARISON WITH A TREATMENT PLANNING PROCEDURE

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The prescribed dose of a prostate brachytherapy treatment depends on several parameters, such as the prostate volume or the seed location and arrangement. In treatment planning procedures, variations of these parameters may lead to significant deviations of the prescribed dose. As such, it is important to understand their influence for dose optimization purposes. This work reports on a dosimetric study of prostate brachytherapy using 125I seeds by means of Monte Carlo simulations and dosimetric measurements performed on a physical anthropomorphic tissue-equivalent prostate phantom and thermoluminescent dosimeters (TLDs). Finally the MC model was also used to simulate a real treatment planning procedure, and determine dose value histograms (DVHs)for the simulated scenarios. The obtained results indicate that the parameters mentioned above represent a source of uncertainty in dose assessment in prostate brachytherapy, and can be detrimental to a correct dose evaluation in treatment plannings, and that this parameters can be accurately determined by means of MC simulations with a voxel phantom.

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S3B.O6

IMPLANTABLE IN VIVO DOSIMETRIC SYSTEM BASED ON GAN RADIOLUMINESCENCE

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This work aims to study the properties of a new dosimeter system allowing a precise and direct measure of the delivered dose to the patient during each radiotherapy session and for the whole treatment. Our dosimetric probe consists of a small volume of Si-doped GaN (LUMILOG, France), as scintillator coupled with an optical fibre, which ensures the transmission of the radioluminescence signal. GaN has a high light yield of ~105 photons/MeV. Photoluminescence characterization of this material shows strong luminescence emission at 3.40 eV (~365 nm) corresponding to band edge radiative recombinations. The photodetection system initially developed consists of a flat field concave spherical grating (Horiba Jobin-Yvon, France) and a 32 channels linear array multi-anode photomultiplier module (H7260M-04-Hamamatsu, France). The grating efficiency is 40% at GaN RL wavelength. It covers a spectral range of 260-900 nm with a resolution of about 24 nm by channel. The 32-channel outputs of the module are connected to a PC for data acquisition, monitoring and processing via a CH-3160 PCI acquisition board (12-bit, 10 MSPS A/D, Acquitek, France). A bi-channel method is proposed to reject the background contribution of the irradiated fiber segment. GaN dosimetric system was found to have no dose rate dependence. Differences in responses are less than +/- 0.5% for a range of dose rates between 76.86 and 384.30 cGy/min. The system has also an excellent linearity response (R^2=1) over a range of doses between 0 and 88 Gy. Measurements of the angular dependence of GaN-fiber system were performed by varying the angle of incidence of the beam between -90° and 90° around the isocenter. The results show that axial angular dependence stays within ±2% for the ±90°. To study and verify the variation of the GaN response for different depths, the curve of tissue-maximum ratio (TMR) was realised using the GaN probe. For 5x5 cm^2 fields of irradiation with 6M photon beams, the response of the probe is within ±1%, as compared to the response of an IC (PTW 31003) placed at the same measurement conditions, over the full depth range up to 20 cm. For larger fields, improvements of the response linearity are still needed. GaN dosimetric system appears as a promizing tool for the independent dose verification of complexe treatments. In addition, this system is an appealing option for small and composite field in situ dosimetry and QA instrument thanks to its small volume and real-time response.

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S3B.O7

AN ASSESSMENT OF DOSE FRACTIONATION EFFECT ON THE LEVEL OF RADIATION INDUCED BYSTANDER EFFECT IN NORMAL CELL LINE

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Radiation induced bystander effect is referred to the effects detected in cells that are not actually exposed to ionizing radiation, but are affected by neighboring irradiated cells. The aim of this study was to compare the level of induced bystander effect due to a single or fractionated dose. Also it was intended to explore if the bystander effect would be repeatedly induced following successive fresh irradiation. Medium transfer technique was used to produce the bystander effect. Two main groups were chosen. In first group QU-DB cells were irradiated and their medium was transferred to MRC5cells. In second group media of MRC5 target flasks were transferred to MRC5 bystander flasks. The target cells were irradiated with gamma rays from a 60Co with 1, 2 and 4Gy single doses and equal fractionated doses of 2 and 4Gy. The cytokinesis-block micronucleous assay was performed to detect the damages induced in bystander cells. The number of micronucleated cells in 1000 binucleated cells were scored in each sample. Statistical analysis revealed that in all bystander subgroups the frequency of MNed cells were higher than their control groups ($P < 0.001$). In group Q-M, there was no significant difference between 1 and 2Gy single dose subgroups ($P = 1$) but the frequency of MNed cells for both groups were significantly higher than 4Gy single dose subgroup ($P < 0.001$). 2Gy single and 2Gy fractionated doses showed similar effects but 4Gy fractionated doses (2×2Gy) was more effective than 4Gy single doses ($P < 0.01$). In group M-M, the number of MNed cells in 1, 2 and 4Gy single exposure were equal, so for the doses in 1 to 4Gy range, the effect was saturated. Also in this group there was no significant difference between MNed cells in subgroups which received single or fractionated exposures. From our result we can conclude, when the bystander effect is reached to a limited saturation level, dose fractionation has no effect on the level of induced bystander effect, and the effect is not repeated as a result of a new irradiation. However when the effect is decreased due to the increase of the dose (increasing dose from 2 to 4 Gy in Q-M group), fractionation is increasing the effect. Our study suggests that the bystander effect was induced in MRC5 bystander cells only after first dose and was not repeated after subsequent irradiation. This observation may be significant in radiotherapy.

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S3B.P1

THE PLACE OF POSTOPERATIVE RADIOTHERAPY IN THE COMPLEX TREATMENT APPROACH OF ADVANCED PARANASAL MELANOMA. IS LOCAL TUMOR CONTROL ACHIEVABLE WITHOUT RADIATION – INDUCED DEMYELINISING SYNDROME?

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We present a clinical case of locally advanced achromatic sinonasal melanoma with achieved local tumor control (LTC), following combined treatment (mediofacial resection, postoperative radiotherapy to a total dose 70 Gy; 5 courses chemotherapy and re-operation). Following diagnostic aspects were discussed: immunohistochemical (IHH) analysis for differential diagnosis (DD) of undifferentiated neoplasms and specification of the status of supraclavicular and neck lymph nodes. Despite the negative lymph nodes status in locally advanced tumors is stressed on the assessment for elective cervical dissection, or elective regional radiotherapy of supraclavicular and neck lymph nodes, because of the high risk for late lymph metastases. After complex treatment /operations and radiotherapy/ was achieved 7 years (LTC) without radiation-induced demyelinising syndrome of the right eye nerve. The conducted 7 years ago radiotherapy was with volume: right eye with retrobulbar space to a total dose 70 Gy, with protection of lateral part of the orbit following application of total dose 40 Gy. Our observations register marked radio-sensitivity of sinonasal achromatic melanoma in contrast to radio-resistant skin melanoma. The seven years free of diseases survival, following the complex treatment of locally advanced achromatic melanoma and marked radio-sensitivity are proof for close pathogenesis with peripheral PNET, i.e. this tumor is subtype of ectraossal Ewing sarcoma in adults.

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S3B.P2

PROTECTIVE, ELECTIVE LUNG IRRADIATION IN NON-METASTATIC EWING'S SARCOMA

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The Ewing's sarcoma in childhood is a disease from family of the peripheral primitive neuroectodermal tumors (PNET). The high incidence of lung metastases necessitated a complex treatment approach, including chemotherapy, radiotherapy and surgery. For a period of 16 years (1984-2000), 34 children with Ewing's sarcoma were treated and followed in our department. Twenty seven of these patients were without distant metastases. Complex treatment was applied to all these patients – chemotherapy VACA, or VAC, local radiotherapy to a total dose of 50-56 Gy +/- surgery. After a local tumor control was achieved in 11 children with non-metastatic Ewing's sarcoma, elective whole lung irradiation to a total dose 12-15Gy was applied. The total dose was adapted to the age of the children. Maximal follow up was 14 years and minimal follow up was 5 years in all patients. Our experience in these 11 patients with non-metastatic Ewing's sarcoma, in whom elective lung irradiation was applied, showed significant reduction of the lung metastases, improved free of disease survival and overall survival. The elective whole lung irradiation to a total dose 12-15Gy was well tolerated. The applied dose of radiotherapy was not exceeding the tolerance of the normal lung tissue. Good lung tolerability was reported, without late radiation complications. The achieved good treatment results necessitate extending this treatment approach through defining the risk groups of patients, suitable for elective lung radiotherapy combined with chemotherapy in non-metastatic Ewing's sarcoma.

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S3B.P3

DEMONSTRATE OCCUPATIONAL RADIATION PROTECTION AT RADIATION THERAPY OF B.P.KOIRALA MEMORIAL CANCER HOSPITAL (BPKMCH) IN BHARATPUR, NEPAL.

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The radiation oncology department of BPKMCH is the nucleus of the therapeutic radiology in Nepal with full range of megavoltage machines like tele- cobalt, two linear accelerators with photons and electrons with MLC and portal vision is providing safe and effective treatment of cancer patients since 2002. Patients received conventional 2D, conformal 3D and few IMRT radiotherapy and High Dose Rate (HDR) brachytherapy applications. Till now there is no radiation regulatory authority in Nepal. Tele Cobalt source changed in 2013. Demonstrate leakage radiation measurements dose rate at different points during, OFF position of Cobalt unit and Ir-192 HDR machine near head, in control console area of machine during beam on conditions. Analyze the thermolumunisence dosimeter (TLD) personnel badge cumulative dose of five years and estimate occupational risk. A calibrated Aloka survey meter is used to measure the radiation level at different points, of head of tele -Cobalt machine and HDR Ir-192 machine during OFF position and control console, door closed, and visitor's area during machine source ON/ photon beam on conditions. All workers of department are using TLD badges for personnel monitoring from BARC Mumbai, India. The maximum permissible dose limit for occupational workers is 20 milli Seivert/year and as low as reasonably achievable ALARA principle is followed. Warning interlocks entry doors and mazes head leakage tested. The leakage radiation dose rate on head of cobalt during OFF condition at 5 cm and at 100 cm will be presented graphically. The annual exposure dose rate is approximately 0.30 milli Seivert in cobalt machine. The mean occupational dose of workers from TLD badges report is 0.21 milliSeivert /year. The quantitative risk due to radiation exposure of workers is compared with other occupation. There is presence of secondary radiation level around the head of high energy 20 MV photon beam use which decays in few minutes.HDR Ir-192 used source is returned back to the supplier after survey and transport index value provided by radiation safety officer in every four months. The working conditional in department is as safe as in other safe occupation. The survey and personnel dose levels demonstrate that the facility is safe for workers, patients and public but strict and sensible working procedure is to be followed.

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S3B.P4

OPTIMIZING DELINEATION ACCURACY OF TUMOURS IN PET FOR RADIOTHERAPY PLANNING USING BLIND DECONVOLUTION

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Accurate tumor delineation in 18F-FDG PET images has been shown to be important in optimizing quality and effectiveness in radiotherapy planning since a high precision determination of the metabolically active region is necessary. However, the poor resolution and high noise in PET images makes this task extremely difficult. The partial volume effect (PVE) which results from the lack of resolution in PET flattens the structures and therefore the real contours of the tumors cannot be assessed. In this work, we aim to use a blind deconvolution technique in order to recover the real tumor shapes. This technique has the advantage that the point spread function (PSF) of the imaging system does not need to be known. We used data obtained from a NEMA NU-2 IQ based phantom with a GE DSTE-16 PET/CT scanner. The artificial tumor diameters were 13, 17, 22, 28 and 37 mm with a target/background ratio of 4:1, with the initial background activity level being equivalent to 15 mCi in a 70 Kg patient. All data belonged to the NCI. We carried out deconvolution using a blind deconvolution algorithm in order to restore the reconstructed phantom images. The method maximizes the likelihood that the image obtained by convolving the resulting deblurred image with the resulting PSF is an instance of the blurred image assuming Poisson noise statistics, using an iterative Lucy-Richardson based algorithm implemented in Matlab. The algorithm iteratively updates the point spread function of the camera. For the largest diameter artificial tumor of 37 mm, the accuracy in volume determination improved from 26% to 16% whereas for the smallest tested artificial tumor of 13 mm, the accuracy improved from %57 to by making use of the blind deconvolution step before manual delineation. Blind deconvolution using maximum likelihood has been shown to decrease errors in tumour volume determinations in a phantom based study. Work is in progress for evaluating blind deconvolution using real patient studies and automated delineation algorithms. Preliminary results of these studies will also be presented.

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S3B.P5

EVALUATION OF EXCESS DOSE TO THE SKIN DUE TO USING THERMOPLASTIC MASK IN RADIOTHERAPY PATIENTS.

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Thermoplastic masks are utilized to set up the patient on the couch as immobilization devices daily. At the time of treatment simulation of patient, a thermoplastic mask is fixing by stretching a heated mask over. While treatment of the patient is under the thermoplastic mask, the skin sparing effect of mega-voltage X-ray beams can be spoiled. Probability thermoplastic mask was raised the percent depth dose and increased beam attenuation of megavoltage X-ray beam. The Monte Carlo method is the most accurate method for simulation of radiation therapy equipment. In this study, the mask effect was examined on percent depth dose added to surface and buildup dose. For percent depth dose and buildup dose measurement used parallel plate Roos chamber in water equivalent slab phantom. For surface dose measurement used EDR2 film so in slab phantom. Measurements were produced with and without the thermoplastic mask on the surface of the water equivalent slab phantom for 6MV and 18MV X-ray beams. These beams were given out from ONCOR linac head. Head simulation was performed with BEAMnrc and dose calculation with DOSXYZnrc for film measurements and 3ddose file produced by DOSXYZnrc analyzed used homemade MATLAB program. At 6 MV, the agreement between dose calculated by Monte Carlo modeling and direct measurement was obtained to the least restrictive of 1 %, even in the build-up region. At 18 MV, the agreement was obtained 1 %, except for in the build-up region. In the build-up region, the difference was 1 % at 6 MV and 2 % at 18 MV. The surface dose in both energy 6MV and 18MV are significant 26.5 % and 20.7 %, respectively. In the buildup region dose variation was lesser to 0 in near of depth max. For percent depth dose, deviation of deposited dose was so minor -0.5 % to -1 %. Key words: surface dose, thermoplastic mask, BEAMnrc code, film dosimetry, X-ray modeling

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S3B.P6

THE EFFECT OF ENERGY SPECTRUM CHANGE ON DNA DAMAGE IN AND OUT OF FIELD IN 6MV PHOTON BEAMS

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To quantify the DNA damage induced in 6 MV clinical megavoltage photon beams at various depths in and out of the field due to photon and electron spectra variations. MCNPX was used to simulate 10x10 cm2, 20x20 cm2 and 40x40 cm2 6 MV photon beams from 2100 C/D Clinac. Photon and electron spectra were collected in a water phantom at different depths and off-axis points. These spectra were used as an input to a validated microdosimetric Monte Carlo code, MCDS, to calculate the RBE of induced DSB in DNA at points in and out of the primary radiation field at three depths for anoxic, normoxic (5%) and fully aerobic (100%) conditions. The photon and electron mean energies were also calculated in different depths and off-axis distances. There was an observable difference in the energy spectra for photons and electrons for points in the primary radiation field and those points out-of-field. For the field size of 10x10 cm2, in the out-of-field region the mean energy for the photon and electron spectra decreased by a factor of about 3.5 and 1.5 from the in-field mean energy, respectively. In the out-of field region of 20x20 cm2 field size, the mean energy of photons and electrons spectra decreased by a factor of about 4.5 and 2 in comparison with in field mean energies, respectively. For the field size of 40x40 cm2 at 1.5 cm depth, in the out-of-field region, the mean energy for the photons and electrons spectra decreased by a factor of about 6.5 and 3.5 in comparison with the in-field mean energies, respectively. These reduction factors for 40x40 cm2 field size at 11.5 cm depth were 4.5 and 3.5 respectively. At 21.5 cm depth of 40x40 cm2 field size these reduction factors were 3.5 and 3 respectively. Despite the differences in spectra and mean energy, the change in RBE was less than 2% from the in-field region to the out-of-field region at any depth and field sizes from 10x10 cm2 to 40x40 cm2. Calculated DSBs for anoxic conditions are lower about 2.7 times with respect to normoxic conditions and lower about 3 times with respect to fully aerobic conditions. Conclusions: Although there are differences in both the photon and electron spectra, these changes do not correlate with a change in RBE in a clinical MV photon beam as the electron spectra are dominated by electrons with energies greater than 20 keV. Key words: Monte Carlo, Spectrum analysis, DNA damage, Radiotherapy

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S3B.P7

INVESTIGATION OF DOSE VARIATION WITH MINOR DISPLACEMENT IN HIGH DOSE RATE BRACHYTHERAPY

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High dose rate HDR brachytherapy dose distribution is highly localized and has a very sharp dose fall-off. Thus one of the most important part of the treatment is the localization and immobilization of the applicator from the implantation to the setup verification to the treatment delivery. The smallest motions of the patient can induce a small rotation, tilt, or translational movement of the applicator that can convert into miss of a significant part of the tumor or to over irradiating a nearby critical organ. The purpose of this study is to revise most of the HDR types of treatments with their applicators and their localization challenges. Since every millimeter of misplacement counts the study will look into the necessity of increasing the immobilization for several types of applicators. This study data indicates that an improvement of the immobilization devices for HDR is absolutely necessary. Better applicator fixation devices are required too. Developing new immobilization devices for all the applicators is recommended.

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S3B.P8

A COMPARISON STUDY ON OPTIMIZATION RESULTS ECLIPSE VERSUS BRANLAB ON SBRT LUNG PLANS

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Treatment planning in any of the planning systems is as good as the goodness of the necessary structures created and the optimization techniques. It has been have found that for each tumor type it is essential to have the proper structures, the proper margins for the organs at risk, and the proper PTV/PTVs generated, since these are the tools of optimization. Constrains, priorities, and the sequence they are applied are also dramatically influencing the resulting fluence per beam and the quality of the dose distribution in the tumor and the normal tissue. The purpose of this study is to compare the optimization procedures for lung lesions when planning Intensity Modulated Radiation Therapy (IMRT) for SBRT plans in the Brainlab treatment planning system and in Eclipse planning system. The goal of the study is to be able detect the best techniques in both and make find a better approach in optimization techniques. This study takes a detailed look at IMRT plans for lung generated in Eclipse and BrainLab and analyzes not only the supporting structures generated and the optimization constraints, but also the number of fields (beams) and their angular distribution. The study analyzes also the correlation between the optimization and the dose calculation algorithms for the two treatment planning systems (TPS). Each patient with tumors having plans generated in Eclipse will be then sent to the BrainLab planning system and keeping the same structures and the same beam placement a new plan will be generated. The data of this study indicates that there are optimal combination of beams (number and placement), supporting structures, and optimization techniques that will improve and expedite the treatment planning in radiation therapy in each of the two planning systems but also there are some features of each that combined can dramatically improve the overall final plan

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S3B.P9

DEVELOPMENT OF DOSE EVALUATION PROGRAM FOR 4-DIMENSIONAL RADIOTHERAPY

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Respiratory motion of thoracic and abdominal region of human body may decrease the target irradiation in radiotherapy for cancer treatment and increase dose to healthy tissues. In the field of clinic, the accurate evaluation of dose distribution delivered to a patient gets more important in the case of lung cancer. In this study, we examined an applicability of respiratory signal of an individual patient for each fraction in 4-dmensional radiotherapy for cancer treatment. Using the commercial moving phantom, we developed a dosimetry system to evaluate quantitatively a dose delivered to an individual patient. When the 4-D planned treatment was executed by the respiratory gating system, data for respiration signals were saved in to the own database for each fraction. The extracted data were transferred as an input to program a respiration with the moving phantom. The moving phantom was located in the couch, irradiated with the treatment plan for the realistic patient. During irradiation with the gating program planned initially with the obtained 4-dimensional CT, the moving phantom was operated according the program with the respiration data for each fraction of an individual patient. By inserting the radiochromic film, we measured the dose distribution to the phantom and compared with that intended by the treatment planning system. The results showed that an application of data for respiration signal to program a motion of phantom might be effective tool for evaluating dose distribution to an individual patient for each fraction in the field of clinic.

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S3B.P10

RISKS OF LUNG FIBROSIS AND PNEUMONITIS USING ELECTRON BEAMS FOR POSTMASTECTOMY RADIOTHERAPY

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Breast cancer patients are treated by a variety of options. Electron beams are utilized in the irradiation of the chest wall post mastectomy due to its dose distribution in the irradiated body. Objectives: to determine the possibility of inducing lung fibrosis and pneumonitis during postmastectomy radiotherapy (PMRT) using electron beams. Electron beams with different energies, and gantry angles were used for irradiating the chest wall in PMRT. The normal-tissue-complications-probability of the lung was evaluated. Three computers codes: EGSnrc, XTING and DORES were used for simulating the beams and patients, generating dose volume histograms and evaluating the dose response of the lung. NTCP increases with energy and with gantry angle. Below 15 MeV the largest value of NTCP of fibrosis was 0.036, for 12 MeV, gantry angle 60. The largest value of NTCP of radiation induced pneumonitis was 0.044, for 12 MeV, gantry angle 60. Key words: Postmastectomy radiotherapy (PMRT), EGSnrc, XSTING, DORES

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S3B.P11

OPTIMIZATION TREATMENT OF ANAL CANAL CANCER USING HIGH DOSE RATE(HDR) BRACHYTHERAPY

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To optimize the dosimetry of the treatment of anal canal cancer by performing a high-dose-rate (HDR) brachytherapy with a vaginal cylindrical applicator. 4 patients with locally advanced anal canal cancer, with lymph node involvement, were included in this planning study. The patients were treated with external radiation therapy (46Gy/23) and receiving a boost through brachytherapy (20Gy) after a mean interval of 3 weeks. The Vaginal CT/MR Multi Channel Applicator from Elekta/Nucletron compagny is designed for treatment of the vaginal cuff and is available in different cylinder diameters to reduce the surface dose and to cover the Planning Target Volume (PTV). Analysis of DVHs showed good coverage for the PTV and the tolerances of organs at risk satisfied the tolerances described in ICRU38 and ICRU58. The results confirm the efficacy of using the Vaginal CT/MR applicator for brachytherapy boost in the treatment of anal canal cancers.

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SCIENTIFIC SESSION 4B

RADIATION THERAPY: PREVENTING ACCIDENTS AND AUDIT


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S4B.I1

SETTING UP A PROTON THERAPY FACILITY- RADIATION PROTECTION ASPECT

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Proton therapy is becoming a matured radiotherapy modality. Such a facility is proposed as part of an advanced medical centre to be built by our institution for cancer treatment service. Therapeutic proton beam is more efficient in producing neutrons than X-ray and electron beams and hence activation of machine parts and consumables, building materials, clinical consumables, cooling substances and room air can potentially have radiological safety implications in the operation, maintenance and decommissioning of a PT facility. Apart from provision of adequate room shielding, a radiological risk assessment, including radiation exposure to operating staff, members of the public and hospital visitors should be carried out to assess the radiological impact to human and the environment in running a PT facility throughout its life cycle from installation to decommissioning. The safe management and disposal of the radioactive wastes generated due to activation should also be considered. The compliance of a PT facility with the national legislative requirement and international safety guidelines on radiation and equipment safety, including shielding design and management plan for handling of the radioactive wastes produced and in decommissioning of the facility should be appropriately addressed before the required licence can be granted by the controlling authority for clinical operation of the PT facility. The concerns or even opposition of the local communities on the potential impact of the facility to the local environment can be a major issue. Their concerns include radiation leakage, air quality, clinical and radioactive wastes, and potential traffic problems resulted from the installation and operation of the PT facility and they should identified and assessed. Appropriate mitigation measures should be implemented to address these issues and alleviate any environmental impacts identified. Other considerations such as radiation shielding design, equipment selection, personal and environmental radiation assessment and monitoring, specific patient safety, quality and safety control, and staff training should also be considered.

S4B.O1

RCONRES: A 3D-CRT ALTERNATIVE TECHNIQUE TO IMRT FOR THE TREATMENT OF LOCALIZED PROSTATE CANCER

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Prostate cancer is now the commonest cancer in men, accounting for almost 25 per cent of all new male cancer diagnoses and is the second most common cause of cancer related death in men. Intensity-modulated radiation therapy (IMRT) is the most reported technique as it enables both target dose coverage and organ-at-risk (OAR) sparing. However, during the last 20 years, three-dimensional conformal radiotherapy (3D-CRT) techniques have been introduced, Some more advanced 3DCRT treatment planning techniques have been developed to improve dose distribution to planning target volumes (PTVs) and OARs. In this study, we present the RCONRES (Revised Conformal Rectum Sparing) non-coplanar 3D advanced technique as an alternative to IMRT prostate treatment. The RCONRES has been tested experimentally in a sample of 20 patients . A dose of 78 Gy was delivered. A standardized 4-fields "box" technique was used for the Phase1 of the treatment, then the RConRes non coplanar technique was applied for the phase 2 . A 6 fields isocentric coplanar technique was considered for phase 3 . Dose-volume histograms and dose statistics of the rectum, the bladder and the femoral heads were collected for all patients. The dose tolerance criteria below were evaluated for each patient : For the rectum : Dmean, V40,V50,V60,V70 and V75; For the bladder : Dmean,V65,V70 and V75; For the femoral heads : Dmean and V10. To assess the homogeneity of dose distribution in the PTV, an homogeneity index was defined as HI = (D1% - D99%)/mean dose. The results of statistical analysis of the PTVs and OAR's doses showed an adequate coverage for the PTVs and a good rectal and bladder sparing .The dose tolerance criteria of IMRT and VMAT were satisfied. This let us conclude that, in centers where IMRT equipment is not available or for patients not eligible for IMRT, optimization of treatment may be feasible with such a 3D-CRT technique. The technique is relatively easy to implement and does not require an investment as important as that requested by IMRT. In the future, we intend to reduce the PTVs margin using IGRT. Key words : Prostate, 3D-CRT, IMRT, DVH

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S4B.O2

CLINICAL IMPLEMENTATION OF A PROTOCOL FOR 3D IMRT QUALITY ASSURANCE

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Define a set of statistical parameters and plan structures that characterize the pass/fail criteria for a 3D prostate, head and neck and thoracic pre-treatment IMRT quality assurance protocol. For this study, 3D IMRT (Intensity Modulated Radiation Therapy) quality assurance (QA) measurements were performed on 13 prostate, 25 head and neck and 25 thoracic IMRT patients using IBA's COMPASS system. All patients were treated with step-and-shoot IMRT on Raysearch Raystation planning system for Elekta Infinity linear accelerator. All patient plans passed traditional QA methods, including point measurement and 2D gamma analysis at 3mm/3%.A total of 52 measurements were performed on prostate patients, 25 measurements each on thoracic and head and neck patients. After establishing QA threshold parameters we implemented COMPASS as the primary IMRT QA system. We include results from the first 50 prostate patients with the COMPASS system. For each treatment planning structure included in the QA protocol the following statistical parameters were evaluated: average dose difference, 3D gamma test and volume with dose difference greater than 6%. After performing 102 measurements on 13 prostate, 25 head and neck and 25 thoracic patients we found for all patients and all treatment plan structures the maximum average dose is 5%, the maximum structure volume with absolute dose difference is 3.8% and the maximum volume failing 3D gamma test is: 3.67%. Based on the measurements performed, we established a uniform set of tolerance levels to determine if QA passes for thoracic, prostate and head and neck IMRT cases: maximum allowed average dose difference is 6%; maximum 4% of any structure volume may fail 3D gamma test and maximum 4% of any structure volume with absolute dose difference greater than 6%. 3D IMRT QA is a powerful and versatile tool for pre-treatment IMRT QA, with ability to perform a variety of anatomy-specific statistical tests. However, a protocol is needed to establish pass/fail thresholds for such tests. In this work based on statistical evaluation os 102 measurements we have established such thresholds for prostate, head and heck and thoracic IMRT plans and have demonstrated the applicability of this protocol for clinical use.

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S4B.O3

NEW METHOD FOR ESTIMATION OF FLUENCE COMPLEXITY IN IMRT FIELDS

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IMRT planning and verification is a complex and time-consuming process. At busy clinics this can lead to contraindication of IMRT for patients who would otherwise profit from the technique. However, IMRT verification can be simplified without compromising patient safety. One such way is suggested in our work. A new method for estimation of fluence complexity in IMRT fields is proposed. Unlike other previously published works, it is based on portal images calculated by the PDC algorithm in Eclipse (version 8.6, Varian Medical Systems) in the plane of the EPID aS500 detector. Fluence complexity is given by the number and the amplitudes of dose gradients in these matrices. Our method is validated using a set of clinical plans where fluence has been smoothed manually so that each plan has a different level of complexity. Fluence complexity calculated with our tool is in accordance with the different levels of smoothing and correlates well with DVH parameters. Thus, it is possible to estimate plan complexity before carrying out the measurement, which saves time in the replanning and remeasuring process.

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S4B.O4

PHOTONEUTRON SHIELDING IN A MEDICAL ACCELERATOR ROOM

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Medical linear accelerators operating above 10MV require door shielding for neutron as well as photon. Thermal and epithermal neutrons are absorbed with great effectiveness by 10B. Inelastic scattering or absorption may again produce potentially hazardous gamma rays. Neutron capture in hydrogen and boron releases a gamma ray. In this study, the photoneutrons and photons generated by linear accelerator of 18MeV energy electrons were simulated using radiation transport code MCNPX. Dose equivalent and fluence for neutrons and photons were calculated at various points inside treatment room and outside door. The shielding performance of borated polyethylene (BPE) and lead as shielding material was evaluated. The calculation of the reduction in neutron and photon fluence was performed for various shield thickness as well as the secondary radiation generated by the reaction with BPE and Lead. To determine an optimal arrangement of lead and BPE for neutron and photon shielding, shielding performance was evaluated considering arrangement of BPE and lead. The dose from neutrons is about one order of magnitude higher than the photon dose inside the door. In the case for the BPE thickness-40mm, the fluencies from additional photons generated by the reaction between neutrons and shielding material is about 6.58% and 29.89% of the neutron fluencies at the surface on the source side and outside, respectively. However, for lead, the ratio of additional photon fluence is much smaller than that of BPE. The obtained results suggest that an additional lead is necessary to attenuate neutron-capture gamma ray.

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S4B.O5

BE AWARE OF NEUTRONS OUTSIDE SHORT MAZES FOR 10 MV FACILITIES

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During the radiation survey of a new installation of a 10MV linac in an old radiation treatment facility, high dose rates of neutrons was observed. The area outside the maze entrance is regarded as a waiting room area. Both patients and staff, other than those involved in the actual treatment, can freely pass outside. Measurements were carried out using different instruments measuring both gamma and neutron dose rates. One detector showed effective dose in uSv/h for both gamma and neutrons and two detectors were fluence counters showing cps for neutrons. Measurements were carried out just outside the maze entrance and in the treatment room, at a distance of two meters from the gantry. For the in-treatment room measurements, the dose rate detector was connected to a computer allowing a continuous reading in graph format. Measurements were performed during a few minutes, until the reading showed a steady level. Measurements were performed for two old treatment rooms with short mazes (4-5m) with a Varian iX and an Electa Precise. Measurements were also performed for a Varian Truebeam at a new facility were the maze length is more than 8m. All systems operated at 10MV. Outside the treatment rooms in the old facility, neutron dose rates reached levels of 20-30uSv/h, whereas gamma dose rates were in the order of 5uSv/h. At the entrance of the maze in the new facility the neutron dose rate was below 5uSv/h. The in-room measurements showed neutron dose rates in the order of 10mSv/h, this was considered to be within the expected values, which should be less than 0.05% of the treatment gamma dose rate according to IEC. The dose rate levels dropped immediately after beam-off. Discussion: The neutron dose levels within the treatment room were considered to be within the levels that can be expected. However, due to the short maze design of our old facility, considerable amounts of neutrons still existed at the maze entrance where the maze lengths were 4-5m. At our new facility the maze length is minimum eight meters and neutron dose rates are less than 5uSv/h. An acceptable dose rate in an supervised area, assuming 500 hours of radiation a year is 2uSv/h, and for a controlled area it is 12uSv/h. Previously the normal routine at our facility has been to neglect neutron doses for linacs operating at 10MV or below, this will now be changed. If the maze is short be aware of neutrons even at machines operating at 10MV.

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S4B.O6

PROTECTING A CT SIMULATION ROOM TO ACCOMMODATE A CYBERKNIFE FACILITY

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The Radiotherapy Department at the Hermitage Medical Clinic consists of a two-bunker design with associated diagnostic and treatment planning facilities. In January 2012, a plan to develop stereotactic treatments using a Cyberknife was unveiled at the Clinic. Due to planning restrictions the new facility had to be contained in the existing blue print with the only available location in the department been an unused CT simulation room. The CT room barriers were originally designed to protect against radiation generated in the kV range from a diagnostic x-ray tube and would need considerable beefing up to protect against the 6MV beam emanating from the Cyberknife's linear accelerator. The room design would also be different from conventional radiotherapy bunkers due to the fact the Cyberknife can fire an unfiltered beam in any direction bar the roof (restriction of 220 above the horizontal). Therefore all walls must be primary barriers with the roof designed to protect against the large leakage/scattered radiation resulting from the high MU's used during the treatments. Space consideration indicated that concrete alone could not be used to restrict the radiation beam to acceptable limits. To this end a combination of lead, heavy concrete, steel and normal concrete were used to meet the dose constraints established by the Irish licensing authorities. Difficulties with the design especially the protection afforded around the door and concerns regarding ground shine were encountered. In addition trying to meet dated national guidelines on dose constraints in radiotherapy departments also further complicated the design. Plans were developed using the above-mentioned building materials with associated calculations to estimate the dose rates at various locations outside the room. Unlike rooms in diagnostic radiology, the integrity and adequacy of the bunker design in radiotherapy may only be assessed following the installation of the linear accelerator, as the high-energy beam is required to practically assess the protection afforded by the boundaries. This could be too late, with costly remedial work required to correct any deficiencies encountered. Given the relative few number of Cyberknife facilities in any given country, the presentation will be of interest to design engineers, architects, physicists or hospitals embarking on installing such a treatment unit. Measurements revealed the extra precautions taken were justified considering the lack of experience and obstacles encountered in modifying a room to house a linac mounted on a robotic arm. Work commenced on the bunker in June 2013, taking three months to complete, followed by installation of the unit on the 19th August. The first patient was treated on the Cyberknife facility at the Hermitage Medical Clinic in November 2013.

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S4B.P1

RADIATION PROTECTION OF LINAC BUNKERS. A USER-FRIENDLY APPROACH WITHOUT SCATTER CALCULATIONS.

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The purpose of this work was to develop a simple and easy to use formalism to calculate the photon and neutron radiation dose related to bunkers containing linear accelerators (linac's) used for radiation therapy. A formalism was developed for calculation of dose levels originating from linac leakage at different reference points both inside and outside 3 different bunkers containing 3 different linacs. A well-known but complex formalism was considered and simplified. The simplifications made were based partly on literature and partly on measurements. We have furthermore included photon scatter originating from the irradiated patient in the formalism. We compared two different types of bunkers, i. e. bunkers with and without a 'nose' mounted on the maze wall. In this way, simple formulas were obtained to calculate the dose levels inside and outside the bunker for both photons and neutrons. These formulas are valid for the most common linac bunkers and yield results that agree just as well with the measured doses as the results found by other authors in a more complex manner. The formalism can be used as a tool to estimate the doses especially at the outer maze entrance and at the operating area and can thus be used to calculate doses received by the relatives of the patients and the staff alike.

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S4B.P2

BYSTANDER CELLS COULD PRODUCE BYSTANDER FACTORS AND INDUCE RADIATION BYSTANDER EFFECT

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The radiation induced bystander effect is an example of non-targeted effects induced in cells that are not irradiated directly, but are far from the irradiation site. Some previous studies have revealed that bystander effect can be developed at a large distance from the irradiated cells. The aim of the present study was to determine whether cells receiving bystander signals would emit a bystander signaling response themselves and induce bystander effect in other non-irradiated cells. Normal human fetal lung cells (MRC-5) and human large lung tumor cell line (QU-DB) were studied. The target cells were irradiated by gamma rays emitted from a 60Co RT unit to deliver doses equal to 0.5, 2 and 4Gy. Medium transfer technique was used to produce the bystander effect. Transferred media to first bystander cells was replaced with fresh medium after one hour. Formation of micronuclei was evaluated by the cytokinesis-block micronucleus test as an end point of induced bystander effect in first and second neighbor cells. Formation of micronuclei were examined in first MRC5 bystander cells which received different doses. It also was assessed in second bystander cells when they were placed in fresh media derived from first bystander cells. Similar results were obtained QU-DB cells. The frequency of MN cells was significantly different from their corresponding control samples ($P < 0.05$) in all subgroups. However, the induced bystander effect in second bystander QU-DB cells was dose-dependent, but this dependency was not observed in MRC5 cells. Comparison of MN abundance in first and second bystander cells showed intensity of bystander effect is not decreased in second bystander cell. Treatment of MRC5 bystander cells with DMSO scavenger reduced the abundances of MN in first and second bystander cells. Our results are evident that non-irradiated cells which received bystander signals initiated a bystander signaling response and affect other adjacent cells which lead to a cascade effect. However intensity of second order bystander effect depends on cell type and delivered dose. ROS may play an important role in transferring this effect to other bystander cells

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S4B.P3

ABSORBED DOSE CALCULATION OF FIRST AND SECONDARY PARTICLES IN BRAIN PROTON THERAPY BY MONTE CARLO METHOD

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Nowadays, proton therapy has been one of the rife and new approaches of Cancer radiotherapy. The advantages of proton therapy are being focal, specified and limited protons' range, Bragg peak energy placement, ability to spread Bragg peak, small size of the particles, and so forth. Therefore, healthy tissues are less damaged. However, this method has some drawbacks such as high cost and contribution of produced secondary particles in dose distribution. Dose distribution and dose rate received by various tissues, especially for the brain because of the brain's critical components, are pivotal parameters in an appropriate treatment planning. The dose received by the brain is not only due to the initial protons, but also secondary particles such as neutrons, electrons, photons contribute to the dose distribution. These secondary particles resulted from nuclear interactions between the proton and constituent elements of tissues such as carbon, nitrogen and oxygen. Therefore the calculation of secondary particles' dose distribution is very important due to their additive effect in relative biological effectiveness (RBE). Because of dose distribution of these particles; it is possible that undesirable doses which have produced by secondary particles reach to the normal and healthy tissues. Therefore, in this research secondary particles' dose has been considered and calculated. For dose calculation, Mont-Carlo method and MCNPX2.6 code were used. In this study, MIRD head phantom (volume = 1.20973E+03 cm3, weight=1.25812E+03 g) with an spherical tumor with the diameter of 1cm was placed in the center of phantom. The tumor was irradiated by a mono-energy unmodulated pencil beam of protons with specifications of 150MeV, 2 nA current for 60 s. This beam is equivalent to 18E+06 numbers of particles. The results showed the absorbed dose of brain tissue (tumor) for proton, neutron, electron and photon are 0.1724256 (32.23026) mGy, 5.18211E-04 (1.23069E-02) mGy, 5.50244E-05 (4.65329E-04) mGy, and 6.2003E-05 (9.97205E-04) mGy, respectively. These results showed the amount of produced dose in brain (tumor) by all of the secondary particles is 0.36% (0.042%) of the total. So it should be noted, although the dose contribution of secondary particles is small but it is not negligible and cause undesirable dose. Also it should be mentioned, the results strongly depend on the target material; and so if the target material is changed, different results are expected.

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S4B.P4

ADDITIONAL DOSE DELIVERED TO THE PATIENT DURING THE POSITIONING AND TRACKING AT CYBERKNIFE X-RAY

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CyberKnife Robotic Radiosurgery uses stereoscopic X-ray imaging not only for patient set up, but also for real-time target tracking throughout the treatment delivery process The system is totally robot-controlled (the 6-fredom degrees manipulator), and includes a 6 MV linear accelerator. During treatment the patient is positioned on a remote-controlled 5-fredom degrees table and connected to the tracking system, which consists of 2 standard kilovoltage X-ray tubes and 2 amorphous silicon flat-panel detectors for instantaneous imaging. The images obtained with the two detectors are processed with a specific software. The aim of the present study was to create a base for the estimation of additional absorbed dose delivered during the target localization and tracking for the next treatment. The experimental data were obtained with CyberKnife system G4 8.5. The absorbed dose in an anthropomorphous human body phantom was measured with dosimeter PTW Unidose with ionizing chamber Farmer 30013. The phantom PTW RW3 Slab Phantom consists of polystyrene C8H8 with addition of 2% TiO2 (density ρ=1.045 g/cm3). The recalculation of the phantom thickness to water thickness was done; h=1/1,045≈0,96 cm. During the experiment the Farmer chamber was installed at identical height from the table. The experiments were done using standard CyberKnife software. The charge generated in the Farmer chamber under the action of γ-beam was measured with the electrometer. The charge (coulomb) was recalculated to dose. The experiments were performed at constant tube potential 120 kV. The measured dose delivered to the patient during the imaging and positioning procedure is consistent with the results of other authors. The results of relative dose value obtained during the additional exposure to the patient will be used for the estimation of absolute values. This calculation gives a possibility to account the additional exposure to total therapeutic dose.

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S4B.P5

SKIN DOSE DUE TO THE SCATTERED RADIATION BY EMPLOYING A BLANKET FOR CANCER TREATMENT

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We employ a blanket to keep patients' body warm in a medical accelerator room for cancer treatment. This study estimated skin dose elevation due to scattered radiation by blanket. We designed to perform comparison of superficial dose of a phantom, considering two plans with and without a blanket. We considered two types of blanket, thin and thick, which are usually used in our institution. After acquiring three sets of CT simulation data of a bare phantom, a phantom with the thin and the thick blanket, we registered all of three images as a phantom for treatment plan. For the identical plan of clinical mode for the model patient, three plans were created with three phantoms. With the dose statisitics data of planning system, superficial doses were compared with each others. In addition, the phantoms with three setups were irradiated and the superficial dose were measured with the ion chamber at the depth of 0.5cm and 1.5cm. The results obtained from treatment planning sysyem showed that the surface dose was 25Gy, 36Gy, and 30Gy in the case of a bare phantom, and the thin and the thick blanket, respectively. The experiment for dose measurement using an ion chamber showed that the dose at the depth of 0.5cm was 2.323Gy when a fractional dose, 5 y, was delivered to the bare phantom. In the same setup with the thick blanket, the 0.5 cm depth dose was increased to 2.351Gy. At the depth of 1.5cm, the dose to bare phantom was 1.946Gy and that to the thick blanket was increased by 1.986Gy. It is concluded that skin dose elevation should be carefully examined, as far as a blanket is concerened for keeping warmth in a medical accelerator room.

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S4B.P6

DEVELOPMENT OF BRACHYTHERAPY TREATMENT PLANNING SYSTEM USING MONTE CARLO METHOD

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Currently, three methods have been used for the treatment of cancerous tumors including surgery and chemotherapy as well as radiotherapy. Radiotherapy is conducted in several approaches which one of them is brachytherapy. Accuracy and efficiency of treatment planning is vital in achieving the radiation therapy goals. One of the most important steps in treatment planning is the calculation of dose distribution within the body. Monte Carlo approach is considered as the most accurate dose calculation method. In this study, a brachytherapy treatment planning system based on MCNPX Monte Carlo code has been designed using MATLAB (UIBMCTPS). In this system, the CT data of patient are imported in DICOM format and after choosing the brachytherapy sources; the input file in MCNP format deck is generated and sent to the cluster for execution. Finally simulation results are presented as isodose curves on the CT images.

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S4B.P7

STATUS OF RADIATION PROTECTION AND SAFETY AT RADIATION ONCOLOGY, BPKM CANCER HOSPITAL, NEPAL

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The objective of this work was to evaluate all the safety procedures toward the radiation protection for workers in the radiation oncology department. The annul thermoluminescent dosimeters (TLDs) reports for five years of the staffs were evaluated, radiation surveys were done in the control consoles, radiotherapy machines room and waiting areas of all machines using Aloka survey meter. The five years TLD reports shows that the whole body dose of the individual staffs is found within the annual dose limit except the accidental exposures. Radiation exposures in the working areas are also safe limits. The radiation safety practices for radiation protection are satisfactory and the radiation workers of the departments are found working within safe limit. * Presenting author: surendrachanda@yahoo.com

S4B.P8

ADVANCES AND CHALLENGES IN RADIATION PROTECTION OF PATIENTS IN RADIOTHERAPY

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The Goal of Radio Therapy (RT) is to deliver optimum dose to the Target with minimum acute and long term toxicity. The new techniques image guided radio therapy (IGRT) intensity modulated radiation therapy (IMRT) allow to reach curable dose in the target and decrease the dose in organs at risk with about 30% - 50%. This high level techniques require a good staff education and knowledge for implementing them safely in daily routine. Advantages of this techniques are discussed. All steps of the workflow from the LINAC commissioning, patient data acquisition, plan preparing, dose plane verification, are presented. IGRT is an useful tool in patient protection because it allows accurate set-up during the whole radiotherapy course. Cone beam computer tomography CBCT makes possible to recalculate the dose distribution of the plan for different structure position within the body during the RT. The safety of the patient is depended strongly on regularly following of the Quality Assurance Program, which is developed for every part of techniques components - CT,Linac,TPS(treatment planing system),treatment delivery.

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S4B.P9

RADIATION PROTECTION OF PUBLIC AND STAFF IN VICINITY OF RADIOTHERAPY CT SIMULATOR

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The purpose of this work is to review the process of establishing measures for assurance of Radiation Protection (RP) of public and staff in areas surrounding Radiotherapy (RT) CT Simulator. Different RP shielding and radiation survey inspection approaches are included and analyzed in this study. RP inspection of RT simulator includes radiation survey measurements of ambient dose equivalent H*(10) at 100 mA.s and ambient dose equivalent rate during CT scan. Results are compared with standard values for measured quantities according Basic Safety Standards and DIN 6812 standard. Additionally Computed Radiography (CR) cassettes were used to check the quality of RP on critical points such as doors overlapping, etc. Required protection was calculated using recommendations of DIN 6812, NCRP 147 report, the National RP Regulations and current enforcement practice of Radiation Inspectorate in Bulgaria. The radiation protection survey measurements showed availability of good protection at all areas around the simulator, except at door between CT room and technical lab ocupaed ny a non-radiation workers staff next to it. Maximum Ambien Dose Equivalent Rate measured was 18 ± 2,7 μSv/h at Control Level of: 0,5 μSv/h. The integral Ambient Dose Equivalent measured at 100 mA.s CT tube load was 4,5 μSv at control level of 0,0003 μSv. The deficit of protection was confirmed on X-ray images obtained from CR cassettes positioned at two parts of the doors and door to wall junctions. Lack of satisfactory protection at one of the doors of CT simulator room was observed. Required shielding of the door between CT simulator and adjacent technical staff room calculated using different International recommendations approaches was assessed to 2 mm Pb equivalent. In contrast a shielding of 3 mm Pb equivalent is required by radiation inspectorate. Reason for the difference is due to misunderstanding of international recommendations and their transposition into National RP standards. A necessity of more ALARA related approach for assurance of RP to public and staff around medical X-ray facilities is discussed and proposal for improvement of present optimization measures is given.

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S4B.P10

INVESTIGATION OF THE COMPLIANCE OF THE REQUIREMENTS OF NATIONAL REGULATION CONCERNING BASIC COMMISSIONING TEST OF THE NEW INSTALLED CO-60 MACHINES

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Five Terabalt 80 ASC machines have been installed recently in Bulgaria. Ordinance №30 of the Ministry of Health is effective and article 36, appendix 10, table 1 gives the national recommendations and regulation regarding commissioning of Co-60 machines. The aim of this study was to investigate the relevance of the mechanical and dosimetric requirements of Ordinance №30 and coincidences in the basic parameters of the machines. Sets of mechanical and dosimetric measurments have been performed on four of the machines SN 53, 56 90 and 91. Tests were conducted according to the methodology developed at the National Hospital of Oncology. Basic mechanical checks are: mechanical isocenter; lasers; source to surface distance, SSD indicator; scale's accuracy for collimator and gantry rotation; optical field size; accuracy of table movement indicators and table deflection under load. The coincidence of the optical and radiation field size and mechanical and radiation isocenter is checked using ready pack films. All dosimetric checks were performed in an isocenteric setup. Relative basic dosimetric parameters as radiation field size, output factors, wedge factors, symmetry, homogeneity and penumbra and absolute dosimetry calibrations have been performed in water at depth of 5 cm and SSD 75 cm. Dosimeter Unidose with Farmer type ion chamber has been used for absolute dose measurements, and Semiflex ion chamber, for relative measurements with the beam analysing system MP3. The results obtained from the commissioning tests are: All mechanical tests except the SSD indicator are within the tolerance level required in Ordinance 30. The indicator has no deviation at SSD 80 cm and is in the tolerance level from 80 to 120cm, but at SSD 70 cm for two of the machines deviation is up to 5 mm. The dosimetry checks are in the required tolerance levels. We should note that the homogeneity of the radiation field varies from 2% for 5X5 cm2 up to 6% for 30X30 cm2. The regulation does not specify a field size and conditions of measurement for this parameter. Basic dosimetric parameters of the tested machines are in very good coincidence, the maximum difference in output factors is 0.5% and for wedge factors is 0.9%. There is good accordance of the dosimetry field sizes and penumbra. Required tolerance limits for the mechanical and dosimetric parameters in Ordinance №30 are consistent with Terabalt 80 ASC. The main relative dosimetric characteristics of the machines show good agreement.

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S4B.P11

COMMISSIONING OF BRACHYTHERAPY SYSTEM

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Integrated Brachytherapy Unit (IBU) has been installed at the National Hospital of Oncology. It consists of C-arm, microSelectron HDR afterloading unit and Oncentra Brachy treatment planning system. Aim of this study is to perform commissioning of the brachytherapy planning system and to establish a program for quality control of the system by conducting series of tests to check the parameters of the treatment unit, the activity of the radioactive source and accuracy of calculation algorithm of the planning system. Commissioning was performed of the brachytherapy module of Oncentra treatment planning system. Tests were divided into five categories: checking the activity of the radioactive source, checking the positioning of the radioactive source, image import accuracy, reconstruction accuracy and dose calculation accuracy. To check the activity of the radioactive source (Ir-192) measurements with a well - type chamber and electrometer Unidose Webline have been performed. For verification of the correct treatment position of the source a source position check ruler was used. Tests were conducted for all 30 channels, for the two mainly used lengths and in several positions. Image import and reconstruction accuracy was checked with an IBU QA phantom and gafchromic films. Commissioning test results for dose calculation accuracy were compared to manually point dose calculations and to measurements of a point dose in a homemade Plexi phantom, in water medium performed with a semiflex ion chamber and electrometer Unidose Webline. Measurements of the activity of the radioactive source show good coincidence within 2% of the value from the source certificate. Differences between programmed and measured position of the source are less than 0.5 mm. The maximum deviation between dimensions and proportions of the initial and reconstructed object is 0.6%. Point dose agreement between Oncentra, manual dose calculation and measurements in the Plexi phantom was better than 2% with source data and dose calculation protocols following the American Association of Physicists in Medicine (AAPM) guidelines. Commissioning tests show that Oncentra Brachy system can be applied with confidence for patient planning and irradiation on HDR afterloader machine. Testing of image accuracy (import and reconstruction) generated a more comprehensive set of testing procedures than previously listed in published national recommendations.

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S4B.P12

A STUDY ON RELIABILITY OF ESTIMATING ABSORBED DOSE IN EYE DURING PROTON THERAPY USING ADULT MALE REFERENCE PHANTOM

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Because of the sensitivity of the eye to ionizing radiation, its exposure to radiation may cause changing the normally transparent lens of the eye. To evaluate the deterministic effects of ionizing radiation on the eye lens, several papers have been published. In 2007 International commission on radiological protection stated that the lens of the eye may be more sensitive to radiation than what previously was considered. In this research a mathematical model of the eye including the inner structure was used to test the reliability of the results obtained with adult male reference phantom. The calculations of the absorbed dose of the eye using the mathematical model located in a whole body mathematical phantom and the adult male reference phantom were performed using MCNPX monte carlo code. Comparison results obtained using reference computational phantom and mathematical eye model in a broad parallel beam of incident protons with energies between 20 MeV and 10 GeV indicates that in each energy the total lens absorbed dose of reference phantom is in good agreement with that of the sensitive region of mathematical model. However the absorbed dose in total eye bulb is different for reference phantom and mathematical model when proton energy is less than 50 MeV. It is seen that the calculated absorbed dose in total eye bulb of the mathematical model is three times greater than what calculated for the reference phantom when proton energy is 10 MeV. Therefore, it is concluded that the results obtained by the reference phantom can be used to evaluate the absorbed dose of the sensitive part of the eye lens during proton exposure, but using reference phantom is not reliable for estimating the total eye absorbed dose.

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SCIENTIFIC SESSION 4A

EYE DOSE ASSESSMENT AND MANAGEMENT


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S4A.I1

EYE DOSE ASSESSMENT AND MANAGEMENT: OVERVIEW

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Much less work is currently on-going on developing methods and tools for eye dose assessment, whereas there are promising actions on dose management. Eye dose assessment can be done by four means: a) Passive dosimeters b) Active dosimeters c) Retrospective dose assessment using scatter radiation dose levels and d) Correlations between patient dose indices and eye doses to the operators. For patience dosimetry, Monte Carlo method based simulations include considerations of: Spectra as a function of beam energy, scanner geometry (focal spot to isocenter distance, fan angle, beam profile), filtration, that are typically proprietary and protocols. The most appropriate method for practical use in day-to-day practice is estimation of eye lens dose from CTDI. While the assumptions behind the CTDI metric fit well to many CT clinical applications, they are not ideal for CT perfusion imaging where there is no table increment, where a relatively narrow swath of tissue is irradiated, and where eye lens dose is of greater interest. CTDIvol generally overestimates the eye lens dose. Depending on tube potential, the scanner and patient model, CTDIvol can overestimate the eye lens dose anywhere from 30% to 100%. Some authors suggest simplification by dividing by two. There is need for active research both on measurement methods and on estimations of eye dose for patient as well as for occupationally exposed. The availability of wide range of tools for dose management for occupational workers provides great hope of keeping doses within dose limits. However, patient dose management poses challenge.

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S4A.I2

NEW DOSE LIMIT FOR THE LENS OF THE EYE

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The IAEA Safety Requirements: GSR Part 3: Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (the BSS) was approved by the IAEA Board of Governors at its meeting in September 2011 and was issued as No. GSR Part 3 (Interim Edition) in November 2011. This edition of the International Basic Safety Standards superseded the previous edition published in 1996. The equivalent dose limit for the lens of the eye for occupational exposure in planned exposure situations was reduced from 150 mSv per year to 20 mSv per year, averaged over defined periods of five years, with no annual dose in a single year exceeding 50 mSv. This reduction in the dose limit for the lens of the eye followed the recommendation of the International Commission on Radiological Protection (ICRP) in its Statement on Tissue Reactions of 21 April 2011. This paper will also consider development of guidance by the IAEA on the implications for occupational radiation protection of the new dose limit for the lens of the eye.

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S4A.I3

EYE DOSE ASSESSMENT AND MANAGEMENT IN NUCLEAR MEDICINE

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In recent years epidemiologic research has shown that lens opacities and cataract can occur at much lower doses than previously assumed. High occurrence of opacities has been shown with staff of interventional cardiology and radiology, one of the group of workers most at risk. In response to this new data, the ICRP has issued a statement recommending to reduce the occupational dose limit of the eye lens from 150 mSv to 20 mSv per year. This recommendation is taken over in the Basic Safety Standards, and will thus become a legal requirement. For nuclear medicine, hardly any data have been published. Only few papers up to now show very limited measurement data. In these papers it is estimated that the eye lens doses can reach values similar to whole body doses, i.e. several mSv per year. A result of this is that monitoring of eye lens doses will become necessary in routine in some cases. At the moment only one passive dosemeter exists that can measure the eye lens doses in the right quantity Hp(3), but this is not used a lot. At SCK•CEN we have performed a measurement campaign in the nuclear medicine departments of 4 different hospitals, using a specific eye lens dosemeter. This was done for the most common nuclear medicine procedures (Tc-99m, F-18) and for some nuclear medicine therapy applications. In total 16 operators were monitored. Of course the doses depend on many aspects: the type of radionuclides, the activities, the procedure, the set-up and shielding,… We have extrapolated the measured eye lens doses to yearly doses, based on the workload. We found that no operators would reach the new 20 mSv limit, but that monitoring might be required in some cases. We also compared the eye lens doses with the whole body doses, and found a reasonable correlation.

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S4A.I4

EYE DOSE ASSESSMENT AND MANAGEMENT IN DIAGNOSTIC AND INTERVENTIONAL RADIOLOGY

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Eye dosimetry has recently become an active research area due to increased evidence on eye injuries associated with radiation exposure. This implied a decrease of annual dose limit for lens of the eye from 150 mSv to 20 mSv. Contrary to whole body dosimetry, routine eye dosimetry is not yet well established. However, it is extremely important for correlation of observed radiation effects with dose and for verification of compliance with dose limits. It also contributes to better radiation protection in clinical practice. For dose assessment in clinical practice different dosimeters as TLD, OSL, film or active personal dosimeters are used. Dose levels are reported in different operational dosimetric quantities as Hp(3), Hp(0.07) and Hp(10). Reported doses are assessed using various combinations of protective tools as eye glasses, ceiling suspended screens or disposable pads. Doses are reported mainly for the first operator and in some cases for nurses and radiographers. At present, there are evidences that unprotected eye dose varies up to 250 fold for different views in fluoroscopy and reported dose per procedure range from less than 0.1 to 1100 μSv. Important influencing factor to eye dose in clinical practice are acquisition mode and shielding configurations. Challenging issue is fact that dose reduction factors for different collective and personal protective devices are obtained mainly in phantom studies (static conditions) and later, applied to real clinical situations. Typical dose reduction factor for one shielding tool is 2-10 and for combination of tools is 5-25. There is no clear consensus on the correlation between eye dose and patient dose indices as kerma-area product (KAP). The correlation is highly dependant on the X ray tube configuration and use of protective tools. Often, it only available approach for eye dose assessment and could be applied if normalized eye dose per unit KAP is based on local practice. The paper reviews the most important aspects of eye dosimetry as: development of new dosimeters and calibration procedures used in clinical practice, results of the recent clinical studies in terms of design and reported dose levels, individual monitoring arrangements, correlation of eye dose with patient dose indices and methods and results of retrospective dose assessment. In addition, the most important influencing factors on staff dose and most effective dose reduction methods are presented.

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S4A.O1

STAFF LENS DOSES DURING INTERVENTIONAL PROCEDURES. COMPARING CARDIOLOGY, NEURORADIOLOGY AND INTERVENTIONAL RADIOLOGY

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To estimate lens doses using over apron active personal dosemeters on a sample of individual procedures in interventional catheterization laboratories (cardiology IC, neuroradiology IN, and radiology IR). To evaluate correlations between estimated lens doses and patient doses for the three interventional specialties. Active electronic personal dosemeters placed over the lead apron, in the operator's left pocket at chest level, were used on a sample of 204 IC procedures, 274 IN and 220 IR ones (all performed at the same university hospital). Another dosemeter was placed in a fixed position at the C-arm of the x-ray system to measure the level of scatter radiation. Patient dose values (kerma area product) were recorded to evaluate correlation with C-arm and lens doses. Operators all certified in radiological protection used the ceiling suspended screen in most cases. Available literature mentions a poor correlation between chest dose measurements and eye lens doses during clinical procedures, the use lens dosemeters is problematic in routine practice. Thus, the value measured at the chest, over the apron, is suggested as a conservative approach to estimate lens dose. Values of equivalent dose Hp(10) per procedure (median / 3rd quartile) measured over the apron for cardiology, neuroradiology and interventional radiology resulted, respectively, in: 21/67; 19/44 and 24/54 μSv. The values recorded at the C-arm (45º down from the isocenter plane) were: 682/1298; 646/1470 and 449/1120 μSv. Patient dose values (median / 3rd quartile): were; 75/128; 83/176 and 61/159 Gy cm2. Median values of the ratio between Hp(10) at the C-arm and patient dose values were: 9.6; 8.3 and 8.1 μSv /(Gy cm2). Median ratios for the dosemeters worn by the operators over the apron (working protected by the ceiling suspended screen) and patient doses, were: 0.36; 0.21 and 0.46 μSv/(Gy cm2) for cardiology, neuroradiology and interventional radiology, respectively. Median values of Hp(10) measured with over apron dosemeters for the three interventional specialties resulted in the range 19-24 μSv/procedure: more than 800 procedures/year were necessary to reach the new lens dose limit with the approach used. When the correlation between estimated lens doses and patient doses was investigated, differences of 133% were found between the different specialties, the highest value belonging to interventional radiology.

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S4A.O2

EYE DOSIMETRY AND PROTECTIVE EYEWEAR FOR INTERVENTIONAL CLINICIANS

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Doses to the eyes of interventional radiologists and cardiologists could exceed the annual limit of 20 mSv proposed by the International Commission on Radiological Protection. There are various protective devices that can afford protection to the eyes, such as ceiling suspended screens and radioprotective pads, if used properly. The final barrier is personal protective equipment in the form of protective eyewear. The use of lead glasses offers challenges in terms of quantifying the protection provided, as the majority of dosimeters currently available are not designed to be worn under the protection. The aim of this study has been to derive dose reduction factors (DRFs) equal to the ratio of the dose with no eyewear, divided by that when lead glasses are worn. Thirty sets of protective eyewear have been tested in X-ray fields using anthropomorphic phantoms to simulate the patient and clinician in two centres; Glasgow, Scotland and Gothenburg, Sweden. DRFs for X-rays incident on the front of lead glasses vary from 5.2 to 7.6, while values for orientations similar to those used in the majority of clinical practice are between 1.4 and 5.2. Results suggest that application of a DRF of 2 would provide a conservative factor that could be applied to personal dosimeter measurements to account for the dose reduction provided by any type of lead glasses provided certain criteria relating to design and consistency of use were applied. Approaches to personnel dose monitoring in radiology will also be discussed, including the feasibility of using a collar dosimeter worn outside the lead apron as the first dosimeter to provide an assessment of both eye dose and effective dose.

S4A.O3

EYE LENS DOSE MONITORING IN INTERVENTIONAL CARDIOLOGY

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The ICRP has recently recommended reducing the occupational exposure dose limit for the lens of the eye to 20 mSv per year, averaged over a period of 5 years, with no year exceeding 50 mSv, instead of the current 150 mSv /year. This reduction will have important implications for interventional cardiology and radiology personnel. In this work, lens dose received by personnel working in interventional cardiology (IC) is studied in order to determine whether eye lens dose monitoring or/and additional radiological protection measures are required. Eye lens dose exposure was monitored in 9 physicians and 6 nurses. The major IC procedures performed were ACTP and diagnostic explorations. Three Philips X-ray systems were used, two Allura and one Clarity. The personnel were provided with two TL dosemeters, one calibrated in terms of Hp(3) located close to the left ear of the operator and a whole-body dosemeter calibrated in terms of Hp(10) and Hp(0.07) positioned above the lead apron. The estimated annual eye lens dose for physicians ranged between 16 to 40 mSv, for a workload of 100-150 procedures per year. Hp(3) of 780 μSv was measured during a long procedure (DAP=259884 mGycm2). Lower doses were collected for nurses, with estimated annual Hp(3) between 5 and 9 mSv per year. It was observed that for nurses the Hp(0.07) measurement above the lead apron is a good estimate of eye lens dose. Unfortunately, this is not the case for physicians, where the influence of both the position and use of protective devices such as the ceiling shield is very important and produces large differences among doses both, at the eyes or on the thorax. In general, there is a good correlation between Hp(3) and DAP. However, this is also highly dependent on the type of procedure and the protection tools used. Finally, it was verified that for the same type of procedure, personnel doses were lower when the Clarity X-ray System was used. Data show that the new annual dose limit for the lens of the eyes can be easily surpassed for some workplaces. It highlights the need to improve training and awareness in order to improve the use of protection systems in practice. Monthly DAP or number of procedures are probably good parameters to identify personnel that would need regular lens monitoring or the use of lead glasses. Further studies are required on the relationship between eye lens dose and whole-body dosemeter measurements.

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S4A.O4

STAFF EYE DOSES IN A LARGE MEDICAL CENTER IN SAUDI ARABIA: ARE THEY MEETING THE NEW ICRP RECOMMENDATIONS?

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The new recommendation of the ICRP on the dose limit for the lens of the eyes bears a big impact on cardiology staff eye doses due to the complexity of some procedures that may lead to longer fluoroscopy time. A 5-year retrospective analysis of the cardiology staff eyes doses was performed on 35 staff from different categories (nurses, technologists and cardiologists) at King Faisal Specialist Hospital and Research Centre (KFSHRC) in Riyadh, Saudi Arabia. KFSHRC is a tertiary medical center with 800 bed capacity having more than five thousand cardiac catheterization procedures performed annually. The aim of the study is to estimate staff doses to the lens of the eyes using the Hp (0.07) values from the annual TLD dose report from year 2008 to 2012 and determine the category of staff with high estimated eye doses. The study also aims to investigate the causes for high doses and recommend dose reduction techniques. The dose to the lens of the eye was estimated by multiplying the Hp (0.07) reported doses at the collar level (unprotected) by 0.75. The mean annual doses of each staff over the 5 year monitoring period was determined. The statistical analysis showed a skewed distribution of eye doses with 72% of staff receiving less than 1 mSv. The mean annual dose for the 5 year monitoring period ranged from 0.1 to 5.4 mSv. One staff was identified to have the highest annual eye dose of 13 mSv (2012) and 3 staff obtained eyes doses ≥ 5 mSv (2010 to 2012). Large variations exist in the mean annual doses of the different categories of staff. Cardiologists tend to receive high doses exceeding 10 mSv and the dose constraint of 20 mSv averaged over 5 years might be exceeded. There is a need to identify competencies of staff for the different procedures from simple to complex. The eye dose per DAP coefficient should be established for a faster estimation of staff eyes doses. Staff identified to have high eye doses should be regularly monitored.

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S4A.O5

ASSESSMENT OF EYE LENS DOSES FOR WORKERS DURING INTERVENTIONAL RADIOLOGY PROCEDURES

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In recent years the number of performed inerventional procedures increased. The exposure of interventional radiology workers increased also. These workers have higher risk for formation ionizing radiation induced cataract. Reduced annual occupational equivalent dose limit to the lens of the eye is incorporated in the international legislation (Council Directive, 2013). With this new dose limit it is necessary to determine and optimize the eye lens doses of interventional radiology workers. The purpose of this study was to estimate radiation doses to eye lens and offer practical recommendations for monitoring of eye lens dose and for use protection measures. During this study the results of routine monitoring where analyzed and compared with the results obtained from measurements performed with new eye lens dosemeter. According to national legislation the eye lens dose can be assessed using Hp(10) measured with whole body dosemeter used above protective measure near the collar. Hp(3) was measured at the level of the eyes with new eye lens dosemeter. The average dose for one interventional procedure was presented. The information about use of protective devices, number of performed interventional procedures and their fluoroscopy time was collected also. In 2012-2013 50 physicians, nurses and technicians attending interventional radiology procedures from 9 hospitals participated in this study. If does not take into account that was used protective lead glasses the predictive maximum annual equivalent dose for eye lens is 82 mSv. The study results show that annual doses to eyes for interventional radiology physicians might result in more than 10% of the annual dose limit to the eyes. The dose measured near the collar can overestimate the dose to the eye. More accurate results are obtained when the dose is measured with the dosemeter near the eye. On the basis of study results and aiming to reduce the dose for the lens of the eye all interventional radiology physicians were recommended to use protective lead glasses and mobile ceiling screens during interventional radiology procedures.

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S4A.O6

ASSESSMENT OF THE OCCUPATIONAL EXPOSURE IN REAL-TIME DURING INTERVENTIONAL CARDIOLOGY PROCEDURES

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Occupational doses of the medical staff involved in fluoroscopy-guided procedures have become a subject of growing concern. Cardiac interventional practices can be complex, requiring the operators to work at short distances from the patient, during long exposure times. Due to the scattered radiation in the patient and the fluoroscopic equipment, the staff is exposed to a non-uniform radiation field characterized by dose-rate values which rapidly vary from point-to-point inside the room. Consequently, the medical staff can receive high radiation doses during these interventional examinations. The whole-body exposure of the medical staff is generally described by the personal dose equivalent, Hp(10), used to estimate the effective dose (E) and measured through dosimeters, properly located on the operator's body. In this study, we propose to analyze the staff radiation doses in real-time, during interventional cardiology procedures executed in a cardiac catheterization room at a Portuguese Hospital. For this work an electronic system for occupational dosimetry in real-time was used, composed by individual electronic dosimeters with wireless connection that sends the dose rate and the accumulated dose to the equipment's display. In order to study and assess the potentially high radiation dose received by the medical staff during these interventional procedures, Monte Carlo (MC) calculations were performed in order to simulate some complex clinical scenarios. The state-of-art MC code MCNPX 2.7.0 and voxel phantoms were used for the identification of some parameters that may affect the staff doses. The dose measurements made with the monitoring system during these fluoroscopic interventions, together with the complementary MC simulations, allowed us to identify some actions of the medical staff that could be considered a risk under routine working conditions. An analysis of the occupational dose data were performed for different staff members and several correlations were established between occupational and patient doses and between staff doses and several procedure related factors. Our results suggest that the implementation of the real-time monitoring system for the personnel exposure may have a positive effect on optimization of the occupational radiological protection in fluoroscopically guided cardiac procedures.

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S4A.P1

RISK OF RADIATION EXPOSURE TO MEDICAL STAFF INVOLVED IN INTERVENTIONAL ENDOUROLOGY

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The purpose is to evaluate scattered doses to medical staff performing interventional endourological procedures with emphasis to eye lens exposure. Taking into account the workload in the department, the aim is to estimate the possibility the new annual dose limit for eye lens of 20 mSv to be exceeded, and to study the impact of an extra protective shield. Full characterization of a dedicated urological X-ray system with over-table tube was performed using a PMMA phantom of 15, 20 and 25 cm. Entrance surface kerma rate was measured with a reference dosimeter at different modes and field sizes. Simultaneously, scatter radiation exposure was measured with EDD-30 dosimeter at a height of 160 cm from the floor, in positions of operating surgeon, assisting doctor and nurse, for two groups of typical endourological procedures. Measurements were made also with additional lead shield between the phantom and operating staff. At the operator's typical position for diagnosis and treatment of the urinary tract the lens dose rate was 0.9 mSv/h and 0.06 mSv/h without and with lead shield. At the operator's position typical for percutaneous intervention dose rates were 1.9 mSv/h and 0.02 mSv/h, respectively. Doses to other staff members will be also presented and correlation with patient doses will be analised. At typical workload, the annual eye lens dose without protective screen was estimated to be 44 mSv. With lead screen, operator lens dose can be reduced by a factor of 15 to 95 according to the procedure. Dose to assisting doctor can be similar to the operator, while the nurse exposure is 3 to 6 times less. Installation and use of lead screen and use of lead glasses were recommended to the endourology medical team.

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S4A.P2

REDUCTION OF STAFF RADIATION DOSE IN CARDIAC CATHETERIZATION LABORATORY BY PROTECTIVE MATERIAL PLACED ON THE PATIENT

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In recent years new protective shields for cardiac catheterization laboratories that complement the traditional structural, mobile and personal shields have been developed. The aim of this study is to evaluate the reduction of radiation dose received by staff using different geometric configurations of the protective shield draped over the patient. Measures of personal dose equivalent Hp(10) were performed by electronic dosemeters located at a height of 130 cm from the floor at the usual positions of the chest of cardiologist (CARD), anesthetist (ANEST) and nursing (NUR) in laboratory when access is right radial artery. A dosemeter was also located on the C-arm at axis rotation level (ARC). Standard coronary angiography was designed with right coronary projections PA, LAO 45°, RAO 30°, and left coronary projections PA, LAO 45° and caudal 20°, LAO 45° and cranial 20°, RAO 15° and caudal 20°, RAO 15° and cranial 20°. Fluoroscopy time was 2.4 min for PA projections and 3.6 min distributed among the other projections. Each acquisition consisted in approximately 60 images. The measurements were performed on a C-arm dedicated to cardiology interventions. An anthropomorphic phantom was located at treatment couch free of shield, with shield on the side of the radial approach, abdomen and both together. Any other protective material was not used. The average KAP in the four experiments was 9.008 ± 2.7% Gycm2. The average fluoroscopy time was 360 seconds ± 0.1% and the average number of images 354 ± 2.9%. Readings in μSv Hp (10) for the different configurations in CARD, ANEST, NUR and ARC positions were as follows: free of shield (31, 32, 9 and 20 μSv); lateral shield (10, 30, 6 and 20 μSv); abdominal shield (30, 34,6 and 19 μSv) and lateral+abdominal shield (7, 31, 5 and 19 μSv). Dose reduction for shield in lateral, abdominal and lateral + abdominal on the dummy in several points of interest were: CARD 68%, 3% and 77%, ANEST 6%, -6% and 3%, NUR 33%, 33% and 44% respectively. In all cases the dosimeter located in ARC no variations greater than 5% were obtained. The protection system evaluated helps in protecting the staff performing interventional cardiology procedures. Operators must assure that the protection drape is not included in the brightness automatic control area of the image detector.

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S4A.P3

EYE LENS RADIATION EXPOSURE TO ORTHOPAEDIC SURGEONS DURING A VARIETY OF PROCEDURES

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Orthopaedic surgeons commonly use x-rays as a diagnostic and visualisation tool during various procedures. Despite its widespread use during orthopaedic surgery, information about x-ray radiation is scarce. In general, orthopaedic staff are exposed to both direct and scattered radiation during procedures. Anatomical regions such as the eyes are more sensitive to radiation considering the limited use of personal protective devices in the workplace and the relatively high sensitivity of the eye lense. Over the past few decades, the number of orthopaedic surgery procedures under fluoroscopic control have increased. Reports indicate that among the procedures which require fluoroscopic monitoring, closed locked femoral nailing is responsible for the higher level of radiation dose to surgeons. The aim of the present study is to assess the radiation dose to the eye lens of orthopaedic surgeons during a variety of procedures, and to find whether optimization of the radiation protection is possible. The study was performed with C-arm fluoroscopy system OEC Fluorostar 7900, GE and mobile Biplaner 500e fluoroscopy system in orthopaedic operating theatre of Military Medical Academy in Sofia. Eye lens dose measurements were performed with EDD30 Educational Direct Dosimeter (Unforse Instruments), calibrated Hp (0.07). The dosimeter detector was secured to the operating surgeon's glasses or elsewhere near the eyes of the surgeon. Eye lens dose of orthopaedic surgeons was measured during the following procedures: fractura femoris status post repositionem sanguine cum Nail/Placae and fractura cruris status post repositionem sanguine cum Nail/Placae. Fluoroscopy time varied between 1.6 - 5 min for the first and between 0.13 – 2.88 min for the second procedure. The mean radiation doses to the eye lens of orthopaedic surgeons were 1.8 μSv during Fraktura cruris procedures performed with C-arm and 46.2 μSv during Fraktura femoris procedures and 15.6 μSv for Fraktura cruris procedures performed with Biplaner fluoroscopy.

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S5A.I1

CONE BEAM CT: TECHNOLOGY, APPLICATIONS, DOSE AND ICRP GUIDELINES

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Cone beam computed tomography (CBCT) is a form of x-ray computed tomography (CT) in which the x-rays, in the form of a divergent cone, illuminate a wide area-detector for image capture. While conventional multi-detector CT (MDCT) scanners acquire consecutive tomographic slices, in CBCT two-dimensional (2-D) projection images are acquired by an area detector and directly reconstructed into a three-dimensional (3-D) dataset. CBCT represents an emerging technology that enables high-resolution volumetric scanning of the anatomy under consideration. Just as in MDCT, use of CBCT is steadily increasing in clinical practice. Even though it is a relatively new modality, CBCT is being used for a variety of clinical applications such as dental imaging, head and neck imaging (including sinus CT), high-resolution bone imaging, and intra-operative and interventional imaging. CBCT imaging is also used in radiotherapy for pre-treatment verification of patient position and target volume localization. The purpose of this talk is to review the CBCT technology, identify radiological protection issues for patients and staff, and provide dose recommendations for all stakeholders ranging from day-to-day clinical users, auxiliary support staff, buyers, manufacturers, and policy directing committees.

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S5A.I2

CONE BEAM CT FOR DENTAL AND MAXILLOFACIAL IMAGING: DOSE MATTERS

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Cone beam CT (CBCT) was introduced into dental imaging more than fifteen years ago. It has proven to be a useful modality for imaging of the hard tissues and air cavities of the dental and ear-nose-throat areas. It is currently applied for several dental applications, such as implant planning, endodontics, orthodontics and maxillofacial surgery. The widespread use of CBCT in dentistry has lead to increasing concern regarding justification and optimization of CBCT exposures. About 50 CBCT models are currently on the market, exhibiting a wide range in selectable exposure parameters (kVp, mAs, field of view size, etc.). When used as a substitute to multi-detector CT (MDCT), CBCT can lead to significant dose reduction; however, low-dose protocols of current-generation MDCTs show that there is an overlap between CBCT and MDCT doses. More importantly, CBCT is being used as a complement or substitute for 2D imaging techniques (e.g. panoramic and cephalometric radiography). Although the 3D information provided by CBCT can often lead to improved diagnosis and treatment compared with 2D radiographs, a routine or excessive use of CBCT would lead to an exorbitant increase of the population dose. The potential use of CBCT for pediatric patients (e.g. developmental disorders, trauma, orthodontic treatment planning) further increases concern regarding its proper application. This presentation will provide an overview of justification and optimization issues in dental and maxillofacial CBCT. Radiation dose in CBCT will be briefly reviewed. Appropriate and inappropriate use of CBCT will be illustrated for various dental applications, and the European Commission's Evidence Based Guidelines prepared by the SEDENTEXCT Project Consortium will be summarized. Finally, future prospects for dental CBCT imaging will be discussed.

S5A.O1

DOSIMETRIC STUDY OF MANDIBLE EXAMINATIONS PERFORMED WITH THREE CONE BEAM COMPUTED TOMOGRAPHY SCANNERS

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Cone beam computed tomography (CBCT) examinations of the mandible are the gold standard for implant planning and are used for several other applications such as: impacted teeth; periodontal evaluation; trauma and anatomical malformations. Although doses from CBCT are lower than from helical multislice CT scanners, patient dose remains a concern in dental diagnostic imaging because the radiation field is close to relevant organs with respect to radiological protection, such as the thyroid and the salivary glands. Objective: The aim of this work is to evaluate the air kerma-area product (PKA) and the equivalent dose in the region of the eyes, salivary glands and thyroid of the patient due to mandible examinations performed with three cone-beam computed tomography scanners. Materials and methods: The measurements were performed using the following CBCT scanners: i-CAT classic, Gendex CB-500 and PreXion 3D. The first is the most frequent scanner in Brazil and the other two are relatively recent models. For the dosimetric evaluations, an anthropomorphic head phantom (model RS-250) was used to simulate an adult patient. The CBCT examinations were performed using all available protocols for mandible acquisitions for adult patients. During the phantom's exposure the air kerma-area product (PKA) was measured using a calibrated ionizing chamber (PTW Diamentor E2 PKA-meter), positioned at the end of the X ray tube of each CT scanner. The equivalent doses to the skin in the region of the eyes, thyroid, and salivary glands were estimated using thermoluminescent dosimeters (TLD-100) previously calibrated in terms of Hp(3) for the eye lens dose and Hp(0.07) for the other measurements. The dosimeters were positioned on the phantom's surface. Results: The PKA values estimated with the CBCT scanners varied from 24.3 to 138.4 mGy.cm2. The equivalent doses in the region of the eyes varied from 0.04 to 1.39 mSv; at the salivary glands, from 1.09 to 4.49 mSv; and at the thyroid, from 0.20 to 1.50 mSv. PKA and the equivalent doses showed the highest values for the PreXion scanner, due to the use of continuous exposure mode, while the other scanners use pulsed exposures which cause lower doses.

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S5A.O2

EVALUATION OF ORGAN DOSES IN ADULT AND PEDIATRIC CT EXAMINATIONS BASED ON MONTE CARLO SIMULATION AND IN-PHANTOM DOSIMETRY USING ANTHROPOMORPHIC PHANTOMS

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The increase in the frequency of CT examinations has raised concerns about the possible detriment to the health of patients. The estimation of radiation risks requires organ doses for patients in CT examinations. Monte Calro (MC) simulation is a useful tool to estimate dose distribution and assess organ doses for patients. In the MC method, X-ray beam data such as the spectrum and bow-tie filter shape of a CT scanner is required for the dose estimation. The aim of this study is to estimate the X-ray spectrum and bow-tie filter shape of a CT scanner and validate the simulated doses in adult and pediatric CT examinations by comparing with the doses evaluated by the method of in-phantom dosimetry. We estimated organ doses using ImpactMC (CT imaging GmbH, Germany) as a MC simulation tool. The X-ray spectrum and the bow-tie filter shape of a CT scanner (Aquilion 64, Toshiba Medical Systems, Japan) were estimated from aluminum attenuation data and dose profile along the fan angle direction. The dose estimation with ImpactMC also requires the computational model of phantoms. 3D voxelized data of adult and 1-year-old phantoms were derived from the acquired CT images. We measured radiation doses using photoluminescence glass dosemeters set in various organ positions within the phantoms. The dose simulations and mesurements were performed with CT scan conditions of chest, abdomen and pelvis. The simulated doses for each tissue and organ were compared with measured values point by point. Percent differences between simulated and measured doses for organs within scan range were within 17% for adult chest CT and 13% for abdomen and pelvis CT, and were within 12% for pediatric chest CT and 10% for abdomen and pelvis CT. The simulated doses for superficial organs in a CT scan with high pitch varied with different tube start angles. The maximum doses for breast were 1.4 times higher for adult chest CT and 1.6 times higher for pediatric chest CT than the minimum doses, depending on tube start angles. The X-ray beam model estimated in this study would be useful to evaluate organ doses for adult and pediatric patients in a CT examination. Percent differences between the simulated and measured doses for organs within scan range were within 10-20% for adult and pediatric CT examinations. However, the variation of the tube start angle would have the significant influences on the doses for superficial organs in a high pitch CT scan.

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S5A.O3

RADIATION DOSE TRACKING AND PROTOCOLS ADJUSTMENT. HOW WE DID IT?

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The purpose of the talk is to present the local experience in optimization the MDCT protocols based on the information retrieved from a dose tracking software. The experience of the Radiology Clinic in Tokuda Hospital Sofia is presented, based on the existing data collected through the PACS for the period 2009-2013 and analyzed by the DoseWatch software (GEHC). With the help of the dose tracking software analysis of the dose profile was made and several processes in optimizing classification of radiological procedures, archiving system, patient workflow and examination protocols have been done. Significant reduction of the dose has been achieved for two main groups of protocols – the most often used (brain, chest) and one of the highest radiation exposure – lower extremity angiography (peripheral CT angiography). In addition some further steps for patient dose reduction have been planed and an optimization in the quality control process has been achieved. Dose tracking software is of extreme help in radiology protocols optimization and standardization of the dose profile as well as in radiology department management.

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S5A.O4

CUTTING DOWN THE RADIATION DOSE ON CT UROGRAPHY – HOW WE DID IT AND WHAT RESULTS WE RECEIVED?

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Computed tomography urography (CTU) is one of the most advanced imaging modalities and became the mainstream method in uroradiology in the new century. Our goal is to present the initial experience from the diagnosis of non-malignant kidney diseases and congenital variants in the anatomy of the urinary system using low-kV protocols. The image quality and patient dose in CTU was compared when replacing the standard 120 kV protocol with two different low-kV protocols. Our study was performed with a 64- row detector CT system. Three groups of patients examined with different kV in urography phase - standard 120; 100 and 80 kV protocols were included in the study. We used three phases and late excretory one, after the introduction of contrast medium, using a single – bolus technique. Reconstructions are made on Maximum intensity projection and on Volume rendering. CTDIvol was recorded and effective dose was calculated using CT Expo 2.1. software. Phantom measurements were performed to compare with patient dosimetry data and image quality. Image noise, signal to noise ratio (SNR), contrast to noise ratio (CNR) and figure of merit (FOM) were estimated based on measurements in clinical and phantom images. Image quality in phantom showed similar SNR, CNR and FOM for 100 and 80 kV CT protocols. Clinical image quality of low-kV patient images was adequate. We observed detailed examination of urinary tract. Phantom measurements in automatic exposure control resulted in reduction of CTDIvol by 35% when changing from 120 kV to 100 kV and by 62 % when using 80 kV protocol. Higher than 47 % reduction of patient CTDIvol when using 100 kV and more than 60 % when using 80 kV was achieved. Effective dose was lowered by more than 60 % with introduction of 80 kV protocol. At the same time patient images obtained with the new low-kV protocols have maintained their diagnostic quality.

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S5A.O5

USE OF BISMUTH SHIELDING FOR PATIENT DOSE REDUCTION IN CT: A COMPARATIVE STUDY OF GEANT4 AND MCNPX

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Centro de Ciências e Tecnologias Nucleares, Instituto Superior Técnico, Universidade de Lisboa, Estrada Nacional 10 (km 139,7), 2695-066 Bobadela LRS – Portugal, Lisboa, Portugal The use of computed tomography (CT) has significantly increased in the past decades revolutionizing the diagnostic imaging in clinical routine. However, it brings very relevant concerns about radiation protection due to the much higher doses to the patient, especially after the implementation of multi-detector CT (MDCT). This new technique meant faster scans and better image quality with great cost on the dose delivered to the patient. As a consequence, problems associated with radiation exposure are an important concern and it is of paramount importance to study and develop methods to reduce the patient dose during a CT scan. According to ICRP Publication 103 the eye lens, the thyroid gland, the gonads and the breast are amongst the most radiosensitive organs in human tissue. The use of bismuth shielding to reduce the dose in radiosensitive organs during CT scans has been recently studied with the objective to attenuate the X-ray beam entering the patient and hence reduce the dose whilst not significantly disturbing the image quality necessary for diagnostic purposes. This work aims at assessing the dose reduction obtained by bismuth shields in CT exams, performing measurements and Monte Carlo (MC) simulations, in order to protect the eye lens, the thyroid and the breast. The measurements were performed using head and body PMMA phantoms and an ionization chamber in order to obtain CTDIs (Computed Tomography Dose Indices) values. In order to performed the Monte Carlo study, two different state-of-the-art MC computer codes were used: GEANT4 which was not used before to simulate CTDIs, and MCNPX which is a well-established computational tool to calculate absorbed doses in PMMA phantoms during a CT scan. After the successful validation of the MC model to simulate a CT examination, a comparative study of the results obtained using the two computer programs was undertaken and the assessment of dose reduction using different bismuth shields and scan parameters was performed. The computational results were compared with measurements. The difference between the experimental and the simulation results with GEANT4 and MCNPX were within 5%. The use of bismuth shielding shows a significant dose reduction (between 15 and 20%), depending on the bismuth shield used, making the case for their use in clinical routine a priority in terms of the radiation protection of the patient.

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S5A.O6

ABDOMINAL EXAMINATION IN KNH USING 16 MULTI SLICE CT SCAN: REVIEW OF ALARA PRACTICE IN MANAGING PATIENT DOSE

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To assess the justification of abdominal CT examinations carried out, quantify radiation dose and evaluate the optimization of scanning parameters that contribute to radiation dose determination within the ALARA principle in comparison to international standards. A retrospective study of 76 patients aged between 30 and 80 years of age referred for abdominal CT scanning at KNH, s department of diagnostic radiology during the period between April to December 2013 using the new protocol were all considered. The standard protocol has been three phase triple study for most of the abdominal examinations, but previous study during the period between July 2008 and March 2009 found the radiation doses to be higher. The purpose of this study is to review the CT protocols to reduce the patient dose without compromising the quality. The new protocol is determined by the patient's clinical history.In oncology patients on follow up treatment only a portal venous protocol was required. Dose quantification was done through estimation of effective dose, calculated from the dose length product (DLP) displayed on the console during scanning. Justifications of CT examinations were done by perusing on request forms from clinicians for the patients being scanned to establish how specific the indications were. The CT diagnostic findings were also analyzed in view of how they offered clinical solutions to the requesting clinician. Association between the specificity of the indication and the result was also studied. Optimization was studied by analyzing the matching of scan protocol (triple phase to two phase) with the clinical indication and evaluation of the operator control of scan parameters during the image acquisition process. Patient descriptors including the transverse abdominal width and scanning protol practices were also interrogated as possible contributors to this relatively high dose. Data collection was through a structured table and management was done using SPSS and MS-Excel software. 18.4% of the examination had a non specific clinical indication and 26.3% of the CT findings did not support a clinical diagnosis. The averages E was five times higher using the local protocol of three phase compared to two phase protocol, than internationally published guidelines for abdominal scanning and within epidemiological concerns.39.5% of the examinations were done with mismatched protocols. Specificity of the request and corr

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S5A.P1

CT UROGRAPHY AND CONVENTIONAL UROGRAPHY - THE CHOICE BETWEEN HIGH DIAGNOSTIC QUALITY AND LOW PATIENT DOSE

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CT urography (CTU) is increasingly becoming alternative to conventional urography. While the appropriate use of examination is important, optimization of imaging protocols can further justify the selection of CTU because of the advantage of visualization of the entire urinary tract and high diagnostic accuracy. The goal of the study is to optimize CTU protocol aimed to reduce patient dose at level of dose from conventional urography, maintaining sufficient image quality. The study was performed with a 64- row detector CT system for CTU and Process (CGR) for conventional urography. Three groups of patients examined with different kV in urography phase - standard 120; 100 and 80 kV CT protocols were included in the study. CTDIvol and DLP were recorded and effective dose was calculated using CT Expo 2.1 software. For a number of patients undergoing conventional urography Kerma Area Product (KAP) was recorded and then utilized to calculate effective dose using PCXMC 2.0 software. Phantom measurements were performed for comparison with patient dosimetry data and image quality. Image noise, signal to noise ratio (SNR), contrast to noise ratio (CNR) and figure of merit (FOM) were estimated based on measurements in CT clinical and phantom images. Phantom images demonstrated similar SNR, CNR and FOM for 100 and 80 kV CT protocols. Clinical image quality of low-kV patient images was adequate. Phantom measurements with automatic exposure control resulted in reducion of CTDIvol by 35% when changing from 120 kV to 100 kV and by 62 % when using 80 kV protocol. Similar reduction of CTDIvol was achieved for patient procedures. Effective dose was lowered by more than 60 % with introduction of 80 kV CT protocol but it is still twice higher that dose from conventional urography. Despite the achieved significant dose reduction, the use of CTU needs still to be clearly justified.

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S5A.P2

ACCEPTANCE AND VALIDATION OF FIRST DUAL HEAD MDCT IN OMAN : INITIAL EXPERIENCE

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Computed Tomography (CT) has revolutionized diagnostic imaging since its discovery in early 70's. In Oman, 50,302 CT examinations were carried out in the year 2012. The increase in CT examinations will eventually result in the increase of population dose and the consequent risk of cancer in adults and particularly in children. Here, we discuss and share our experience with the acceptance and validation of first Dual Head MDCT installed in Oman using Ministry of Health's radiation acceptance and quality assurance protocol, before handing over for routine patient care work. The parameters measured included - scatter radiation, CTDI, Noise, CT numbers and Slice thickness. Scatter radiation levels were measured using body phantom and Victoreen NERO 8000 by connecting externally a 400 cc scatter chamber to it. CTDI was estimated using 100 mm pencil CT ion chamber along with NERO 8000, PMMA head and body phantoms. Weighted CTDI (CTDIw) and normalized weighted CTDI (nCTDIw) were estimated. nCTDIw was estimated for each tube separately and in the combined dual energy mode as well. Image noise, slice thickness and CT numbers were measured with AAPM CT performance phantom (Victoreen). The normalized weighted CTDI (nCTDIw) values for head and body phantoms were measured for various kVp's and collimations for each tube separately and in dual energy mode as well which were in good agreement with manufacturer's values. The CT number insert in the phantom had Polyethylene, polystyrene, nylon, polycarbonate and acrylic with HU -92, -24, 92, 102 and 120 respectively. The measured CT values were in good agreement. The image noise was analysed by measuring the mean CT number of the ROI and standard deviation. This value also hold good for the DE MDCT. The measured slice thickness were also analysed. In this study we have tried to validate the standard QA protocol of Ministry of Health for CT scanners in this DE MDCT as well. Results showed that the measured parameters were in close agreement with the manufacturer's specs. Surveys shown that CT scanners operating at correct parameters deliver optimal radiation exposure to patients where as dose to the patients will be significantly affected if not set properly. Thus a well performed QA programme in accepting CT scanners will yield good quality scans which in turn delivers an optimal dose to the patients undergoing CT investigations.

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S5A.P3

EVALUATION THE REDUCTION AMOUNT OF ABSORBED DOSE IN WHOLE BODY CT SCAN BY USING TUNGSTEN AND LEAD SHIELDS

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CT scan application has been and is on rise. In order to do CT scan the ionized radiations are used, which are harmful for healthy cells and tissues; therefore, reduced absorbed dose are preferable. The conducted studies in this area have been accompanied with shield. The concept of shielding through different method regarding radiation dose on whole body has not been studied widely. Here by Monte Carlo simulation method and applying MCNPX code, dose absorption level on the patient‘s whole body was evaluated by applying MDCT (multi detector CT). A female human body phantom made of Cl, S, P, Mg, Na, O, N, C, H, Zn, Fe, Ca, K was designed where the absorption dose measured in specific tissues means the eyes, thyroid, breast, ovaries, uterus. The two 80keV and 120keV energy sets were applied here. The calculations were made once without shield and once with Tungsten and lead shields too. On breast, ovaries, uterus the Tungsten shield thickness was considered 4.3mm and on eyes and thyroid the thickness of 3.2mm was used. By using shields, the range of the absorbed dose level was reduced to 21-70 percent. The dose reduction statistical significance through both the shields, Tungsten and lead, is negligible. It is found that the x-ray characteristic of Tungsten in relation of lead shield with respect to the applied energy for CT imaging has lengthier interval that leads to minimized image artifacts. Furthermore the toxicity rate of Tungsten is lower than that of lead. Therefore using from Tungsten as shield is better than lead in CT imaging. Also because lower energy causes lower absorbed dose in human tissues so using lower energy in CT scan is recommended where it is possible.

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S5A.P4

THE INFLUENCE OF THE NOVEL CT RECONSTRUCTION TECHNIQUE AND ECG-GATED TECHNIQUE ON THE IMAGE QUALITY AND PATIENT DOSE

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The aim of the present study is to compare image quality and patient dose in terms of CTDIvol in cardiac computed tomography (CT) examinations, when changing from filtered back projection (FBP) to adaptive iterative dose reduction (AIDR) reconstruction techniques. Further aim is to implement prospective ECG-gating into the practice thus reducing patient dose. The study was performed with Aquilion ONE 320-row detector CT of Toshiba Medical Systems. Analysis of cardiac CT protocols was performed before and after integration of the new software. For a number of patient studies CTDIvol were recorded and entered into a database. The database included also the exposure parameters, and patient age, sex and weight. Image quality was assessed by measuring noise in phantoms, as well as at fixed anatomical structures in clinical images. Cardiac CT is routinely acquired with retrospective ECG-gating which leads to increased patient dose, since data is acquired at the entire cardiac cycle, and not all data is used for postprocessing or reconstruction. Potential approach for dose reduction is to apply prospective ECG-gating for well-selected patients. Image quality acquired by AIDR was comparable to FBP technique. The AIDR technique showed more than 50% reduction in the CTDIvol values. The subjective estimates by radiologists confirmed adequate image quality of clinical images acquired by the AIDR technique. The preliminary results indicated significant dose reduction when using prospective ECG-gating by keeping the adequate diagnostic quality of clinical images.

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S5A.P5

ESTIMATION OF BREAST DOSE AND CANCER RISK IN CHEST AND ABDOMEN CT PROCEDURES

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The use of CT in medical diagnosis delivers radiation doses to patients that are higher than those from other radiological procedures. It has been estimated that CT examinations make up approximately 11% of the number of radiologic procedures and that radiation from CT delivers approximately 70% of the medically related radiation dose. Radiation dose to the breast tissue is of critical importance, especially in girls and young women. The aims of this study were to measure patient doses during CT chest and abdomen procedures, estimate the radiation dose to the breast, and to quantify the radiation risks during the procedures. A total of 30 female patients were investigated in this study (12 chest CT procedure and 18 abdomen CT procedures). The patient's dose values were obtained from four hospitals in Khartoum. The departments were equipped with four different CT modalities. Data were collected to study the effects of patient-related parameters, exposure-related parameters. The organ dose conversion factor f (organ, z) was obtained from the NRPB datasets (NRPB-SR279) based on the Monte Carlo simulations. The mean patient dose values (DLP) were 165.9-3353.0 mGy.cm and (217.5-1790) mGy.cm for chest and abdomen procedures CT respectively. Radiation dose to the breast ranged from1.6 mSv to 32.8 mSv during the chest CT and 2.3 mSv to 18.8 mSv during the abdomen CT procedures respectively. The overall patient radiation risk estimation for fatal cancer per procedure was found to be 8.1 × 10-6. It was concluded that current clinical chest and abdomen protocols result in a very high radiation doses to the breast in the light of the current practice. A large variation of mean organ doses among hospitals was observed for similar CT examinations. These variations originated from different CT scanning protocols used in different hospitals and scanner type. Lack of trained personnel and absence of breast shielding during CT abdomen are additional source of increased dose to the patients.

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S5A.P6

DOSIMETRY METHODS FOR MULTI DETECTOR COMPUTED TOMOGRAPHY

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The aim of this study is to compare different dosimetry methods for Multi Detector Computed Tomography (MDCT) in terms of Computed Tomography Dose Index free in air (CTDIfree-in-air) and Computed Tomography Dose Index measured in phantom (CTDIphantom). The study was performed with Aquilion ONE 320-row detector CT (Toshiba), Ingenuity – 64-row detector CT (Philips) and Aquilion 64, 64-row detector CT (Toshiba). In addition to the standard dosimetry three other dosimetry methods were applied. The first method, suggested by IEC for MDCT, includes free in air measurements with a standard 100 mm CT pencil ion chamber, stepped through the X-ray beam, along the z-axis, at intervals equal to its sensitive length. Two cases were studied – with integration length of 200 mm, and with integration length of 300 mm. Phantom measurements were performed with a standard PMMA dosimetry phantom. The second approach comprises measurements with a twice longer phantom and two 100 mm chambers positioned and fixed against each other, forming a detection length of 200 mm. As a the third method, phantom measurements were performed to study the real dose profiles along z-axes using TLD. Fabricated PMMA tubes of total length of 300 mm in cylindrical shape containing LiF detectors were used. The results indicated that CTDIfree-in-air measured with an integration length of 300 mm for 160 mm wide beam is 194 % higher than the measured using the standard method. For integration length of 200 mm the differences were about 18 % for 40 mm wide beam and 14 % for 32 mm wide beam in comparison to the standard CTDI measurement. For phantom measurements, the first method, suggested by IEC indicates difference of 41 % for the beam width 160 mm, 19 % for the beam width 40 mm, and 18 % for the beam width 32 mm compared to the standard measurement method of CTDIvol. CTDI values from direct measurement in the phantom central hole with two chambers differ by 20 % from calculated values applying the IEC method. Dose profile for beam widths of 160 mm, 40 mm, 32 mm and 16 mm will be presented, and analysis and conclusions will be derived. Dosimetry results will be compared to CTDI values displayed at the CT scanner console.

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S5A.P7

CORONARY CT ANGIOGRAPHY: REDUCTION OF EFFECTIVE RADIATION DOSE USING THE PROSPECTIVE ECG-GATING

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The purpose of the study was to compare the patient radiation dose and image quality of coronary CT angiography (CTA) examinations, performed with retrospective and prospective ECG-gating. 60 CTA studies (prospective ECG-gating, n = 30; retrospective ECG-gating, n = 30) of patients with coronary artery disease were selected retrospectively from the hospital database. All examinations were performed with 64-row MDCT. Image quality of coronary arteries was evaluated using a four-point grading scale (4 - nondiagnostic images; 1 - excellent quality). Contrast level, image noise; signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) were also measured. Effective radiation doses of prospective and retrospective CTA were calculated using volume CT dose index (CTDIvol) and dose-length product (DLP) with a conversion coefficient 0,014 mSv/ mGy*cm. Receiver operator characteristic (ROC) analysis was used to determine the cut-off point of body mass index (BMI), average heart rate (HR) and HR differences for the prediction of diagnostic image quality for coronary CTA with prospective ECG-gating. Age, HR, BMI and scan parameters (tube voltage, tube current and scan range) were not statistically different between the two groups. Image quality in coronary artery branches was similar between the retrospective and prospective gating protocols (image quality scores were 1,5±0,7 vs 1,45±0,39, p=n.s.). There was no significant difference between the contrast level, image noise, SNRs in these two groups, but the CNR was higher in the group with prospective ECG-gating (8,2±3,24 vs 5,4±2.2, p=0,034). CTDIvol and DLP in the prospective ECG-gating group were 19,7±4,2 mGy and 273,9±64,9 mGy/cm, which were significantly lower (P<0.05) than those values in the retrospective ECG-gating group (38,3±7,7 mGy and 665,7±180 mGy/cm). Calculated effective dose for prospective CTA was 59% lower than that for retrospective CTA (3,8±0,9 mSv vs 9,3±2.5 mSv; P < 0,001). ROC – analysis revealed that a BMI cut-off point of 31 kg/m2 (100% sensitivity, 78 % specificity) and HR of 62 bpm (88% sensitivity, 86% specificity) were the best threshold for the prediction of diagnostic image quality. Prospective ECG-gating can substantially reduce radiation dose during coronary CTA without decrease of image quality for the patients with BMI less than 31 kg/m2 and HR less than 62 bpm.

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S5A.P8

OPTIMIZATION OF RADIATION DOSE IN CT CHEST EXAMINATION

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Computed tomography (CT) examinations can involve relatively high doses to patients. The objectives of this study were to optimize the radiation dose for patient during CT chest scan, and to estimate the lifetime attributable to risk of cancer. A total of 50 patients were studied. Control group (A) (38 patients) and optimization group (B) (12 patients). The optimization protocol was based on CT pitch increment and lowering tube current. The mean CTDIvol was 21.17 mGy and DLP was 839.0 mGy.cm for group A and CTDIvol was 8.3 mGy and DLP was 339. 7 in group (B). The overall cancer risk was estimated to be 8.0 and 3.0 cancer incidence per million for group A and B, respectively. The patient dose optimization during CT chest was investigated. Lowering tube current and pitch increment achieved a radiation dose reduction up to 60% without compromising the diagnostic findings.

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S5A.P9

BRAIN SOFT TISSUE VISUALIZATION STUDY USING LOW DOSE DUAL ENERGY CT DATA: PRELIMINARY RESULTS

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Brain CT scan is performed to inspect the structures of the brain and evaluate the presence of pathologies. However, brain CT demonstrates limitations in the ability to depict the different soft tissues of the brain (gray and white matter), the visualization of which is important for many pathologies such us Alzheimer's disease, dementia, aging disorders, low grade gliomas etc. Dual Energy Computed Tomography (DECT) scanners are available since 2006, but up to now their use is restricted in intracerebral hemorrhage differentiation, bone removal and angiography. The purpose of this study is to investigate the use of a non-linear subtraction algorithm in discrimination of brain soft tissues, while keeping radiation dose to the patient as low as possible. An in-house subtraction algorithm has been developed and tested on simulated data and applied on real low dose DECT images obtained from clinical dual source system in actual medical practice. Investigations were carried out using patient DECT brain images obtained at the University Hospital "Saint Marina" in Varna, from a dual source/dual detector SOMATOM Definition Flash (Siemens Healthcare), by applying conventional low dose medical protocol. Prior to the application of subtraction algorithm, filtering of the images is performed using a Nonlinear Anisotropic Diffusion filter. The filter is based on nonlinear evolution partial differential equations and seeks to remove the image noise while preserving details and enhancing their edges. A series of experiments were preformed, in order to determine the optimum parameters and number of iterations needed in filter's application. Combining low and high energy filtered images, was performed using an in-house developed non-linear subtraction algorithm, based on Lehman's theory proposed in 1981 along with application of various mathematical optimization solvers. In the case of healthy patient the increased contrast between brain's soft tissues that has been achieved, resulted to a noticeable differentiation of white and grey matter, while in the case of the presence of hemangiomas, differentiation of the lesions and better identification of their exact boarders was demonstrated. Application of DECT for improved imaging of brain's soft tissues, while keeping the radiation dose levels low, is feasible and further refinement of the approach, testing and evaluation, could lead to very promising results.

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S5B.I1

PATIENT DOSIMETRY IN NUCLEAR MEDICINE

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In spite of considerable progress, much remains to be done in the estimation of absorbed doses to organs and tissues in the body and in the prediction of biological effects from radiopharmaceuticals. In patients undergoing diagnostic procedures, the biokinetics of the radionuclide has to be determined for a number of representative patients. When radiopharmaceuticals are used for therapy, it is essential to determine the individual kinetics to be able to calculate the absorbed doses to critical normal organs/tissues and to the target volume(s) with high accuracy. There is still a lack of quantitative determinations of the organ/tissue contents of radionuclides and their variation by time. Planar gamma camera imaging – using the conjugate view technique - is the main method for such studies. To get acceptable statistics in SPECT-images, very long acquisition times are needed. New more sensitive SPECT cameras may help. In SPECT/CT, the CT images are used, not only for identification of anatomical details but also as a basis for attenuation correction. In a similar way as SPECT/CT, PET/CT is used for patient specific 3D image based internal dosimetry using the patient´s own anatomy and spatial distribution of activity as a function of time. In diagnostic nuclear medicine, the transition from stylized reference phantoms to voxel phantoms, representing a broad population of patients will lead to improved dose estimates. The real challenge – at least for the therapeutic situation - is to describe the individual patient by imaging (CT, MRI) and then make individual calculations. For therapy, there is an increasing interest to combine targeting substances (antibodies, peptides, etc.) with alpha particle or Auger electron emitters. It is a challenge to develop a dosimetry that predicts the biological effects of these short-range particle emitters.

S5B.I2

ISSUES IN RADIONUCLIDE THERAPY RELATED TO RELEASE OF PATIENTS

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In many countries hospitals and clinics approved to administer therapeutic quantities of a radionuclide may release a patient when the amount in the patient's body is less than a defined quantity or when the measured dose rate at 1 meter from the surface of the patient is no greater than a defined value for that radionuclide. Many countries specify very conservative quantities and dose rates to prevent members of the public from receiving more than very small radiation doses if they should come in contact with the patient. In the United States, the patient may be released if the administered activity or measured dose rate do not exceed predefined values or if patient specific dose calculations show that the maximum likely dose to an individual exposed to the patient is no greater than 5 millisieverts. The National Council on Radiation Protection has determined that with adequate instructions of the patient, no member of the public is likely to be exposed to more than 5 millisieverts of radiation by a released patient. The patient specific dose calculations include consideration of retained activity, an occupancy factor at 1 meter from the patient, effective half-life of the radionuclide, and shielding by tissue. Even though a number of authors have published radiation doses to members of the public exposed to released patients, there appear to be gaps in empirical data related to: 1) internal doses to members of the public from close physical contact with patients or radioactive contamination from bodily fluids, and 2) internal and external doses to members of the public from patients released to locations other than their primary residences (e.g., houses, apartments). This paper will discuss the data that are available, which describe internal and external doses to members of the public exposed to patients treated with therapeutic quantities of radionuclides and released from the hospital.

S5B.O1

JUSTIFICATION OF THE HYBRID NUCLEAR MEDICINE EXAMINATIONS.

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Clinic of Nuclear medicine Medical University, Sofia, Bulgaria The annual rate of Nuclear Medicine examinations significantly increases worldwide and respectively increases the medical exposure caused by them. This is partially consequence of the recently introduced SPECT/CT and PET/ CT techniques which combine functional, metabolic and morphological information and play important role in the diagnostics of many benign and malignant diseases. However, since the effective radiation dose is the sum of the dose of two components, the hybrid examinations (particularly diagnostic ones requiring high-resolution CT) result in increased patient exposure and a higher theoretical radiation induced cancer risk. Accordingly the justification for the hybrid examinations becomes mandatory. It starts with their clinical importance: their opportunity to resolve a clinical problem decisive for patients' management, continue with the choice of the appropriate diagnostic algorithm and protocol. The knowledge of the indications, contraindications and the examinations' limitations is responsibility of the nuclear medicine physician. His obligation is also the choice of the most adequate examination and the adjustment of the protocol, which can be stopped, or prolonged by the CT-component, according to the sufficiency of the obtained information. The choice between the low dose CT (LDCT) and high resolution, or contrast enhanced CT is another issue, which depends on the diagnostic yield v/s exposure. In many cases 18F- FDG (Fluoro-Deoxy-Glucose) PET/CT is more convenient for tumor diagnostic than SPECT/CT, because of its higher sensitivity (higher resolution, whole body character). However it cannot replace the sentinel lymph node mapping and biopsy - more sensitive and with less exposure (2.1 mSv v/s 12-25 mSv). When two different radiopharmaceuticals should be used for tumor characterization like 18F-FDG and 131-iodine (flip flop phenomenon) is advisable to start the diagnostics by the method with higher probability for visualization and lower exposure. For benign diseases examinations (still done mostly by SPECT/CT) a flexibility of protocols should be considered with evaluation of the adequacy of information before adding the CT component. In conclusion: the cost and the accessibility of the examinations should not be the principal considerations instead of the diagnostic value and the exposure. Flexible protocols and algorithms should be used for the hybrid nuclear medicine examinations.

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S5B.O2

PATIENT DOSES FROM PET-CT PROCEDURES

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Positron Emission Tomography (PET) was installed for first time in Bulgaria in 2011, and nowadays two hybrid PET-CT are in operation. Because of combination of two methods using ionizing radiation and high image quality requirements, PET-CT procedures are connected to high radiation doses to patients. The aim of this work is to estimate for first time in the country patient doses from PET-CT systems and to explore potential for optimization by comparison with other data. The systems in operation are GE Discovery 600 and Philips Gemini TF, both with 16-detectors row CT. Data were retrospectively collected for 58 patients examined with the first system and for 50 patients examined with the second one. Whole body examinations with radiopharmaceutical 18F-2-fluoro-2-deoxy-D-glucose (FDG) were performed on all patients. Patient effective doses from the CT component of the examination were calculated with CT Expo software and compared with doses estimated applying the NRPB conversion coefficients. Effective doses from the PET component were calculated applying the ICRP 80 conversion coefficients. For the first system, average effective doses from CT component were 7.5 mSv and 8.9 mSv, applying CT Expo and NRPB coefficient respectively, and 6 mSv from PET component. For the second system the corresponding values were 8.5 mSv, 10.3 mSv and 4.9 mSv. Our results for patient effective doses are relatively low compared to other similar surveys. Reasons for the observed differences will be analyzed and presented.

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S5B.O2

PATIENT DOSES FROM HYBRID SPECT-CT PROCEDURES

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The aim of this work is to estimate patient doses from hybrid single photon emission computed tomography (SPECT) and computed tomography (CT) procedures. The study was performed on four SPECT-CT systems: two Symbia 2T (Siemens), one Symbia T16 (Siemens) and one Discovery NM/CT670 (GE). These represent all SPECT-CT available in the country. Effective dose was estimated for about 100 patients per system. Low dose CT was performed on all patients. Eight types of examinations were considered, that represent all kinds of diagnostic procedures performed on the SPECT-CT systems. Effective doses from the SPECT component were calculated applying the ICRP 53 and ICRP 80 conversion coefficients. Computed tomography dose index (CTDI) and dose length product (DLP) were retrospectively obtained from the archive of the systems and effective doses from the CT component were calculated with CT Expo software. Parallel estimation of CT component contribution with the NRPB conversion coefficients was done where applicable. Results showed some differences between systems. Analysis of the reasons will be presented. Some suggestions for optimization are proposed and diagnostic reference levels are established.

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S5B.O3

THYROID CANCER RADIOIODINE THERAPY: HEALTH SERVICE PERFORMANCE AND RADIATION SAFETY

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The current standard treatment for differentiated thyroid carcinoma (DTC) consists of surgery followed by radioiodine I-131 therapy (RAIT), to destroy any remaining thyroid tissue or existing concurrent micro-metastatic satellites. This work investigates radiation safety and health service performance outcome indicators, such as efficiency, utilization, access and sustainability for thyroid cancer RAIT delivery in Greece, during the last decade. Method: The operation of hospitals' nuclear medicine (NM) therapy wards, where RAIT is delivered, is monitored by Greek Atomic Energy Commission (GAEC) in terms of radiation safety. Based on relevant data collected by GAEC for the period 2003-2013 (100% of total) and the population census of the Hellenic Statistical Authority (EL.STAT.) for 2011 (last available), the following key indicators are assessed: hospitals' allocation, therapy ward availability, RAIT workload per hospital, bed percent occupancy, DTC patients' waiting lists, average hospitalization time and strategic planning. The numbers of hospitals and NM therapy wards, as well as the annual frequency of RAITs, have increased by 23.1%, 57.7% and 105.8% respectively, in the last decade. DTC patients' waiting lists, possibly depending on patients' mobility, hospital's efficiency, radiation safety and treatment compensation, range from 0 to 10 months in public hospitals and are equal or less than 1 month in private hospitals. RAIT workloads appear, in general, higher in public hospitals than in private ones. In 2012, the average hospitalization time ranged from 2.2 to 3.9 days in public hospitals and from 2.3 to 3.4 days in private hospitals. Geographical inhomogeneous distribution of the existing infrastructure is observed. New NM therapy wards, in public hospitals, have been constructed and licensed a few years ago, although only some of them initiated their operation in 2013, due to human resources shortage. Thyroid cancer RAIT delivery has increased during the last years. Regular assessment of appropriate key indicators could serve as a useful tool for radiation safety monitoring and health service performance improvement, in the effort for efficiency gains.

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S5B.O4

SAFETY MANAGEMENT OF NUCLEAR MEDICINE PERSONNEL WITH VISUALIZATION OF AIR DOSE

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Many people are anxious about radiation exposure for the reason that radiation cannot be seen. With the aim of devising a way for medical personnel to perform their medical duties without worry about radiation exposure, we attempted safety management using a system that displays the air dose of radiation in real time. Measurements were made in a lung ventilation scintigraphy examination room with the use of Xe-133. An SCI-type RI detector from Hamamatsu Photonics, which displays the air dose rate in real time, was used for the measurements. These radiation measurements were continued from the start to finish of the examination. The measurements were made in two locations, on the patient inhalation tube side and on the opposite side. Measurements were made on the patient tube side in 24 tests and on the opposite side in 12 tests. The maximum air dose rate was 3.7±2.1 μSv/h on the patient tube side and 1.1±0.5 μSv/h on the opposite side. Thus, the level on the opposite side was about 1/5 that of the tube side. To accurately perform lung ventilation scintigraphy, a medical worker needs to observe the patient's breathing status up close. Because of this, some medical workers are worried about radiation exposure during tests. The simplest way to reduce exposure would be to maintain a distance from the examination tube that is the source of radiation. The measurements in this study were made to encourage medical workers' recognition of this fact. Displaying specific numbers not only serves as basic data for managing staff operations, but is also thought to reassure workers through visualization.

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S5B.O5

AN EVALUATION OF THE SHIELDING EFFECTIVENESS OF LEAD APRONS USED IN CLINICS FOR PROTECTION AGAINST IONIZING RADIATION FROM NOVEL RADIOISOTOPES

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Ionising radiation can cause irreparable damage to biological cells. It is imperative radiation workers' exposure is kept to an absolute minimum. One way to achieve this is to physically block the radiation with shielding. The purpose of this study was to evaluate the effectiveness of personal radiation shields currently worn in hospital and other diagnostic environments. The study included investigating whether the shields were providing adequate protection for the radiation worker and the effect different types of radiation may have on the shield. This research considered dose reductions provided by personal shields and if the benefits outweighed the negative aspects of wearing shielding, such as weightiness and cumbersomeness. This study was performed with four different radioisotopes; the commonly used diagnostic isotope Tc-99m, therapeutic isotope I-131, commonly used PET isotope F-18 and the novel isotope I-124. Radiation monitors and TLDs were used to measure the dose unshielded and again after the radiation had passed through the shielding. TLDs were sited on a chest/abdomen phantom and exposed to the I-124 radiation; first unshielded then varying layers of shielding were added. Tc-99m tests indicated the lead aprons are suitable to be used clinically. The I-131 test showed that no dose reduction occurred, even when tested with up to 1.25 mm Pb equivalence shielding. F-18 results showed a decrease from 0.5 mm but the reduction provided does not warrant its use clinically. I-124 testing demonstrated that dose enhancement can occur in greater shield thicknesses. The Pb aprons tested were suitable for use when dispensing and administering the radioisotope Tc-99m. The aprons however should not be worn when handling the therapeutic radioisotope I-131 as it does not provide any shielding benefits and may give the wearer a false sense of safety. Other radiation safety measures such as reducing the time near I-131 and increasing the distance between the worker and the isotope should be employed. The novel PET isotope I-124 can be adequately shielded using 0.25 mm Pb equivalent aprons but any thickness higher than this will actually increase the wearer's dose due to scatter and the bremsstrahlung phenomenon. As a result more shielding does not always equal more protection. Novel radioisotopes being used in the laboratory and clinic should be individually tested as each requires specific shielding testing.

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S5B.O6

MEASUREMENT AND ANALYSIS OF CORRECTION FACTOR RELATED TO PATIENT ATTENUATION DURING RADIOIODINE THERAPY AND POTENTIAL RADIATION PROTECTION IMPLICATION.

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Measurement and analysis of correction factor related to patient attenuation during radioiodine therapy and potential radiation protection implication. Realistic estimation of radiation dose rate levels from radioiodine therapy patients is an essential aspect of an effective operational radiation protection program. Such estimation when properly performed will reduce cost and optimize radiation protection practice. For the patient it will improve his quality of life by imposing fewer restrictions on his social activities and it will reduce his time of stay in strict isolation. It will allow a longer period of interaction with the comforters and the health care professionals. Accurate radiation exposure rate estimations will give more confidence to staff while working around the patient. For the medical institution it will provide more flexible booking schedules and reduced waiting list for the patients waiting to be admitted for treatment. It will provide the medical staff caring for the patient with plausibly more accurate risk estimate and assessment. In this work we have demonstrated quantitatively the existence of an important patient attenuation factor when comparing the dose rates from the patients to those measured in air just before administrating the dose to the patient; in other words the ration of the attenuated to the free in air dose rate. We have statistically examined the correlation between factors that may influence the patient body attenuation such as BMI, ECD and weight and the measured dose rates from the patient normalized to a unit activity. Using the data from the patients' records treated at our medical institution during the past year as a sample. Finally the results are discussed and compared with the available published data in the literature.

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S5B.P1

EVALUATION OF PATIENT DOSES IN RADIOGRAPHIC IMAGING AND SCINTIGRAPHY PROCEDURES OF THE RENAL SYSTEM

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Imaging of the renal system is performed with different techniques depending mainly on clinical symptoms and signs. Renal Scintigraphy and computed tomography urography (CTU) and Intravenous urography (IVU) provide the radiologist with useful detailed information of urinary system disorders. However, during these procedures, patients are exposure to unavoidable radiation doses. This study intended to evaluate patient radiation doses undergoing renal scintigraphy (Technetium-99m-diethylene-triamine-pentaacetate (Tc-99m-DTPA)), CT and IVU. A total of 60 patients referred to Alnelein diagnostic center (Khartoum, Sudan) with renal disturbances. The patients were divided as 20 patients for each technique. Machine used for renal scan was Orbiter 37 Gamma camera single head 37PMTs/ FOV 387mm, CT machine, Siemens-Somatom emotion and Shimadzu X ary machine with computed radiography (CR) processing unit. Patients dose were measured using the administered activity, Dose cal software, and dose length product (DLP) value for renal scan, IVU and CTU procedures, respectively. Effective doses were estimated using software from National Radiological protection Board (NRPB-SR250). Patients' effective doses during renal scan, CTU and IVU procedures were 0.78 ±0.18 mSv, 2.53± 0.94 mSv and1.81±0.20 mSv, in that order. Patients were exposed to a higher effective dose during CTU compared to other two procedures. Patient doses depend on the size of patient, the type of scanner and the imaging protocol used. Patients dosed showed wide variation for the same imaging technique, suggesting that optimization is not accomplished yet. Effective doses considered low compared with previous studies.

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S5B.P2

MEASUREMENT OF OCCUPATIONAL EXPOSURE DURING BONE SCINTIGRAPHY

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Bone scintigraphy is a frequent imaging procedures used to evaluate the skeleton using radioactive substances in worldwide. During the procedure, staffs are exposed to a significant radiation dose during patient scan. This study intended to evaluate the radiation doses received by the nuclear medicine staff during the whole body bone scan procedures. Staff doses were measured for staff using calibrated thermoluminancent dosimeters (TLDs, GR200A) at chest and hand of the three operators during 21 procedures. The mean administered radiopharmaceutical was 20 mCi of 99mTc-MDP. Anterior and posterior data acquisition achieved using MiE single head gamma camera. Quality control performed before administration of the radiopharmaceutical and doses are carefully calculated. The mean chest and hand doses for the three staff were 0.24 mGy, 0.63 mGy per procedure, respectively. The staff organ doses received by the lung, bone marrow, colon and stomach were of magnitude of 0.77 mSv, and the skin dose is equal 0.032 mSv, hence only 15.4 mSv is received by the staffs' organ what is within the acceptable 50 mSv annual organ dose limit determined by ICRP. It had been observed that, chest doses was higher than hand doses because of direct handling with the injected patient and leaning the patient during submitting to scanning procedure. Increasing of staff and co-patient awareness about radiation safety and wearing lead apron inside any controlled area is recommended to enhance radiation protection in Al-Nilein diagnostic center.

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S5B.P3

EVALUATION OF AN AUTOMATIC INFUSER TO DELIVER FDG TO PET-CT PATIENTS

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PET-CT examinations are useful diagnostic tools whose use has significantly increased in the last ten years. They offer important benefits, but also present a risk linked to the use of positron emission isotopes that must be handled by operators and delivered to patients. Automated systems may help reduce occupational exposure to radiopharmaceuticals (in particular positron emission isotopes) when manipulating and delivering them to patients. This paper presents occupational doses in operators' finger tips for two different scenarios: 1) using manual and semiautomatic methods to prepare the fluorodesoxiglucose (FDG) injections and 2) using an automated infusion device that prepares and delivers the FDG dose to the patient. The accuracy of the activity prepared by the automatic system was also verified. Materials and methods: Small size (1 x 1 x 0.2 cm3) optically stimulated luminescence dosemeters (OLSD) protected with gloves were carried at forefinger and thumb tips by operators (personnel in charge of FDG preparation) and nurses (in charge of FDG administration), during periods from three to five days. Data about the workload of each measurement with OLSD were recorded. A licensed laboratory with 137Cs energy calibrated the dosemeters. The activity prepared and reported by the automatic infuser was additionally tested with an independent dose calibrator. For comparison purposes, 12 measurements were analyzed with the manual/semiautomatic system and 18 measurements with the automatic infuser system. A reduction of 80% for nurses (during administration) and 50% for operators (during preparation) was observed in average fingertip dose. When using the automatic preparation and administration, two single cases were measured with high doses in operators as a result of an improper manipulation of the FDG vial during the dilution operation (when the FDG is received in an excessive concentration) and load into the automatic infuser. The activity prepared and reported by the automatic device differed in 2% from the reference dose calibrator. The automated infusion device prevents occupational radiation exposure and reduces the risk of contamination events, allowing significant dose reductions in fingers and hands. Nevertheless, the system in itself does not guarantee a significant exposure reduction if radiation protection rules are not followed.

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S5B.P4

ROLE OF CARDIAC ULTRAFAST CAMERAS WITH CADMIUM-ZINC TELLURIDE SOLID STATE DETECTORS AND SOFTWARE DEVELOPMENTS ON RADIATION ABSORBED DOSE REDUCTION TO THE PATIENTS

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Myocardial perfusion imaging (MPI) is one the most contributing nuclear medicine technique to the annual population dose. It has been widely used in clinical practice because of its well-documented value in the diagnosis of coronary artery disease (CAD). The new cardiac dedicated ultrafast cameras with cadmium–zinc-telluride (CZT) solid state detectors and multiple-pinhole detector design increase sensitivity 5-10 times when compared with conventional single photon emission computed tomography (SPECT). There are also significant innovations in reconstruction software which allows gaining at least a factor of 2 in sensitivity. These innovations reduce dose while maintaining image quality. The purpose of this study is to compare radiation absorbed doses to the patients examined by conventional SPECT cardiac gamma camera and cardiac dedicated ultrafast SPECT camera. MPI were taken by cardiac dedicated ultrafast camera (GE Discovery NM 530c) and GE Optima cardiac camera. Two days protocol was applied and 740 MBq (20 mCi) Tc-99m MIBI injected both for stress and rest cardiac imaging when conventional cardiac camera was used. One day protocol was applied and 185 MBq (5mCi) and 555MBq (15 mCi) Tc-99m MIBI injected for stress and rest imaging when images were taken by ultrafast cardiac camera. There was no need for rest imaging in approximately 40% of patients due to normal stress perfusion. Total injected activity was reduced by 50% (from 40mCi to 20mCi) when both stress and rest images were required and by 75% (from 20mCi to 5mCi) when only stress images were taken with ultrafast cardiac camera. In this way total effective dose to the patients were reduced from 11.69 mSv to 5.84 mSv when both stress and rest images were taken and from 5.84 mSv to 1.46 mSv when only stress images were taken by ultrafast cardiac camera. The new cardiac ultrafast cameras with CZT detectors has reduced the patient dose considerably. Using this novel cameras, MPI can be conveniently used for the detection of CAD much less increasing annual population radiation dose as had been before.

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S5B.P5

STATISTICAL STUDY OF REACTION MECHANISMS IN THE SIMULATION OF NUCLEAR PROCESSES FOR ARTIFICIAL PRODUCTION OF 103PD AND 201TL MEDICAL RADIOISOTOPES USING TALYS, EMPIRE AND LISE++ NUCLEAR REACTION AND EVAPORATION CODES

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Production of medical radioisotopes is one of the most important tasks in the field of nuclear technology. These radioactive isotopes are mainly produced in a variety of nuclear processes. In this research, excitation functions and dominant nuclear reaction mechanisms are studied to simulate the production of 103Pd and 201Tl radioisotopes in the TALYS, EMPIRE and LISE++ reaction codes. Then, parameters and different models of nuclear level density (NLD), as one of the most crucial components in statistical reaction models (equilibrium and pre-equilibrium reactions), are studied and adjusted for optimum production of desired radioactive yields.

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S5B.P6

OPTIMIZATION OF PET-CT PROTOCOL FOR A REDUCTION OF THE PATIENTS' RADIATION DOSE

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The number of performed PET/CT examinations increase, because of their importance in the diagnostics and staging of the malignant and some benign diseases. The aim of this work was to share the experience in the PET-CT center, University Hospital "Alexandrovska", Sofia, during 3 years working period, in an attempt to reduce the patients' radiation dose, keeping a high image quality. The protocol for the investigations was as followed: the patients were injected with 4,2MBq/kg 18F-FDG (the average injected activity 200-350 MBq) simultaneously with 10mg diuretic (furosemide). They were encouraged to drink plenty of water (1l) for an hour and void frequently, starting 20 minutes after injection. Whole body PET/CT investigation were performed on GE Discovery 600 with 16-detectors row CT, one hour after injection. Dose rates were measured immediately and 75 minutes after injection of 18F-FDG after finishing the investigation) in two groups of patients – the first one was with injected diuretic and the second one – without.The image quality of the hybrid images was also compared.The results showed better quality of images and a tendency of a lower dose rate for patients with diuretic application. The dose rate 75 min after injection of 18F-FDG and furosemide was average 38.7% of the dose rate immediately after injection. The dose rate 75 minutes after injection of 18F-FDG without furosemide was 47.5% of the dose rate immediately after injection.We have considered that the forced diuresis in our protocol reduced the biological half life of 18F-FDG and lowered the patients radiation dose. Additionally, the applied protocol reduced the cases with false positive results due to retained activity in the abdomen and thus higher accuracy of the diagnostic result could be achieved.

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S5B.P7

SPECT-CT IN PATIENTS WITH LYMPHOPROLIFERATIVE DISEASES

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Bone marrow involvement as well as the bone distribution is a characteristic and usual future of myeloma. Standard diagnostic imaging methods, such as radiography and bone scan, have certain limitations for the early evaluation of bone marrow lesions in multiple myeloma. In patients (pts) with malignant lymphomas exact diagnostic and staging of all affected lymph node groups from both sides of the diaphragm and extranodal tissue involvement are important for the treatment planning and disease prognosis. Clinical usefulness of radionuclide imaging with 99mTc-MIBI/TF and 99mTc-MDP is well known. SPECT-CT is a new qualitative approach in pre-treatment staging and post-treatment restaging of Hodgkin's disease, Non-Hodgkin's lymphomas and myeloma multiplex. The purpose of this work was to assess the role of SPECT-CT for imaging of disease extension in pts with lymphoproliferative disorders. SPECT-CT studies with 99mTc-MIBI/TF and 99mTc-MDP were performed in 57 pts (25 with myeloma and 32 with HD and Non-HL). SPECT-CT camera Symbia T2, Siemens was used with Low-dose CT: 130 KeV, 30 mA, 3-5 mm slide thickness. Topographic localization and morphological substratum of "hot" abnormal foci were evaluated in all pts. Bone marrow infiltration and bone secondary destruction were scanned in 15 pts before treatment and in 7 pts after treatment with myeloma. SPECT-CT images increased sensitivity and specificity of scintigraphic studies in detection of small bone and bone marrow lesions localized in complex cranial osseus structures and axial skeleton in this group of pts. Axillary, cervical, mediastinal, abdominal and iliac lymph nodes were scanned in 24 pts with HD and Non-HL before treatment showing exact disease extension. Extranodal involvement of lung and axial skeleton were imaged in 5 of these pts. Post-treatment follow-up was performed in 8 pts: 2 were with complete treatment response, 2 – with partial response and 4 – with disease relapse. SPECT-CT was very useful for differential diagnosis of pathological from physiological and benign "hot" foci especially of these with small size localized below the diaphragm. SPECT-CT imaging has clinical role for: 1.Pre-treatment correct N-staging and M-staging of pts with lymphoproliferative disorders. 2.Monitoring of treatment response. 3.In order to determinate disease recurrence in cases with abnormal clinical and laboratory indices. 4.Precise topography of metastatic foci in patients. 5.Differential diagnosis of proliferative tumoural tissue from fibrosis, benign lesions and physiological uptake

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RPM 2014

SCIENTIFIC SESSION 6

CHILDREN AND PREGNANT PATIENTS


INTERNATIONAL CONFERENCE
ON RADIATION PROTECTION IN MEDICINE
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S6.I1

TITLE: JUSTIFICATION AND OPTIMIZATION: WHAT REALLY NEEDS TO HAPPEN IN RADIATION PROTECTION FOR CHILDREN

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According to the International Commission on Radiological Protection, there are three fundamental principles of radiological protection. They are justification, optimization and the application of dose limits. These principles take on greater significance when talking about children, who as a population in general more sensitive to the potential effects of ionizing radiation compared to adults, have a longer life expectancy and at identical settings absorb higher organ doses compared to adults. This talk will discuss strategies to justify pediatric imaging exams including evidence based referral guidelines and protocols and the use of clinical audit to justify imaging by the referring clinician and the radiologist. The talk will also discuss Image Quality and how the dose to the patient should be kept as low as reasonably achievable, but not so low as to compromise the quality of the exam. Other approaches to optimization such as the need for specialized training in pediatric imaging, optimization of equipment and a team approach will be explored.

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S6.I2

PROTECTING THE UTERUS DURING IMAGING AT PREGNANCY

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Based on the existing evidence base of deterministic and stochastic risks of ionizing radiation during pregnancy, the principles of radiation protection of pregnant patients will be discussed. Dose to the uterus is the most important parameter, determining both justification and optimization, and imaging examinations are classified according to their direct or scattered radiation dose to the uterus. The phase of pregnancy is the other critical parameter, both due to the varying sensitivity of the embryo/foetus and the changing position of the uterus within the pelvis and abdomen; weeks 3 to 15 after conception are the most sensitive period for deterministic effects, above all malformations, an IQ deficit or mental retardation. Planning and timing imaging examinations in women in the fertile age without known pregnancy will be considered first. Answering different frequent imaging indications during proven pregnancy will then be discussed, such as the suspicion of pulmonary embolism, of appendicitis, of urinary stones or of abdominopelvic trauma. Furthermore, the approach to occupational exposure of pregnant women will be suggested.

S6.O1

ADVANCED PAEDIATRIC IMAGING: A VIEW OF THE PAST TEN YEARS

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Recent trends in paediatric imaging involving radiation have been examined in Australia and the US. Such literature in Europe is sparse and out-dated. This research investigated; 1) population-based trends in the use of advanced medical Imaging in children from 2003-2012; 2) their use across age groups and gender; and 3) the most commonly performed procedures within each specialist modality. A retrospective cohort analysis study was carried out within each paediatric hospital in Ireland (N=3). All Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound (US) and Nuclear Medicine (NM) examinations from 2003-2012 were obtained from the Radiology Information Systems (RIS) within each hospital. The retrieved data included the number and type of examinations performed per annum in each modality and the number of patients. Age and gender data was included. The rates of exams per patient were calculated for each age group. 224,173 imaging procedures were carried out on 84,511 patients, 68% of which were ultrasound, 15% MRI, 11% CT and 6% NM procedures. While the use of each modality increased between 2003- 2012, MRI (+280%) and CT (+80%) saw the largest increases, followed by US (+70%) and NM (+10%). The number of CT and MRI scanners across hospitals both increased from two to three scanners in 2007. Advanced imaging was commonly performed in young children; approximately half of all exams were conducted on children aged 0-3 years. No significant difference in the rate of exams per patient between age categories was found (p=0.873). The ratio of male to female patients was 50:50. Regions most frequently imaged included the abdomen and pelvis (64% and 24% of ultrasound scans), head and spine (57% and 13% of MRI), head and chest (49% and 15% of CT) and renal and bone scans (69% and 21% of NM). The use of MRI, CT and US in the paediatric population has risen substantially over the past ten years. Most advanced imaging examinations were performed on children aged 0-3years.

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S6.O2

CLINICAL INDICATIONS AND DOSIMETRY IN PEDIATRIC CT EXAMINATIONS: A BELGIAN LEUVEN EXPERIENCE

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The purpose of this retrospective study was to determine the clinical CT indications for pediatric CT at our institution and the typical DLPs for each indications and/or exam. From July 1st, 2010 until Dec 31st 2010, 680 pediatric patients (1 day old till the age of 19 years) underwent CT examinations on one of five CT scanners in the radiology department. Following information was retrieved from the database: (1) patient related data (age, number of CT exams, etc.) ; (2) the clinical indication for the CT scan and scanned anatomical region; (3) exposure related data (CTDIvol, dose length product (DLP) and number of scans per single examination). Anatomical regions were differentiated: head, neck, chest, abdomen, skeletal and combination scans (head+chest+abdomen). Indications were gouped in 11 categories: trauma, infection and inflammation, headache and shunt/drainage problems, musculoskeletal pathology, epilepsy, interstitial lung diseases including lung embolism, oncology, middle-ear pathology, congenital heart and developmental anomalies, pre- or postoperative setting, miscellaneous. (1) 842 CT-examinations (386 for girls, 456 for boys) for the pediatric population in this six months period were analyzed. The mean number of examinations per patient was 1.24 (range 1-8, 8 occurred in 2 cases). In 11% (96) of the children more than 1 CT scan was performed in this time frame. (2) The two most frequent clinical indications were trauma (> 18%) and infection (> 17%).Moderately frequent were the indications headache and musculoskeletal (13%), oncological pathology (12%). All other categories account for 5% or less. The majority (51%, 431 scans) were CT head exams, followed by chest (18%, 150 scans), skeletal (17%, 142 scans), abdomen (7%, 61 scans), chest--abdomen (4%, 33 scans) and neck 3 (%, 25 scans). (3) The highest mean DLP was found for the combination scans head+chest+abdomen, with an average DLP value of 875 mGycm (range 268 – 1621 mGycm). The highest mean DLP was for oncological pathology (540 mGycm, range 50 – 2037 mGy cm). The absolute maximal DLP was registered for a chest CT, with a DLP of 3781 mGy cm, while the absolute minimum DLP was noted for a CT examination of the sinus (27 mGy cm). There is a wide variety of clinical indications of which trauma and infection are the most frequent. The availability of all dose related data allows stratification of future optimization strategies.

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S6.O3

CHALLENGES OF IMPLEMENTING TUBE CURRENT MODULATION DUE TO BODY SIZE VARIATIONS IN PEDIATRIC CT IMAGING

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To investigate the complex relationship of noise index, image noise, radiation dose and phantom size from using tube current modulation in pediatric CT imaging. Six tissue equivalent abdominal CT dose phantoms (CIRS 007TE) were scanned using a GE HD750 scanner. Four of them are in a pediatric phantom set including: Newborn, 1-year-old, 5-year-old, 10-year-old, and 15-year-old. This set was first scanned at 80kV; followed by scanning the 5, 10 and 15 year-old phantoms at 100 kV. To simulate large size pediatric patients, two phantoms from the adult size group: the Small-Adult and the Medium Adult phantoms, were scanned at 120kV. Clinical size based abdominal CT scan protocols were used in image acquisitions: 0.8s rotation time, 40mm beam width, 0.984 pitch, 2.5 mm image thickness. With Auto-mA and Smart-mA enabled, Noise Index (NI) was varied resulting in various levels of image quality and radiation doses. Acquired images were reconstructed using Standard algorithm. For each phantom size and NI combination, ROI measurements in 10 consecutive images were performed. The relationship of average noise versus NI, dose vs NI, KV effects, and bowtie filter effects were analyzed for each phantom size. For each phantom size and at each kV condition, noise increased linearly as NI value increased. However, using the same NI produced different image noises when scanning different phantom sizes. At 80kV, for the newborn, 1 year-old, 5 year-old, 10 year-old group, the measured noise values were substantially different each other. As observed at 80kV, when 4 pediatric size phantoms were scanned using the same NI value, the higher the noise the larger the phantom size. If the same noise level is to be achieved, e.g. 20HU, the NI of 16, 17, 19, and 23 could be used for scanning phantoms of 10 year-old, 5 year-old, 1 year-old, and newborn, respectively. Additionally, in general, when different sizes of phantoms were scanned at the same kV, the noise is lower in images of smaller size phantom. In term of radiation dose, in general, when NI is constant for scanning the same phantom, the higher the KV, the lower the noise. There are limitations in obtaining constant noise level across phantoms of different size when using the same NI, especially at 80kV station. An appropriate NI and kV require to be carefully selected based on patient size for achieving optimal image quality and patient radiation dose reduction.

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S6.O4

COMPUTED TOMOGRAPHY IN PEDIATRICS: BE CAREFUL WHEN OPTIMIZING PROTOCOLS!

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Radiation protection of pediatric patients undergoing medical procedures involving ionizing radiation requires special attention, as children are more sensitive to radiation than adults. Many investigations show that the number of Computed Tomography (CT) scans in children is rapidly increasing. The objective of this work is to assess dose level in large dedicated pediatric hospital in Serbia, to investigate the possibilities for optimization of protocols and impact of dose reduction actions. Data were collected in terms of CTDIvol and DLP values for head, chest and abdomen examinations. Patients were divided into four groups according to the patient's age (0-12 months, 1-5 years, 5-10 years, 10-15 years). Dose values in pediatrics' CT after first data collection in Serbia were similar to the results of other national surveys. For head exam CTDIvol values were 27, 44, 50 and 68 mGy depending on age group. For chest and abdomen values were 4, 4, 5 and 6 mGy and 13, 6, 5 and 5 mGy, respectively. However, widely spread values indicated possibilities for dose reduction. Thus, new protocols were created. The optimization of protocol was done by manufacturers' engineers, without medical physics support, as there are no medical physicists in diagnostic radiology departments in Serbia. The results of such activity led to a higher exposure level for children of all ages. Depending on children age and body part examined CTDIvol values were from 2 to 3 times higher than before protocols were optimized. The reason for such higher doses lies in the fact that protocols were changed by decreasing the kV values while mAs values were significantly increased. Dose indicators for child under the age of 1 year in head exam are now higher than internationally set Diagnostic Reference Levels for adults, 80 mGy for CTDIvol and 1121 mGy•cm for DLP. Hospital was informed about this and new protocol optimization is going to be performed. However, this time engineer will be working together with medical physicist from external technical service. Understanding the particular CT units being used and implementation of appropriate dose reduction methods is an important part of the optimization strategy in CT. This case where doses became higher after optimization can be used as a good example on how careful one should be when optimizing CT protocols for children.

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S6.O5

PEDIATRIC CT PROTOCOLS OPTIMIZATION: A DESIGN OF EXPERIMENTS TO SUPPORT THE MODELING AND OPTIMIZATION PROCESS

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In the last decade, several studies have emphasized about the need to understand and optimize the Computed Tomography (CT) procedures (protocols) in order to decrease the radiation dose applied to pediatric patients. To evaluate the influence of the technical parameters on the radiation dose and the image quality, a statistical model has been developed using the Design of Experiments (DOE) method that has been succefully used in various fields (industry, biology, finance) applied to CT procedures for the abdomen of four different pediatric body sizes. This project has been entirely carried out with non-human subjects. A DOE model was developed using Microsoft Excel. DOE was chosen in order to avoid the complexity due to all the possible combinations of CT protocol parameters to get the best balance between image quality and dose. This method allows us to exclude non-relevant examinations by minimizing their number and focusing on the interaction between the CT parameters. The measurement of image quality criteria has been realized using a CATPHAN 500 phantom with the CTP 515 module (for Low Contrast Detectability). To reproduce the size of four pediatric bodies, a conversion factor has been applied to the collected data. The images were analyzed using the Image J software framework and all values of interest were automatically extracted in a table format for further analyzes. A total of 144 examinations were included in the study: 72 examinations were realized on the phantom and 72 examinations were simulated for different body sizes. A list of the most influencing parameters and the relations between them has been derived. The tube current, tube voltage and the type of reconstruction (iterative and FBP) were the most influencing CT protocol parameters with the regard to image quality and dose value. A predictive model for understanding the CT behavior and for setting up an optimization process has been realized. An innovative approach using the DOE method has been applied to pediatric CT protocols for evaluating the influence of different CT parameters on the image quality and dose. The results of this study will be used in a second study focused on the optimization process.

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S6.O6

EFFECTIVENESS OF THE CTDIVOL METHOD IN PAEDIATRIC CT EXPOSURE: MONTE CARLO AND PHANTOM MEASUREMENTS STUDY

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Computed Tomography (CT) is one of the most used techniques in medical diagnosis. Over the last two decades, CT has become responsible for the significant increase of the exposure of patients to ionizing radiation, as doses received by the patients during CT exams are much higher than those received in conventional radiography examinations. This work concentrates on the paediatric CT exposures, since newborn, babies, children and adolescents exhibit higher radiosensitivity than adults. The patient doses are estimated by the majority of manufactures using the CTDI body phantom (32 cm) as a reference to calculate Computed Tomography Dose Index Volume (CTDIvol) values. This study aims at improving the knowledge about the radiation exposure to children and to better assess the accuracy of theCTDIvol method during clinical dose estimations. To achieve this goal, measurements were performed at two different CT scanners in two Portuguese Hospitals, using three CTDI phantoms (10, 16 and 32cm in diameter) and a standard pencil ionization chamber (100 mm long). The influence of parameters such as kV, mA or collimation of different scanning protocols was investigated. In order to assess organ doses and more complex scenarios, Monte Carlo (MC) simulations, using the state-of-the-art MCNPX v2.7.0., were executed with paediatric voxel phantoms of different ages. The effectiveness of the CTDIvol method for patient dose estimation was then investigated through a sensitive study, taking into account the doses obtained by three methods: CTDIvol measured, CTDIvol values displayed in the CT equipments and the recent proposed method Size-Specific Dose Estimate (SSDE). The use of an appropriate phantom, taking into account the patient size, could be more appropriate to evaluate doses in paediatric patients than the standard CTDI phantoms, which can underestimate the doses.

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S6.O7

PEDIATRIC PATIENT DOSES IN INTERVENTIONAL CARDIOLOGY PROCEDURES

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The purposes of this paper were to estimate the dose received by pediatric patients who underwent cardiac interventional procedures and to correlate the maximum entrance surface air kerma (Ke,max), estimated with radiochromic films, with the cumulative air kerma values displayed at the end of procedures. This study was performed in children up to 6 years. The radiation dose from cardiac diagnostic and therapeutic is particularly relevant when treating children because of their greater radiosensitivity compared with adults. The study was performed in two hospitals, one located in Recife, capital of the state of Pernambuco, located in the Northeast of Brazil and the another in an hospital located in São Paulo, capital of the state São Paulo, located in the Southeast of Brazil. The x-ray imaging systems used in this study were Phillips Allura 12 model with image intensifier system and a Phillips Allura FD10 detector system. To estimate the Ke,max on the patient's skin radiochromic films (Gafchromic XR-RV2) were used. These values were estimated from the maximum optical density values measured on film using a calibration curve performed for each lot of film used. Procedures of 18 patients, between 0 and 6 years, undergoing complex therapeutic and diagnostic cardiac examinations were evaluated. Radiation parameters such as tube potential, tube current, pulse width, fluoroscopy time were collected during each procedure. The total number of runs and images per run as well as the cumulative air kerma displayed were registered. The entrance reference air-kerma (Ka,r) values displayed by the Allura FD10 system were also documented. The results showed cumulative air kerma values ranging from 78.3 mGy to 500.0 mGy, with a mean value of 486.56 mGy. The resulting Ke,max values ranged from 20.0 to 461.8 mGy, with a mean value of 489.3 mGy. The Ke,max values were correlated with the displayed cumulative air kerma values. The correlation factor R^2 was 0.78, meaning that the value displayed in the equipment's console can be useful for monitoring the skin absorbed dose throughout the procedure. The routine fluoroscopy time records is not able by itself alert the physician about the risk of dose exceeding the threshold doses of adverse reactions, which can vary from an early erythema to serious harmful skin damage.

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S6.O8

NUCLEAR MEDICINE EXAMINATIONS OF CHILDREN IN RUSSIA

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Examinations of children form a small part of nuclear medicine (NM) procedures. In Russia during the last decades there was no information available about the structure of radionuclide diagnostic procedures among pediatric patients and their doses. This study aimed to analyze the state of the nuclear medicine examinations in pediatric patients in order to reveal the type of the used radiopharmaceuticals, the administered activities, and the resulting effective doses. Data on 1876 children at the age from a few months to 17 years old were collected in 7 hospitals in 2011 by analyzing the performed examinations and radiology' questioning records. All the patients were divided in four age groups: 0-2, 3-7, 8-12 and 13-17 years, where the number of patients in the each group was 261, 491, 501, and 616 persons respectively. About a half of all the radionuclide examinations in each age group is formed by the renal pathology diagnostics. The share of bone, lungs, heart examinations increase with the age, others remain more or less the same or some of them decrease with the age (whole-body, liver examinations). The administered activity for children was 2-10 times lower than that for adult patients. The effective doses in pediatric patients were at the same level as the doses of adults or higher. Children get especially high doses due to the PET-examinations with 18F-FDG, their doses are 2-3 times higher than the ones of the adults during the same diagnostic procedures. The average effective doses in children varied in the reviewed NM departments for the kidney examination within 0.1-2 mSv, for whole-body examinations – 2-3 mSv, for bones – 1-6 mSv, heart – 3-8 mSv,, lungs – 0.5-3 mSv, liver – 1-4 mSv. The doses due to PET examinations were: for brain examination – 3-8 mSv, for whole-body – 6-10 mSv. The individual doses could be up to 2-3 times higher than the mean values. The doses approximately doubled when SPECT/CT or PET/CT were used for diagnostics. Considering high radiosensitivity of children, these doses could increase a risk of late radiation effects, especially if the examinations have to be repeated. The referring physicians and radiologists should be properly informed about inferred doses and associated radiation risks of pediatric patients in order to account for the risks in justification of nuclear examinations.

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S6.O9

REDUCTION OF PATIENTS EXPOSURE DOSE IN THE CHEST RADIOGRAPHY WITH THE IMPROVED GADOLINIUM X-RAY SCREENS COMPARED TO GADOLINIUM AND CESIUM IODIDE

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The improved gadolinium (Gd DRZ) screens provide a strong possibility to reduce exposure dose delivered to patient during the radiographic diagnostics of lung cancer and tuberculosis. The disadvantage of cesium-iodide (CsI) screens is expensiveness which is actual problem due to numerous chest screen procedures in Ukraine required to be performed. The aim of the study was to find an optimal solution for patient exposure dose reduction using different X-ray absorbing screens and image post processing. Radiographic X-ray chest screening system included photons generator, digital receiver Iona–R4000, and ionizing chamber. Image conversion effectiveness criteria was estimated due to the contrast of test-object image. Focus-to-source distance was 125 cm. In the experiments three types of X-ray absorbing screens: Gd2SO2, Gd DRZ, and CsI were used. The digital X-ray image processing was performed with ContextVision CVIE-teleoptic-XR2-ADI software (based on the principle of non-linear signal filtering). The patient chest was simulated with water chest phantom. CsI screen demonstrated the higher absorption factor compared to Gd DRZ and Gd2SO2. But Gd DRZ screens allow proposing of reasonable balance between exposure dose and price of the screens. During the experiments the exposure dose delivered to the standard patient (water chest phantom 9 cm thickness) under the condition of Gd DRZ screen application was 33.0 mR (compared to 27.0 mR obtained with CsI and 45.0 mR with Gd2SO2). These doses were required to obtain images with visual contrast of 1.8%. The next image software post processing improved image contrast up to visual threshold of 5.0%. The optimal solution for reduction of exposure dose delivered to the patients (approx. in 1.5 times) under the conditions of mass screening can be provided with application of improved Gd DRZ screens and image post processing.

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S6.P1

EVALUATION OF THE KAP IN PEDIATRIC PATIENTS SUBMITTED TO FLUOROSCOPY UPPER GI SERIES IN A CHILDREN'S HOSPITAL IN CURITIBA-BRAZIL

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Radiological procedures in pediatric patients bring a greater concern because children are more susceptible to the deleterious effects. They have a higher life expectancy and are also more radiosensitive. In recent studies fluoroscopic procedures (especially the interventional and the upper GI series) provided lower doses only when compared to CT scans. Other studies showed that the mean kerma-area product (KAP) delivered to 0-1 year old, 1-7 years old and >8 years old children are, respectively, 6.4 cGy.cm2, 9.5 cGy.cm2 and 24.7 cGy. cm2. Based on those data, the aims of the current study are: to analyze the procedure of fluoroscopy upper GI series (performed in a large children's hospital in Curitiba-Brazil), collect the KAP from the pediatric patients and verify the application of optimization concepts. A form was filled with information about the anthropometric characteristics of the patients (sex, age, weight, height and thickness of the upper-chest region) and technical data about the exam (cine kVp and mAs, fluoroscopy kVp and mAs, field size and focus-detector distance). Next, the KAP was determined using 8 pairs of thermoluminescent dosimeters (TLDs) LiF:Mg,Ti positioned in the upper-chest region. The anatomy thickness of the patient, as well as the focus-detector distance and the field size on the examination table, were verified for subsequent calculation of the field area on the patient. The KAP and its mean value in the upper-chest area were obtained multiplying the field area and the doses. The results from the data collected from the patients showed a discrepancy in the kVp range when compared to the European Commission (EC) recommendations. It was noticed that the mean values of kVp varied from 59.3 (0-1 year old) to 66.3 (>8 years old). However, the EC recommends a kVp range from 60 to 90, according to the patient age. In the 0-1 year old children the mean value of KAP in the upper-chest region was 13 cGy.cm2; in the 1-7 years old children was 205.1 cGy.cm2 and in the >8 years old children was 644.9 cGy.cm2. The values are higher than the literature data. Comparing the obtained data with other studies it can be inferred that it is important to implement a control quality program, so that lower KAP values in the skin of pediatric patients can be ensured. Work supported by CNPq, CAPES and Fundação Araucária.

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S6.P2

BEST SINGLE SLICE LOCATION TO MEASURE VISCERAL ADIPOSE TISSUE IN CHILDREN

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Visceral adipose tissue (VAT) is a significant risk factor in obesity-related metabolic diseases. While the optimal CT single slice location for measuring VAT has been widely investigated in adults, it has yet to be investigated in children. This study investigates 1) the optimal single CT slice location for predicting total abdominal VAT volume in paediatrics and 2) the relations between anthropometric measurements, gender, age and VAT volume. With ethical permission, 112 abdomen CT scans were retrieved from the PACS systems of paediatric hospitals in Ireland (N= 3), via a random stratified sampling, according to age and gender. VAT area was measured at each intervertebral level between T12 and S1 using Image J analysis software by setting threshold values of -190 to -30 HU and manually segmenting VAT. Abdominal VAT volume was then derived from these measurements using an established formula. Waist circumference (WC) and sagittal diameter (SD) were measured at L3-L4 and L4-L5 slices, respectively. Single-slice VAT measurements were correlated with total VAT volume for each slice to identify the optimal slice location for VAT measurements. Regression analysis was used to evaluate WC, SD, age and gender as VAT volume predictors. Preliminary results have shown that VAT area measured at L4-L5 (r=0.907) was best correlated to abdominal VAT volume in children (male and female combined). While L4-L5 correlated best to overall VAT volume in males (r=0.919), L2-L3 VAT measurements were best in females (r=0.951). Regression between WC, SD, age, gender and VAT volume showed that waist circumference was most predictive of VAT volume. (Beta=1.076, p=0.001). Mean abdominal VAT volume was lower in males (2,443.7⟦cm⟧^3) than in females (3,490.5⟦cm⟧^3) although this was not significant (p=0.237). Mean abdominal VAT volumes in females were; 975.4⟦cm⟧^3 (0-5 years); 729.2⟦cm⟧^3 (5-10 years); 4,905.7⟦cm⟧^3(10-15 years) and in males; 1,029.8⟦cm⟧^3 (0-5 years); 2,240.5⟦cm⟧^3 (5-10 years); 3,252.6⟦cm⟧^3 (10-15 years). The optimal CT slice location for VAT measurements was L4-L5 in male and L2-L3 in female children.

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S6.P3

OPTIMISATION OF CHEST X-RAY EXAMINATIONS OF PAEDIATRIC PATIENTS

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The purpose of this work is to present the algorithm used to optimise paediatric radiological practice and to reduce patient doses in a paediatric hospital, at assuring sufficient image quality. Dose audit was performed first, with recording data for 109 paediatric patients using a questionnaire including patient's age, height, weight, gender, exposure parameters, radiographic technique and displayed KAP (air kerma-area product) values. Practice of two radiographers performing paediatric chest X-ray examinations with the same x-ray system was assessed and compared. Data were analysed in four age groups: 1-12 months; 1-4, 5-9 and 10-15 years. Entrance surface air kerma (ESAK) was calculated from the KAP and field size measurements to allow comparison with available diagnostic reference levels (DRL). Effective dose and organ doses were calculated using the software PCXMC. Image quality of chest AP/PA projections for each patient was evaluated by clinical staff using image quality criteria established in the European Guidelines EUR 16261. Differences in the radiographic practice of different radiographers was assessed. Exposure parameters from first stage were selected as baseline for the next steps of improvement of the radiographic technique. Then, kVp, exposure time and mAs were carefully adapted to patient size using point system and based on available guidelines of quality criteria for diagnostic radiography of children. Image quality was evaluated by clinical staff. Five different age and weight based protocols with optimized exposure parameters and radiography technique were suggested. The optimized protocols lead to decrease in the ESAK and the effective dose values in a factor of between 1.5 and over 6 for different age groups. The ESAK values for the optimised protocols of all age groups were lower than the DRL proposed by EUR 16261.The average effective dose was: 0.01 mSv (1-12 months); 0.01 mSv (1-4 years); 0.011 mSv (5-9 years) and 0.017 mSv (10-15 years). The optimisation of clinical protocols for paediatric patients should include the following steps: recording and analyzing the X-ray technique (positioning,exposure parameters, immobilization devices, lead shielding, etc.); preparation of optimisation algorithm based on the literature and the "good practice"; development and implementation of protocols for X-ray examinations according to age and body size of the patient; evaluation of image quality; measurement and evaluation of patient dose.

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S6.P4

AN OVERVIEW OF THE PRACTICE IN PAEDIATRIC COMPUTED TOMOGRAPHY

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A study was carried out in 2013 at the main hospitals in the Ministry of Health (MOH) to examine the overall paediatric computed tomography (CT) practice in Malaysia. Survey forms drafted by a committee comprising senior radiologists, medical physicists and radiographers were sent to the MOH hospitals. A total of twenty CT equipment of various brands ranging from single slice to 64 slices were surveyed. The main aim was to check the availability of CT paediatric protocols and whether they were utilized by the staff manning the CT equipment. The presence or absence of the Computed Tomography Dose Index (CTDI) display on the console including the type of CTDI displayed was also recorded. Besides this, the type of mA mode, the iterative reconstruction practised and contrast media usage were also noted. The survey showed that the radiographers at all the hospitals used dedicated protocols provided by the manufacturer of the CT equipment to ensure that child-size exposure factors were used for all the paediatric examinations. This was as a result of the increased awareness of the radiographers due to the IAEA RAS 9055 project on 'Patient dose management in CT with special emphasis on paediatric patients' which was initiated in 2010 and carried on till 2012. The need to optimise radiation dose to children undergoing CT protocols is given maximum consideration by the radiographer. In addition, the radiologist always conferred with the referring doctor on the absolute necessity of the paediatric CT examination and where possible other alternative modalities were considered. The medical physicist at the radiology department ensured the verification of the doses displayed on the console. This survey will be extended to include other hospitals in both the government and private sector. The doses will also be recorded for each CT examination as part of the total quality management system. This will be part of an on-going exercise to ensure the radiation dose used to obtain quality images is constantly optimised.

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S6.P5

RADIATION EXPOSURE DURING X-RAY EXAMINATIONS IN A LARGE DEDICATED PAEDIATRIC HOSPITAL IN SERBIA

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Children are specific group of patients in diagnostic radiology due to their higher radiosensitivity. There are fewer radiation dose reports for children compared to adults and lack of such report in Serbia. Objective of this work is to evaluate radiation exposure from x-ray examinations in a large paediatric hospital in Serbia, including radiographic, fluoroscopic and computed tomography (CT) examinations in four age groups: 0-1, 1-5, 5-10 and 10-15 years. Entrance surface air kerma (ESAK) was assessed for the following radiographies: chest (AP, PA, LAT), spine (AP, LAT), pelvis (AP), urinary tract (AP, PA) and skull (AP, PA, LAT). Kerma-area product (KAP) was measured for the fluoroscopy examinations barium swallow, barium meal, barium enema and micturating cystography (MCU). Dose in CT was assessed in terms of CT dose index (CTDIvol) and dose-length product (DLP) for examinations of head, chest and abdomen. In chest PA examination, mean dose in four age groups was: 3.6, 4.9, 8.0 and 10 μGy, respectively . For chest PA, assessed ESAK was 7.8 μGy for children of age 5-10 and 16 μGy for children of age 10-15. In LAT projection dose was 6.8, 58 and 76 μGy for age groups of 1-5, 5-10 and 10-15. Mean ESAK for other examination was: 23, 61, 26 and 134 μGy (spine AP), 23, 5, 11 and 267 μGy (spine LAT), 37, 37, 27 and 67 μGy (pelvis) and 9.3, 34 and 157 μGy (skull AP for age 0-1, 1-5 and 5-10), 51 and 60 μGy (skull PA for age 5-10 and 10-15), 7.8, 17 and 70 μGy (skull LAT for ages of 0-1, 1-5 and 10-15), 15, 24, 21 and 24 μGy (urography AP) and 14, 27, 18 and 25 μGy (urography PA). Doses in barium swallow in two younger age groups were 25 and 37 mGycm2, while KAP values in barium meal and barium enema in four age groups were 6,39,128 and 144 mGycm2 (meal) and 8.6, 42, 190 and 203 mGycm2 (enema). In MCU, dose levels were 45, 50 and 50 for age groups of 0-1, 105 and 5-10 years, respectively. Assessed mean CTDIvol for head examination was 15,19,21 and 23 mGy in four age groups. Corresponding DLP was 247,335, 507 and 609 mGycm. For chest CT examination, CTDIvol was 3, 3,4 and 5 mGy and DLP was 90,130,127 and 197 mGycm in four age groups, respectively. Dose values for abdominal CT were 3,4, 7 and 6 mGy in terms of CTDIvol and 153, 184, 408 and 403 mGycm in terms of DLP. The collected data was compared to other similar studies, which indicted a need to expand such survey to other paediatric hospitals in Serbia.

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S6.P6

DOSIMETRY AND QUALITY OF DIAGNOSTIC IMAGING EXAMS PERFORMED IN NEONATES IN A NEONATAL INTENSIVE CARE UNIT

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Radiosensitivity is higher in younger patients and depends on the type of organs exposed to a radiation source. Children are more sensitive to injury caused by radiation due to the higher cell replication and they have a longer life expectancy. The objective of this work is to present results of entrance surface air kerma (ESAK) and image quality measurements in newborn children hospitalized in a Neonatal Intensive Care Unit (ICU). Chest X-rays examinations in the AP projection were chosen because they have a great demand in ICUs. For five months the thoracic examinations were accompanied and the dose received by the neonates was measured. The ESAK measurements were performed with TLD dosimeters, simulations with the software DoseCal (developed by the Radiological Protection Center of Saint George's Hospital, in London) and dosimetric simulations with ionization chambers. Medical evaluations of the images of the exams were made, according to the criteria for the visualization of structures and physiological aspects of the anatomical area studied. The dose levels measured were above the international reference levels, possibly caused by the variation of the techniques applied in the procedures. The quality of the diagnostic imaging was evaluated by medical doctors and showed satisfactory results. Among the contributing factors for the high dose level recorded was also the small distance between the focus and the patient's skin, as the ambient conditions do not favor a proper distance from the X-ray tube. Work supported by CNPq, CAPES and Fundação Araucária.

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S6.P7

EFFECTIVE DOSE DETERMINATION IN PEDIATRIC PATIENTS IN SKULL COMPUTED TOMOGRAPHY EXAMS

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Computed Tomography dosimetry in children has been a matter of great concern lately in the scientific community because of the high dose received by the patients. The present work was performed at a large children's Hospital in Curitiba-Brazil, using a fifth-generation CT scanner. In accordance to the recommendation of the European Commission (EC) data were collected from 625 patients divided into 4 age groups, 0-1 year 1-5 years, 5-10 years and 10-15 years. The dose for different ages was analyzed and compared with 3 international protocols regarding the CDTIw, CDTIvol and effective dose for a cranial CT scan study was performed with multiple scan. The results obtained were compared with computer analysis values. They were used in this study to calculate the effective dose and to compare with the reference dose levels established by the ICRP 103, AAPM 96 and EUR 16262 protocols. Using the computer simulation program of the ImpaCT Scan group, the relevant radioprotection magnitudes to the study which are the effective dose values related to the procedure, were determined. The level of dose length product (DLP), using the CTDI100, air previously established, was also obtained and compared with the dose reference level established by the EC and the Good Practice Guide from the UK. The values found so far are within the limits of the Reference Levels. Work supported by CNPq, CAPES and Fundação Araucária.

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S6.P8

COMPARISON OF PEDIATRIC WHOLE SPINE IMAGING DOSE OF A DIGITAL RADIOGRAPHY, A CR AND A NEWLY INSTALLED SLOT SCANNING SYSTEM

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Spinal deformities such as scoliosis usually require several radiological images throughout childhood and adolescence. The increased sensitivity of children and the risk of a radio-induced cancer is not a negligible factor for the radiological imaging departments. For years spine imaging to children was performed with Computed Radiography (CR) systems in Luxembourg offering an acceptable image quality and diagnosis. Direct digital imaging (DR) followed in the imaging sector offering an increased image quality and workflow. The latest arrival is a slot scanning device allowing the simultaneous acquisition of whole spine images (frontal and lateral). Given the possibilities as well as the limitations of each of the three imaging systems (CR, DR, scan), the comparison of radiation doses was a challenging subject. The purpose of the comparison was to evaluate the different systems and furthermore communicate and advice the medical professionals directly involved with the dose delivered to the pediatric patients. Local Diagnostic Reference Levels (DRL) have been already defined for the CR spine imaging by manually collecting and analyzing the values of Kerma Area Product (KAP). Doses corresponding to the DR and scanning systems were retrieved with the use of a Dose Archiving and Communication System (DACS). Two pediatric age groups were taken into account: 6-10yrs and 11-16yrs. Statistical evaluation was performed for a period of 6 months. Mean, maximum, minimum and 3rd quartile KAP values were defined. Results : The scanning spine imaging system featured with KAP values up to 42% lower than the CR and DR systems. Moreover, its protocols offer the possibility to furthermore decrease the dose to lower levels. This is an on-going process and waiting for the results. Radiation management and optimization is very important especially for pediatric patients that have to undergo multiple radiological imaging over their lifetime. New technology dedicated imaging systems can offer the possibility of lowering the dose to patients and at the same time keeping a good diagnostic image quality.

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S6.P9

EFFECTIVENESS OF DOSE REDUCTION METHODS TO CHILDREN IN CT PROCEDURES

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Effects of the software methods on distribution of organ doses in the trunk of child during CT procedure were evaluated. Exposures were performed using 128-slices CT scanner. Child patient was represented by 5.years CIRS antropomorphic phantom. The organ doses were obtained using TL dosimeters placed in the areas referring to anatomical localization of the particular organs. CT exposure were performed for the three software solutions: a)the current-voltage parameters routinely used for adults, without their automatic modulation, b)the current-voltage parameters reduced appropriately for 5.years child, without their automatic modulation, c)the current-voltage parameters reduced appropriately for 5.years child, with their automatic modulation. The absorbed organ doses for the above protocols were compared to evaluate how modified exposure parameters affect on child irradiation in CT. Additionally, the CTDIvol was measured to check the value automatically computed by the scanner' software and displayed on the console monitor. Significant effect of adequately chosen parameters for dose reduction was found. The obtained results show the necessity of control CTDIvol values through measurements using the proper dosimetric phantom. This work was partly supported by the Foundation for Polish Science (FNP), co-financed by EU structural funds under Action 1.2 'Strengthening the human resources potential of science' of the Innovative Economy Operational Programme 2007–2013) in the frames of the project POMOST 2010-2/6.

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S7.I1

CHALLENGES IN QUALITY ASSURANCE OF DIGITAL BREAST TOMOSYNTHESIS

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Digital breast tomosynthesis (DBT) is a technique in which a series of planes through the breast are reconstructed parallel to the detector, from a set of projection images acquired over a limited angular range. The DBT systems currently available and in clinical use are able to perform standard planar (2D) mammography with/without an antiscatter grid and DBT acquisitions. Digital breast tomosynthesis aims to improve detection or characterization of lesions based upon the reduction of overlaying tissue in reconstructed planes when compared to mammograms. Quality assurance of DBT has to make sure that DBT achieves the performance it was aimed for. Therefore, next to classical issues as known from 2D mammography such as stability of tube output, alignment of X-ray field and imaged volume, response function, etc… newer elements are needed to allow assessment and prediction of the 3D visualization of lesions. Today there is no phantom with which a global consensus can be achieved. A first European protocol is being compiled by the euref team. First evidence for the quality of DBT came from clinical trials, with some trials still on-going today. Whereas these results are often promising for DBT applications, they have limited applicability as they are linked to the specific implementation of a given technology in a particular diagnostic setting or screening regime. Next, 3D metrics such as 3D modulation transfer function (MTF) or 3D noise power spectra can be measured. The difficulty of this approach is with the interpretation of the results. There is no direct link with reduction of overlaying tissue. However, the system can be well characterized, with all parameters ready for 'virtual clinical trials', considered a next approach for acceptance testing or QA. In the next part of the presentation we will elaborate a few approaches: virtual trials can be partial, with lesions simulated into real patient images or in images of 3D structured (anthropomorphic) background. Trials can also be completely simulated, with simulated lesions in voxel models of the breast. The physics community can play a particular role in this phase of the project of DBT by exploring virtual clinical trials to answer some of the many unsolved questions. At the same time, the same community could help develop virtual clinical trials as a means to evaluate the appropriateness of X-ray radiation and patient safety in general.

S7.O1

DESCRIPTION AND BENEFITS OF DYNAMIC COLLIMATION IN DIGITAL BREAST TOMOSYNTHESIS

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X-ray field alignment with the image receptor is generally part of mammographic QC. In usual 2D imaging, the test checks the relative positions of x-ray field and detector active area. In digital breast tomosynthesis (dBT) the source moves during the acquisition, generating a displacement of the x-ray beam edges relative to the detector, in or out the detector active area depending on the initial adjustment. To avoid cropping the useful field of view (FOV), one solution is to keep the collimation aperture fixed at maximum opening during the dBT acquisition, within the limit of the primary barrier. Another possibility is to dynamically modify the collimation with the source rotation to keep the X-ray beam aligned with the detector. The dynamic collimation implemented in the GE Healthcare SenoClaire dBT equipment is described and tested here. The dynamic collimation is implemented using the capability to control all collimator blades independently. The blades positions are computed with the rotation of the X-ray source, and the blades moved accordingly. In this dBT system the detector active area is 240x307mm, the source to image plane distance is 660mm, the rotation pivot is 40mm above the image receptor plane, and the sweep angle ±12.5°, in 9 discrete angular positions (step & shoot). For this configuration and a collimation fixed at the standard 2D opening, the edges of the X-ray field would move from 15mm outside to 13mm inside the detector active area (total: 28mm). For a fixed collimation adjusted to avoid FOV cropping, the edges of the X-ray field would always cover the detector active area, but would exceed it by up to 37mm. The implementation of the dynamic collimation was tested using a radiopaque object placed on a non-screen film on top of the breast support. A dBT sweep was performed and the developed X-ray film was digitized. Distances in the digitized image were calibrated measuring the size of the radiopaque object in both detector and digitized film images, taking the detector image as a reference. The transition measured from the digitized film image between fully exposed and non-exposed film was 4mm wide, with the position of the X-ray field extending from 2.2mm inside to 1.8mm outside the detector active area. Using dynamic collimation it was possible to reduce the displacement of the edges of the X-ray field by a factor up to 9 (37mm to 4mm), allowing to maximize the tomosynthesis field of view while limiting unnecessary irradiation.

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S7.O2

AN INVESTIGATION OF BACKSCATTER FACTORS IN BREAST TOMOSYNTHESIS USING MCNPX SIMULATIONS AND MEASUREMENTS

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Mammography is the gold standard technique in breast cancer screening. However, due to the masking effect of overlying breast tissue produced by the projection of a three-dimensional object onto a plane, a new imaging modality, known as Digital Breast Tomosynthesis (DBT), has been developed to overcome these limitations. Several prospective studies indicate the benefits of adding DBT to standard mammography in screening, which raise some concerns in terms of the dose absorbed by the fibroglandular part of the female breast, since it is the tissue at risk for cancer development. Thus, an accurate estimation of the Mean Glandular Dose (MGD) is of paramount importance, although, there are still no standard protocols for dosimetry of breast, regarding DBT. The aim of this study is to introduce a backscatter factor (BSF) to calculate the entrance skin air kerma directly on patients or on standard phantoms and to further correct MGD estimation, taking into account the formalism proposed by Dance et al. For this, Monte Carlo simulations, using the state of art computer program MCNPX v2.7.0, were performed to mimic the DBT acquisition process. The simulations were made for a wide range of x-ray spectra (between 24-34kVp), with W/Rh target/filter combination. A homogeneous breast computational phantom, with 50% of glandular tissue, was considered and several thicknesses (2, 4, 6 and 8cm) of the female breast were evaluated. Also, free in air kerma measurements were performed with an ionization chamber, using a DBT clinical system at a Portuguese hospital, in order to validate and support the simulation results. The determination of the BSF can give an indication about a real MGD estimation in vivo, during DBT examinations in clinical environment and can contribute for the improvement of the current guidelines used in breast tomosynthesis applications.

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S7.O3

EFFECT OF THE GLANDULAR COMPOSITION ON DIGITAL BREAST TOMOSYNTHESIS IMAGE QUALITY AND DOSE OPTIMIZATION

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The biggest challenge in Digital Mammography (DM), which is used in breast lesion screening, is the effect of overlapping tissues, which leads not only to the occurrence of false positives (specificity) but also to the reduction of the ability of tumor detection (sensitivity) in dense breasts. In recent years, Digital Breast Tomosynthesis (DBT) has emerged as an innovative diagnostic technique, which allows to increase the sensitivity of the lesions' detection. Currently to evaluate image quality in DBT, an average percentage of 50% glandular tissue is employed, which may not be representative in the population. The aim of this work is to study the influence of different compositions of glandular tissue and different tumor thicknesses and microcalcifications in the breast on the image quality as well as to evaluate the absorbed dose by exposed tissues. This assessment becomes a priority for the future implementation of tomosynthesis in clinical practice. Monte Carlo simulations were performed using the PENELOPE state-of-the-art computer program to model the image acquisition system in a tomosynthesis equipment in operation in a Portuguese Hospital. After experimental validation of the developed model with standard dosimetry using an ionization chamber, the anthropomorphic breast phantom was developed for different compositions of glandular tissue and different thicknesses of lesions. Then, 2D simulated projections were obtained using a specific image tool of the PENELOPE Monte Carlo package (PenEasy). The simulated projections then underwent a reconstruction process using the Algebric Reconstrution Techniques method. Finally, the mean glandular dose (MGD) was calculated using different compositions of glandular tissue (25%, 50%, 75%) and the analysis of images was performed taking into consideration the signal – to – noise ratio (SDNR) and the calculation of figure of merit (FOM) for tomosynthesis. After this analysis, the voltage that maximizes the image quality for each clinical situation (breast thickness, granularity, lesions) was evaluated.

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S7.O4

EIGHT YEARS OF QUALITY CONTROL IN BULGARIA – IMPACT ON MAMMOGRAPHY PRACTICE

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Requirement for quality control (QC) of X-ray equipment was introduced in Bulgarian legislation in 2005. Medical physicists working in oncological hospitals, and several private medical physics services are responsible for implementation of QC program. The aim of this study is to analyze data from QC measurements in mammography and the impact of QC introduction on mammography practice in the country. The study was coordinated by the National Centre of Radiobiology and Radiation Protection. All medical physics services were requested to fill in standardized forms with information about most important parameters that are routinely measured during QC. All groups responded. Results demonstrated improvement in practice for the 8 years period. The oldest systems, which do not meet the acceptability criteria from the national regulation, were suspended from clinical use. One of the most common problems at the beginning - low luminance of the viewing boxes, often correlated to low optical density of the films – was improved with time. Comprehensive analysis of the data collected will be performed and presented.

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S7.O5

AUTOMATIC PATIENT DOSE REGISTRY AND CLINICAL AUDIT ON LINE FOR MAMMOGRAPHY

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The use of automatic registry systems for patient dose in digital mammography allows clinical audit and patient dose analysis of the whole sample of individual mammography exposures while fulfilling the requirements of the European Directives and other international recommendations. Further parameters associated with radiation exposure (tube voltage, X-ray tube output and HVL values for different kVp and target/filter combinations, breast compression, etc.) should be periodically measured and used by medical physicists to evaluate patient doses. This study presents an experience in routine clinical practice for mammography using automatic systems. Exposure parameters required for dose calculation and manufacturer dose estimations were extracted from the Digital Imaging and Communications in Medicine (DICOM) header of every image, using a locally developed system (MammoQA online). Entrance surface air kerma (ESAK) and mean glandular dose (MGD) were calculated with conversion factors taking into account X-ray beam and breast characteristics. A comparison with the values reported by the manufacturer was also made. A sample of 14,273 images was evaluated. Mean and SD values for the full sample were 6.81 ± 2.44mGy for ESAK and 1.48 ± 0.40 mGy for MGD. Differences with the values reported by the manufacturer were statistically significant. Differences ≥ 20% in doses were found in around 15% of the sample. Grouping the sample in thin (< 4.5 cm), medium (4.5-6.0 cm) and thick (> 6.0 cm) breasts, median ESAK resulted in 4.96; 6.46 and 8.73 mGy respectively. MGD were 1.26; 1.46 and 1.63 mGy for the three groups. When using mean values for the full sample, the global correction factor was MGD (calculated) = f * MGD (manufacturer) with f=0.93 ± 0,83. Trigger values for on line alarms were set for individual exposures (e.g. low compression, high ESAK values, etc) and for mean values over determined periods of use (e.g. weekly retake rates). These alarms are used to launch correction actions in a continuous process of optimization. Automatic dose registry for mammography offer the benefits of allowing online clinical audit and correction actions when radiographic techniques, compression or dose values are not in accordance with standard ranges. Parameters related to patient doses and supplied by the manufacturers need to be verified and corrected if appropriate, with the results of the periodic constancy checks.

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S7.O6

EVALUATION OF EXPOSURE IN MAMMOGRAPHY: LIMITATIONS OF AVERAGE GLANDULAR DOSE AND PROPOSAL OF A NEW QUANTITY

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The radiation risk in mammography is usually evaluated using the average glandular dose (AGD) for the reference breast. AGD "can be used as a basis for comparing doses delivered with different radiographic techniques" (Hammerstein, 1979), without taking into account the heterogeneous distribution of glandular tissue in the direction of the X-ray beam or the amount of glandular tissue if it deviates significantly from the average. An extreme example is the totally adipose breast where the AGD is higher than for the average breast in absence of tissue at risk. To provide an individualized quantitative evaluation of the radiation risk in mammography an improved metric is proposed. AGD is used as the organ dose for collective risk evaluation based on the linear-non-threshold hypothesis. Keeping this hypothesis at cellular level, the radiation risk can be evaluated by integrating the cellular dose over the total glandular mass resulting in the glandular imparted energy (GIE). GIE is expressed in joules (J) and when normalized to the incident air kerma in μJ/mGy. We used Monte Carlo simulations to compute the AGD and GIE for a MoMo 28kV spectrum and six semi-circular phantoms and compared the normalized AGD results with the mean glandular dose (MGD) tables from Dance (2000). Phantom 1 is the Dance reference breast model, i.e. 80 mm radius, 45 mm thick, 10 mm adipose tissue skins and 35 mm homogeneous mixture of 50% glandular-50% adipose tissue. Phantom 2 differs from 1 by a glandular area reduced by 50%, i.e. 58 mm radius. Phantom 3 differs from 1 by 0% glandular tissues. Phantom 4, 5 and 6 differ from phantom 1 by compacting the glandular tissue into 17.5 mm high glandular tissue region. The glandular region is centered in phantom 4, at 5 mm from the top in phantom 5 and at 5 mm from the bottom in phantom 6. Relative to phantom 1 all values of MGD are 1 except for phantom 3, for which it is 1.3. Relative to phantom 1 MGD the AGD values are 1 for phantom 1 and 2, 1.3 for phantom 3, and 0.6, 1.7 and 0.3 for phantoms 4, 5 and 6. Relative to phantom 1 GIE is 0.5 for phantom 2, 0 for phantom 3 and 0.6, 1.7 and 0.3 for phantoms 4, 5 and 6. AGD is non-sensitive to the projected glandular area, but is sensitive to the glandular distribution by a factor 6. The GIE variations reflect both the amount and distribution of the glandular tissue, confirming the expected capability to provide an individualized quantitative evaluation of the radiation risk in mammography.

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S7.P1

EVALUATION OF AUTOMATED CDMAM READINGS FOR NON-STANDARD CDMAM IMAGING CONDITIONS

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Nowadays, dose optimization studies are often based on computer readings of contrast detail images. In a previous study the achievable dose reduction for grid-less acquisitions was calculated from CDMAM images (Artinis, NL, serial number 1033). CDMAM images were made at various dose levels and PMMA thicknesses, with and without anti-scatter grid. The purpose of this study is to verify whether human predicted values from computer readings (as described in Young et al 2006) correlate with real human readings for the non-standard imaging conditions that were used to acquire the phantom images. Hence, in Young's paper, human predicted values from computer readings had only been derived for the CDMAM phantom with 4 cm of PMMA and grid-in condition. For 12 conditions, 3 images were scored by 4 human observers using Sara software (Qaelum NV, B) that randomly rotates every square in the image, and a curve was fitted through the reader averaged results. The same fitting was performed for the computer readings (CDCOM software, www.euref.org, from 16 input images per condition). The correlation between the automated readout and the human readout was calculated for our 4 readers. Threshold gold thicknesses obtained with the original and the newly obtained conversion were compared by averaging the ratios of threshold gold thicknesses from automated readout and human readout over all diameters. Next, the number of discs, from automated readout for which threshold gold thicknesses are within 1 standard deviation of the human readout, were counted for 4 gold diameters. A linear conversion curve was found with slope 2.157 and off-set 0.024 (R^2=1). The threshold thickness ratio of computer and human reading averaged over all conditions was 0.73±0.08 with Young's transform and 1.02±0.11 with the new transform. The largest deviation was for standard conditions with a ratio of 0.90±0.12 for Young's method and 1.25±0.11 with the new method. With the new transform, 20 out of 48 discs were found within 1 standard deviation of human reading, confirming the fact that a single transform can be used for all conditions. The transform reflects also the reading capacity of our human readers. The threshold values of our previous optimization study including several thicknesses and grid-less conditions will be revised with the new transform. Yet, as the same transformation can be applied to all threshold values, it can be anticipated that the results will not change.

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S7.P2

RETAKE ANALYSIS IN DIGITAL BREAST IMAGING

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The DICOM header of digital mammography images contains information that can be used to automatically detect potential retakes in digital radiology. The aim of this work is to analyze time trends in image retake rate, to determine direct causes and factors contributing to breast image repetitions and to plan optimization actions to decrease image retake rate. Data from breast digital imaging in the Department of Radiology at a University Hospital were collected using locally developed software (MammoQA online) able to read the DICOM header of the images, enter the data into a database, make queries to the PACS and visualize images when needed. For the same patient, digital breast images with the same laterality, study and projection are marked for further investigation as potential retakes. The software offers the possibility to enter the reason for image retakes, which facilitates the analysis of repeated images and raises awareness on the main causes of image retake. Data from a sample of 14,273 breast images collected during 2013 were analyzed. Not all the images retaken are so because the first image is of poor quality: further investigation is thus needed for images marked as potential repetition. A total of 812 images were marked as repeated, meaning a 5.7% image retake rate. In 3.7% of the studies, at least one image was retaken. For many of the repeated images, direct causes were found, such as improper positioning (clipped anatomy, motion), compression, exposure (collimation, automatic exposure control, kV, time, anode-filter combination) or artifacts. The time trend showed that adequate training is an important contributing factor to the direct causes described earlier: repeated images were two times more numerous during summer holidays, when inexperienced radiographers replaced those normally in charge. Repetition of images can result from equipment errors (inadequate functioning of the mammographic equipment or the image processing), attempts at optimization (repetitions aimed at improving image quality when the diagnosis is not clear), but also human errors (either at the positioning of the patient or when selecting the appropriate technical parameters for the exposition). To reduce equipment and human errors, different strategies are proposed.

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S7.P3

DUAL-ENERGY CONTRAST-ENHANCED DIGITAL MAMMOGRAPHY: PATIENT RADIATION DOSE ESTIMATION USING A MONTE CARLO CODE

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Mammography is a standard and cost-effective procedure that facilitates breast cancer detection. However, both conventional, as well as full-field digital mammography has limited value in dense and/or treated breast tissues. Contrast enhanced CT and/or MRI breast techniques although helpful, are expensive and high radiation dose (CT) procedures. Initial clinical results of Contrast Enhanced Digital Mammography (CEDM) are promising. The purpose of this study is to assess the radiation dose of CEDM using a Monte Carlo code. Dual-energy CEDM is performed by acquiring a pair of low and high-energy images. This is achieved in a single breast compression, using Mo or Rh filter at 26 to 31 kVp values, for low energy images and double-layer filter (0,3mm Cu ± 0,3mm Al) at 45 to 49 kVp, for high energy images. EGSnrc Monte Carlo code was used to simulate the interaction of photons with matter and estimate the glandular dose (Dg) to the breast. One million X-ray photons were input to breast geometry of a voxel female human phantom with a 2 to 8 cm thickness range and a breast glandular composition of 50%.Compressed breast was simulated in both the Cranio-Caudal (CC) and the Medio-Lateral oblique (MLO) views. Air Kerma measurements for various settings of tube current-exposure time product were performed with a Radical (model 2026c with ionization chamber) dosimeter. Dg values ranged between 0.974 to 2.470 mGy. For a breast with compressed thickness of 5.0 cm and a glandular fraction of 50%, Dg values for CC and MLO view are 0.926 (low energy image contribution is 0.811mGy) and 0.55(low energy image contribution is 0.479mGy) mGy, respectively. This is lower than the European Diagnostic Reference Level of 2mGy. The dose contribution analysis of each projection for all voxel phantom thicknesses indicates that low dose part mammography is the main contributor to total glandular breast dose.

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S7.P4

IMPACT OF IMAGING PROTOCOL IN DIGITAL BREAST TOMOSYNTHESIS: A META-ANALYSIS OF READER TRIALS

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Purpose: To evaluate the pooled performance of clinical tests comparing digital breast tomosynthesis (DBT) and digital mammography (DM). Materials and methods: Observer data of twenty-six studies performed in 2008 to 2013 was used as in the meta-analysis, including 1130 subjects with abnormal finding(s) and 4539 subjects with normal or benign findings. The studies were stratified and analyzed according to those that evaluated DBT as a stand-alone imaging modality, performed in one respective two views, mediolateral oblique (MLO) and craniocaudal (CC) views, and those that evaluated DBT combined with regular mammography (DM), all in comparison to DM alone. The pooled sensitivity and specificity was calculated in addition to the area under the summary receiver-operating characteristic curve (SROC). Results: For tomosynthesis as a single imaging modality there were individual studies with significant improvements (e.g. in 5 out of 16 comparisons, 31%). In studies comparing multiple tomosynthesis imaging protocols, a trend of increased performance was seen as the image information increased, either by the addition of tomosynthesis views or mammography views. A majority of studies evaluating DBT combined with DM found significant improvements in breast cancer detection (e.g. in 7 out of 9 studies, 78%). The overall analysis yielded an improvement in pooled sensitivity/specificity of +0.8%/+3.4% for one-view DBT, +0.3%/-0.1% for two-view DBT and +7.4%/+6% for DBT read together with DM. Conclusion: With respect to individual studies, significant improvements using DBT has been evident in all different types of imaging protocols. However, the most stable improvement across studies was found when DBT was read in adjunct to regular mammography, usually in two views. This could, however, change as DBT experience increases, along with advances in technology and reconstruction algorithms.

S7.P5

TESTING AND EVALUATION OF A CR MAMMOGRAPHY SYSTEM IN CLINICAL CENTER OFMONTENEGRO

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Computer mammography is an accepting method of performing women breast imaging for screening and diagnostic purposes. A special cassette, containing a charge storage phosphor, is used in place of the conventional x-ray screen-film cassette. It is exposed to radiation using standard techniques and the latent image, stored in the phosphor, is released by a laser scanner as visible light. Finally, the quantity of light emitted at each location is recorded and the scanner formed a digital image. The mammography system used in the Clinical Hospital Centre of Montenegro is designed with units from different manufacturers and thus suitability of system is carefully investigated. The system contains Planmed Sophie mammographic x-ray unit, Konica Minolta CR mammography imaging plate RP-6M, Konica Minolta Regius 190 CR reader, Kodak Dry View 6800 Laser printer, Rogan View Pro-X workstation, displays and viewing boxes. The purpose of this work is to test this system in order to determine whether this system meets the main standards in European protocols due to absence of national one. The testing methods are mainly derived from the European protocols using IBA Dosimetry GmgH MagicMax-mam multimeter, densitometer Unilight D, and different test objects (PMMA plates, IBA Anthropomorphic tissue equivalent phantom Mammo AT and Pehamed Europhantom Mammo). The main measured parameters are: the specific tube output (μGy/mAs) and the output rate (mGy/s); reproducibility and accuracy of tube voltage, half value layer, reproducibility and accuracy of the AEC system, exposure control steps, image receptor's response function, printer stability test, and ESAK. The derived quantity is AGD dose. The main findings are: The reader produces images with a pixel size of 43.75μm, and thus, is compatible with the laser printer which has 39μm laser spot spacing; In clinical practice the mammograms are printed and thus, display testing is avoided; The image processing algorithm embedded in the reader always allows to process mammogram with desirable image brightness and contrast before final printing; The all measured parameters are within the range described in European protocols except the tube voltage which deviated more than ±1kV. The derived AGD ranges from 0.66 to 7.02mGy for the thickness of the PMMA test objects from 20 to 70mm, and is in accordance with literature data.

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S7.P6

ABSORBED DOSE ASSESSMENT OF HEALTHY AND GLANDULAR BREAST TISSUE IN MAMMOGRAPHY

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Nowadays, mammography is used as an effective and precision tool to detect primary and small lesions in the breast. Screening by mammography has been suggested for women over 50 years old. Because of using X-ray mammography and sensitivity of the breast tissue to radiation, the use of this device may stimulate healthy cells and even cause cancer spread in subjects. Therefore, the amount of patient radiation absorbed dose is very important in a mammography exam. The aim of this study is, assessment of radiation absorbed dose inside the breast during a mammography exam, by using Monte Carlo simulation and comparison the results with arised experimental data from TLD data. To achieve this goal, the Mammography system (Siemens MAMMOMAT NovationDR) and its components such as X-ray lamp, compression plate and … was simulated by using MCNPX. Then the breast was simulated by a cube phantom with the dimensions of 14 × 14 × 4 cm3. The simulated breast phantom was filled by real and natural materials such as H, C, N, O, Na, Mg with the average density of 0.95 g/cm3. Then the average absorbed dose (AAD), entrance surface dose (ESD) and scatter dose fraction (SDF) was calculated in different depths of breast phantom in two conditions, means, healthy breast and glandular and healthy breast with the ratio of 50%. The results showed the amounts of AAD and ESD are equal to 1.432 and 4.006 mGy respectively in the condition of 50-50% of healthy and glandular breast components. Also the SDF when the breast was considered as glandular and healthy breast with the ratio of 50% is 10% more than of when the breast consists of only healthy tissue. The outcome results of the simulations were compared with experimental results that were done by TLD dosimeters too. The difference of the average glandular dose between the results of the simulations and the experimental results was about 6%. So the developed package based on Monte Carlo simulation can use as a simple, cheap and fast tool to evaluate the breast absorbed dose in most common studies of mammography with a very good accuracy.

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S7.P7

MEAN GLANDULAR DOSE IN SIX DIGITAL MAMMOGRAPHY SERVICES IN SANTIAGO OF CHILE: PRELIMINARY REFERENCE LEVELS.

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The purpose of this paper was to estimate the mean glandular dose (DG) in digital mammography systems in Santiago of Chile and to propose preliminary reference levels to execute mammography in Chile. Six digital mammography systems (two with direct digital mammographs (DR) and four computed radiography (CR) systems) were evaluated. The DG was determined using the usual clinically selected exposure factors. This was done using Automatic Exposure Control and auto-time mode. All the measurements were made with compressor and grill. The DG was calculated using polymethyl methacrylate (PMMA) blocks with thicknesses of 20, 30, 40, 50, 60 and 70 mm. The methodology used to calculate DG is based on the quality control protocols in digital mammography of the Spanish Society of Medical Physics and NHSBSP Equipment Report 0604 Protocol Version 3. On the measurement an Unfors dosimetry system, MAM Xi was used. The dosimetry system was positioned on the midline of the detector at 4 cm from the chest wall edge. Then the incident air kerma was measured for each PMMA thickness along with the half value layer, which was delivered by the dosimetry system. The preliminary reference levels for each of the different thickness of PMMA were calculated using the 75th percentile. The DG values were ranged between 0.64 and 7.26 mGy for a range from 20 and 70 mm thickness, respectively. The 100% of the DG were higher than desirable levels of dose. The 36% of the DG are above the acceptable level according to the applied protocol. The preliminary reference levels for DG is ranged between 0.90 and 6.40 mGy for a ranged to 20 and 70 mm thicknesses. The values obtained in this study are an initial proposal to establish reference levels in mammography in the country, a starting point, in which future dose results in digital mammography may be compared to optimize dose and obtain a national reference in accordance with the European protocol.

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S7.P8

2D ENTRANCE SKIN DOSE MAPPING AND DEPTH DOSE PROFILE USING RADIOCHROMIC FILM DOSIMETRY IN FULL FIELD DIGITAL MAMMOGRAPHY.

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The aim of this work is to study the entrance skin dose distribution and to identify the location of the overlapping x-ray fields on the breast skin surface during a multiple exposure mammographic examination routinely performed in our medical institution. The objective is to show the non uniformity of the spatial dose distribution and to identify the location or the area of the breast skin receiving the highest radiation exposure, maximum entrance skin dose (MESD). Another objective will be to evaluate the difference in percentage using dose units between the highest dose level recorded on the skin and the average dose from the rest of the breast skin areas exposed to the x-ray beam. Radiochromic film dosimetry newly available in the market will be used and tested, in theory the films are sensitive enough to be used for dosimetry in digital mammography. The exposed films will be analysed in order to present a 2D map of the entrance skin dose of the breast during a multiple views exams. Commonly available breast phantoms will be used to simulate the patient breast tissue for dosimetry purposes. This study will be much more interesting when the measurements are done using equipment with tomosynthesis capabilities because it involves systematic angular exposure of the breast tissue and most probably a non uniform breast tissue exposure on the surface of the breast. Another aim of the study is to examine the breast depth dose profile by placing the radiochromic films at different depth using the breast phantom and to compare the average dose recorder for each depth. Depth dose curve can then be obtained and presented graphically. It is expected that the maximally exposed area on the breast surface will be identified using the film dosimetry analysis method used previously in low dose fluoroscopic examinations with success. The film dosimetry method will be cross checked with the standard ionisation chamber dosimetry system commonly used in digital mammography. Results of the proposed measurements will be used to document the average total dose to the breast tissue received during multiple views average mammographic examination along with the associated entrance skin dose distribution for clinical full field digital mammography equipment used in our medical institution.

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S7.P9

THREE-DIMENSIONAL DIGITAL TOMOSYNTHESIS FOR BREAST IMAGING USING MONOCHROMATIC BEAMS

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Breast Tomosynthesis (BT) is a three-dimensionalbreast imaging technique approved for screening and diagnosingbreast cancer at its earlier nascence. Presently, BT is performed with polychromatic beams. Studies have shown that the use of monochromatic beams may provide increased image quality compared to conventional mammography.The aim of this study is to develop and evaluate a breast tomosynthesis setup using monochromatic beams for improved breast lesion detection. A computer-based platform integrating basic reconstruction algorithms such as the filtered back projection and the Multiple Projection Algorithm (MPA), as well as, several filters used prior to reconstruction, has been developed for studying BT.The study involved three phases: adaptation of algorithms for synchrotron geometry; optimization of acquisition parameters and filters; comparison to clinical tomosynthesis system. Two computational breast models, 4cm thick, with inserted masses and calcifications (Cs), were used. X-ray transport was simulated with an in-house developed Monte Carlo application. The optimization study, showed that breast masses with a diameter of 6 mm are better visualized at extended arc length, since from all tested combinations, the acquisition arc of 56° with 15 projection images demonstrated the highest image quality. For Cs, the image quality was less sensitive to the length of acquisition arc. Breast Cswith size between 170 and 500 μm, were well identified and visualized in all arcs. Among the reconstruction filters used, a median filter in combination with a sinc filter applied on the projections prior to the reconstruction with MPA, demonstrated best results. The comparison between mono- and polychromatic BT, revealed thatfor the same exposure, the use of monochromatic beam resulted in higher image quality compared to the one using polychromatic acquisition, especially in terms of contrast. For different exposures, comparable image quality in terms of signal-difference-to-noise ratio and higher contrast for all features was obtained when using monochromatic beam at lower mean glandular dose compared to the polychromatic one. BT using monochromatic beams has the potential to provide better detail and lead to substantial improvement in visualization of low-contrast masses, even at lower doses, compared to polychromatic acquisition.

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S7.P10

OPTIMIZATION OF X-RAY IMAGING SETUPS FOR IMPROVEMENT OF MICROCALCIFICATION DETECTION IN BREAST WITH PRESENCE OF SILICONE GEL IMPLANT

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Breast imaging in the presence of implants, necessitates higher doses to overcome the artifacts and improve the detection of breast lesions on x-ray mammographic images. This work investigates the relation between the incident beam energy and the silicone gel thickness, in the detection of microcalcifications (μCs) obscured by the implant material in the cases of 2D mammography and Breast Tomosynthesis (BT), applying doses that are typical for mammography imaging. We modeled two breast phantoms with escalating geometries. The first one composed of 18 adjacent cuboids, modeled from a silicone gel, with a thickness in the range from 2mm to 36mm forming a step wedge. A small μC modeled as a sphere having a radius 0.2mm was inserted at a distance of 2mm under each cuboid. The second phantom composed of 49 silicone gel cuboids of size 2×2×y mm3, where the values of y are from 1mm to 49mm forming a snail. 49 μC spheres with a radius 0.2 mm were placed at a distance 1 mm under each cuboid. Both escalating geometries were placed in homogenous blocks of mixture 50% adipose and 50% glandular tissue. Two x-ray imaging modalities: mammography and BT were simulated for energies between 20keV and 30keV with a MonteCarlo based code. With the use of the first phantom an upper implant thickness limit was established for feature detection. In detail, at 20keV we can detect μCs until 12mm of implant thickness, at 22keV until 16mm, at 24keV until 18mm, at 26keV and 28keV until 20mm and at 30keV until 22mm. Furthermore, BT was able to bring in focus the μC under one of the thickest block (the one of 36mm). 2D mammography failed to detect this μC for the complete energy interval between 20keV and 30keV. For the second phantom the maximum slab thickness under which μCs were detected is 33mm at 30keV. BT imaging resulted in improved detection of μCs even for an implant thickness of 49mm. 2D projection images resulted in higher CNR for thicknesses up to 15mm but failed to detect μCs under 30mm of silicone gel and upper. BT on the other hand resulted in lower CNR for thicknesses up to 20mm but was able to detect some of the μCs in the area 20-49mm such as the one under 49mm of silicone gel. These preliminary results suggest further investigation towards optimizing imaging setup for breast examination when an implant is inserted in order to succeed the best imaging at low doses.

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S7.P11

EVALUATION OF RECONSTRUCTION ALGORITHMS IN DIGITAL BREAST TOMOSYNTHESIS

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Three algorithms for digital breast tomosynthesis (DBT) were compared in this paper; filtered back projection (FBP), iterative adapted FPB (iFPB) and maximum likelihood-convex iterative algorithm (MLCI) reconstruction. A three-dimensional contrast-detail phantom, consisting of a 26 mm slab of breast equivalent material (210 mm x 300 mm) was developed for quantitative analysis of image quality in tomosynthesis. The slab has spheres embedded approximately at the central plane, representing clinically relevant contrast levels and sizes (diameters of 4-20 mm). A 20 mm thick PMMA slab was added to yield a phantom with attenuation properties similar to 45 mm PMMA to simulate a 'standard breast' (50 mm thick, 50% glandular tissue). The DBT system acquired 20 low-dose images of the CD-phantom over an angular range of 40° using an amorphous selenium flat-panel detector. Quality metrics such as signal difference to noise ratio (SDNR), artifact spread function (ASF) and normalized line-profiles were used for quantitative evaluation of the reconstructed tomosynthesis images. The ML-convex algorithm had the best SDNR values, followed by the iterative adapted FBP and the standard FBP. Differences in SDNR were primarily due to the lower noise properties; the FBP having most noise fluctuations. The iterative algorithms reduced the magnitude of artifacts substantially more than the standard FBP algorithm, both in-plane artifacts and out-of-plane artifacts. As shown by the ASF, the most prominent artifact reduction was achieved when using the ML-convex iterative method. The MLCI was superior in image quality as measured by quantitative metrics, which is encouraging. However, because of the absence of anatomical noise in the CD phantom, it is important to verify the result in images from clinical studies.

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S8.I1

THE MEDRAPET PROJECT AND ITS IMPACT FOR RADIOLOGISTS

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To provide an improved implementation of the Medical Exposure Directive provisions related to radiation protection education and training of medical professionals in the EU Member States, the European Commission (EC) invited tenders to study the implementa-tion of the Medical Exposure Directive's requirements on radiation protection training of medical professionals in the European Union (ENER/D4/212-2010). This MEDRAPET tender was awarded to a consortium led by the European Society of Radiology (ESR), including the European Federation of Organisations for Medical Physics (EFOMP), the European Federation of Radiographer Societies (EFRS), the European Society for Therapeutic Radiology and Oncology (ESTRO), the European Association of Nuclear Medicine (EANM), and the Cardiovascular and Interventional Radiological Society of Europe (CIRSE). The activities of the proposed project focused on three main tasks: The conduction of an EU-wide study on radiation protection training of medical professionals in the EU Member States, the organisation of a European Workshop on radiation protection training of medical professionals in the EU Member States, and the development of a European Guidance document on radiation protection training of medical professionals. The presentation will summarise the results of the three tasks, demonstrate the harmonised structure of the guidance document with defined standard sets of competences at various levels for minimum radiation protection training and CPD required for all different groups of medical staff working with ionising radiation. This was the basis for the revised Radiation Protection Guidelines on Education and Training in Radiation Protection for Medical Exposures (EC 175, 2014). For radiologists, the set of competences has already been integrated in the new ESR Training Curriculum for Radiologists defining knowledge, skills, and competences in all areas of professional activities that radiologists have to acquire during 5y of training. A permanent multidisciplinary working party will update and maintain these European standard sets of competences.

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S8.I2

EUTEMPE-RX, AN EC SUPPORTED FP7 PROJECT FOR THE TRAINING AND EDUCATION OF MEDICAL PHYSICS EXPERTS IN RADIOLOGY

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The core activity of the medical physics expert (MPE), as defined by the EU BSS, is to ensure optimal use of ionising radiations in patient healthcare and to bring new knowledge and expertise from physics into healthcare. It is therefore essential that these healthcare professionals are trained to the highest level. This level has been defined as EQF level 8 by the EU funded 'Guidelines for the MPE' project . These Guidelines have developed a harmonized qualification framework for Europe and a curriculum development model linking curriculum content to professional role. The main objective of the EUTEMPE-RX project is to provide a training scheme that allows the medical physicist in Diagnostic and Interventional Radiology to reach EQF level 8. This is necessary because in many European countries financial considerations will preclude the development of local training schemes and not all expertise may be available. A European network of partners was brought together in a new FP7 EC project to ensure sufficient expertise in all fields of study and to create a harmonized programme of courses. The learners that are targeted by the project are medical physicists in Diagnostic and Interventional Radiology (hospitals), in medical devices industry and in regulatory authorities. Courses will be designed using a blended learning scheme. As part of this scheme, e-learning education and teaching sessions (courses) will be developed. This will, in particular, help support medical physicists that cannot be released from their duties for long periods, especially those with childcare responsibilities. A business plan will be developed to ensure the sustainable continuation of this programme of courses following the end of the project. While the project will be limited to the area of Diagnostic and Interventional Radiology, it is recognised that this work should be built upon to extend the training to the work to other areas, such as Nuclear Medicine and Radiation Oncology. The EUTEMPE-RX project will develop 12 courses at EQF level 8, with radiation safety and efficacy being prevalent subjects. Some of the topics covered will be: developments in professional issues (legal aspects, communication, leadership etc.), quality assurance, advanced performance measurements, CT imaging, breast cancer screening, high dose interventional procedures, phantoms (anthropomorphic), dosimetry (for foetuses, infants and adults), radiation biology and Monte Carlo simulation techniques.

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S8.I3

MEDICAL PHYSICS EXPERT IMPLEMENTATION IN THE UK

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The revision of the European Basic Safety Standard Directive will place specific requirements on EU Member States in regard to the recognition, training and regulation of Medical Physics Experts (MPEs). Whilst the requirements of the BSSD will not be brought into UK law until 2017/18, the UK has established a working party to undertake a review of the implications of this change in EU legislation in the light of the published EU Guidelines on Medical Physics Expert (RP174) and to recommend a route to compliance. This paper will provide details of the proposed implementation within the UK and the linkage to the wider Medical Physics scientist training programmes. There are a number of important issues to be considered in a transition from a landscape where there is no formal recognition of the MPE including the establishment of a formal training and education programme, the establishment of an appropriate register, the scope of practice of the MPE, the transition of existing MPEs to the new registers and methods for recognizing services as MPE providers. Significant progress has been made on an integrated approach to training and recognition of MPEs with the existing career framework for Medical Physics. This will potentially provide a model for the development of specialist scientific expertise in a number of healthcare science areas and provide clear career development pathways.

S8.O1

BASIC RADIATION PROTECTION TRAINING FOR NURSES AND PARAMEDICAL PERSONNEL: BELGIAN EXPERIENCE AND FUTURE PERSPECTIVES

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When using ionising radiation for medical diagnosis or treatment of patients, relevant understanding of radiation protection issues is necessary. In Belgium, nurses and paramedical personnel are required to obtain knowledge and skills in protecting the patient against the detrimental effects of ionising radiation, by means of a 50h minimum vocational training course. The content of this training course is defined by legislation. The focus lies on topics such as the fundamentals of radiation physics, dosimetry, legislation and guidance in radiation protection, quality assurance and operational radiation protection of different medical applications. The ultimate goal is to provide the trainees with the tools needed to adopt the right attitude and behaviour towards RP of the patient and thus nurture the radiation safety culture. The course is delivered by various institutes of higher education across Belgium, therefore, the detailed course content and way of delivery may vary. In this presentation, the challenges for education and training of nurses and paramedical personnel are presented from a lecturer's point of view. It is clear that a theoretical basic radiation protection training course does not, in itself, warrant a safe use of ionising radiation to the patient in daily practice. Recommendations for continuous professional development in this highly technological and rapidly changing environment are given. The long-term collaboration between the training providers, the safety authority, the medical device industry and the healthcare sector is discussed for the Belgian situation. The added value of implementing the EQF and ECVET principles in order to facilitate the mutual recognition and European cross-border mobility will be investigated.

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S8.O2

LESSONS LEARNED FROM FUKUSHIMA DAIICHI NUCLEAR POWER PLANT ACCIDENT -EFFICIENT EDUCATION ITEMS OF RADIATION SAFETY FOR GENERAL PUBLIC-

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The Fukushima Daiichi nuclear power plant (FNP-1) accident, while as tragic as the tsunami, was a manmade disaster, created by ignorance of the effects of radiation and radioactive materials. Therefore, it is important that all specialists in radiation protection in medicine sympathize with the anxiety of the general public regarding the harmful effects of radiation, and advise people accordingly. All questions and answers were collected related to inquiries from the general public that were posted to reliable websites, including those of the government and radiation-related organizations, from March 2011 to November 2012. The questions were summarized and classified by similarity of content. 1. The total of questions were 372. The content was broadly classified into three categories: inquiries for radiation-related knowledge and about health effects and foods. Questions asked to obtain radiation-related knowledge were the most common, accounting for 38 %. 36 % of the questions were related to health effects, and 26 % involved foods, while 18 % of the questions as a whole related to children and pregnancy. 2. The change over time was investigated in the 290 questions for which the time of inquiry was known. Directly after the earthquake, the questions were primarily from people seeking radiation-related knowledge. Later, questions related to health effects increased. The anxiety experienced by residents following the nuclear accident was caused primarily by insufficient knowledge related to radiation, concerns about health effects, and uncertainties about food and water safety. The development of educational materials focusing on such content will be important for risk communication with the general public in countries with nuclear power plants. Physicians and medical physicist should possess the ability to respond to questions such as these, and should continue with medical examinations and treatments in a safe and appropriate manner.

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S8.P1

AN ASSESSMENT OF FINAL YEAR MEDICAL STUDENTS AND INTERNS AWARENESS OF RADIATION EXPOSURE FROM COMMON DIAGNOSTIC IMAGING PROCEDURES

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To evaluate the level of knowledge about the radiation exposure of diagnostic imaging procedures among the final year medical students and intern's and to suggest how education could be improved. All 355 final year medical students and interns from Tikur Anbessa teaching hospital in Addis Ababa were included in the study. Participants were asked to complete a questionnaire consisting of their actual knowledge on ionizing radiation and on their preferred method of learning. All questions were in multiple choice formats ranging from 4 to 7 choices. The obtained data were analyzed using statistical software Results: A total of 343 completed questionnaires were received. Up to 78.9% of respondents underestimated or do not know the radiation dose from commonly requested radiological procedures. Surprisingly, 71.4 % (n = 245) and 79.3% (n = 254) incorrectly believed that ultrasound and MRI, respectively, emit ionizing radiation or they do not know if they emit radiation or not. Both interns and medical students did not have significant difference (p=0.56) in their knowledge of ionizing radiation. A combination of tutorials or workshops (29.7%) and learning modules (19.8 %) were their first and last preferred methods of teaching for future radiation awareness respectively. This study has clearly shown that awareness of ionizing radiation from diagnostic imaging is lacking among senior medical students and interns. The results highlight the need for improved education to minimize unnecessary exposure of patients.

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S8.P2

AN EVALUATION OF THE EDUCATION IN RADIOPROTECTION RECEIVED BY STUDENTS X-RAY TECHNICIANS IN THE MEDICAL COLLEGE "Y. FILARETOVA" – SOFIA

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The goal of the survey is to record the students' evaluation of their education in Radioprotection in MC "Y. Filaretova" – Sofia and to assess the extent to which they are motivated to apply the knowledge acquired in their work with ionizing radiation. The course enables students to learn the principles of radioprotection for both medical staff and patients: it includes modern concepts of radioprotection and contemporary legislation in this field. A sociological survey was carried out using an anonymous questionnaire containing 14 questions – direct and indirect. 25 2nd grade students and 29 3rd grade students were questioned in The Department of Radiography at Medical College "Y. Filaretova" – Sofia. Opinions of the course in Radioprotection were obtained and students were examined on their intention to apply the knowledge received in order to minimize radiation hazards in their practice. A comparative analysis of the two groups allowed an assessment of the quality of teaching in two consecutive years; also the attitude of students of different grades towards the knowledge they had acquired. A statistical analysis of the results was carried out. The quality of education in Radioprotection meets contemporary standards for presentation and visualization and includes possibilities for discussion and clarification. The students are familiar with new standards in diagnostic imaging but these are not always applied on a consistent basis. 64% of the 2nd grade students and 83% of 3rd grade students acknowledged that the instruction in radioprotection made them more responsible in their practice with ionizing radiation. The machines used in diagnostic imaging allow for optimization of radioprotection. Operating procedures for X-ray machines directly influence the degree of irradiation of staff and patients. Improved skills in Radioprotection play a major role in the students' education in Diagnostic Imaging as a whole. 56% of 2nd grade and 69% of 3rd grade students who took part in the survey acknowledged that in addition to information contained in the course in Radioprotection, the material in the Radiographics module provided an additional key element in their qualification and skills in radioprotection

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S8.P3

GREATER POLAND CANCER CENTRE'S PARTICIPATION IN THE DEFICIT COURSES FOR SPECIALIZING PHYSICIANS IN COOPERATION WITH CENTRE OF POSTGRADUATE MEDICAL EDUCATION.

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Greater Poland Cancer Centre is accredited by the Minister of Health in terms of training for the following specialties: General surgery, surgical oncology, gyneacologic oncology, cliniclal oncology, anatomical pathology, radiology and diagnostic imaging, nuclear medicine, radiation therapy. Specialization programmes for physicains who started their specialization according to Regulation issued by the Ministryof Health on 6th August 2001 consist of course register that a given physician has to undergo. The courses may only be organized by the accredited institutions/units, their programme has to be accepted every time by the National Consultant and submitted to the Centre of Postgraduate Medical Education. GPCC organizes specializing courses for the physicians in the following disciplines: radiation therapy, gyneacologic oncology and otolaryngology. Centre of Postgraduate Medical Education organized Project 'Education within specialization process for physicians from deficit areas, i.e., oncology, kardilogy and occupational medicine in the period of 20.01.2007 – 30.06.2015. The Project is financed by the EU within European Social Fund. In line with the Project's rules a given accredited institute has to participate in the public procurement in which an offer is submitted. Course programme consists of lectures and workshops, during which the participants may interact and find out the ins-and-outs of the medical practice. The lectures are presented and outlined solely by the specialized staff. Catering (breakfast and lunch), didactic materials (including all the course presenatations) are provided for each participant. In order to get the certicifate of the completion of the course organized by the Centre of Postgraduate Medical Education participants have to take the test.

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S8.P4

RADIATION PROTECTION ASPECTS OF EMITEL ENCYCLOPAEDIA OF MEDICAL PHYSICS

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The Encyclopaedia of Medical Physics EMITEL was developed under the EU pilot project European Medical Imaging Technology e-Encyclopaedia for Lifelong Learning. This large reference material includes 3400 articles on 2100 pages supported by thousands of illustrations. All materials are available free at the web site www.emitel2.eu EMITEL includes also a Dictionary cross-translating any of the terms (article titles) into 27 languages, while the text of the articles is in English. The model of the Encyclopaedia was built around a larger number of short (encylopaedic entries) specific articles, rather than a small number of multi-page articles. This model allows effective search for information. The articles are grouped in 7 categories – Physics of: X-ray Diagnostic Radiology, Nuclear Medicine; Radiotherapy; Magnetic Resonance Imaging; Ultrasound Imaging; Radiation Protection and General terms. All terms were developed around a common template, refereed, and included in a large web database with two search engines. The Radiation protection part of EMITEL includes 450 articles. These were organised in several sub-groups including: Nuclear and Atomic Physics; Ionizing Radiation Interactions and Biological Effects; Radiation Detection and Measurement; Dosimetric Quantities and Units; and General Radiation Protection and International Bodies. Other EMITEL groups also included articles on Radiation Protection, specific to their subjects as Nuclear Medicine, Radiotherapy, MRI, etc. EMITEL also includes a Content Management System for update of the web site. EMITEL project was developed over 3 years and attracted as contributors 250+ senior specialists from 35 countries. After its successful launching EMITEL is actively used by thousands of professionals around the world.

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S8.P5

STUDY OF IONIZING RADIATION PROTECTION AMONG RADIATION WORKERS IN X-RAY DEPARTMENT IN ERBIL HOSPITALS

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Ionizing radiations are hazardous agents in the workplace and all forms of ionizing radiation produce some type of injury that is incurable. Therefore, application of protection against ionizing radiation exposure can play an important role in the health of workers. The objective of this study is to evaluate the application of radiation protection among radiation workers in x-ray department in Erbil hospitals. Six hospitals (General and Private) were visited and samples of 110 workers were randomly selected from among 135 radiation workers. Data was collected through structured questionnaires. The surveyed data was coded and entered into MS Excel software. Further data has been exported to SPSS 18 for analysis. Analysis was performed by means of frequency distributions and cross tabulations. The results show that there are 47 (42.3%) female and 63 (57.3%) male. A large majority of them 51 (46.4%) were aged between 21 - 30 years and Diploma holders 68 (61.8%). Only 49 (44.5%) undergone primary examination while 47 (42.7%) were never done periodical examination. According to ICRP regulation of radiation protection, it is mandatory for radiation workers to wear personal detective devices during work. But a large majority 89 (80.9%) has not been supplied with such devices. The study also revealed that a large majority of radiation workers are engaged in work beyond 40 hours per week. Calibration of the X-rays machine and radiation survey of the work place have not been regularly done. Only 30 of the sample have no awareness and knowledge about the ionizing radiation while 95 (86.4%) were said have no health physicist. It is suggested that the level of workers education must be increased and short courses be implemented such as dosimetery and radiation protection performance. Keywords: Radiation workers, Radiographers, Radiation protection, knowledge

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S8.P6

EDUCATION AND TRAINING IN RADIATION PROTECTION FOR MEDICAL PERSONNEL: INITIATIVES OF THE SCK•CEN ACADEMY FOR NUCLEAR SCIENCE AND TECHNOLOGY

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Thanks to its thorough experience in the field of nuclear science and technology, its innovative research and the availability of large and unique nuclear installations, SCK•CEN is an important partner for education and training in Belgium as well as at international level. Within the SCK•CEN Academy, more than 60 years of expertise and experience gained from our different research projects is collected. In the interests of maintaining a competent workforce in industry, healthcare, research, and policy, and of transferring nuclear knowledge to the next generations, the SCK•CEN Academy takes it as its mission to: (i) provide guidance for young researchers; (ii) organise academic courses and customised training for professionals; (iii) offer policy support with regard to education and training matters; and (iv) care for critical-intellectual capacities for society. Specifically towards the medical sector, the SCK•CEN Academy organises general radiation protection education for nurses and radiographers, and specialised training courses in the framework of continuous professional development of medical doctors, radiation protection experts, nurses and paramedics, service engineers, etc… In this presentation, we will highlight the mission of the SCK•CEN Academy and will show how cooperation with several stakeholders like universities and industry, also at international level, contributes to a more efficient transfer of knowledge, skills and competences in radiation protection.

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S8.P7

EXTERNAL FUNDS FOR TRAINING MEDICAL STAFF IN HEALTHCARE INSTITUTIONS IN POLAND ON THE EXPERIENCE OF THE GREATER POLAND CANCER CENTRE.

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The aim of the following paper is to analyze the possibilities of applying for external funds, e.g., European funds, for the training of both medical and administrative staff in healthcare institutions in Poland. Due to lack of money and unclear regulations Poland is subject to constant changes within Health Ministry. However, since Poland's EU accession, funds aimed at investments and training became more accessible. Human Capital Programme – supports medical sector and pays special attention to employees' adaptation within workplace environment. GPCC participates in a Project funded by Centre of Postgraduate Medical Education concerning the education of physicians from shortage/deficit areas such as oncology. Courses on radiotherapy and gyneacologic oncology for specializing physicians have been organized within this Project. Qualified physicians are eligible for reimbursement of travel and accommodation expenses in line with the established rules. EEA and Norway Grants – irreclaimable financial aid for the new EU Member States. GPCC applied for EEA and Norway Grants to finance the project on head and neck cancer prophylaxis for encompassing trainings for General Practitioners and nurses. ACCIRAD – Guidelines on a risk analysis of accidental and unintended exposure in radiotherapy. GPCC has won a tender announced by the European Commission to perform a study on the implementation of the Council Directive 97/43/EURATOM (Medical Exposure Directive, MED) requirements aimed at the reduction of the probability and the magnitude of accidents in radiotherapy and to develop guidelines on a risk analysis of accidental and unintended exposures in external beam radiotherapy. Poland faces the biggest challenges in terms of financial standing of its healtcare institutions since many years. In the face of mounting debt and change of ownership many healthcare institutions have to increase the already high management and medical standards. Thus, it is worth noting that external funds play crucial role in Poland's healtcare institutions as they are essential for their proper functioning.

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S0.P1

DIRECT DIGITAL IMAGING; CAN WE REALLY REVEAL THE REASONS BEHIND THE IMAGE REJECTION.

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Since the 80's and reject analysis is considered a useful tool used for quality control, to evaluate radiographs as it leads to the retake of images again. In addition it helps improve the quality of service in imaging departments, increase the cost effectiveness. Direct Digital Radiography DR is the new imaging technique and a replacement to computed radiography CR in imaging. DR suppliers claim it reduces the necessity of unneeded repeats of imaging which results in a reduced radiation exposure of patients. Old CR systems have shown reject rates of 5% on the other hand DR has shown a reject rate of 12% on a couple of system in Norway. In 2011 our hospital installed 6 DR machines, our current study aims to determine the reject rate of DR systems in hospital, benchmark it with other institutes, explore the main causes of rejection and introduce a plan for improvement. reject analysis data were collected over a period of 12 month from Jun 2012 till May 2013. 27 technicians would rotate over the year to work on every machine; the rejected analysis is automatically registered in the system which is a Kodak installed software built in the machine. Rejection reasons could not be deleted, and no imaging is allowed for the same patient without reporting the reason for rejection. All possible reasons for rejection are predefined by the machine. 89797 images were acquired in which 13371 were rejected, giving a rejection rate of 14.98%. Positioning errors accounted for 30.92% of the rejected images. Followed by artifact 28.46% and motion 17.1%. As for body parts; pelvis, abdomen spine and knee recorded reject rates higher than the average with no correlation between the number of scans and reject rates. 25% of the rejected images were ordered towne view. the study has shown that there is a high number of unnesscesry repeated imaging for patients. In addition reject analysis proven to be an indicator for quality in imaging, reject reasons that have high percentage of occurrence should be given more focus while scanning the patients. * Presenting author: mawya@hotmail.com

S0.P2

COMPARISON OF THREE X-RAY SYSTEMS FOR CHEST DIGITAL RADIOGRAPHY: FIRST STEP IN OPTIMIZATION

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The aim of this study was to compare three digital X-ray systems in terms of the dose delivered to patients for chest radiography in adults and the image quality through the numerical evaluations using test object images. The evaluation was performed in the Image Service of Regional Hospital Dr. Ernesto Torres Galdames in Iquique city for a three-phase Philips Digital Diagnost VM12 system (system A) and in the Image laboratory of Tarapaca University in Arica city for two single-phase Shimadzu UD150l-40E with iCR 3600LF digitizer system (systems B and C). For measuring dose and image quality, 20 cm of polymethyl methacrylate (PMMA) phantom that simulates the primary and scatter transmission through the patient was used in combination with a Leeds test object TOR 18-FG. The measurements were carried out with a constant focus detector distance of 180 cm, kVp of 125 and tube current-time (mAs) settings of 0.6, 1, 2, 4, 8, 16 and 32. Simultaneously, a solid state detector, positioned at the phantom surface, measured the entrance surface air kerma (ESAK). The noise, signal to noise ratio (SNR) and high contrast spatial resolution (HCSR) was the numerical parameters evaluated. The ESAK mean values (in μGy) were 473.75, 388.46 and 404.98 for systems A, B and C, respectively. For all the mAs used, the image quality for the system A showed the highest values of SNR respect to systems B and C in an average factor of 1.3. The trend is the same in the case of noise, in an average factor of 10.6. About the HCSR parameter, the values were greater for the system C in an average factor of 1.86 respect system A and 0.99 for system B. The correlation for mAs was statistically significant with a Pearson correlation coefficient of 0.95 for SNR, 0.76 for HCSR and 0.88 for ESAK (p=0.00), however, the correlation with the noise was low. The characterization of a radiographic system is essential because it allows us to know the exposure settings that generate the best image quality with the lower cost to patient in terms of the dose and the potential damage result of use. The importance of assessing the chest radiography is that it is one of the most performed exams in imaging departments. Therefore, this survey should be considered as a part of the first effort to achieve optimization in digital radiology for Chile.

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S0.P3

PATIENT DOSE MEASUREMENTS FROM CONVENTIONAL DIAGNOSTIC RADIOLOGY EXAMINATIONS: FIRST RESULTS IN MONTENEGRO

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The primary objective of this work is to assess patient doses for the most frequent diagnostic radiology examinations for the first time in Montenegro. Dose estimates are based on measurements Entrance surface air kerma (ESAK) and kerma-area product (KAP) for at least ten patients for each examination type in five major Montenegrin health institutions. A total of 723 patients for 10 different examination categories were included in the survey. Mean, median, third quartile values ESAK and mean effective doses of patient doses are reported. Attention is focussed at diagnostic procedures which contribute most significantly to collective dose of the population. Exposure settings and individual data were recorded for each patient. The estimated mean ESAK values obtained are as follows: 4.7 mGy for pelvis AP, 4.5 mGy for lumbar spine AP, 7.8 mGy for lumbar spine LAT, 3.1 mGy for thoracic spine AP and 4.3 mGy for thoracic spine LAT. When compared with the European Diagnostic Reference Values, the mean ESAK for all studied examination types are found to be below the reference levels, except in chest radiography. Mean ESAK values for chest radiography are 0.9 mGy for PA projection and 2.0 mGy for LAT. Values of max/min factors for all these institutions are 78 for PA and 88 for LAT projection in chest radiography. This implies that diagnostic radiology in Montenegro urgently needs practice optimisation – through regular patient exposure measurement, modification of radiographic techniques, assessment of diagnostic image quality, association of measurement uncertainties to each measurement and continuous training of personnel.

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S0.P4

IMAGE QUALITY AND DOSE ASSESSMENT IN DIGITAL PELVIS IMAGING USING TWO DIFFERENT COMPUTED RADIOGRAPHY UNITS

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A study was conducted for image quality and radiation dose measurements in computed radiography (CR) imaging of the Pelvic. Totally 200 patients, equally divided between different image plate type, Fujifilm (columnar granular) and Kodak (granular phosphor), CR units were studied. Radiation doses were assessed in terms of entrance air kerma (ESAK) and effective dose (E) determined from exposure setting using CALDOSE Monte Carlo- based Dosimetry software. Image quality was measured using both subjective and objective physical methods. Experienced radiologists did the subjective image quality evaluations using the European Quality Criteria. Objective image quality evaluations were done by measuring the physical characteristics of two systems in terms of the detective quantum efficacy (DQE). Image quality and dose assessment of the two radiography units were evaluated for statistical significance. The estimated mean ESAK values (4 mGy) were lower than its corresponding UK diagnostic reference level. Statistical analysis of image score between the two units under study showed a significant different between two data points ($p \leq 0.05$). Analysis of clinical image quality showed a mean overall score in the range (77-82%). Pelvis radiographs using the Fujifilm can be acquired with significantly lower patient dose compared with the Kodak. The obtained results of the physical characteristics indicated that the DQE for Fujifilm was superior (80%) than Kodak. Pelvis radiographs using the Fujifilm can be acquired with significantly lower patient dose compared with the Kodak. In conclusion patient dose and image quality for both systems were in agreements with the international reference levels.

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S0.P5

MEASUREMENTS OF PATIENT DOSES IN CERTAIN PROJECTION UROGRAPHY PROCEDURES

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Projection urography procedures are a radiologic imaging technique used for the evaluation of the genitourinary system. However, patients exposed to significant radiation doses during diagnostic or intervention procedures. Therefore, since the procedures are justified, patients must be protected from unnecessary radiation exposure to reduce the avoidable radiation risks. This study was intended to measure patient entrance surface air kerma (ESAK) and effective dose during intravenous urography (IVU), extracorporeal shock-wave lithotripsy (ESWL), ascending and descending urethogram procedures. ESAK were measured for patient using calibrated thermo luminance Dosimeters (TLDs, GR200A) and DosCal software. Effective doses (E) were calculated using the national Radiological Protection Board (NRPB) software. A total of 179 procedures were investigated. 27.9 % of the sample was IVU procedures, 27.9 % were undergone ESWL procedures while 19.0 % and 25.1 of the sample were ascending and decending urethrogram procedures, respectively. The mean ESAK (mGy) were 2.1±0.64 mGy, 4.18±0.15 mGy 5.2±14 and 4.6±0.3 for IVU, ESWL, and descending urethrogram procedures at the same order. The mean ESAK and effective doses during are comparable with previous studies for IVU procedures previous studies. Staff training will reduce patients' doses during urologic interventional procedures. Since patient has no dose limits, an extensive effort should be given in order to reach the final diagnosis or treatments of the procedures.

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S0.P6

ESTIMATION OF EFFECTIVE DOSES IN CHEST RADIOGRAPHY BY USING PCXMC 2.0 PROGRAM

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Determining radiation doses to patients is important for two essentially reasons: for estimation radiation risk and for optimisation of image quality versus radiation exposure. There are very different conventional radiography units in Montenegro, from old to modern one, distributed in twenty five cities. The purpose of this work is to test these systems and clinical practice in order to determine whether this system meets the main standards in national and European protocols as well. The testing methods are based on providing necessary input data for Monte Carlo program for calculating patients' organ doses and effective doses in medical x-ray examinations PCXMC 2.0. There are a lot quantities that influence patient exposure. These main data are: patients' ages, height and mass than geometric data of x-ray beam, parameters of the unit setting as x-ray tube potentials, anode angle and filtration, and finally incident air kerma. The air kerma is measured at the position of skin surface of a patient by using Barracuda multimeter. The examination procedure is chosen to be PA chest radiography. The main findings are: The program gives estimated organ's doses with estimation of accuracies together with risk assessment of a cancer inducing due to radiation exposure. It is found that main parameters which determines effective doses are the incident air kerma and radiation field. The incident kerma is within the range of the European guidelines i.e. 0.3mGy. More investigation is needed to get statistically meaningful data for determination national dose referent level.

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S0.P7

THE WAY OF OPTIMIZATION OF PATIENT' DOSES IN CHEST RADIOGRAPHY

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One of the important aspects of quality assurance in X-ray imaging is to obtain the acceptable diagnostic image with the decrease of patient's doses. In Ukraine the most common type of radiography diagnostic investigations is the chest radiography (about 40%). The majority of X-ray Departments carries out the chest radiography in technique of low voltage - 60-80 kVp and high expositions - 20-40 mAs. In this case the entrance surface doses (ESDs) were in the range of 0.1-7.5 mGy (our measurements of doses for more than 1000 patients). The third quartile of ESD's distribution should be accepted as DRL. For chest radiography (PA) the national DRL was 0.92 mGy and exceeded the Guidance level of BBS-115 for Chest, PA - 0.4 mGy - in 2.3 times. In accordance with European Guidelines on quality for diagnostic radiographic images (EUR 16260) the radiography of chest (PA) should be performed at the "high-voltage technique" - 125 kV, exposure time – less than 20 ms. The aim of this study was to implement the "high-voltage technique" for chest film radiography for optimization of patient doses. The image quality was estimated for two techniques of film radiography of chest (PA): technique of routine practice on X-ray unit and "high-voltage technique". The assessment of quality film images of chest (PA) were performed on 32 films by seven independent radiologists in accordance with 10 quality criteria of EUR 16260. At the same time the doses of patients were evaluated. Using the high voltage technique the tube voltage was increased in 1.5-2.0 times up to 90-110 kVp, while exposition was reduced up to 2.0-7.5 mAs. Using high voltage technique the patient ESDs were reduced in 1.5-3.0 times in compare with previous technique for each X-Ray Unit. The measurements on the Rando phantom in high voltage technique demonstrated the possibility to decrease the ESDs up to 5.0 times. The quality of film image of chest was acceptable when total assessment was 7-10 points on 10 image quality criteria of EUR 16260. The results of expert evaluation of quality of film images in high voltage technique were not deteriorated in compare with film images in low voltage technique: the 61% and 64% of films respectively had the acceptable image quality. The introduction of high voltage technique in routine practice of X-Ray Diagnostic Departments gives the possibility to decrease the patient doses up to 3 times while maintaining an acceptable film image quality for diagnostic purposes.

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S0.P8

A COMPARATIVE EVALUATION OF ADULT PATIENT DOSES IN SCREEN FILM AND COMPUTED RADIOGRAPHY X-RAY EXAMINATIONS

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A study was performed to compare adult patient doses in screen film (SF) and Computed Radiography diagnostic X-ray examinations. Radiation doses were estimated for 354 patients in hospitals (two SF and three CR units) in Khartoum, Sudan. Entrance surface air kerma (ESAK) was estimated from incident air kerma (Ki) using patient exposure parameters and tube output Y(d). Dose calculations were performed using CALDOSE X 3.5 Monte Carlo-based software. In SF, 3rd quartile of ESAK amount: in skull PA, skull LAT, chest PA, lumbar spine AP, lumbar spine LAT amount: 1.5, 1.3,0.3,1.9,2.8,5.9 mGy respectively in skull PA, skull LAT, chest PA, lumbar spine AP, lumbar spine LAT. While in CR, 3rd quartile of ESAK amount: in skull PA, skull LAT, chest PA, lumbar spine AP, lumbar spine LAT amount: 2.7, 1.3, 0.22.7,1.7, 3.2. 10.8 mGy, respectively in skull PA, skull LAT, chest PA, lumbar spine AP, lumbar spine LAT. For chest PA, pelvis AP imaging the results reported here indicate that screen film doses were much higher than CR for a chest PA exam, CR higher than screen film for the pelvis AP exam. No statistically significant difference was observed in the means of the two imaging technology for the other examinations (skull PA, skull LAT, lumbar spine AP, and lumbar spine LAT. The conclusion is the tradition FS imaging system can still have a place in imaging procedure as it generates a lower radiation dose for certain organs, namely, the skull (PA) and lumbar spine (LAT), whereas the newly introduced CR imaging has a lower radiation dose for imaging other organs. Therefore, the transition from SF to the new CR imaging system is possible because of the improvement in the reduction of doses. For the time being both systems can be used side by side, each for the area of merits and advantages. The results presented will serve as a baseline data needed for delivering reference doses for digital X-ray examinations in Sudan.

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S0.P9

RADIATION DOSE TO PATIENTS' ORGANS UNDERGOING RADIOGRAPHY OF ABDOMEN

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Ever since the discovery of X – rays, they are being used for diagnosis and treatment of diseases. However because of possible health hazards of radiation, in recent years there has been widespread concern regarding radiation exposure to patient undergoing radiological procedure. The present study deals with measurement of radiation doses to cornea, thyroid, gonads and skin of patients undergoing radiography of abdominal region. For measurement of radiation doses, after the patient is positioned for the radiography of abdomen, pre-annealed CaSO4: Dy thermoluminescence discs [TLD] were kept over eyelid of patient for measurement of corneal doses, on the neck for thyroid dose, in the center of radiation field on the patients skin for skin dose, on the scrotum for testicular dose in male and in case female patient, 5 cm above the pubic symphysis in the midline on the skin for the ovary doses. Since the ovaries in female do not lie on the surface of skin, a suitable conversion factor was estimated and used to convert the surface dose to ovary dose. After the exposure the TLD's were collected, kept in radiation free area for 24 hours before reading on Thelmador-600 TL reader to estimate the doses. In this study result of 500 patient doses is reported. The skin entrance doses were 2 mGy – 8 mGy. The detailed results are presented in this communication.

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S0.P10

SURVEY OF PATIENT EXPOSURE DURING CERTAIN DIAGNOSTIC RADIOLOGY PROCEDURES IN SUDAN

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Medical x-rays are the largest man-made source of public exposure to ionizing radiation. Therefore, it is important to avoid conditions where the amount of radiation used is more than that needed for the procedure. The objectives of this study are to measure the radiation dose to patients in routine x-ray examination and to estimate difference organs equivalent and effective doses. The entrance surface air kerma doses (ESAK) was calculated for five radiographic examination using thermoluminescence dosimeters (TLD-GR200A). Effective doses (E) were calculated using published conversion factors and methods recommended by the national Radiological Protection Board (NRPB). A total of 314 patients were examined in eight hospitals. The mean ESD for the skull, chest, upper limbs, lower limbs, and spine were 0.27±0.18mGy, 0.63±0.13mGy, 0.32±0.35mGy, 0.23±0.18mGyand 1.03±0.81mGy, respectively. The overall effective dose was 0.36±0.05mSv.The results of radiation (ESD) were comparable with previous studies. Patients doses showed wide variations for the same types of x-ray examination due to the choice of exposure factors, technique, focus-to-film distance, filter, film-screen speed and the output of the x-ray units and processor quality were used. The results of this dose survey provide valuable primary data for awareness from situation of patient dose in these hospitals in Khartoum.

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S0.P11

EVALUATION OF RADIATION ENTRANCE SKIN DOSE AND ESTIMATION OF EFFECTIVE DOSE FOR ADULT PATIENTS DURING LUMBER SPINE EXAMINATIONS IN SUDAN

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Radiation protection is an important point in diagnostic radiology that should considered while imaging the patients. The most important consideration in protecting the patient is to ensure that images of sufficient quality for accurate diagnosis are produced without the need for any repeat. The means to achieve this are the design and maintenance of equipment, training and experience of staff, robust operating procedures. The aims of this study were to measure the radiation dose to the skin surface, by usage of DOSCAL software which required to introduce exposure factors, distance, tube output and back scattered factor (BSF), and also to estimate organs radiation dose for some radiosensitive organs and also to estimate effective radiation dose using Monte Carlo program developed by National NRPB (NRPB-262). The study involved examinations of lumbo-sacral spine in two projections, Anterior-posterior (AP) and lateral (LAT) for 100 adults patients, with variation in their height, age, weight and body mass index (BMI), in the Khartoum teaching hospital, Omdurman teaching hospital and Ribat National hospital. The mean radiation ESD were (11.2) and (19.8)mGy for AP and LAT Projection respectively, While the highest the radiation dose were for bone marrow and ovaries for female patients. More studies are recommended for dose optimization in order to derive and establish local diagnostic reference level as recommended by (NRPB,1993) also this in line of ICRP philosophy of dose reduction .

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S0.P12

FREQUENCY AND ANALYSIS OF X-RAY EQUIPMENT MALFUNCTIONS AND FAILURES TO MEET THE SUSPENSION LEVELS

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During the clinical use every X-ray equipment undergoes an acceptance test, annual status tests and regular constancy tests with higher frequency (daily, weekly etc.). To evaluate the effectiveness of this system of QC tests, an analysis of the results of the acceptance tests and annual status tests was carried out. The analysis focused on the malfunctions and failures to meet the suspension levels. Protocols of the acceptance and status tests of all type of X-ray equipment were checked for this analysis. To avoid bias, all protocols from at least one year period were selected for the analysis. This ensures that almost every piece of X-ray equipment was included in the analysis. Therefore the results are neither region nor equipment type specific, and the analysis is representative for the situation within the country. In total 3600 protocols of general radiography, fluoroscopy, interventional, dental, mammography and computed tomography equipment were checked. Found failures were divided in two categories with respect to severity based on the degree of negative influence on image quality and patient dose. Further for every malfunction or failure it was identified, whether the problem should has been identified during the regular constancy tests, which have higher frequency than the annual status test. The failures to meet the suspension levels mainly occurred in the tests of light field/radiation field/image receptor alignment, linearity of air kerma, automatic exposure control, image quality and for mammographic equipment also in the tests of compression device. The total number of failures found in the protocols was 580. The imaging modality which is most error free is computed tomography. It is caused by the regular preventive monthly service of the CT equipment, which identifies and solves the problem usually before the annual status test. The two imaging modalities/equipment with most failures were mammography, mainly due to more strict suspension levels which are applied for the screening centers, and equipment used only for fluoroscopy, since these X-ray machines are rather old. Surprisingly high percentage (in the average more than 50 %) of the found failures should have been identified during the regular constancy tests. It indicates that the constancy tests, which are not performed by medical physicists or licensed companies, are performed irresponsibly in some cases and more emphasis should be placed on this type of tests within the QA system.

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S0.P13

EVALUATION OF PATIENTS RADIATION DOSES DURING HYSTROSALPINGOGRAPHY IN SUDAN

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Hysterosalpingography (HSG) is the most frequently used diagnostic tool to evaluate the endometrial cavity and fallopian tube by using conventional x-ray or fluoroscopy. Determination of the patient radiation doses values from x-ray examinations provides useful guidance on where best to concentrate efforts on patient dose reduction in order to optimise the protection of the patients. The aims of this study were to measure the patients' entrance surface air kerma doses (ESAK), effective doses and to compare practices between different hospitals in Sudan. ESAK were measured for patient using calibrated thermo luminance Dosimeters (TLDs, GR200A). Effective doses were estimated using National radiological Protection Board (NRPB) software. This study conducted in seven radiological departments: Three Teaching Hospitals (A,B and C), Three Private Hospitals University (D,E, and F) and one University Hospital (G). The mean ESD was 20.1 mGy, 28.9 mGy, 13.6 mGy, 58.65 mGy, 35.7, 22.4 and 19.6 mGy for hospitals A,B,C,D, and E, F and G), respectively. The mean effective dose was 2.4 mSv, 3.5 mSv, 1.6 mSv, 7.1 mSv, 4.3 mSv, 2.6 mSv and 2.1mSv in the same order. The study showed wide variations in the ESDs with three of the hospitals having values above the internationally reported values. Number of X ray images, fluoroscopy time, operator skills X ray machine type, clinical complexity of the procedures were shown to be a major contributor to the variations reported. Results have demonstrated the need for standardization of technique throughout the hospital. The results also suggest that there is a need to optimize the procedures. A local DRLs were proposed for the entire procedures

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S0.P14

EVALUATION OF NEW TRANSPARENT TUNGSTEN CONTAINING NANOCOMPOSITES FOR RADIATION PROTECTION SCREENS

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Radiation protection screens/shielding is a mandatory measure implemented in radiology departments for radiation protection of personnel against scattered X-rays. However the majority of shielding screens contains highly toxic lead which should be replaced according to the recommendations of EC authorities. Evaluation of the new lead free optically transparent nanocomposites as possible materials for the construction of X-ray protective screens/shields is provided in this paper along with the introduction to their fabrication technologies and the results of investigation of their X-ray attenuating and optical properties before and after irradiation to high doses. Phosphotungstic acid or ammonium metatungstate was dissolved in different solvents (distilled water, ethylene glycol, diethylene glycol, glycerol, glacial acetic acid) or in their mixtures. Some in water soluble polymers (eg. polyvinyl alcohol) wear used for preparation of tungsten containing polymeric nanocomposites. Prepared high-concentration solutions and polymeric nanocomposites were poured in cuvettes, tightly closed and left in the dark room for 24 hours. Irradiation of samples was performed in diagnostic X-ray machine MULTIX PRO. Measurements were performed once before sample irradiation and multi times after it's irradiation to different doses. X-ray attenuating properties were measured using standard procedure described in NCRP Report 147 and compared to those obtained from theoretical calculations using XCOM database. Optical properties of the experimental samples were measured using UV/VIS spectrophotometer Jasco V650. It was found that the lead equivalent thickness of fabricated experimental samples varied from 0.475 to 0.750 mmPb and was higher for samples, containing polyanions of phosphotungstic acid. Some deterioration of X-ray attenuating properties was observed for all samples irradiated up to 50 Gy doses. Transparency of the initial samples to visible light varied from 10 to 50% and was slightly increasing with irradiation dose. Samples containing metatungstate or phosphotungstic acid dissolved in distilled water or acetic acid solutions showed almost stable transparency of ≥ 50% to visible light after their irradiation to10 Gy. Results of investigation showed potential applicability of polymeric nanocomposites containing ammonium metatungstate in the construction of radiation protection screens. This research was granted by Research Council of Lithuania, grant No. MIP-091/2012

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S0.P15

EFFECT OF OFF-AXIS INCIDENT X-RAYS ON MODULATION TRANSFER FUNCTION, NOISE POWER SPECTRUM AND DETECTIVE QUANTUM EFFICIENCY FOR VARIOUS DIGITAL DETECTORS

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The introduction of digital x-ray imaging systems in clinical practice has allowed the use of objective image quality parameters such as the Modulation Transfer Function (MTF), the Noise Power Spectrum (NPS) and the Detective Quantum Efficiency (DQE) as a means of evaluating image quality and such tests are now part of routine quality control surveys. Objective analysis measurements are performed at the centre of the detector and doing so, gives good evidence regarding its performance in that area. However, there is little evidence about how these parameters vary across the detector, in areas where the incident x-rays are not perpendicular to its surface. Three different detectors were used for this study; one of them is used in mammography and two in general radiography. X-ray images of a sharp test-object were obtained in various positions across the detector's x and y directions. Flat field images at standard clinical dose settings were also obtained in order to calculate the NPS at various positions. Finally, DQE was derived from the MTF, NPS and photon fluence values for each measurement. Initial results have shown that there is a significant reduction in MTF as the measurement position is moved away from the central x-ray. Signal degradation can be up to 25% for CsI detectors used in mammography. NPS is unaffected by the geometric effect for the low energy range used in mammography but the effect becomes more apparent for higher energies such as those used in radiography. Finally, the effect on DQE is highly dependent on MTF variations and therefore the detective efficiency of the detector is significantly degraded towards its sides. It is shown that there is a significant miss-match in detector performance between the periphery and the central region of an image. This implication may impair diagnosis and therefore, manufacturers face a practical compromise between maximizing the incident x-ray intensity and minimizing the incident x-ray angle on the detector.

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S0.P16

MEASURING SCATTER RADIATION IN DIAGNOSTIC X-RAYS FOR RADIOPROTECTION

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The optimization of radiation protection of people and medical personnel, which have to be present in an X-ray room during typical X-ray procedures is of importance. The knowledge of the X-ray dose spatial and energy distribution is necessary for designing radiation practices. The aim of this study is the measurement of secondary radiation in a conventional radiographic room and the estimation of measurement setup errors. A conventional radiographic system with HVL equals to 3.2 mmAl at 80 kVp, was used. A cylindrical water phantom acted as a patient. The simple symmetrical shape of the phantom and the conventional system allowed for better control in the measurements and diminished the effect of the phantom shape to the measured scattered radiation. The dose rate was measured, with a survey meter at variable distances in the room for variable kV, mAs combinations. Measurements were repeated at 100kV with additional filtration of 2mmAl to account for different X-ray modalities. The surveys meter orientation was allowed to vary in order to investigate the measurement accuracy with regards to survey meter placement. Finally the scatter X-ray energy distribution was measured with an Amptek XR 100 CdTe spectrometer. A setup difference of 1 to 2 cm in the focal spot to phantom distance had no significant result on the measurements. Furthermore survey meter angular errors did not change the measurements much, but the absolute verticality of the survey meter towards the center of the phantom did. It was found that an increase in distance from 1.0m to 1.5m yields a dose rate decrease of 49.2%. The added filtration of further reduced the scatter dose by 21.4%. The mean secondary X-ray energies for 60 kV and 100 kV were calculated as 34.41 KeV, 69.03 KeV respectively. The ratio of the scatter radiation dose rate per tube output was calculated as 45.55 mSv/hr/mGy/mAs at 1.5m for 80KV. The results of this study are of practical value for optimizing the radiation protection of people involved in practices inside the X-ray room. The normalization per tube output generalizes the present results to different X-ray equipment.

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S0.P17

NEED OF NATIONALLY AGREED METHODOLOGY FOR RADIATION SHIELDING DESIGN CALCULATIONS

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The purpose of this paper is to present analysis of the results from the monitoring the effectiveness of the radiation shielding of radiological installations, performed by the Radiation health inspectorate at the National centre of Radiobiology and Radiation Protection. According to the existing national regulatory system, radiation health inspectorate acts at different stages before the commissioning of new radiological instalation. At the early stage of issuing permission for installation inspectors are acquainting with the actual condition of the site and the organization of work. For new techologies not covered by existing legislation, information from manufacturer is important. In a case of positive decision, radiation shielding design is prepared by radiation protection expert. Because of the lack of nationally agreed methodology, radiation shielding calculations are based on available international guidelines. Most of the experts use German DIN standard for X-ray equipment, and IAEA and NCRP guidelines for radiotherapy equipment. Intended occupancy of the rooms and workload declared by the local medical staff are used for shielding calculation, but often subjectively increased by expert. After the room construction, dose measurements are performed by radiation inspectors to compare measured values to the calculated dose values in specific control points defined in the radiation shielding design, checking this way the effectiveness of the constructed protective barriers. The experience of monitoring new high technology equipment like angiography, CT, linear accelerators, etc., revealed the wicknesses of the existing approach, which often leads to unrealistic over-shielding and increased cost of radiological rooms. Examples from practice will be presented. Updated regulation and radiation shielding calculations guidelines are urgently needed in the country to guarantee the effective radiation protection at minimum cost. Special attention is needed to the correct definition of weekly workload and occupancy factor.

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S0.P18

THE LICENSING AND COMPLIANCE VERIFICATION PROCESS IN CANADA FOR DIAGNOSTIC AND THERAPEUTIC APPLICATIONS IN MEDICINE

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The Canadian Nuclear Safety Commission (CNSC) regulates the use of nuclear substances and radiation devices used across Canada, including their use in diagnostic and therapeutic nuclear medicine. Canada has a very strong nuclear safety programme, as noted in by the IAEA in its IRRS Mission to the country in 2009. Canada has also been a leader in the implementation of additional controls and measures, such as the protection of risk-significant sealed sources and the response following the events at Fukushima. Under the Nuclear Safety and Control Act, established in May 2000, the CNSC has broad regulatory authority to issue licences and conduct regulatory compliance evaluations. On the other hand, the Provinces and Territories of Canada have jurisdictional authority for the industrial and medical applications of x-ray emitting equipment. This presentation will illustrate the process of licensing and compliance verification used at the CNSC for the authorization of nuclear substances and radiation devices in all medical applications. The risk-informed principles upon which the licensing and compliance verification system are established will be explained. In addition, the clarification of the roles of the provinces and other stakeholders in the delivery of authorization to use radiation in Canada will be provided. The presentation will include a description of the types of information required on an application for a nuclear substance licence and the assessment process. Information will also be presented on the approach used for compliance verification and the options available for the application of enforcement tools, as may be necessary.

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S0.P19

ROLE OF STATE RADIATION HEALTH CONTROL FOR IMPROVING RADIATION PROTECTION OF CHILDREN

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Radiation health inspectorate in Ruse controls radiation safety in North-East region of Bulgaria. In the eight years period after enforcing the new national regulation for radiation protection at medical exposure, radiation inspectorate put in focus protection of children. Departments where x-ray procedures on newborn and children are performed were inspected, with the aim to improve patient protection. Radiation surveys were carried out in Diagnostic radiology and Neonatology departments of seven regional hospitals and one specialized pulmonary children hospital, which is the only hospital in the country for long-term treatment of children with chronic lung diseases and tuberculosis. Dedicated checklist was used to survey the availability and use of protective and immobilization devices and gonad shields, as well as the status of x-ray equipment in respect to the acceptability criteria for radiological equipment and regulatory requirements for quality control. Initial survey demonstrated often use of obsolete equipment and impaired radiation protection particularly in neonatal departments. Medical staff was not aware of patient doses and they were not recorded. Measures were recommended and implemented as result of inspections. X-ray equipment was replaced in four neonatal departments, and additional protective measures were applied. All medical imaging departments were equipped with individual protective aprons and gonad shields, and fixed equipment was equipped with patient dose monitoring devices (KAP-meters). Patient dose recording was implemented in imaging departments, and establishment of typical local doses in short period of time was required. A weak place is the lack of sufficient medical physics support in small hospitals, especially for optimization of patient protection. Radiation health inspectorate plays important role in improving patient protection, with special emphasis to children. Two qualified medical physicist work in our department, and this is proved to be important for the quality of inspections.

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S0.P20

CONTEMPORARY ASPECTS OF THE CONTRIBUTION OF RADIATION CONTROL FOR REDUCING RADIATION EXPOSURE OF PATIENTS DURING MEDICAL RADIOLOGICAL PROCEDURES

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The contemporary changes in radiation control, in particular the control for reducing radiation or patients, have completely changed the vision and priorities of the health and radiation control following the coming into effect of Regulation No. 30 on the conditions and procedure for protection of individuals against ionising radiation. Sharing the experience in the enforcement of Council Directive 97/43/Euratom and Regulation No. 30 on the conditions and procedure for protection of individuals against ionising radiation. At the beginning of the enforcement of the Regulation the whole radiological equipment was tested, which lead to decommissioning of radiological equipment. The replacement of the outdated radiological equipment was conducted at the highest rate in 2009-2012. Nowadays, in 2014, the healthcare control shall be focused on the justification and optimisation of the application of radiological procedures. Stricter restrictions regarding the commissioning of used equipment should be stipulated. 'Compulsory' X-ray examinations under clinical pathways cannot exist and screening X-ray examinations should not be performed in the absence of ratified screening programmes setting forth strict requirements for the characteristics of the equipment, the qualification of the staff and the continuous control of the physical and technical parameters of the equipment, in the absence of which the screening is compromised. The provision of continuous and authentic control of the characteristics of the equipment, as well as an independent expert appraisal of the condition of the radiological equipment, is at the basis of all. The protection of both the staff and the patients against the dangers of radiation are two aspects of radiation control. However, the dynamics of and challenges faced by the control are definitely the result of the measures for the protection of patients against the dangers of medical radiation.

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S0.P21

A STUDY ON SHIELDING DESIGN FOR NEUTRON SOURCES USED IN MEDICINE

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The 252Cf and 241Am-Be are portable neutron sources used in laboratories and medical centers. Actually in medicine, some recent studies show the capability of using portable neutron sources for diagnostic purposes by the analysis of outgoing 10.8 MeV gamma rays produced by neutron interaction with 14N during the neutron activation of the whole body. Unfortunately these neutron sources generate high energy gamma rays in addition to neutrons. These gamma rays emitted from the source can be piled up and cause a disturbing effect on the spectrum of outgoing gamma-rays produced by neutron activation of the body. This disturbing effect leads to increasing the needed time for analysis and causes the increase of harmful biological effect on the patient. So, the gamma-rays generate by these sources must be eliminated in a practical way using a suitable shield with considering that the flux of thermal neutrons shouldn't decrease. In this work, the shielding effects on the 241Am-Be and 252Cf neutron sources were studied using MCNP simulation code. To investigate the validation of the simulation results, they were compared with experimental results obtained for an 241Am-Be source with 5 Ci activity. The results show that a spherical Bismuth shield of radius 2 cm and a spherical lead shield of radius 8 cm are suitable for 252Cf and 241Am-Be neutron sources respectively to reduce the gamma-ray component up to 80 % relative to a bare source. Experimental results show that using different layers of lead shield around the 241Am-Be source doesn't reduce neutron flux considerably which is in good agreement with simulation results that shows increasing less than 1 percent. Also experimental result show that using a spherical lead shield of radius 5 cm around an 241Am-Be source with 5 Ci activity decreases about half of piled up pulses which lead to false signals in Nitrogen region (9MeV-11MeV).

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S0.P22

RADIATION AND PATIENT SAFETY SERVICES IN KENYA

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Since each X- ray procedure imparts energy with ionizing capability to the tissues of the body, specific action must be taken to minimize any associated risk to the patient by eliminating any radiation exposure that is not required for the formation of the images necessary for each clinical objective while minimizing exposure to Patients, Radiation Technicians/technologist and the general public proximal to the exposure units. While there are some common principles of protection that apply to all X ray imaging procedures, many of the most significant issues and actions are related to the methods and modalities being applied. I and other stakeholders believe that training and equipping (through workshops, fellowships, adequate quality assurance equipment etc.) for health professionals on protection matters related to radiology, nuclear medicine and radiotherapy is one of the most effective means of achieving radiation safety. Medical exposures in Kenya are under regulatory control, with appropriate authorizations by the regulatory body specifying, through regulations, license conditions and Standards and requirements for radiation safety. Most of these providers are using unqualified or in-appropriate personnel to carry out the QA and monitoring services, adding to the risks. Aims of the paper •To align the healthcare professionals in Kenya and beyond to take the leading role and ensure that biomedical engineers are spearheading the various country radiological policies and developments. •Ensure the prime participation in quality assurance through liaison with the radiation protection board of Kenya in certifying Radiation safety service providing companiesand personnel in the two areas of Quality assurance and control including dose monitoring. •Identify the techniques required to entrench safety culture among health workers in this area. •Dose Limits, reference levels and effects to personnel and its implications. Expected outcomes: 1.Biomedical engineers and technical personnel to show active and strong authoritative presence in the radiology field. 2.Alignment to be part of all the regulatory bodies, bureau of standards handling hospital engineering and medical equipment in Kenya. 3. Radiology engineering professionals' inventory and promotion unit at nationally, to advocate for fellowships, training and equipment funding.

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S0.P23

THE CALIBRATION PROCESS OF OSL DETECTORS USED FOR STAFF AND PATIENT DOSIMETRY IN HOSPITAL ENVIRONMENT

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The optically stimulated luminescence (OSL-BeO) dosimeter is increasingly being used as a dosimetric technique in various fields such as medical,environmental and spacedosimetry. The in hose calibration process for usage of OSL's at hospital was arranged according to the encapsulated Iodine-131 radioactive source which is used in nuclear medicine department. This process is helpful for confidence of OSLs used for dosimetry of staff and patients treated with high activity I–131. I–131 is the most frequently used source for thyroid carcinoma therapy. In the fixed activity protocol, a high activity 3.7-7.4GBq(100-200 mCi) I–131 is administered. The beta is often dominant radiation for treatment, although the associated gamma emission gives rise to exposures to other tissues and even to other individuals. In this study high activity (100mCi) encapsulated I-131 was used as calibration source. This source was placed in Plexiglass tube. The measurement point was planned in different radial distances which are 30, 50 and 100cm from source free in air. These positions were used to measure dose rate by Geiger–Muller (GM) detector. On the other hand 3 pieces of OSL with cover carrier which are used in calibration process was placed in the same positions. The irradiation exposure time was one hour for all of OSLs. The OSLs were supplied by a private organization and the reading process performed by them. The standard calibration process was carried on with beta emitter sources like Sr–90.For two type detectors the background values were measured in the room which planned to perform calibration process. The background value was 0.11mR/h. The corrected readings at mentioned positions were 136.9, 54.9 and 15.5mR/h. Also the mean background value of OSLs was 0.12 and 0.11 mSv based on Hp10-Hp007. The corrected OSL Hp10-Hp007 read outs at same distances were 1.67, 0.59 and 0.14mSv and 1.90, 0.77 and 0.18mSv respectively. The measured values in mR/h by GM were converted to mSv. These were 1.19, 0.477 and 0.135mSv for the queue geometric positions. The inverse square law consistency in both measurements was found (R2=0.99). The reliable use of OSLs in dosimetry of staff and particularly patients was provided. In a typical yearly workload, the average annual dose to the whole body for all staff by OSL was 0.80mSv. After administration of 100mCi therapeutic dose to specific patient,this value was 97.5+32.6mSv.

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S0.P24

REGULATIONS, STANDARDS AND IMPLEMENTATION.

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Laws, Regulations, and Standards Guidelines are the key in implementing a successful Radiation protection program. In United Republic of Tanzania, regulation of radiology and radiation facilities, is provided by two Regulatory Authorities, established by Laws namely “The Tanzania Atomic Energy Commission” the Atomic Energy Act No 7 of 2002, and “The Medical Radiology and Imaging Professionals Council” the Medical Radiology and Imaging Professionals Act No.21 of 2007. While the later regulates facilities producing radiation and the latter regulates profession and practice. Strengthen capabilities of Radiology and Imaging practice so that procedures are performed in accordance with regulatory requirements and licencing conditions. Inspection tools were developed in form of checklists, QC Kits and Inspection manuals acquired. Teams with mixed expertise selected, oriented and facilitated to make inspection visits. Study was conducted through supervisory and inspection visit. Public and Private facilities in Dar es Salaam were visited and on spot guidance to professionals were done. In some facilities practice was conforming to a number of prescribed requirements. Radiation symbols, protective shields and door protection guides were available in most facilities. In others such requirements were not known and documents of these guides were not available. Some Professional were not very conversant with the Regulatory Bodies. Regulatory bodies play an important role in ensuring adherence to laws, regulations and standard guidelines. On spot inspection of facilities enhances compliance and Professionals gains greater experience in implementing good radiation protection practice.

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S0.P25

MODELLING THE EFFICIENCY OF SSNT DETECTORS FOR LONG-TERM RADON RADIATION DOSIMETRY, THROUGH IN-SITU MEASUREMENTS AND MONTE-CARLO TECHNIQUES

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International studies of radon indoors and in workplaces have shown significant radiation dose burden of the general population due to inhalation of radon (222Rn) and its short-lived decay products (218Po,214Pb, 214Bi, 214Po). As far as atmospheric radon concerns, 222Rn, is not necessarily in equilibrium with its short-lived daughters. For this reason, radon's equilibrium factor F was solved graphically as a function of the track density ratio R = D/Do, namely of the ratio between cup-type and bare CR-39 (Solid State Nuclear Track Detectors SSNTD) detectors. Utilising Monte-Carlo methods, CR-39's sensitivity to radon's decay alpha particles was calculated. Monte-Carlo inputs were adjusted according to actual concentration measurements of radon, decay products and F. From output of the, so adjusted, Monte-Carlo codes, Do was calculated. Concentration measurements were further utilized for the calculation of the unattached fraction, fp, in terms of PAEC. This was employed for the calculation of F in terms of ratio (A4/Ao) and (A1+A4/Ao), where Ai represents the activity concentration of radon (i = 0) and progeny (i = 1,2,3,4). Measured and calculated values of F were plotted versus the track density ratio R. The results were fitted and checked with model's predictions. The present study verifies findings of similar work in the literature that CR-39 registers alpha particles from radon and progeny identical either if enclosed in a cup or bare. Observed track density differences are attributable only to the fact that cup type CR-39 dosemeters are proportional to radon concentration only, while bare CR-39 SSNT Detectors register proportional to the concentrations of all alpha-emitters.

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S0.P26

A HOLISTIC APPROACH TO RADIATION SAFETY

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Each year approximately 3.6 billion x-ray examinations are performed worldwide1 leading to earlier and more accurate diagnosis of medical diseases. However, considerable concern has been voiced regarding the stochastic and even deterministic impact on both patients and medical staff2. Authorised bodies have therefore emphasised the importance of ensuring the proper performance of x-ray equipment and of keeping the dose to medical staff and patients as low as reasonably achievable. This suggests that a holistic approach is required to ensure overall radiation safety. One central aspect of radiation safety is the regular quality assurance and servicing of diagnostic x-ray equipment3. Only when equipment complies with legal regulations, can it be assumed that it emits only the selected dose during diagnostic x-ray applications. To ensure accurate measurements and dependable results, the measurement devices used for the quality assurance of diagnostic x-ray equipment need to be precise and easy to handle. Safety awareness among medical staff working with the equipment who are exposed to scattered radiation represents another important aspect affecting radiation safety. As empirical studies indicate a causal relationship between x-ray dose exposure in interventional radiology and an increased risk of severe diseases such as brain tumours4 and cataracts5, wearing the legally-required badge might not be enough. In order to avoid unnecessary radiation exposure, it is recommended that medical staff should be able to monitor their exposure to scattered radiation during interventional procedures in real-time. In this regard, ICRP6 recommends a second dosimeter worn outside the lead apron to better monitor personal dose exposure. A third central aspect of radiation safety concerns the dose to the patient. When it comes to best practices in radiation safety for patients, some basic guidelines are widely referenced7: Medical imaging examinations should only be performed if medically justified (Justification) and if so, patients should receive an optimal x-ray dose which is as low as reasonably achievable (ALARA) while maintaining sufficient image quality to meet the diagnostic need (Optimisation). Comprehensive systems for patient dose management have been identified as valuable means of supporting these guidelines.

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