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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 IOMP Journal Medical Physics International (MPI) successfully completed its first 4-year term in 2017. During this time the IOMP Journal that is dedicated to educational and professional issues published more than 650 pages of reviewed papers and c. 1300 pages with abstracts of IOMP- supported Conferences. A number of the papers in the first 10 issues were downloaded more than 5,000 times each.

The success of the MPI Journal proved the need of a forum for discussion of our educational, professional and other related issues. This is specially important for topics related to e-Learning (e-L), as often e-L materials have short period of life and require quick dissemination and use. Behind the establishment of the Journal was the necessity of an e-L forum. This was identified in the Special Issue on “e-Learning in Medical Engineering and Physics”, published by the Journal Medical Engineering and Physics (Guest-Editor S Tabakov, 2005). This idea was further developed through the ICTP College on Medical Physics, which was regularly served by the free web-sites of Sprawls Educational Foundation and Emerald/Emit/Emitel projects. The IOMP ExCom approved the idea of Journal establishment in 2012 and by the end of the year the foundations of MPI were laid down: the name was suggested by W. Hendee; an ISSN number was obtained (2306-4609), a web site was made by M Stoeva, and an Editorial Board was formed including colleagues from IOMP ExCom and representatives of the IOMP Regional Organizations (Federations).

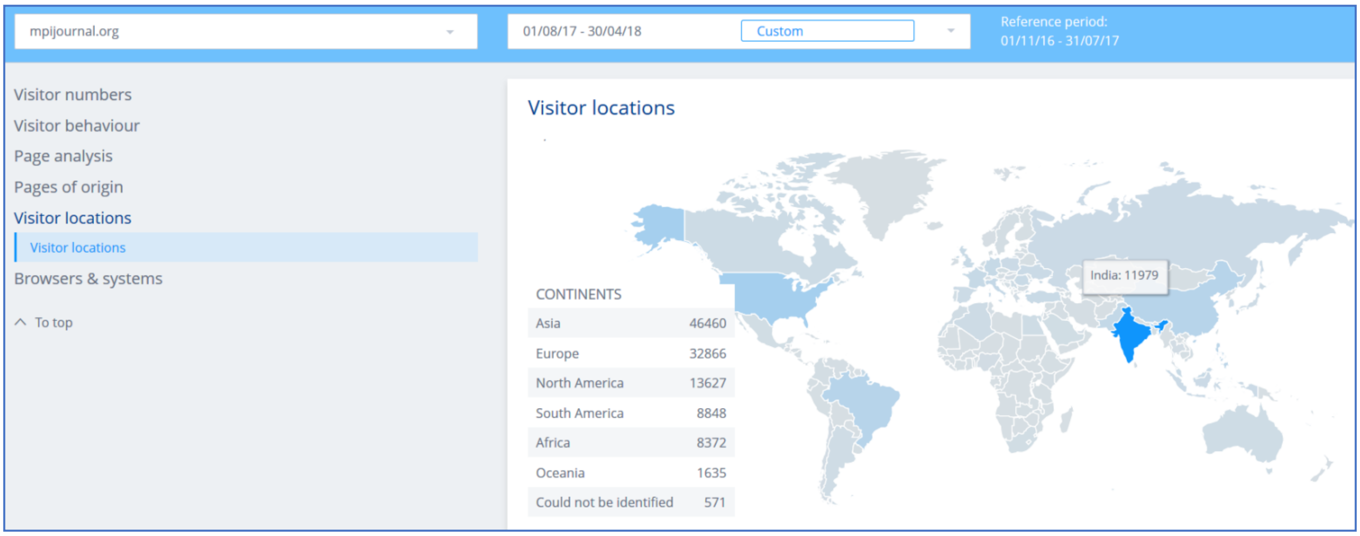
We are grateful to all Founding members of the MPI Editorial team: KY Cheung; Madan Rehani; William Hendee; Tae Suk Suh; John Damilakis; Virginia Tsapaki; Raymond Wu; Simone Kodlulovich-Renha; Anchali Krisanachinda; Taofeeq Ige; Technical Editors: Magdalena Stoeva and Asen Cvetkov; Editorial Assistant: Vassilka Tabakova.

We are also specially grateful to the authors of all papers submitted and published in the MPI Journal. It was mainly due to them that the Journal had such a successful start and continues to engage an ever growing number of readers and authors.

As usual, we are including some brief statistics from the server of MPI Journal. This official statistics includes not only the readers, but also the geographical spread of the Journal usage and the most frequently read papers. For example only in one randomly selected day (10 Sep 2017) there have been between 10 and 50 readers per hour. The figure below shows part of the server statistics of MPI during the period covering August 2017 to April 2018 – the visits are about 11,000 per month, while their geographical spread indicates that more than 50% of readers are from Low-and-Middle-Income countries.

At the IOMP ExCom meeting in Jaipur (Nov 2017), the Founding MPI Editors-in-Chief (S Tabakov and P Sprawls) were approved to continue leading the Journal for another period of 4 years and additional members were included in the Editorial Board. The new period of the MPI Journal started with the first Special Issue of MPI, dedicated to the large IOMP Project “History of Medical Physics”. This Speciall Issue is available for free download from: www.mpijournal.org/pdf/2018-SI-01/MPI-2018-SI-01.pdf It includes the first chapters of the History of the profession, related to X-ray Tubes, Radiographic Receptors and e-Learning. The new current issue here includes a number of new papers, as well as abstracts from the IOMP School from Prague (WC2018). We are looking forward to the further success of the MPI – the IOMP Journal dedicated to education, training and professional issues.

Slavik Tabakov and Perry Sprawls
MPI Journal Co-Editors-in-Chief



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MPI SPECIAL ISSUE No.1 (2018) - HISTORY OF MEDICAL PHYSICS

This first Special Issue of the IOMP Journal Medical Physics International (MPI) from April 2018 begins the series of publications linked with the IOMP project "History of Medical Physics", announced last year at MPI, 2017, No1, p. 68-69 (April 2017).

This MPI Special Issue can be downloaded free from: www.mpijournal.org/pdf/2018-SI-01/MPI-2018-SI-01.pdf

In this Special Issue, prepared for publication during 2017-2018, there are three chapters from two of the volumes. The chapters are about the History of X-ray Tubes development (49 pages), the History of Film-Screen Receptors development (31 pages) and the History of e-Learning development (30 pages). Here below is the Content of the three Chapters:

X-Ray Tubes Development (Rolf Behling)

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Acknowledgements

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These Chapters were prepared to be used as Guides for the development of future chapters in this large project. Using the experience from another large project (e-Encyclopaedia of Medical Physics), we are aware that such Guides are setting important trails in the parallel work of various specialists from many countries.

The results (chapers and volumes) of the project will be published by the MPI Journal. Contribution to this large project is welcome from all colleagues (in the various volumes of the History). To facilitate the progress of the project we sent Questionnaires to all Societies and included a History session during the World Congress in Prague.

MPI Co-Editors: Slavik Tabakov and Perry Sprawls

EDUCATIONAL

MATRAD - AN OPEN-SOURCE TREATMENT PLANNING TOOLKIT FOR EDUCATIONAL PURPOSES

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Abstract— **We present educational aspects of matRad – an open-source treatment planning toolkit for three-dimensional intensity-modulated radiotherapy treatment planning supporting photons, scanned protons and scanned carbon ions. matRad is publicly available for download on GitHub and does not require payable software-products to run or to change its source code. This manuscript helps new users to get familiar with the basic concept, the matRad GitHub environment, and potential applications. Specifically we discuss seven novel workflow examples that illustrate usage of matRad's code base and we introduce three practical treatment planning examples from a planner's point of view. The workflow examples and the treatment planning tutorial are available in the form of Matlab scripts and documented with pdf files and wiki pages, respectively. They are intended as both learning and teaching material, e.g., in a classroom setting. The provided examples range from simple to complex treatment planning scenarios and can all be executed in a couple of minutes on a standard desktop computer.**

Keywords— **radiotherapy, treatment planning, DICOM, open-source, optimization, dose calculation**

I. INTRODUCTION

According to the World Health Organization nearly every sixth death in 2015 was caused by cancer. There are various approaches to treat cancer, such as surgery, chemotherapy, radiotherapy, immunotherapy or target agents. More than 50% of all cancer patients are either treated with radiation therapy as primary treatment or in combination with aforementioned approaches [1]. The most common type of radiation therapy is external beam therapy, which is characterized by directing ionizing radiation from the outside into the patient's body in order to sterilize cancerous tissue.

Integral part of radiation therapy is a computer-aided process called treatment planning, which is performed upfront to the actual patient treatment by the usage of specialized software. The aim of the treatment planning process is firstly to simulate the dose deposition within the patient body and secondly to optimize the dose distribution according to clinical objectives and constraints that define a trade-off between tumor irradiation and normal tissue sparing.

In the past decade, the advancement of radiation therapy in general and treatment planning in particular correlated strongly with the technical developments of computer hardware. This led to conceptually more complex treatment techniques, such as intensity- (IMRT) or volumetric-modulated arc radiation therapy (VMAT) which are accompanied by more sophisticated treatment planning software and algorithms.

Nowadays, the software landscape in radiation therapy is dominated by commercial closed-source products, also due to safety regulations. This limits a flexible application for education and research. Besides the closed-source characteristic, such specialized treatment planning software is usually very expensive, thereby limiting its availability for research and education in developed and even more in developing countries.

Consequently, there is a need for educational open-source treatment planning software in the medical physics community to ease the way of teaching basic workflow principles and concepts along with their algorithms. In the past, various open-source systems evolved in the radiotherapy area, whereby most of them focus on specific treatment planning aspects [6, 12, 14].

Recently, we have introduced matRad [17], an open-source dose calculation and optimization toolkit for intensity-modulated radiation therapy with photons, scanned protons, and scanned carbon ions. Here we report on potential applications of the matRad toolkit in an educational setting. Hence, this manuscript will not be a typical research paper but rather a description of matRad's functionalities and characteristics and how they can be used for teaching. Furthermore, we provide learning material to support beginners getting started with matRad and course material for medical physics instructors.

II. METHODS

A. Overview

matRad is an open-source multi-modality treatment planning toolkit that is entirely written in the interpreted numerical programming language Matlab and covers a wide range of functionalities from DICOM import, photon, scanned proton and scanned carbon ion dose calculation, dose optimization to plan visualization. matRad's code base corresponds to a flexible and modular set of functions containing well established radiotherapy algorithms with clearly structured function interfaces.

The software package is published under the GNU public license[1] and the complete source code along with a standalone version and open-source patient data sets can be downloaded for free from the file hosting service GitHub[2]. Moreover, the source code, excluding the graphical user interface (GUI) is compatible, with GNU Octave.

matRad was developed with the intention (i) to support gaining experience with radiation therapy treatment planning, (ii) to allow for algorithmic developments on top of the basic toolkit, (iii) to be used as a learning and teaching tool, and (iv) to enable its application in research.

Throughout the manuscript we will highlight matRad data, i.e., Matlab variables, and algorithms, i.e., Matlab functions, using the Courier New font (`e.g., matRad_fluenceOptimization`). In section II.C we start explaining the semantics of the main variables used in matRad, before we focus on specific matRad functionalities and aspects, e.g., DICOM import, plan visualization, base data format, and educational characteristics of the source code repository in II.D-II.I. In section III, we present online course material of detailing different matRad workflows.

B. Prerequisites

In order to run matRad, we recommend to use a system having at least a 64-bit processor with 1 GHz, 4 GB RAM and 100 MB hard disk space. Besides the image processing toolbox, which is required for the DICOM import, no other Matlab toolbox is needed to run matRad in its entirety including inverse optimization. We have actively tested compatibility with Matlab version ≥ 8.3 (R2014a).

This manuscript refers to matRad version 3.0.0. Being under active development, function- and variable-names may change in future releases.

C. Understanding and setting up matRad

matRad models a radiotherapy treatment planning workflow by consecutive function calls and organizes the relevant data for treatment planning in multiple structures in the base workspace of Matlab as illustrated in Table 1. The main sequential treatment planning steps are briefly described next.

Patient data can either be imported using matRad's import interface (compare section II.E) or by loading one of the existing open-source patient data sets. Two variables (`ct`, `cst`) have to be available in the Matlab workspace in order to proceed. The first variable (`ct`) holds the computed tomography (CT)/imaging data stored as a structure array; the corresponding segmentations of volumes of interests (VOI) are stored in a cell array labeled `cst`. Apart from the voxel index list for each VOI, the `cst` contains meta information for dose optimization, such as the overlap priority and constraints/objectives used to calculate the objective function value during inverse optimization.

In the next step, meta treatment planning parameters, e.g. the radiation modality, beam angles, and bixel spacing, have to be defined in the `pln` structure array by the user before the beam geometry information is generated in `matRad_generateStf` and stored in the `stf` structure array.

Table 1: matRad variables as of version 3.0.0.

Variable name	Description
`ct`	ct images and ct meta information
`cst`	segmentations along with constraints & objectives for dose optimization
`pln`	treatment plan information
`stf`	beam geometry information
`dij`	dose influence information
`resultGUI`	dose distribution with corresponding bixel/pencil beam weights

Once the beam geometry information is available, photon or particle dose calculation in water for unit fluences can be carried out (`matRad_calcPhotonDose` or `matRad_calcParticleDose`). The dose calculation function outputs a structure array labeled `dij`, which holds the dose contribution for each individual bixel/pencil beam. Next, the fluence optimization function (`matRad_fluenceOptimization`) can be called in order to optimize individual bixel/pencil beam weights such that the resulting dose distribution produces

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[1] The license agreement is available on https://github.com/e0404/matRad/blob/master/LICENSES.txt

[2] http://www.matrad.org/

a minimal objective function value according to given constraints and objectives. The optimized dose distribution is ultimately stored in a structure array called `resultGUI`, which allows plotting of dose volume histograms (DVHs) and computation of quality indicators, such as mean dose and maximum dose. If the optimization does not produce acceptable results, a re-optimization using different parameters can be carried out until the dose distribution is deemed satisfying.

For photons, we also provide an experimental multileaf collimator sequencing and a direct aperture optimization algorithm.

To illustrate the sequential workflow and the compactness of the code, Figure 1 presents the complete source code for an intensity-modulated scanned proton treatment plan that consists of dose calculation, inverse dose optimization and visualization.

```
load('TG119.mat'); % load ct and cst
%% define treatment plan
pln.radiationMode = 'protons';
pln.machine       = 'Generic';
pln.numFractions  = 30;
pln.propStf.bixelWidth   = 5;
pln.propStf.gantryAngles = [0 45 315];
pln.propStf.couchAngles  = [0  0   0];
pln.propStf.numOfBeams   = 3;
pln.propOpt.bioOptimization = 'const_RBExD';
pln.propStf.isoCenter = ones(3,1) *  ...
matRad_getIsoCenter(cst,ct,0);
%% generate geometrical steering information
stf       = matRad_generateStf(ct,cst,pln);
%% perform dose calculation
dij       = matRad_calcParticleDose(ct,cst,stf,pln);
%% perform optimization
resultGUI = matRad_fluenceOptimization(dij,cst,pln);
%% start visualization
matRadGUI
```

Figure 1: matRad code generating a proton treatment plan on phantom TG119

In principle, there are three different ways to run matRad. The first possibility is given by executing scripts directly from the command prompt in the integrated development environment (IDE) of Matlab. For instance, users can start the script `matrad.m` in the root folder of matRad, which defines a default intensity-modulated photon treatment planning workflow. Alternatively (or complementary), users may want to work with the GUI by executing `matRadGUI` from the command prompt.

The second option to run matRad is given by using GNU Octave instead of Matlab, which is explained in detail in section II.F.

The third option is intended for users not familiar with the scripting language or users who do not intend to make code changes. For this group of users, we provide a matRad standalone executable for Windows 7, 8, and 10, which is able to run all functionalities via the GUI. The standalone does not require a Matlab product license. Only the freely available system-specific Matlab runtime package[3] is needed and automatically downloaded during the installation of the matRad standalone.

D. Base data format

matRad 3.0.0 comprises three open-source base data sets for treatment planning that can be used for analytical photon, proton and carbon ion dose calculation, respectively. As a side note, for photons we provide the possibility to interface to the Monte Carlo (MC) photon dose calculation VMC++.

Each base data set is stored in a separate file using Matlab's file format (*.mat) and is named according to the concatenation of the radiation type and the treatment machine (e.g., `protons_Generic.mat`). Since we provide base data sets for generic treatment machines, all base data sets end with `Generic`. The differentiation of radiation modality and treatment machine allows to keep multiple base data sets in parallel, whereas each depicts a different radiation modality or a different treatment machine.

Base data sets are stored as Matlab structure arrays. The base data sets contain, apart from the actual beam data, also meta information such as the name of the selected treatment machine, the utilized lateral beam model, the creation date and radiation modality. In the following, we explain the photon and particle specific base data set properties separately.

Photon base data format

matRad facilitates a singular value decomposed pencil beam algorithm for analytical photon dose calculation [3]. This reduces the beam description of a fully depth-dependent convolution pencil kernel to three depth-independent radial kernels. These kernels are stored in the `photons_Generic.mat` file as a structure together with the primary fluence of the accelerator and geometrical information about the treatment device. The photon base data set provided for free with matRad describes a 6 MeV SIEMENS Artiste 3; detailed instructions how to establish the base data set for your own accelerator can be found in [3].

The photon base data set was obtained from the clinically approved photon dose calculation engine PDC++ for 501 different source to surface distances (from 500 mm to 1000 mm in 1 mm steps). Besides the source to axis distance (SAD), the source to collimator distance (SCD) is also stored in the base data set. These distances are required during dose calculation to determine the treatment-specific source to surface distance (SSD) in order to select the corresponding scattering kernels and depth dose components.

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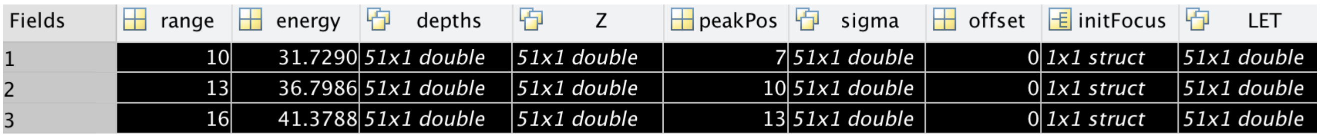
[3] http://www.mathworks.com/products/compiler/mcr

Particle base data format

matRad facilitates a conventional pencil beam algorithm for analytical particle dose calculation [15] supporting protons and carbon ions. In total, we provide for each modality around 120 different beam energies, which are all stored in the multi-dimensional substructure `data`. Figure 2 depicts an overview of the first three proton energies of the generic base data with ranges of 10, 13 and 16 mm, respectively. For each individual beam energy, we store the range [mm], initial beam energy [MeV], peak position [mm] and an offset [mm] as scalar values. The offset value measured in water equivalent path length allows to shift the entire beam to model additional material in the beam line. Moreover, we store the integrated depth dose (IDD) profiles [MeV cm^2 / g / 10^6 primaries] and the lateral spread (sigma) [mm] due to Multiple Coulomb scattering using a single Gaussian approximation at given depth values as vectors.



Fields	range	energy	depths	Z	peakPos	sigma	offset	initFocus	LET
1	10	31.7290	51x1 double	51x1 double	7	51x1 double	0	1x1 struct	51x1 double
2	13	36.7986	51x1 double	51x1 double	10	51x1 double	0	1x1 struct	51x1 double
3	16	41.3788	51x1 double	51x1 double	13	51x1 double	0	1x1 struct	51x1 double

Figure 2: The first three entries of the proton base data set

If a single Gaussian lateral beam model is used, as it is the case for the public base data set, the lateral spread is stored in a subfield named `sigma`. If a double Gaussian lateral beam model is facilitated, then the component modelling the inner core is stored in the subfield `sigma1` and the broader low dose component is saved in `sigma2`. Their relative contribution is controlled using the subfield `weight`.

For protons and carbon ions there are, compared to photons, additional parameters available to accurately model the beam divergence in air and to consider multiple initial beam widths (also known as beam foci).

First, the `SAD` parameter corresponds again to the geometrical source to axis distance in millimeter. The second one, `BAMStoIsoDist` denotes the geometrical distance from the beam application monitoring system (BAMS)/beam nozzle to the isocenter. Next, a lookup table `LUT_bxWidthmimFWHM` is stored, which determines the initial beam width to be used during treatment planning. Let N be number of depth values used in the lookup table, then `LUT_bxWidthmimFWHM` is of size 2xN. In the case of the public base data set, this table contains only four values (2x2 matrix). As we provide only one beam width, we set the minimum required full width half maximum (FWHM) to a constant value for lateral pencil beam spacings from 0 to infinity. This lookup table allows users to specify, the usage of a certain beam width given a certain lateral pencil beam spacing.

Last, we keep for each initial beam energy a substructure named `initFocus`. This structure allows to store lookup tables for the beam widening in air as function of the geometrical distance for multiple initial beam widths. As we provide one focus in the public base data set, only one lookup table can be found in here. However, if desired, the beam widening in air of multiple initial beam widths can be added to each initial beam energy in the base data set. The actual beam width on the patient surface is then calculated considering the constraint given by `LUT_bxWidthmimFWHM`, the SSD and the spread in air of the utilized beam width. A detailed description of the particle base data set format can be found in the wiki[4].

For protons, we additionally provide the linear energy transfer (LET) according to [18], which allows the future usage of phenomenological variable relative biological effectiveness (RBE) models or LET-based optimization. In contrast, for carbon ions we supplementary provide dose-averaged radio sensitivity parameters of the linear quadratic (LQ) model to enable variable RBE calculations based on the local-effect model (LEM) IV for a generic early and late responding tissue. For a detailed explanation of the carbon base data set we refer to [17].

If users want to perform treatment planning mimicking a specific particle treatment machine, then Monte Carlo particle transport simulations (e.g., using TOPAS, FLUKA) need to be performed considering beamline specific geometries and machine specific characteristics. Simulating the dose deposition of individual pencil beams for various initial beam energies in water allows in a further step to extract the IDD profiles. In addition to the IDD, the lateral beam profile represented by either a single or a double Gaussian needs to be fitted to the lateral dose distribution in each depth, respectively.

E. Import and Export

The matRad code base comprises the open-source CORT dataset, i.e., three segmented patient CTs, [5] as well as two phantom CTs. We provide the data as Matlab files, organized in the matRad data structures `ct` and `cst`.

Furthermore, own patient data may be imported either via a DICOM import interface based on Matlab's image

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[4] https://github.com/e0404/matRad/wiki/Particle-Base-Data-File

processing toolbox or via custom import interfaces for binary data formats (e.g. NRRD).

matRad's DICOM import functionality allows to import CT images, radiation therapy (RT) structure set, RT Dose, and RT Plan files. In order to load patient data, the user has to specify the input directory. The directory can contain files of multiple patients and multiple image series of a single patient. After reading the input directory, the user is able to choose the desired patient and select suitable RT DICOM files. The use of a Hounsfield unit look up table (HLUT) is recommended and can be provided in the directory *.../dicomImport/hlutLibrary*. Specifically, HLUTs need to be accessible by matRad to convert Hounsfield units in case of photon dose calculation to electron densities relative to water or in case of particles to stopping powers relative to water. If no HLUT can be found for the corresponding CT, a generic table will be used independent of the radiation modality.

By default, all images (segmentation and dose) are resampled at the import resolution of CT. The user may chose the grid of the CT, the grid of the dose or specify any resolution in x, y, and z directions. When a plan file was selected for import, the user is asked to specify a proper machine base data set to be able to perform a dose re-calculation. After successful import of the DICOM files, the user is prompted to save a binary Matlab file containing `ct`, `cst`, and - if applicable `pln` as well as `resultGUI` structures corresponding to CT images, RT structures, and plan data. This file can be loaded directly to matRad for treatment planning.

Other than DICOM, binary data export and import supports only a limited set of file formats. So far, matRad can export any image/cube to the established formats NRRD [19], MetaImage (MHA/MHD) [20], and VTK image [2]. Import is possible only for NRRD files with basic functionality; an image file for the CT and binary images for the segmentations are required, with the meta-information (i.e. resolution, dimensionality etc.) being collected from the file headers. Users must take care of matching resolutions and dimensionality, and additional tweaking of the resulting workspace variables might be necessary.

F. Visualization and Plan Evaluation

The GUI includes a visualization engine to display axial, sagittal and coronal slices of the CT image set. Using the GUI, different colormaps, value windows (with available presets), and units (i.e. Hounsfield units or electron density/stopping power) may be selected, depending on the CT in use. Segmentations are displayed as (pre-computed) contours. Optimized or imported dose distributions can be displayed as a transparent colorwash overlay with a set of available colormaps, and users can define which isodose lines should be displayed explicitly. For particles, matRad calculates besides the total dose distribution also the dose distribution of each individual beam.

Complementary to the slice view in the GUI, a 3D view can be opened, rendering VOIs as isosurfaces and additionally visualizing the plan geometry. While the matRad GUI contains sliders and input fields to adjust the color mapping as well as selectors to hide or show certain entities, the visualization may be modularly executed from a script or the command line, allowing to draw the desired sub-images also within other Matlab figures/axes apart from the GUI to create graphics for publication or presentation purposes. Alternatively, the GUI provides a "screenshot" functionality to export the current slice view directly to an image or Matlab figure file. Apart from visualization of the optimized or imported dose distributions, calculation of volume-based clinical endpoints, i.e., quality indicators, is available in matRad. This includes basic indicators like mean and standard deviation of the dose in a VOI, DVHs [7] and the corresponding dose-volume points, as well as conformity and homogeneity indices [10, 13].

G. Matlab and GNU Octave

Matlab is a proprietary high-level programming language developed by The MathWorks, Inc. primarily intended for numerical computations. The matRad toolkit is also compatible with GNU Octave [8, 9] which is an open-source alternative to Matlab. Since Octave is part of the GNU project, it is free software under the terms of the GNU General Public License. Octave development is intended to be mostly compatible with the Matlab language. Similar to Matlab, GNU Octave also contains an integrated development environment in addition to the traditional command line interface and a graphical user interface with limited functionality compared to Matlab.

There are two main limitations of using matRad with GNU Octave. First, the matRad GUI is not supported in Octave. While matRad's GUI is not mandatory for the treatment planning workflow, it provides a valuable graphical interface for data visualization and handling of DICOM data. The second limitation is related to the dynamically loadable MEX-files of the Matlab interface for the Ipopt (Interior Point OPTimizer) software package [16]. The Matlab interface of Ipopt available from COIN-OR under the Eclipse Public License is linked against the linear solver MA57 included in the Matlab software. In order to use Ipopt with GNU Octave, the Ipopt package as well as a linear solver, e.g., MUMPS[5], needs to be compiled for the user's platform and the Matlab interface of Ipopt has to be compiled and linked with GNU Octave. This procedure is also described in detail on our wiki page (see section H).

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[5] http://mumps.enseeiht.fr

H. How to access and contribute

We host our complete source code on the web-based version control system GitHub. The code itself is stored and structured as part of a project repository.[6] This allows for version control and the management of different code bases, i.e. branches.

The most stable and tested code can always be found in the 'master' branch, whereas the development branch 'dev' combines the latest feature developments. Individual feature developments can be found in 'dev_feature1' before being merged into the 'dev' and then further into the 'master' branch. By using GitHub, we can publicly perform transparent source code management keeping track of all changes.

When using the versioning control system git, the source code can either be directly cloned from the public project repository or it can be forked into the user's public GitHub environment and then be cloned to the users local system. Alternatively, the source code can simply be downloaded without version control as zip file from the corresponding code branch.

Besides source code management and public accessibility, GitHub also provides bug tracking, project/task management and a wiki functionality.

The issue page on our GitHub project page serves, besides matRad@dkfz.de, as a contact point to report bugs, to ask questions, and to leave ideas for feature requests. Furthermore, GitHub enables transparent code development and clear authorship tracking. Since matRad is intended to be a medical physics community toolkit, we encourage also others to contribute to the public code base either via bug fixes, code improvements, or new features.

In particular, the GitHub 'pull request' workflow provides a suitable solution to easily integrate code contributions from others. Once a pull request has been made, we as the repository owner can review, comment on the new code contribution and can then further accept, reject, or leave the pull request open. In most cases, an iterative code review process is started to further improve the new code contribution. After successful code integration into the public project repository, the contributor is automatically listed in the public URL[7] and is associated as author of the corresponding code lines.

I. Wiki and training material

Along with the actual source code, GitHub allows to host a project wiki.[8] The matRad project wiki is a collaborative effort to provide various kinds of information about matRad. As of now, the wiki comprises 29 pages. It is the best starting point for new users to get familiar with matRad. The wiki page can be edited directly by any GitHub user in the web browser by using the markup language.

The wiki is mainly comprised of three parts. The first part is a quick overview page about what matRad actually is. The second part provides a quick-setup guide intended to help new users getting started with matRad for the first time. The third part of the wiki includes detailed technical documentation describing among others, the general workflow, the main variables used in matRad, and the implemented algorithms along with their functionality.

Furthermore, the wiki links to a 40-minute long webinar which was given by Dr. Mark Bangert for the medical physics brown bag seminar in summer 2016 at the Massachusetts General Hospital.

For additional information, we also want to explicitly refer to two previously published manuscripts about matRad. The first paper [4] describes the initial version and core functionalities of matRad in 2015 and the second paper [17], published in 2017, reports on recent developments and the validation of matRad's core components (ray tracing, photon and particle dose engine).

III. RESULTS

In the first part of the result section, we present selected planning workflow examples based on matRad. In particular, we focus on executing functions from a script and explain how to run a dose calculation, how to trigger dose optimization, how to manipulate variables using the Matlab command prompt, and lastly how to analyze and visualize the resulting dose distributions.

The second part depicts practical radiotherapy treatment planning examples for photons and scanned protons from a treatment planner perspective aiming to teach the ability to create reasonable treatment plans.

A. Workflow Examples

The workflow examples are designed for new users who want to learn how to use matRad. They showcase treatment planning tasks and provide inspiration for customized usage of matRad's functionality. In total, we introduced seven use cases; corresponding Matlab scripts are located in the subfolder 'examples' of the matRad code base.

The first workflow example explains how to create a user-specific cubical or spherical phantom geometry (`ct`) in line with a corresponding segmentation, i.e., `cst` variable. The intention of this example is to develop an understanding for the `ct` and `cst` variable. In addition, generic phantoms might be valuable later on for testing user-specific code implementations.

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[6] https://github.com/e0404/matRad

[7] https://github.com/e0404/matRad/graphs/contributors

[8] https://github.com/e0404/matRad/wiki

The second workflow example generates two treatment plans for intensity-modulated radiation therapy with photons for different beam ensembles on the open-source phantom TG119. In the end, a visual comparison of the resulting dose cubes is performed, whereas in the analysis, the dose to 95% of the volume of interest (D95) of both treatment plans is compared.

The third workflow example represents an intensity-modulated photon treatment plan for the open-source head and neck patient. Besides a multifield optimization, multileaf sequencing is applied to translate the continuously optimized fluences into multiple deliverable static segments. Lastly, direct aperture optimization is carried out followed by calculating quality indicators and DVHs.

The fourth workflow example shows a Monte Carlo photon dose calculation based on the VMC++ algorithm for the generic box phantom. The treatment plan is only comprised of a single beam with zero gantry- and zero couch-angle. In the end, the histogram of dose values belonging to the target structure is visualized.

The fifth workflow example demonstrates an intensity-modulated scanned proton treatment plan for the open-source prostate patient using two laterally opposing beams. After dose calculation and optimization, we simulate an isocenter shift and re-calculate the dose (forward dose calculation) using the previously optimized fluence to mimic a patient shift. The resulting dose cubes are then visually and quantitatively compared using the `matRad_plotSliceWrapper` and the `matRad_gammaIndex` [11] function. Exemplary, Figure 3 illustrates the visualization of the unshifted proton dose of the prostate case in the axial isocenter slice using the function `matRad_plotSliceWrapper`.

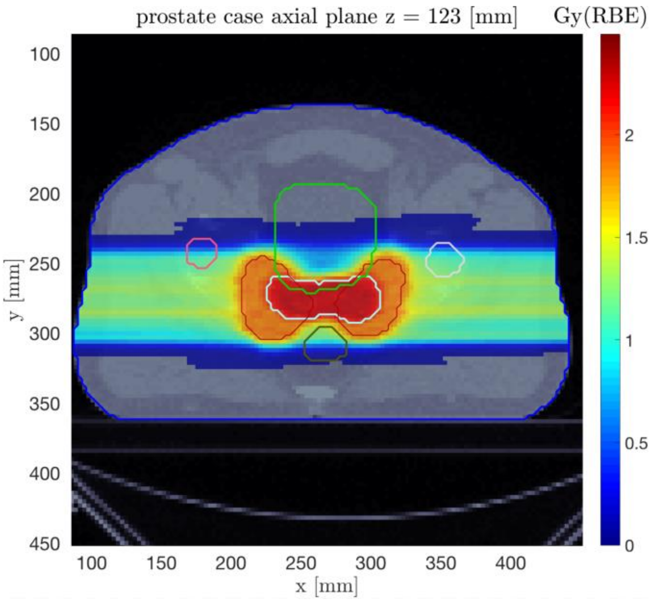

Figure 3: Prostate treatment plan with two laterally opposing proton beams

The sixth workflow example is similar to the one before but instead of shifting the isocenter, we manipulate the stopping power of the CT by adding 3.5% to the initial values in order to simulate a simple range undershoot.

The seventh and last workflow example shows a scanned carbon ion treatment plan for the open-source liver patient. We define a single beam with 300° gantry- and 0° couch-angle. After a dose calculation and optimization of the RBE-weighted dose, we change the radiobiological characteristic of the patient by assuming a different radio-sensitivity and re-calculate the RBE-weighted dose utilizing the existing pencil beam intensities.

Each workflow example has been designed to cover a different aspect of planning, data manipulation, data visualization and evaluation. In addition to the scripts, we provide one pdf per workflow for validation that conveniently combines source code, console output, and figures. The pdfs have been created using the publish command in Matlab.

B. Practical Treatment planning examples

Overall, we provide three practical treatment planning examples hosted on our wiki[9]. A key aspect of these practical examples is that they are consistently carried out using the graphical user interface and not the command line tool.

The first example depicts an intensity-modulated photon treatment on the phantom TG119. After the beam angles are determined, a maximum dose constraint is additionally defined to the existing default objectives. In the next step, optimization and analysis in form of a DVH and quality indicators are performed. The functionality 'Save To GUI' allows to store optimized dose distribution within the GUI in order to facilitate a comparison with a dose distributions based on different treatment plan settings.

The second more advanced practical treatment planning example aims to find an intensity-modulated photon beam setup and objective/constraint definitions that fulfill four given specifications. Exemplary, one of the four is to keep the total mean dose to the parotid glands below 20 Gy.

The third example is targeted to particle therapy and aims to create a simple intensity-modulated proton and carbon ion treatment plan. In the analysis, a comparison of the dose to the OAR, located adjacent at the distal edge of the spread out Bragg peak (SOBP), is performed.

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[9] https://github.com/e0404/matRad/wiki/Practical-treatment-planning

IV. DISCUSSION & OUTLOOK

This paper introduces matRad with a particular focus on educational purposes and available training material. We describe various workflow examples and a treatment planning tutorial that have been made publicly available on our Github page.

Further, we outline the general setup of the matRad project on the GitHub webpage. In particular, we explain how to access the source code, retrieve additional information and how to contribute to matRad's development.

We aim to provide a toolkit with well-established and trusted algorithms to lower the burden for beginners entering this research area. Since treatment planning became a highly computerized process, one can observe that the ability to read and write computer code gets increasingly important. The clear software design and the intuitive Matlab language allows for rapid prototyping. Along with the relatively clean syntax for matrix computations, in comparison to other programming languages, this allows for a steep matRad learning curve, not only as users but also as active developers.

matRad 3.0.0 is the first version that supports seamless operation with Octave; the program code can now smoothly be executed without liability to pay for Matlab licenses. Moreover, the relative low hardware requirements make matRad a suitable tool for self-studying or teaching radiotherapy principles in a classroom setting in both low and high-income countries. The new workflow examples comprise only a few lines of code and demonstrate the full potential of matRad. The examples can be executed by everybody in a matter of several minutes due to optimized vectorized calculations.

As can been seen on the GitHub source code repository, matRad is under constant code development with an increasing number of contributing authors. In the near future, we are planning to include current experimental code for worst case, probabilistic and 4D treatment planning together with variable RBE models for protons in matRad's main release. In a collaborative effort with colleagues from Carleton University we are also working on the integration of optimization functionality for volumetric modulated arc therapy (VMAT).

V. CONCLUSIONS

The open-source software project matRad, which comprises dose calculation and optimization functionality for intensity-modulated radiation therapy with photons, protons, and carbon ions, is ideally suited for educational purposes.

Here we introduce seven workflow examples and a treatment planning tutorial to help students and new users to get started with radiation therapy treatment planning. This material is freely available online on our Github page, which further facilitates wide-spread use of our software.

We outline how matRad can be used independently from the proprietary numerical computation environment Matlab using GNU Octave. This allows to run matRad without any software costs - which may be particularly interesting for students and centers with budget limitations.

matRad not only significantly facilitates access to well established radiotherapy algorithms but also lowers the burden of entering into the research field of radiotherapy treatment planning.

VI. ACKNOWLEDGMENT

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Further we want to thank the growing matRad community on GitHub in particular Eric Christiansen at Carlton University and Josefine Handrack at the German Cancer Research Center.

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DEVELOPING EFFECTIVE MENTAL KNOWLEDGE STRUCTURES FOR MEDICAL PHYSICS APPLICATIONS.

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Abstract --- **The performance of many medical physics functions in both medical imaging and radiation oncology require knowledge consisting of mental networks of concepts in addition to the traditional verbal and mathematical representations provided in classroom teaching. The classroom is limited as an effective learning environment because it is separated from the "real world" of clinical physics that is the source for interactive learning. Collaborative teaching is a method used to provide the classroom with enhanced visual access to medical physics applications and enable classroom instructors to guide learners/students in developing higher-level and more effective knowledge structures.**

Keywords **--- Knowledge, Concepts, Learning, Teaching, Collaboration**

I. INTRODUCTION AND OVERVIEW

A significant goal of all medical physics education and training programs is the development of medical physicists who can perform specific functions in the various professional activities including clinical medical physics, risk management, education, and research. That is the process of *effective education*. It is education that prepares for specific and well defined functions or tasks. One of the continuing challenges of medical physics educational programs around the world is that of providing truly effective education, especially to meet the expanding roles of medical physicists relating to the many innovations and developments in both medical imaging and radiation oncology. Our purpose here is not to describe specific educational methods or materials but to focus on the basic characteristics and requirements for learning and teaching activities to produce effective medical physics knowledge. We consider how humans learn and the conditions that contribute to effective learning.

II. PHYSICS KNOWLEDGE

Knowledge of physics is a mental representation of segments of the physical universe in which we live, ranging from sub-atomic particles and interactions to outer space. Medical physics is a specific area or component of this universe. We begin with a general model of medical physics knowledge and the learning process is illustrated in Figure 1.

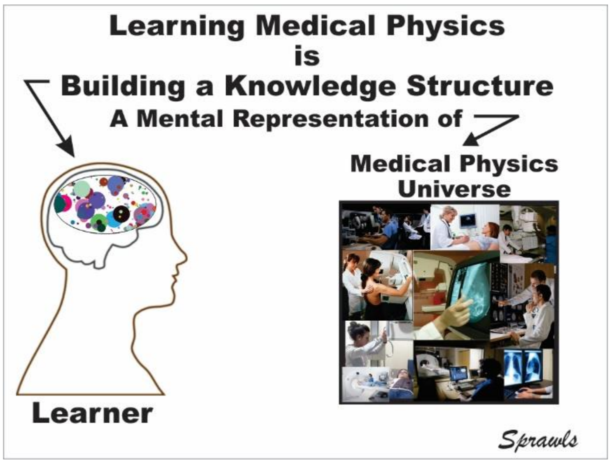

Figure 1. Learning medical physics is a continuing process of building mental representations of a specific area of the physical universe as we study and gain experience.

Each of us has our unique and personal knowledge structure that is determined by our education and interactions with medical physics activities throughout our career. Our specific interest here is the knowledge that enables us to perform specific activities or functions, which is different from general knowledge or just knowing a topic.

We will now consider the general knowledge structure for physics, then the process of learning or building knowledge structures, and conclude with conditions to develop effective medical physics learning activities and knowledge.

Our knowledge structure or mental representation of physics, including medical physics, is composed of three types of elements--sensory concepts, quantitative, and verbal--as illustrated in Figure 2.

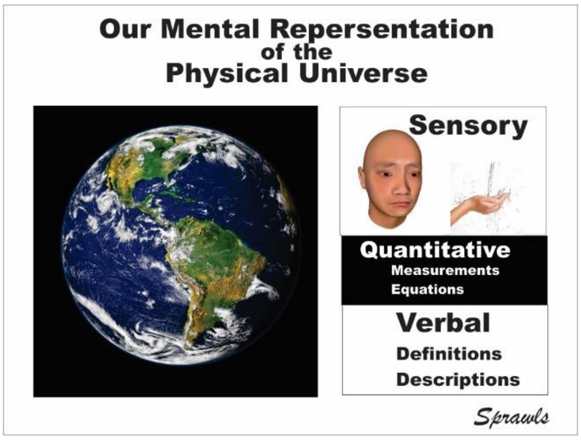

Figure 2. Three types of elements that are components of our knowledge of physics: sensory, quantitative, and verbal.

An effective knowledge of medical physics requires the appropriate combnation of these three elements, depending on the functions or task to be performed. Developing these appropriate knowledge structures is one of the major challenges within medical physics educational programs and activities.

III. EFFECTIVE AND EFFICIENT EDUCATIONAL ACTIVITIES

Every educatonal activity, including classroom lectures, selfstudy with books and online resources, laboratory exercises, and continuing work experience is charactized by two often opposing conditions, *effectiveness* and *efficiency*.

The *effectiveness* of a learning activity determines its ability to produce knowledge structures to enable the learner to perform specific functions that can range from providing verbal definitions on a written examination to performing higher-level analytical and creative activities within the scope of medical physics.

The design, development, and delivery of an effective learning activity requires a clearly defined learning outcome or objective. There must be a match between the knowledge structure and the activity or task to be performed.

The *efficiency* of a learning activity relates to the cost of providing it, including human effort and time, facilities and resources, and much more. A prevailing factor in education is the opposing effects of effectiveness and efficiency. An activity that is effective, especially for higher-level medical physics functions, is generally low in efficiency and requires much more time, effort, and resources to provide.

IV. VERBAL AND LINGUISTIC KNOWLEDGE STRUCTURES

Words and language are the elements forming the major component of our knowledge in virtually all topics. Two valuable characteristics: it can be written or recorded and used for communicating both aural and in script form. In the field of physics language provides a *symbolic representation* of the various areas of the physical universe but not a more direct representation as described later. Language represents the physical universe primarily in terms of verbal descriptions, facts, and definitions. While this form of knowledge is important it has significant limitations in enabling a learner to perform many medical physics activities.

A major issue with physics knowledge consisting of words is that it is *high* in efficiency for teaching but *low* in effectiveness for many medical physics activities. It is relatively easy to teach through lectures and written materials giving verbal descriptions and definitions. It is also easy to test using written examinations.

However, verbal knowledge has major limitations with respect to performing many medical physics activities.

V. QUANTITATIVE AND MATHEMATICAL KNOWLEDGE STRUCTURES

Physics is truly a quantitative science. Every component and element of the physical universe has a quantitative value for which specific names have been assigned along with a variety of units in which quantitative values can be expressed. One example is the *quantity* energy that can be expressed in *units* ranging from electron-volts (eV) to kilowatt-hours (KWH), depending on the specific application. Every area of the physical universe, including medical physics, consists of a dynamic and often complex relationship among many physical quantities. These relationships can be expressed with mathematical equations and several types of visual and graphical representations.

In the field of medical physics a quantitative knowledge (including relationships expressed with equations) is *essential* but not *sufficient* for many functions to be performed, especially in clinical support activities.

VI . PHYSICS EDUCATION

In the broad spectrum of physics education, ranging from introductory to advanced graduate courses, for the most part it is the verbal and quantitative (definitions, facts, equations) representations of the physical universe that are being taught and learned. While this is an essential part of physics knowledge and should be taught, it is with limitations. Compared to some other learning activities to be discussed later, teaching the verbal and quantitative representation is relatively efficient requiring less effort and fewer resources. Most textbooks, classroom lectures and discussions, along with problem solving homework and sessions are the foundation to this form of education. While this is sometimes augmented with illustrations and student laboratory exercises, it does not provide the sensory interaction with the physical universe and the formation of conceptual knowledge that is essential for many medical physics activities.

VII. EXAMINATIONS AND KNOWLEDGE STRUCTURES

Often the desired learning outcome or objective is to perform well on written examinations ranging from "pop" quizzes within a course to professional board certifications. This creates a strong correlation between the design of educational activities and examinations. Verbal and quantitative examinations requiring the recall of facts and solving mathematical problems are relatively easy to develop and score. Examinations within academic courses are always testing on what has been taught, both in content and type of representations. Within the fields of medical physics, technology, and radiology written examinations conducted by certifying boards test on verbal and quantitative knowledge. When academic programs are motivated to "teach to the test" emphasis will be on that type of knowledge. Within some of the certifying organizations there is an interest and effort to produce examinations that test on the ability to perform specific "real world" professional functions; for example: analyze an image with respect to its quality characteristics. This cannot be done with just verbal and mathematical knowledge. Oral examinations conducted in person by an examiner provide this opportunity and require knowledge extending beyond verbal and mathematical to include *sensory based concepts*. This is the type of knowledge required for many medical physics activities that we will now consider.

VIII.SENSORY BASED PHYSICS KNOWLEDGE

Learning physics and development of knowledge structures is an ongoing *natural human process* beginning at birth and continuing throughout life. It does not require formal educational programs with classrooms, teachers, and textbooks. Knowledge of physics, that is a mental representation of the physical universe, develops as we sense and interact with specific physical components around us. In Figure 3 we will use water as an illustration.,

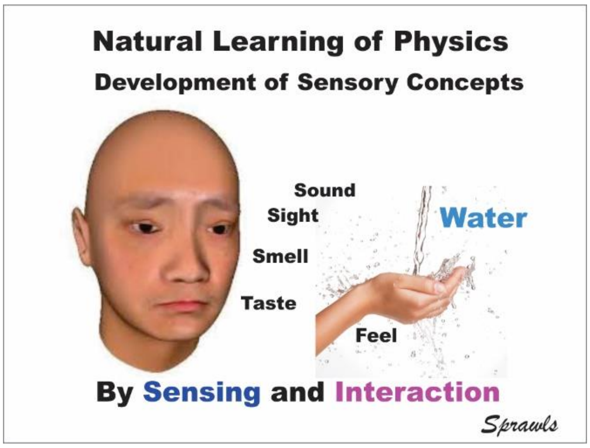

Figure 3. Learning the physics of water through sensory observations and interactions.

Water is a major component of the physical universe and is the object of much of our physics knowledge. This learning begins early in life as we experience the specific physical characteristics of water and also develop concepts of factors such as fluids and temperature. This is the knowledge that prepares us to live with and use water throughout our lives.

In academic physics courses the emphasis is on quantitative and mathematical symbolic relationships generally within the topic of hydrodynamics.

This guides us to a very significant observation. Symbolic quantitative physics, as taught in physics courses, is important and valuable for several reasons. One is to perform well on written examinations. It contributes to a comprehensive understanding in all areas of physics by showing the relationships among the many physics quantities. It is critical knowledge for performing many analytical and design functions. Determining radiation dose to specific patients, treatment planning, and shielding design are some examples.

However, for many activities, ranging from interacting with water in our daily lives to performing a variety of medical physics functions, a physics knowledge structure consisting of sensory based concepts is required.

IX. CONCEPTS

Concepts are the fundamental elements that make up our knowledge structures. They form the major part of our knowledge and play a role in all aspects of learning. Conceptual learning is what results from the natural human learning experience. It is different from symbolic verbal and quantitative learning but does provide a foundation and contribute to the significance and meaning of symbols (definitions and equations), especially in the field of physics.

The significance of conceptual knowledge is two-fold. It is for the most part developed by observation and interactions with specific areas of the physical universe. It is the type of knowledge that contributes to higher level mental functions including analysis, problem solving, innovations, etc. as illustrated in Figure 4.

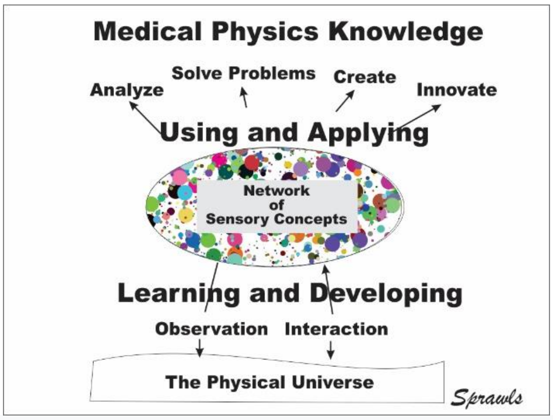

Figure 4. The significance of conceptual knowledge in medical physics education, the link between learning and applying.

Let us now enhance *our concept* of developing *physics concepts* using the illustration in Figure 5 .

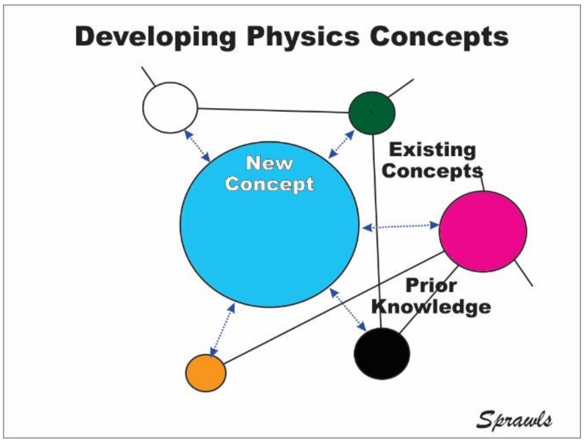

Figure 5. Illustrating the concept of how we develop concepts as part of our knowledge structure.

While developing concepts in our mind is a natural learning process as we observe and experience what we come into contact with, it is also a complex process as illustrated. This is a major factor we must consider as we develop educational programs and activities to promote conceptual learning. A person does not typically develop a new concept in complete isolation from other concepts and experiences. A concept is an element that is connected within our total knowledge structure.

Because knowledge is a network of concepts, development of effective knowledge structures is enhanced by the use of mind maps. An example is shown in Figure 6.

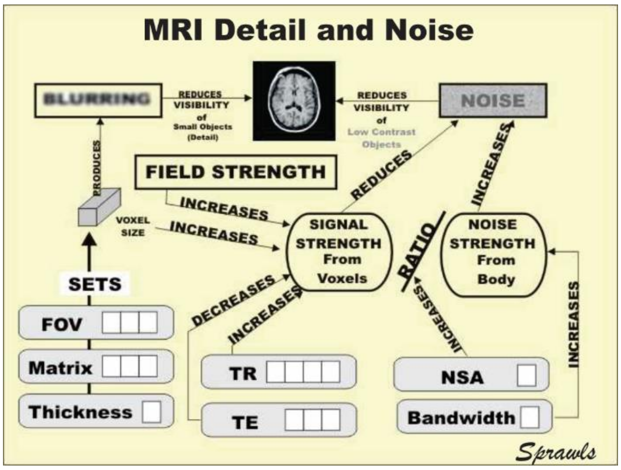

Figure 6. A mind map supporting the development of concepts related to MR image detail and noise. This and other mind maps are available in resources referenced later.

X. DEVELOPMENT OF EFFECTIVE EDUCATIONAL PROGRAMS AND ACTIVITIES

One of the major challenges for medical physics educational programs is that of developing learning activities that provide the appropriate *mixture* or *balance* among the different knowledge types, especially symbolic and conceptual. This requires establishing specific learning outcomes and objectives relating to what the learner/student is being educated to do. This distinction is illustrated in Figure 6.

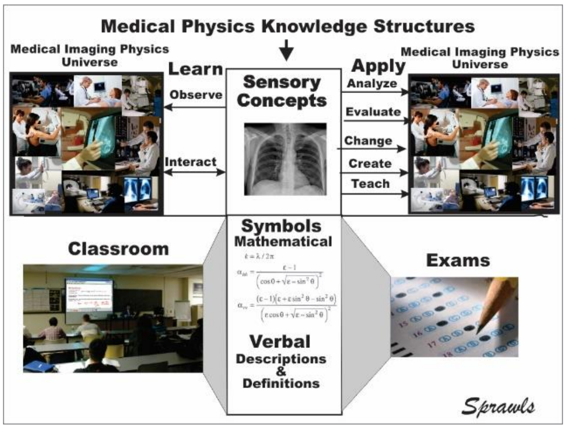

Figure 6. The development and application of the different knowledge structures.

There is a significant difference between preparing for examinations and preparing to perform many medical physics functions as illustrated. Classroom activities heavily based on verbal and mathematical symbolic representations. along with self-study, provide appropriate preparation for most written examinations.

Classroom based educational activities are relatively *efficient,* especially compared to one-on-one guided instruction in an actual physics environment, such as imaging patients with MRI and focusing on analysis and optimization of image quality. The type of education that can be provided in a classroom is extremely valuable but has significant limitations with respect to developing knowledge to support many medical physics activities. The following is a quote from the author.

"A classroom is like a box in which we enclose students separating them from the physical world about which they should be learning".

This is a major challenge in medical physics education. How to combine the *efficiency* of classroom (direct or online) learning with the *effectiveness* of learning by observation and interaction with actual physics functions such as clinical imaging.

Now with advances in technology including digital imaging, graphics, and ability to connect and communicate over the internet, there is the opportunity to provide highly effective medical physics learning activities in institutions anywhere in the world. When high-quality graphics and images are available in the classroom they provide a "window" to the external world of medical physics activities.

The objective is to build on the general efficiency of classroom instruction and make it much more effective in producing higher levels of learning to prepare for many medical physics activities.

XI. COLLABORATIVE TEACHING

The technical infrastructure supported by the internet and World Wide Web makes possible the process of *collaborative teaching* illustrated in Figure 7.

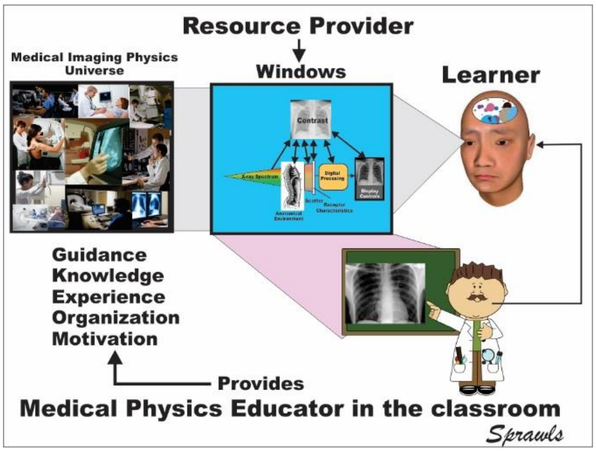

Figure 7. Collaborative teaching combines the knowledge and experience of classroom teachers with that of resource developers and providers to connect and provide windows in the classroom.

The great value and power of collaborative teaching is it makes use of the different knowledge and experience of two different medical physicists, the *classroom teacher* and the *resource provider*. The resources enhance and contribute to the effectiveness of the classroom teacher. The efforts of both are required to provide highly effective education and in a reasonable efficient process.

The resource provider is generally an experienced clinical medical physicist and educator with the capability of developing graphical and visual representations of medical physics phenomena associated with clinical procedures that contribute to the formation of sensory concepts. To contribute to enhanced medical physics education on a global basis the resources should be available at no cost to all educators. For the field of medical imaging physics an example is the *Sprawls Resources* on the web at: www.sprawls.org/resources .

Visuals developed specifically for use in classrooms (PowerPoint) are available at: http://www.sprawls.org/PhysicsWindows/ .

With these resources, especially high-quality visuals and images, classroom teachers can provide highly-effective learning experiences by adding their knowledge and experience and guiding the mental interactions and learning process.

Additional publications relating to collaborative teaching are references [1, 2, 3]

XII. SUMMARY AND CONCLUSIONS

Learning physics is a natural human process as we observe and interact with the physical environment around us. This interaction and experience is through the senses, especially visual, and contributes to the formation of a knowledge structure consisting of a network of concepts. It is this type of mental representation of the physical universe that then enables a person to interact through a variety of high-level mental functions including analysis, problem resolution, and creative activities. This applies both to everyday living and to the practice of medical physics. Symbolic verbal (words) and quantitative (mathematical) knowledge is critical for many human functions but does not support some of the high-level functions that require conceptual knowledge. Classroom activities can be limited in producing adequate conceptual knowledge because of the separation from the actual medical physics clinical activities. Classroom teaching is generally more effective in producing verbal and quantitative knowledge and preparing students for written examinations, but less effective in preparing for many applied medical physics activities.

Collaborative teaching is addressing this challenge by combining the knowledge, experiences, and efforts of different medical physicists to provide highly-effective classroom learning activities.

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About the Author --- Perry Sprawls, Ph.D., is a clinical medical physicist and educator with extensive experience in medical imaging science, technology, and clinical applications. At Emory University, where he is now a Distinguished Emeritus Professor, much of his effort is devoted to introduction and optimization of new imaging methods, especially mammography, CT, MRI, and digital imaging in general. Throughout his career he has used his clinical medical experience to develop educational resources to help others. His belief is that clinically effective medical imaging requires both high-quality imaging technology and optimized procedures supported by medical physicists as members of the imaging staff, consultants, and as educators. This continuing effort is now supported by the Sprawls Educational Foundation, www.sprawls.org

PROFESSIONAL

WOMEN IN PHYSICS:
PIONEERS WHO INSPIRE US

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Abstract — **The 5th International Day of Medical Physics (IDMP) on November 7, 2017, featured six women physicists, including Marie Skłodowska Curie, who pioneered the study of radioactivity. It was held in conjunction with her 150th birthday anniversary. The other five were Chien-Shiung Wu, Rosalyn Yalow, Maria Mayer, Harriet Brooks and Marie Curie's daughter, Irène Joliot-Curie. All of them had dedicated their lives to study physics, despite living in a time when the role of women were rarely recognized in higher-learning institutions, and poverty and conflicts were rife. They left a huge legacy of knowledge to many generations of scientists. Wu's discoveries had paved the way for other researchers to win the Nobel Prize. She was known for her research in beta decay and, through the 'Wu Experiment' in 1956, had discovered a contradiction in the law of parity conservation. Yalow won the Nobel Prize in Physiology and Medicine in 1977 for developing the radioimmunoassay technique. Mayer won the Prize in Physics (1963) for discovering the nuclear shell structure. Brooks, who studied under Ernest Rutherford (the father of nuclear physics), was credited with discovering the concept of atomic recoil. And Joliot-Curie won the Nobel Prize in Chemistry (1935) with her husband for their discovery of artificial radioactivity. In this article, we briefly describe the lives and achievements of each woman. Their fascinating stories serve as an inspiration for hardworking scientists, especially women, who have to rise against the odds.**

Keywords— **women, nuclear physics, physicists, history, Nobel Prize.**

I. INTRODUCTION

It is an honor to be awarded the Nobel Prize. It is a greater honor if you are among the 2% of women who had won any of the prizes in physics, chemistry, physiology or medicine, literature and peace.

In this review, we feature five women who have won the Nobel Prize, or played a critical role that provided someone else with the opportunity to win. However, this is far from their greatest achievement. More importantly, they fought against discrimination and prevailed. They stood up to their goals when society demanded they stay home.

They are all survivors. They are a group that faced a number of obstacles, from professional rejection to racial and religious discrimination, poverty, and war. Their passion for science, together with strong persevering spirit, had kept these brilliant women from giving up on their dreams.

The 5th International Day of Medical Physics (IDMP) was celebrated worldwide on November 7, 2017, marking the 150th birthday anniversary of Marie Skłodowska Curie [1]. The event was dedicated to the improvement of safety for women as patients, hospital personnel and researchers who are exposed to medical radiation.

Besides the well-known Marie Curie, five exceptional women, Chien-Shiung Wu, Rosalyn Yalow, Maria Mayer, Harriet Brooks and Irène Joliot-Curie were recognized for their outstanding roles in nuclear physics (Fig. 1).

We are proud to highlight the achievements of these illustrious women and, at the same time, we also remember their life struggles. Their remarkable breakthroughs and strong personalities can motivate, inspire and make us strive for excellence in scientific research.

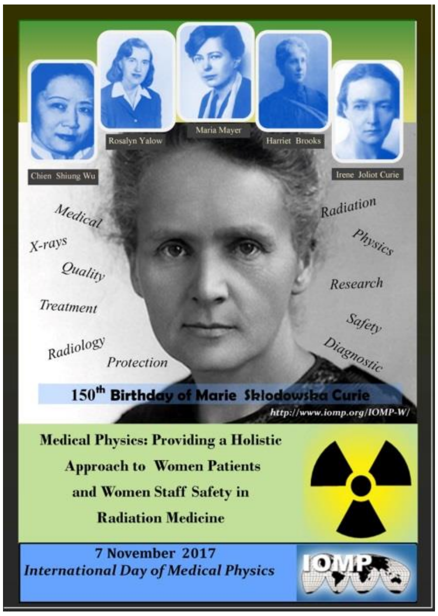

Fig. 1 The 5th International Day of Medical Physics poster produced by the Asia-Oceania Federation of Organizations for Medical Physics (IOMP Member) in November 7, 2017 [1].

II. CHIEN-SHIUNG WU

A. Rising against all odds

Chien-Shiung Wu, whose name means "*courageous hero"* [2], was born in Liuhe, a small town near Shanghai, China, on May 31, 1912 [3]. She is known for her remarkable work in nuclear physics in the United States.

As a young girl, there was very little opportunity for her and her peers to gain a formal education. Her father, Zong-Yi, however, was responsible for opening one of the earliest schools for girls in China. Along with his daughter, they would go door-to-door to recruit students from both rich and poor families, as there was no charge for attending the school [4]. Zong-Yi's goal was to eradicate illiteracy and prejudice against women by giving them a good education.

Chien-Shiung's father was her greatest inspiration to succeed, and he encouraged her to pursue an education beyond their hometown [3]. In 1923, at age 11, Chien-Shiung applied to join the teacher-training program at the Soochow Girl's High School, which provided graduates with a stable teaching job upon completion of their studies [4]. This was a prestigious and highly-competitive program, but Chien-Shiung proved her potential by emerging at 9th place out of 10,000 applicants in the school's matriculation examination [4].

Chien-Shiung graduated from high school in 1929 with the highest grades in her class. From 1930 to 1934, she studied for a degree in physics at the National Central University in Nanjing [4,5] before leaving for the United States in 1936.

She enrolled in the University of Michigan to pursue a PhD, but changed her mind after visiting the University of California in Berkeley (UC Berkeley) in a week [4]. While staying in California, she found the state to be more liberal, which led her to stay on in Berkeley. There, she met physicist Luke Chia-Liu Yuan, who showed her around the campus and introduced her to R. Birge, chairman of UC Berkeley's Physics Department. Birge immediately recognized her potential and offered a position to do a PhD [3,4].

After one year, she decided to apply for a scholarship, and that was the time she felt discriminated over her Asian lineage. Birge apparently awarded smaller stipends to her and Luke [4], which made them unhappy. Luke decided to finish his studies at the California Institute of Technology (Caltech), but Chien-Shiung stayed at UC Berkeley until she graduated in 1940 [4].

Fig. 2 Chien-Shiung Wu in Columbia University (1958). Courtesy of Smithsonian Institution Archives. Image #SIA2010-1511.

Chien-Shiung and Luke were married in May 1942. In the second half of that year, she decided to leave UC Berkeley because women were not offered teaching positions. This discriminatory practice was a norm then, even in the top 20 universities in the US. Chien-Shiung eventually taught at Smith College, a private, independent women's liberal arts college in Northampton, Massachusetts [4].

After that, she worked as a research assistant again before moving up to important positions at Ivy League universities, such as Princeton, Columbia, Harvard and Yale, when the role of women began to receive recognition [3,5,6] (Fig. 2).

When war erupted between China and Japan in 1937, Chien-Shiung lost all contact with her family until 1945, when Japan was defeated in World War 2 [4]. But the turmoil continued with the civil war between the Communists and Kuomintang, thus preventing her from returning to her home country to visit her family.

Chien-Shiung and Luke had started a family of their own and they found it safer to remain in the US. In 1949, when the Kuomintang lost the war, Chien-Shiung suddenly found herself stateless when her Republic of China passport was no longer valid. Fortunately, she managed to become a naturalized US citizen in 1954. When she finally returned to China in 1973, after 37 years of leaving home, she discovered that her parents and brother had died, and she had no chance of seeing them [4].

B. Scientific work

Chien-Shiung made significant contributions to the Manhattan Project, a US government research that notably led to the creation of the atomic bomb. Even though she was an Asian, she had the opportunity to play a crucial role in such important project [4,7].

Her involvement began as soon as she started pursuing her PhD at UC Berkeley. Just after getting her doctorate, she had the opportunity to establish a network with Enrico Fermi, who was famous for constructing the first US nuclear reactor [2].

As her capabilities became known, the theoretical physicist Robert Oppenheimer, known as the “father of the atomic bomb”, would invite Chien-Shiung to talk about the latest developments of her work in nuclear fission at UC Berkeley, where she was known as the “Chinese Marie Curie” [4].

Chien-Shiung is known for her parity conservation experiments in beta decay [3]. She worked in Columbia University after World War 2 to study Fermi’s theory on the subject [2].

In the 1950s, studies using particle accelerators became popular and scientists were discovering new subatomic particles. Tsung-dao Lee of Columbia University and Chen-ning Yang of Princeton University had proposed that the idea of parity conservation applied to electromagnetic and strong interactions did not apply to weak interactions. This was based on the discovery of the K-meson particle [2,4].

They needed help to prove their theory, and it was Chien-Shiung who conducted the experiment [8]. The results of her experiment eventually established parity conservation as a fundamental law of physics. It also significantly helped Lee and Yang to win the 1957 Nobel Prize in Physics.

Even though she did not win the coveted prize, Chien-Shiung continued her research until she retired in 1980. Her achievements were recognised through other prestigious awards and service in important positions. In 1974, for instance, she was named "Scientist of the Year" by *Industrial Research* [6]. In 1975, she became the first woman president of the American Physics Society and in 1978, she was the first Wolf Prize winner in physics [4].

Chien-Shiung Wu died in New York City on February 16, 1997, at age 84 [3]. Her achievements are a permanent inspiration for those striving to attain excellence in nuclear physics research, particularly Asian women.

Her namesake “*courageous hero*” truly describes someone with a brilliant mind, who has risen against all kinds of challenges to succeed in life.

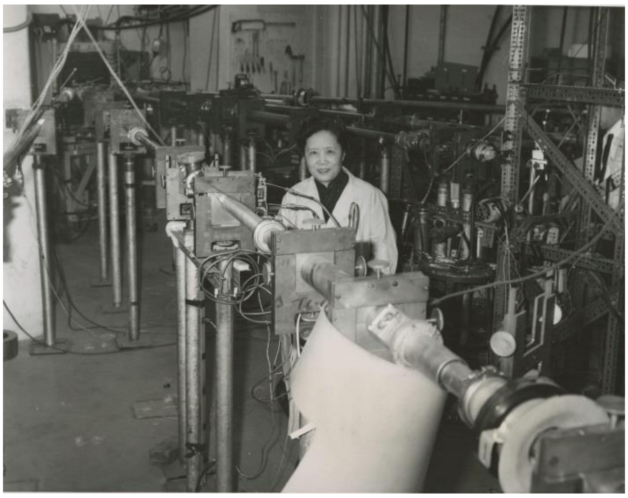

Fig. 3 Chien-Shiung Wu in Columbia University (1963), where she worked as a professor. Courtesy of Smithsonian Institution Archives. Image #SIA2010-1507.

III. ROSALYN YALOW

A. Hard worker who won't clock out

A woman with great determination and brilliant mind, Rosalyn Yalow made a name for herself by working up to one hundred hours a week (Fig. 4). She was born to Jewish parents in the tough neighborhood of The Bronx in New York City on July 19, 1921.

Neither her parents nor most of her neighbors had gone to high school. Her father was a local who dropped out after Eighth Grade to become a streetcar conductor before opening a one-man business. Her mother migrated to the US from Germany when she was a child, and had also quit school after Sixth Grade [9].

Nonetheless, they recognized the importance of a good education for their children. Rosalyn was very close to her father, and he encouraged her to pursue her dreams, regardless of her gender. When Rosalyn was 5 years old, she used to read a lot at the public library with her brother. In school, she was not afraid to question her teachers.

When she was 10 years old, she enrolled in a high school for girls. There, she developed an interest in medical science and earned the praise of her teachers for her excellent results [9].

Rosalyn graduated from high school in 1937 at age 15. Her mother wanted her to become a teacher, which was expected of Jewish girls in the 1930s [9,10], but she deeply wanted to attend medical school.

Unfortunately, not only was she not able to afford the tuition, medical schools then would not even accept Jewish men. As a Jewish woman, Rosalyn knew she her chances were next to nothing. So, she enrolled in Hunter College, a highly-competitive girls' college, but where tuition was free [9]. This gave her the opportunity to pursue a higher education and she chose to major in Physics.

When she graduated in 1941, she worked as a secretary at Columbia University before getting an offer to work as a teaching assistant at the University of Illinois at Urbana-Champaign, where she did her post-graduate study in nuclear physics [2,9].

At the onset of World War II, she became the first woman to be admitted into the university's engineering school since World War 1. The two World Wars, in fact, were the reason why women got to enroll in the University of Illinois in the first place -- the men had been called up to serve in the military, thus graduate schools had no choice but to admit women instead of closing their doors! [9]. Women were also not allowed to teach in the university until after the bombing of Pearl Harbor in December 11, 1941 [9].

While studying for her doctorate, Rosalyn met and married her fellow student Aaron Yalow in June 1943. After completing her doctorate in 1945, she got a job at the Bronx Veterans Administration Medical Center to study the use of radioisotopes in medicine, where she had to set up her laboratory in a janitor's closet [9].

Fig. 4 Rosalyn S. Yalow at the Bronx Veterans Administration Hospital (1977). Photo by US Information Agency (USIA), via Wikimedia Commons.

In 1950, she met and recruited Dr Solomon Berson, a resident physician at her workplace [2,10]. She was impressed by his strong personality and background, which was similar to hers -- he was the son of a Russian Jew who was rejected by 21 medical schools before being accepted by the University of New York [9].

Rosalyn gave up on working with other scientists to focus on her work with Dr Berson [11]. Together, they would form a strong working relationship in developing the radioimmunoassay (RIA) technique [2]. Their work relationship was a perfect match, and they shared the credits in every achievement.

B. Scientific work

Rosalyn and Dr Berson initially chose to study the mechanism of insulin in treating diabetes. They performed radioisotope tracing experiments with insulin injected into patients. It was in this work that they noticed the incompatibility of using pig and cattle insulin to treat humans, which was prevalent in the 1950s [2,10]. This was because the human immune system would produce antibodies to counter the animal insulin.

Nonetheless, their outstanding discovery was not related to the study of insulin, but to the method they developed to carry out their research.

They found a novel way to measure the level of hormones using antigen tagged with radioactive indicators. This so-called radioimmunoassay (RIA) technique [2,9] had revolutionized endocrinology research and the treatment of hormonal disorders, such as diabetes [9].

In addition, Rosalyn and Dr Berson discovered the difference between Type 1 and Type 2 diabetes, which was vital for doctors to identify before treating patients with insulin [2]. They expanded their research to measure the level of various biological substances in blood samples. They were generous and wanted to help people, and the techniques of their research had never been patented. [2,10].

The death of Dr Berson in 1972 from a heart attack had greatly affected Yalow. She became concerned that her work would lose credibility without Dr Berson's contribution. This led her to dedicate more effort in building her research by putting in hundreds of work hours a week, so much that she managed to produce 60 research papers in four years [2,10].

In 1977, she shared a Nobel Prize in Physiology or Medicine with Roger Guillemin and Andrew Schally. Unfortunately for Dr Berson, the Nobel Prize was not posthumously awarded. Rosalyn was the second woman to win the Prize in Physiology or Medicine after Gerty Cori [10]. She achieved an important position in medical research at a time when women suffered a discrimination of their abilities.

Rosalyn Yalow died on May 30, 2011, at age 89 in the same humble neighborhood where she was born. Her grit and determination had played a crucial role in her remarkable achievements. On overcoming the gender discrimination, she once said: "If I wasn't going to do it one way, I'd manage to do it another way." [2].

Fig. 5 Rosalyn S. Yalow, winner of a Nobel Prize in Physiology or Medicine, at The Bronx Veterans Administration Medical Center. Photo by US Department of Veterans Affairs[10].

IV. MARIA GOEPPERT MAYER

A. Alchemy of excellence

Besides perseverance and hard work, the alchemy of a high-achieving person has two distinct virtues: a pioneering spirit and willingness to go the extra mile. These are the values of a woman named Maria Göppert-Mayer, who was born in Kattowitz, Germany, on June 28, 1906. She was the second female Nobel laureate in physics after Marie Curie [12,13].

Mayer grew up in Göttingen, Germany, where her family lived after her father, Dr Friedrich Goeppert, became a pediatrics professor at Georg-August Universität [14]. She was very close to her father, who strongly supported her quest to pursue a higher education instead of encouraging her to just "grow up as a woman" [14].

In 1914, when Maria was 8 years old, Franz Ferdinand, the archduke of Austria and heir to the Austro-Hungarian Empire was assassinated, sparking a chain of events that would plunge her country into World War I.

During the war, there was a shortage of food and Maria’s father had to struggle to feed his family and his patients. After the war ended, Maria was a teenager and began to attend the all-girls' Hohere Tochterschule school, where she excelled in language and mathematics [9,15].

In 1921, she started attending the Frauenstudium private school, which prepared its students for university [9,15]. Her teachers doubted she would be able to enter a university, but she proved them wrong by earning a place at Goerg-August Universität (her father's workplace) in 1924 [15]. Initially Maria loved mathematics but her interest changed when she met Max Born, a famous theoretical physicist, who played a vital role in the development of quantum mechanics [15].

Born was a family friend, and he influenced Maria to take up physics [14] all the way till she finished her doctorate in 1930.

Three years after enrolling in Goerg-August in 1927, her father died, leaving Maria and her mother devastated [15]. Her family faced financial difficulties after his death, and her mother had to rent the rooms foreign students at her university to supplement their income [9,15].

Well, despite such hardship, she met her future husband Joseph Mayer, a researcher from California, the United States, who came to Göttingen to study quantum mechanics [15].

When Maria and Joseph got engaged, she considered quitting her career to become a housewife, but her husband convinced her to keep on working [9]. They got married in January 1930, and she finally earned her PhD a few months later [15].

Fig. 6 Maria Göppert-Mayer, 1963. Courtesy of: Smithsonian Institution Archives. Image #SIA 2008-1865.

Maria knew she would not be able to become a professor in Germany, as women were rarely accepted as faculty staff. Moreover, Germany was experiencing political upheaval with the rise of Adolf Hitler and Nazism, which eventually lead to World War II in 1939 [15].

Maria and her husband moved to the United States, where Joseph secured a position at the Johns Hopkins University. Maria had to work as an unpaid research assistant because she was not allowed to hold a position at the same university due to unreasonable nepotism rules [2,15].

Life became difficult for the Mayers when their children were born in 1933 and 1938. Maria was forced to spend more time at home, even though she missed working in her laboratory for free [9].

In 1938, just before World War II began, her husband lost his job at Johns Hopkins when anti-German sentiments began rising in the university, and Maria blamed herself for her husband's predicament [2,9,15]. But soon, another silver

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1. Retrieved from: https://www.bronx.va.gov/BRONX/features/AtomicMedicineAndRosalynYalow.asp

lining appeared when Joseph was offered a position to teach chemistry at Columbia University.

Recognition came quite late in life for Maria as it was only at age 53 in 1960 that she gained her professorship at the University of California, San Diego, which was a full-time job with fair pay commensurate with her qualifications [2,14].

B. Scientific work

Mayer was known for developing the double-photon emission theory, which was the subject of her doctoral thesis. Her predictions were proven in 1960, with the development of experiments with lasers [15,16]. Her sound knowledge in mathematics had given her an edge to join the pioneering work on the structure of organic compounds in Johns Hopkins University [12,14].

One of Maria's greatest achievements was during World War II while working for the Manhattan Project. She gained her first paid job in 1941, when she was hired by Columbia University to teach mathematics [2,15].

A second job offer came right after from a clandestine research group working on what would later become the Substitute Alloy Materials (SAM) project, one of the most important parts of the Manhattan Project.

Maria's work under this group was to design an efficient way to separate uranium-235 from uranium-238 [15]. Although she felt uneasy working on a project that led to the development of the atomic bomb, she was happy to be respected as a scientist for the first time [15].

When the war was over, Maria was offered a position at the Institute for Nuclear Studies at the University of Chicago. She focused on isotopes research, studying why some isotopes were more stable than others [2,15].

Her knowledge in matrix manipulation eventually led her to win the Nobel Prize in 1963 for discovering the nuclear shell structure (Fig. 7) [13,14]. She acquired data that supported the assumption that neutrons and protons rotated at different orbits in an atom as first proposed by scientists in 1930 [2].

Before winning the Nobel Prize, she had a string of impressive achievements. She became a member of the National Academy of Science in the United States in 1956 and a corresponding member of the Akademie der Wissenschaften in Heidelberg, Germany [14].

Despite largely being considered as just the "wife of a scientist", she never gave up on her passion and work [17]. Maria Goeppert-Mayer died on Feb 20, 1972 in San Diego, California, after a heart attack the previous year caused her to fall into a coma.

An award was created in her name by the American Physical Society to honor young women physicists [18]. Today, her discoveries in double-photon absorption have been applied in dermatological diagnoses [14].

Fig. 7 Maria Goeppert-Mayer (1906–1972), walking in to the Nobel ceremony with King Gustaf Adolf. Courtesy of: Smithsonian Institution Archives. Image #SIA 2008-1866.

V. HARRIET BROOKS

A. Facing a woman's dilemma

Harriet Brooks, born on July 2, 1876, in Ontario, Canada, was one of the pioneer women in nuclear physics research. She was extremely talented and had worked with great physicists of her time, such as Ernest Rutherford, Marie Curie and J.J. Thomson [19].

Harriet was the third child in a family of nine siblings. Her father, George, worked as a travelling salesman in a flour company, where he constantly struggled to feed his large family. Due to this hard situation, only Harriet and her youngest sister were able to continue their studies after high school [19]. She completed her education at the Seaforth Collegiate Institute in Seaforth, Ontario [19].

When her family finally settled in Montreal in 1894, her mother encouraged her and her sisters to keep pursuing their education. She enrolled in McGill University in the same year [20]. She was an outstanding student and supported herself by winning scholarships and awards every year. Those prizes helped to fund her university education [19].

During the first two years at university, she studied mathematics and language. The last two years were almost entirely dedicated to physics. She obtained her BA with first-class honors in mathematics and natural philosophy in 1898 [19,20]. She was also awarded a teaching diploma, which was given to women graduates to encourage them to become schoolteachers.

Harriet had the opportunity to work with distinguished scientists in her field. Right after completing her degree, she had the honor of being hired by Rutherford, known as the father of nuclear physics, as his first graduate student researcher [19].

Besides the Cavendish Laboratory in Cambridge University, Rutherford had just established another laboratory at McGill University to conduct his research [20], where Harriet worked on her master. Her research was related to electricity and she graduated under Rutherford's supervision in 1901 [19].

She created history by becoming the first woman to be awarded a master's degree by McGill University. During her studies, she taught mathematics at the Royal Victoria College, which was a higher-learning institution for women at McGill [19,20].

In 1901, she was offered a position that enabled her to study for a PhD at Bryn Mawr College in the United States. In her first year, she won an important scholarship to spend a year in Europe. Harriet contacted her mentor Rutherford to share the good news, but she had a rather low self-esteem, and she believed that she did not deserve such award [19]. Her family had objected to her traveling alone and she was also concerned whether the money was enough. Rutherford, however, arranged for her to come to the University of Cambridge to work under J.J. Thompson, the British physicist who discovered the electron [19,21].

At Rutherford's Cavendish laboratory, she joined a study on radioactivity and, after a year in England, she did not return to Bryn Mawr to finish her PhD, but instead, joined Royal Victoria College as a tutor.

Fig. 8 Graduation picture of Harriet Brooks (1898). Photo by Wm. Notman & Son. Courtesy of the McCord Museum of Canadian History, Montreal[11].

In 1904, Harriet became a tutor at Barnard College, a women's college that was affiliated to the University of Columbia in New York City [19]. She got engaged to physics professor Bergen Davis in 1906 and unfortunately, being a common practice at that time, was asked by her dean to resign.

As a strong woman who regretted the move as a waste of talent, she wrote to her dean, saying: "I think it is a duty I owe to my profession and to my sex to show that a woman has a right to practice her profession, and cannot be condemned to abandon it merely because she marries." [19,21,22]. She would break up her engagement anyway and would keep working at Barnard College for a while. A month later, she resigned her position [19].

Later in 1906, she traveled to Paris to become an independent researcher at Marie Curie's Laboratorie Curie. Marie Curie invited her to stay for the year, but she decided to apply for a position at the University of Manchester in England [19]. She was still waiting for a response when she decided to marry Frank Pitcher and stop doing research. Some years after the marriage, the couple had three children [19]. Harriet never continued her work in science.

B. Scientific work

Harriet was the first woman to graduate with a master's degree from the renowned McGill University, and was involved in some of the most important discoveries in the early days of radioactivity research [19,21].

Right after finishing her master's project, she was involved in an important discovery. Rutherford gave her the task to study the radioactive decay of thorium. It was observed that the radiation could be carried by air and it was not clear whether it was a gas, vapor or solid particles.

Harriet demonstrated that the radiation originated from a gas – now known as radon. This discovery eventually led Rutherford and Frederick Soddy to realize that one element could transmute to another [19–21].

Her next remarkable discovery, in between 1903 and 1904, was the atomic recoil phenomenon. She observed that a non-radioactive utensil could itself become radioactive simply by being in contact with a radioactive material [19–21]. When a particle is released from the nucleus of an atom, the nucleus recoils at the opposite direction [20].

This discovery would particularly have great influence on the work of Lise Meitner, an Austrian female nuclear physicist who, together with Otto Hahn and his team, discovered the concept of nuclear fission in 1939 [19,21,22]. In fact, Hahn and Meitner had re-observed this phenomenon four years later, and claimed to be the ones that discovered it. But Rutherford wrote to them, stating that this discovery had been made by Harriet. Later, Hahn agreed with Rutherford and wrote in his autobiography that "Brooks may have been the first researcher to have observed the phenomenon of radioactive recoil" [19].

Finally, her dedication to radioactive decay demonstrated that radiation is sequentially released when uranium and thorium decay. This was the first step that would build the concept of radioactive decay sequences. In addition, it was the main topic of Rutherford's 1904 Bakerian Lecture at the Royal Society of London, in which he discussed the successive decays of heavy radioactive elements.

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2. Retrieved from: http://collections.musee-mccord.qc.ca/en/collection/artifacts/II-123880/

Rutherford took the effort to credit Harriet for her contributions in his team [20]. He had always been her loyal co-worker and friend, who would never let the world forget the great achievements of Harriet.

Although she left physics research when she got married, her contributions were honored and recognized. In 1907, she enrolled in the Women's Canadian Club: from 1909 to 1912, she became an honorary secretary of the club and in 1923, she became the president [20]. In 2016, a new building at the Canadian Nuclear Laboratories was named after Harriet [23].

Harriet Brooks died in Montreal, Canada, on April 17, 1933, at age 56, possibly due to the effects of her exposure to radiation in her work [20]. She was an outstanding woman not only because of her research, but also for her strength. It is important to remember that the dilemma faced by Harriet in 1906, when choosing between a career or to start a family, is still a big dilemma among women after more than one hundred years.

VI. IRÈNE JOLIOT-CURIE

A. A legacy of her own

Born in Paris on September 12, 1897, Irène Joliot-Curie was the eldest daughter of the famous radioactive research couple Pierre and Marie Curie. Like her parents, who won the Nobel Prize in physics (1903) and chemistry (1911), Irène became a remarkable scientist and went on to win her own prize in chemistry in 1935 [24]. Until Irène got married in 1926, Marie's and Irène's lives were so tight that it was impossible to write about one without mentioning the other.

Irène was born one month premature [25], believed to be a consequence of Marie's exposure to radioactive materials. During Marie's time, the hazards of radioactive materials were not known, and she suffered illnesses during her pregnancy with Irène because of her exposure to radiation in her work [26]. As a child, it is also likely that Irène was exposed to radiation because of her parents' work, thus she was constantly in poor health [25]. She was only 6 years old when her parents won the Nobel Prize [9].

Irène had a very exclusive education. Marie strongly disapproved the rigid educational system in France. This provided Irène with the privilege to attend a private cooperative school organized by her mother and other eminent French scholars for 2½ years [25].

In the cooperative school, Marie taught physics and impressed Irène with her strictness and dedication to education [25]. During the last two years of high school, Irène attended a private all-girls' school. She furthered her studies at the Sorbonne (University of Paris) in 1914, just before the outbreak of World War 1 [25].

Only a little is known about Irène's relationship with her father, as he was killed in a car accident in 1906. Irène was not told what happened until after the funeral [25]. On the other hand, in 1910, the death of her grandfather affected her more, and she desperately needed her mother's attention. Marie, however, was also suffering from depression, poor health, and stress, which kept her apart from her children [25].

In 1911, Marie was awarded her second Nobel Prize, and Irène had begun to understand the importance of her mother's role in the scientific community [9].

Her studies at the Sorbonne were interrupted with the outbreak of World War 1. Irène, then, joined her mother to work as a nurse radiographer. Marie was a patriot and used the money from her second Nobel Prize to buy war bonds to support the French army. In the hospital where they worked, they used their knowledge to operate crude X-ray machines, which helped to locate bullets and shrapnel in the wounds of injured soldiers. Their work had saved the lives of many during the war [9,25].

After the war, Irène returned to Paris to work as her mother's assistant at the Radium Institute and gained her doctorate in 1925 [24,25]. It was also at the Radium Institute that she met her fiancé, Frederic Joliot.

They were married in 1926 and had two children. Irène perfectly assumed her role both as a researcher and as a mother. Just like her parents, Irène and Frederic worked as a husband and wife team, focusing their research on the atomic nuclei structure.

Fig. 9 Portrait of Marie Curie and her daughter, Irène. Courtesy of: Wellcome Collection[12].

On July 4, 1934, Marie died without the chance to see her daughter win the Nobel Prize a year later [25].

Irène's legacy goes far beyond her accomplishments in chemistry. She was also an activist who joined a number of organizations for the advancement of women's rights. She encouraged women to earn money to support themselves during a time when fascism was widespread and demanded women to stay at home [25]. In 1936, she joined politics

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3. Retrieved from: https://wellcomecollection.org/works/nbpjwgzw

and during World War II, she was threatened with arrest by the German soldiers [25].

Moreover, she was diagnosed with tuberculosis and was forced to stay in Switzerland. Near the end of the war in 1944, her two children joined her to live in the Swiss Alps. After the war, she went to the United States and then, back to France where she stayed until her death [25,26].

B. Scientific achievements

Irène completed her PhD in 1925. Her doctoral thesis was on alpha particles emitted by radioactive polonium during its disintegration. In particular, she focused on how alpha particles decelerate while moving through matter [9].

Polonium was discovered by her parents in 1898 and was extremely useful. Irène's expertise in dealing with this element was exclusive, and the Radium Institute, where she worked, was one of the most important radioactivity centers of the world [9]. Her dissertation defense made it to international news, and it was even reported by the *New York Times* [2].

While working with Frederic Joliot, they produced the world's largest supply of polonium [9]. Such work turned them into radiochemistry specialists, but it was very dangerous due to the high toxicity of the element they produced [9].

In the early 1930s, the whole world started paying attention on French research because of the scientific contributions by Irène and Frederic. They were on par with renowned nuclear physicists, such as Rutherford, Lise Meitner, and Niels Bohr [9]. The most important discovery made by Irène and Frederic was in 1934 and allowed them to win the Nobel Prize in Chemistry in 1935.

In their experiment, they placed their polonium next to an aluminum foil. They were expecting hydrogen nuclei to emerge, but neutrons and positrons appeared instead. A Geiger counter confirmed that the aluminum foil had itself become radioactive, which means that Irène and Frederic were the first scientists to artificially produce a radioactive element [2,9,25].

The discoveries by Irène and Frederic in artificial radioactivity had an enormous impact, not only allowing them to win the Nobel Prize in Chemistry, but also opening the practical applications of radiochemistry in medicine [27].

Irène's contribution to science was recognized a number of times. She was appointed the undersecretary of state for Scientific Research in 1936 by the French government, she was a member of a number of academies and scientific societies, and she was conferred honorary doctorates by several universities [24].

Irène passed away on March 17, 1956, at age 58 from leukaemia, probably because of exposure to radioactivity in her work [27]. Just like her mother, she is certainly a great inspiration to women, who are encouraged and influenced by her achievements in science and politics.

Fig. 10 Irène Curie, 1921. Courtesy of: Smithsonian Institution Archives. Image #SIA 2008-4488.

VII. CONCLUSION

The account of the six women described here inspires us today with their academic contributions, personal struggles and positive attitude. The world has changed in modern times, and it is important to cast aside all forms of discrimination to encourage young women to pursue a career in science. While the majority of women do not have to give up their careers anymore just because they got married, or be shunned from scholarships because men feared their abilities, they still face hurdles in other aspects that hinder them from contributing to society.

The physicists highlighted here role models for young women to persevere when facing their own challenges, before they, too, can rise up to achieve important contributions that shape the future of science, society and the world.

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A MEDICAL PHYSICS PERSPECTIVE: RADIATION THERAPY IN NEPAL

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I. INTRODUCTION

Radiation Oncology is an essential requirement for the safe and effective utilization of nuclear technology in the health care sector. Radiotherapy is highly effective cancer treatment and leads to cancer cure in patients. Cancer is one of the most rapidly growing diseases in Nepal. Over half of all cases of cancer in the world arise in people in low and middle-income countries. About 60% of the cancer cases worldwide occurs in low and middle income countries [1] This proportion will rise to fifty percent by 2020 [2]. In developing country like Nepal, at least sixty percent of all cancer patients can benefit from radiotherapy. However, the existing infrastructure is far behind to successfully cope with this increasing threat not only to public health but also national economies. Technological advancement in radiation therapy has dramatically increased the reduction of side effects and also increased survival rate in some cases and enhanced the quality of life after recovery. Modern Radiation Therapy treatments require trained and qualified professionals and big investment. However, the developing country like Nepal does not benefit from this advancement due to lack of radiotherapy machines and insufficient number of specialized medical professionals mainly medical physicists. Medical Physicists are one of the key components in Radiation Oncology and plays a vital role in improving cancer cure through technology. Upon pursuing the improvement of the situation, timely training in treatment planning, treatment technique and quality control is significant because the investment on human resource, investment on equipment and facility does not bring out an immediate result. Therefore, it is necessary to develop human resources in Radiation Therapy by properly responding to the growing demand for cancer treatment and by overcoming the poor situation of limited resources

The main point to cope with the current situation of radiotherapy service in Nepal is to improve the knowledge, skill and competency of radiation oncology professionals to treat the massive increase in cancer patients in particular throughout the country and also to improve cancer treatment by means of strengthening the application of radiation therapy.

II. CURRENT STATUS

In Nepal the first radiation therapy service was started way back in 1976 at Maternity Hospital with Brachytherapy service (Radium Needle) donated by USA. In 1991, Bir Hospital started first tele-therapy service with cobalt-60. During those initial days of its establishment, the radiotherapy unit was operated with help of experts from India. In 2002, B.P. Koirala Memorial Cancer introduced first Linear Accelerator and HDR Brachytherapy service in the country. Recently newer technology has been introduced by two private clinics with True-beam linear accelerator from Varian and Synergy from Elekta.

Nepal is a developing country with about 26.6 million population and cancer still remains disease of the elderly. The incidence of cancer is 100-120 per 100 thousand populations. Due to the lack of advanced technology, research and proper education, cancer treatment in Nepal has become very challenging. About eighty percent of patients present with advanced stage cancer and can only be treated palliatively.

According to Hospital based National Cancer Registry, the most common cancers in Males and Females are shown in following tables [4].

Table 1: Hospital Based National Cancer Registry Males

Cancer Site	Number	Percentage
Lung cancer	692	17.2
Stomach cancer	305	7.6
Larynx cancer	247	6.2
Bladder cancer	150	3.7
Rectum	139	3.5

Table 2: Hospital Based National Cancer Registry Females

Cancer Site	Number	Percentage
Uterine cervix	852	17
Breast	826	16.4
Lung	549	10.9
Ovary	350	7
Stomach	223	4.4

Unfortunately, Nepal still does not have population based cancer registry system. In the past, patients had to go abroad for radiotherapy. Right now, Nepal has six cancer centers providing radiation therapy services. Out of the six, four cancer centers are confined at Kathmandu valley. Only two cancer centers are out of the Kathmandu, one at Bharatpur middle of the Nepal and one at the Pokhara (currently not functioning). If we look at the map of the Nepal, patient has to travel a long way either from eastern or from western part of the Nepal.

Fig. 1: Map of Nepal

And for the typical course of radiotherapy patients would need to find accommodation close to the cancer center putting additional financial strain on patients.

The following table shows the present status of radiation therapy service in Nepal [5] [6] [7].

Table 3: Radiation Workers in Radiotherapy

Profession	Total number	Number per million* inhabitants
Radiotherapy Technician	24	0.90
Medical physicists	11	0.41
Radiation Oncologists	33	1.24

Table 4: Status of Radiotherapy Equipment

Therapeutic Equipment	Total number	Number of megavoltage treatment units per million*
Cobalt- 60	3 (-1)	0.112
Linac	5 (-3)	0.189
Brachytherapy	4 (- 3)	0.150
Simulator	3	0.113
Blood Irradiator	1	0.037

Negative sign means equipment is not functioning at present
* Population 26.6 million based on November, 2012
(Source: Central Bureau of Statists)

The above table illustrates the very complicated situation in radiation therapy in Nepal. Table 2 (a) indicates that radiation oncology professionals working in radiation therapy are far below the national need. Table 2 (b) shows the alarming situation of the equipment used radiation therapy. The negative sign in the table means the equipment is not functioning. This means right now we are falling behind in terms of equipment compared to in the past. Because of this, cancer patients have to wait for long time to get treatment which significantly affects the outcome. At present facing cancer is even tougher as radiation therapy machine is decreasing. At present two cobalt tele therapy machine at public and semi- public cancer center are in functional. Only two linear accelerators used in private center are functioning.

From the year 2003, Bir hospital has been converted into an Academic Institution as National Academy of Medical sciences and is undertaking the teaching activities in MD Radiation Oncology.

At present, Nepal is below the World Health Organization (WHO) recommendation of one megavoltage machine per million populations which means that Nepal should have at least 27 megavoltage machines. WHO figure also estimate the incidence of cancer in low or medium income countries like Nepal, is likely to increase by 50% to 60% by 2020 [2]. This is a major problem facing Nepal at present: there is a lack of vital equipment needed to effectively diagnose and treat this disease accurately, efficiently with appropriate quality. We still do not have true data on cancer incidence in the country and the cancer center in this field is very limited if compared to the population of Nepal. Radiation Therapy is one of the widely used and the cheapest modality in cancer care. According to the IAEA, almost sixty percent of the cancer patients require radiation treatment during the course of treatment. [3]

III. ISSUES

Though the history of radiation practice is long, Nepal still don't have any radiation act, nor any legal standards for radiation. There are no official records on radiological facilities in operation. The number and types of units, radiation workers and their qualifications, safety measures and conditions of workplace remain virtually unknown. No governmental or private organization has accurate statistics. According to Globocan 2012 data, Nepal had 18802 new cancer cases in 2012 which is predicted to increase to 29206 in year 2030. As about sixty percent of new cancer patients would require radiotherapy during their course of cancer. If we calculate accordingly, Nepal would require at least 32 tele therapy machines, around 65 Radiation Oncologists and at least 40 medical physicists by the year 2030. In order to work towards this target, it is important that Nepal must initiate more projects focused on Radiation Therapy. To meet that target the Ministry of Health, Ministry of Science & Technology of Nepal including cancer institutes and Radiation Oncology professionals must actively participate and contribute. To improve the current situation Radiation Oncology departments have to collaborate with international Societies like the International Organization of Medical Physicists (IOMP), the American Society for Radiation Oncology (ASTRO), the European Society for Radiotherapy and Oncology (ESTRO), the Australasian College of Physical Scientists and Engineers in Medicine (ACPSEM) and local professional societies of medical physicists and radiation oncologist. Here is a lot to be gained: the existing facilites in Nepal are insufficient and most of the radiation therapy departments need additional equipment, expansion of the building and recruitment of the new manpower.

IV. WAY FORWARD

Nepal became a member county of International Atomic Energy Agency (IAEA) in 2008. From 2012 onwards, we have also been involved in various Technical Cooperation (TC) projects associated with the IAEA including the establishment of a radiation regulatory framework and development of health services. Radiation Oncology Professionals working at different institutions have been trained through various IAEA TC projects. We are also participating in various Regional Cooperative Agreement (RCA) projects on Cancer management, Cancer Staging, Education and training of Medical Physicists, IMRT, Brachytherapy, Nuclear Medicine, Diagnostic Radiology and human health related projects. Recently, the IAEA TC project, Developing Radiation Health Service Infrastructure (NEP 9001) was started in 2012. From 2018, one new project on Strengthening Modern Application of Radiation Therapy (NEP 6003) is going to start which main objective is to improve competency of radiation oncology professionals and to standardize radiation therapy treatment techniques. Additionally, there has been a strong interest in more developed countries in participating in clinical training in the region, notably through the development of resources and teaching contributions. Nepal with little infrastructure in radiation oncology, these national projects will provide an avenue for the building up of best practice in radiation oncology.

Some encouraging news is that NAMS, Bir Hospital is going to start its service form new TomoTherapy machine from Accuracy. Bhakatpur Cancer Hospital came with the tender for new Linear Accelerator. B.P. Koirala Memorial Cancer Hospital is buying new linear accelerator [8]. All this means Nepal is going to have three new radiation therapy machines in 2018. This is a good start; however, a lot more work needs to be done before Nepal can offer all its cancer patients the radiotherapy services every patient deserves.

Conflict of Interest

The authors declare that they have no conflict of interest.

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FIVE YEARS OF INTERNATIONAL DAY OF MEDICAL PHYSICS CELEBRATION IN GHANA – THE EXPERIENCE

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Abstract— **The celebration of the International Day of Medical Physics (IDMP) was instituted by the International Organization for Medical Physics (IOMP) in 2013. This initiative was aimed at promoting the role of medical physicists in the worldwide medical scene. During the celebration, national and regional member organizations join the mother organization (IOMP) to organize series of events to mark the day. In Ghana, the Ghana Society for Medical Physics which is affiliated to the Federation of African Medical Physics Organizations (FAMPO) and the IOMP has actively celebrated the IDMP in Ghana on every 7th November since its inception in 2013. This has given the medical physics profession a huge publicity in the country. Based on IOMP's theme for the year, the society selects appropriate speakers and topics reflecting the given theme. Previous speakers have included medical physicists, radiologist, radiation oncologist, nuclear medicine physician, radiation protection practitioners and oncology nurse. The background of participants at such events includes medical physicists, radiation protection practitioners, lecturers, radiologists, oncologists, regulators, allied health professionals, students, media and the general public. The IDMP celebrations in Ghana have been very educative and successful. It is vital that the medical physics society continues to keep engaging other health professionals, general public and media, by making them aware of the extremely dynamic and crucial role medical physicists play in the healthcare delivery with respect to diagnostic medical imaging, radiotherapy, nuclear medicine and radiation protection.**

Keywords— **IOMP, IDMP, Ghana, Medical Physics**

I. INTRODUCTION

Medical physics practice in Ghana began in the 1970s when physicists were trained in developed countries (mostly in Europe) by the kind support of the Government of Ghana (GoG), International Atomic Energy Agency (IAEA) and other organizations [1]. Upon the return of the trained medical physicists, many of them practised with the Ghana Atomic Energy Commission (GAEC), a research institution charged with the peaceful promotion and application of nuclear techniques. Some of the medical physicists also offered clinical services to hospitals. They undoubtedly contributed to the growth of the profession through education, training, clinical and research work [1, 2]. Their pioneering activities drew attention and interest to the medical physics profession, and subsequently influenced the establishment of two state owned radiotherapy centres in Accra, the capital of Ghana, and Kumasi, the second major city. Subsequently, a third radiation oncology centre which is privately owned has been built in Accra [1].

Currently, training of medical physicists in Ghana is done locally in order to provide the requisite work force for Ghana's radiotherapy, nuclear medicine and diagnostic radiology programmes. Plans are on-going to expand and upgrade existing infrastructure in radiotherapy practice by the introduction of advanced radiotherapy techniques and equipment. Equipment available in radiotherapy practice in Ghana include Co-60 teletherapy unit, linear accelerator, low dose rate (LDR) Cs-137 brachytherapy unit, high dose rate (HDR) Co-60 brachytherapy unit, LDR I-125 prostate brachytherapy system. In diagnostic radiology, there is transition from screen film radiology to digital radiology, with a significant increase of diagnostic imaging equipment, as well as mushrooming of private imaging centres. Imaging systems available in Ghana include computed tomography, magnetic resonance imaging, mammography, conventional X-ray, dental X-ray, dual energy X-ray absorptiometry (DEXA) and fluoroscopically guided X-ray equipment.

The local training of medical physicists started in 2004, with the introduction of M.Phil Medical Physics programme by the University of Ghana (UG). This was hosted by the School of Allied Health Sciences (SAHS) of the College of Health Sciences. In 2007, the programme was relocated to the Graduate School of Nuclear and Allied Sciences (SNAS) of the University of Ghana, and has since been hosted at the Ghana Atomic Energy Commission (GAEC) campus of the University. SNAS was established in 2006 by collaboration between GAEC and UG with key support from International Atomic Energy Agency (IAEA). The goal of the School was to promote postgraduate university education and training for preservation and enhancement of nuclear knowledge in Ghana and Africa [3, 4]. In 2008, PhD Medical Physics was also introduced. With time, the Department of Medical Physics grew from initially admitting local students to admitting foreign students from across the Africa Region [2]. The department has become a hub of medical physics training in the sub-region, attracting a number of foreigners from some African countries. This has boosted the number of trained medical physicists locally in Ghana and other African countries.

II. GHANA SOCIETY FOR MEDICAL PHYSICS (GSMP)

In line with the statutes and byelaws of the International Organization for Medical Physics (IOMP), the Ghana Society for Medical Physics (GSMP) was established in 2011 with an ultimate aim of promoting the application of physics to medicine [5]. The Society serves as checks and balances on the activities of professional medical physicists and contributes to the training of medical physics students in Ghana. GSMP is mandated to regulate activities of medical physicists in Ghana as required by the Health Professions Regulatory Bodies Act 2013 (Act 857) [6]. At the International level, GSMP is affiliated to the Federation of African Medical Physics Organizations (FAMPO) and the IOMP. GSMP operates with a Constitution, Code of Ethics and Practice Standards, and achieves its objective through the following:

- Encouraging advancing and disseminating technical information, theory and practice of medical physics and related fields.
- Promoting a high level of ethical practice among medical physicists.
- Ensuring that medical physicists are engaged in technical procedures, which form part of patient care and treatment and
- Ensuring that medical physicists undergo certification examination and are licensed to practice.

Presently, there are about sixty-five (65) trained medical physicists in Ghana, with the distribution as clinical medical physicists (30%), medical physicists in academia (20%), medical physicists in research (15%) and unemployed (35%).

There have been capacity building programmes and projects in Ghana for the profession of medical physics such as;

- Academic, clinical and professional collaboration projects
- Participation in IAEA Technical Cooperation research projects
- Involvement in IOMP activities [7]

III. INTERNATIONAL DAY OF MEDICAL PHYSICS (IDMP) CELEBRATIONS BY GSMP

The IOMP instituted the celebration of the International Day of Medical Physics (IDMP) in 2013. This initiative was aimed at promoting the role of medical physicists in the worldwide medical scene where national and regional member organizations join the mother organization (IOMP) to organize series of events such as seminars, symposia and public lectures, and other activities to draw gatherings and for practitioners and the general public to receive in-depth information about the profession.

Since the inception of the IDMP in 2013 by the IOMP, the GSMP has actively celebrated the occasion in Ghana on 7th November of each year. The observance of the IDMP has given the medical physics profession a huge publicity in Ghana among other professional bodies such as Ghana Society for Radiologists, Ghana Society for Radiographers, Ghana Association for Radiation Protection, etc. and the general public. Based on the theme for each year, the Society selects appropriate speakers for its celebrations.

As part of the strategies to boost recognition of the IDMP celebration in Ghana, at least two weeks to the celebration, it is extensively publicized through banners and posters. Figure 1 shows the poster that was designed for the 2017 edition of the IDMP celebration in Ghana.

Table 1 Symposia for International Day of Medical Physics (IDMP) Celebration in Ghana from 2013-2017.

Year	IOMP Theme	Speaker/Topic	Summary of Presentations
2013	Radiation Exposure from Medical Procedures: Ask the Medical Physicist	Prof. C. Schandorf: *Radiation Exposure from Medical Procedures: Ask the Medical Physicist*	(i) Medical Physicist's role in the medical team for diagnoses and treatment of diseases (ii) Medical Physicist's involvement in equipment purchase, acceptance testing, commissioning, effective use & maintenance of equipment, quality assurance & quality control of medical procedures including dosimetry, protection of the patient, staff & public.
2014	Looking into the body-Advancement in imaging through Medical Physics	(i) Mr. E.C.K. Addison: *Role of Medical Physics in Ultrasound Imaging* (ii) Dr. A.N. Mumuni: *Role of Medical Physics in MRI Applications* (iii) Dr. A. Ankrah: *Nuclear Applications in Medicine (Nuclear Medicine)* (iv) Dr. S. Asiamah: *Computed Tomography Applications in Medicine*	(i) Physics Principles of Ultrasound Imaging (ii) Physics & basic principles in CT (iii) Application of CT in Medicine (iv) Physics of MRI & Clinical Applications of MRI (v) Safety in MRI (vi) Radioisotopes applications in imaging and therapy
2015	Better Medical Physics=Better Cancer Care in Radiation Oncology	(i) Dr. J. Yarney: *Better Cancer Care : Radiation Onologist's Perspective* (ii) Ms. C. Muronda: *General Cancer Care in Radiation Oncology* (iii) Dr. J. K. Amoako: *The Role of the Regulator in Better Cancer Care Management* (iv) Mr. E.C.K. Addison: *Role of Medical Physicist in Better Cancer Care Management*	(i) Contribution of Radiation Oncology to Cancer Management (ii) Improved Imaging (iii) Advanced Treatment Techniques (iv) National Strategy for Cancer Control (v) Role of Efficient and Independent Nuclear Regulator in Cancer Management (vi) Requirements of Nuclear Regulatory Authority Act, (Act 895) (vii) Principles of Radiotherapy in Cancer Management (viii) Introduction of New Technologies & Challenges
2016	Education in Medical Physics: The Key to Success	(i) Dr. S. Inkoom: *Norwegian Partnership Programme for Global Academic Cooperation (NORPART) on Ghana-Norway Collaboration in Medical Physics and Radiography Education* (ii) Dr. M. Afadzi: *Sharing of Experiences as a Student in Norway* (iii) Prof. C. de Lange Davies: *Education and Training in Medical Physics: The Norwegian Experience*	(i) Education & training in (theory & practical) of Medical Physics, Radiation Protection & Radiography Education in Ghana & Africa. (ii) Academic Experience at Norwegian University of Science & Technology (NTNU) ; Teaching, Learning the Research Environment, & Student Life in Norway) (iii) Biophysics, Physics and Medical Technology Program at NTNU (Master & PhD) (iv) Future of Medical Imaging. Nanoparticels Research with Ionizing Radiation & Ultrasound
2017	Providing a Holistic Approach to Women Patients and Women Staff Safety in Radiation Medicine	(i) Ms. T. Dery: *Female Medical Physicist: Global and Regional Perpective* (ii) Ms. V.D. Atuwo-Ampoh: *Radiation Safety Aspects Pertaining to Female Patients and Staff* (iii) Prof. M. Boadu: *Providing a Holistic Approach to Women Patients and Women Staff Safety in Radiation Medicine*	(i) Overview of Radiation Protection & Safety (ii) Principles of Radiation Protection (iii) Radiation Protection & Safety for the Pregnant Staff & Patient (iv) Contribution of Women in Medical Physics (v) Survey of Female Medical Physicists by IOMP (vi) Medical Physics Practice & Training in Ghana (vii) Challenges of Women in Science (viii) National Regulatory Infrastructure for Radiation Protection in Ghana (ix) Occupational Exposure in Radiation Medicine (x) Sources of Exposure in Diagnostic Radiology Nuclear Medicine & Radiotherapy (xi) Documentation of Radiation Protection Program (xii) Medical Exposure (xiii) Cancer Statistics in Ghana (xiv) Strategy for Cancer Management (Awareness & Screening Programmes)

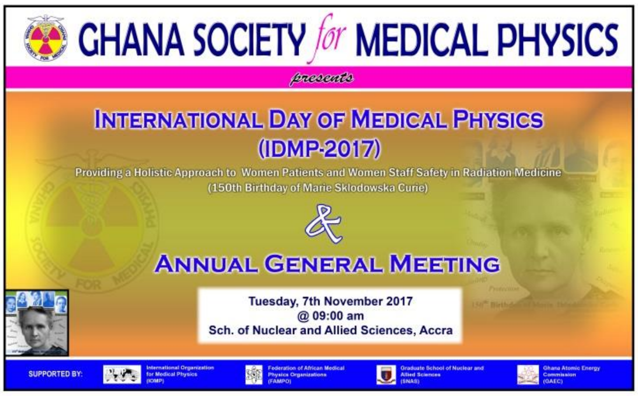

Fig. 1 Poster for the 2017 edition of the IDMP celebration in Ghana.

In addition, at the end of the celebration, journalists publish in the media a summary of what transpired during the celebration [8, 9].

A list of speakers and their topics reflecting IOMP's theme for the year is presented in Table 1. Figure 2 shows a group photograph of participants of the 2017 IDMP celebration in Ghana, under the theme "Providing a Holistic Approach to Women Patients and Women Staff Safety in Radiation Medicine", which was organized by the Ghana Society for Medical Physics.

Fig. 2 Group photograph of participants of 2017 IDMP celebration in Ghana organized by the Ghana Society for Medical Physics.

IV. CONCLUSIONS

For five (5) continuous years, GSMP has observed the celebrations of IDMP in Ghana. The celebrations have been very educative and successful. The participants have come from several backgrounds such as medical physicists, radiation protection practitioners, lecturers, radiologists, oncologists, regulators, allied health professionals, students, media and the general public. It is the expectation of GSMP that Ghana would use the IDMP celebration to influence the application of physics in medicine in health care delivery in Ghana and the rest of Africa.

CONFLICT OFINTEREST

The authors hereby declare that there is no conflict of interest in the publication of this article.

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MEDICAL PHYSICS FOR WORLD BENEFIT (MPWB):

A NOT-FOR-PROFIT, VOLUNTEER ORGANIZATION IN SUPPORT OF MEDICAL PHYSICS IN LOWER INCOME ENVIRONMENTS

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Abstract— **Medical Physics for World Benefit (MPWB, www.mpwb.org) is a young, not-for-profit organization that was developed out of recognition of the limited human resource availability and insufficient training opportunities for medical physicists in low-to-middle income countries (LMICs). Its mission is to support activities which will yield effective and safe use of physics and technologies in medicine through advising, training, demonstrating and/or participating in medical physics-related activities, especially in LMICs. Operationally, its emphasis is on "partnering" with the goal of having individuals and/or educational or healthcare institutions in both LMICs and high-income countries (HICs) work together to meet well-defined needs. Practically, it also seeks to work collaboratively with other organizations wishing to provide similar support. MPWB is a membership-driven organization for individuals who have a passion for reducing global health disparities, especially as related to medical physics. Various projects are in progress, most of which relate to training and mentoring. Its vision, mission and values are summarized on its website along with links to newsletters and other relevant activities.**

Keywords— **Training, mentoring, low-to-middle-income-countries, partnering, collaboration.**

I. INTRODUCTION

There is a growing recognition of healthcare disparities between high-income countries (HICs) and low-to-middle income countries (LMICs). These disparities have been highlighted by the United Nations Sustainable Development Goals, which in 2015 called for a reduction by one-third in premature mortality from non-communicable diseases, including cancer, by 2030 [1;2]. These disparities were also highlighted in a recent seminal Lancet Oncology Commission report by the Global Task Force on Radiotherapy for Cancer Control (GTFRCC) [3] that indicated if equal global access to radiotherapy is to be provided by 2035, another 30,000 radiation oncologists, 22,000 medical physicists, and 78,000 radiation therapists will need to be trained. Recognizing the limited reality of equal global access to radiotherapy by 2035, the GTFRCC recommended an action target for the training of 7,500 radiation oncologists, 6,000 medical physicists and 20,000 radiation therapists in LMICs by 2025. In addition to the cancer problem, medical physicists are also needed in the diagnostic imaging-related subspecialties. Considering staffing levels in HICs to estimate this need, an additional 20-25% imaging physicists will have to be trained, i.e., a total of 7,500 new medical physicists would be needed by 2025, which is approximately the total number of medical physicists currently in North America! These numbers are quite astounding, especially considering the very limited training opportunities for medical physics-related personnel in LMICs.

Medical physics training has been well-defined in HIC contexts, usually involving a post-graduate degree in medical physics, followed by 2 years of residency or on-the-job training. The International Atomic Energy Agency (IAEA) has several reports that define both the academic requirements [4;5] as well as the practical residency training component [6-8]. Both the academic and practical training components have limited availability in LMICs where little or no radiotherapy or diagnostic imaging expertise exists. While the suggestion of setting up "centres of excellence" is noteworthy [9], the scarce resources make the "bootstrapping" difficult. Collaboration and cooperation by multiple organizations has the potential to resolve the training needs [10;11].

II. VISION AND MISSION

It is out of recognition of the limited human resource availability and limited training opportunities in LMICs that the concept of Medical Physics for World Benefit (MPWB, www.mpwb.org) developed. MPWB is a young, non-profit, volunteer organization that was formally registered as a charitable association in Canada on 16 November 2016 and in the United States on 23 December 2016. It has a vision of a world with access to effective and safe applications of physics and technology in medicine. This includes all areas of medical physics although MPWB recognizes that radiation therapy has the largest need. MPWB's mission is to support activities which will yield effective and safe use

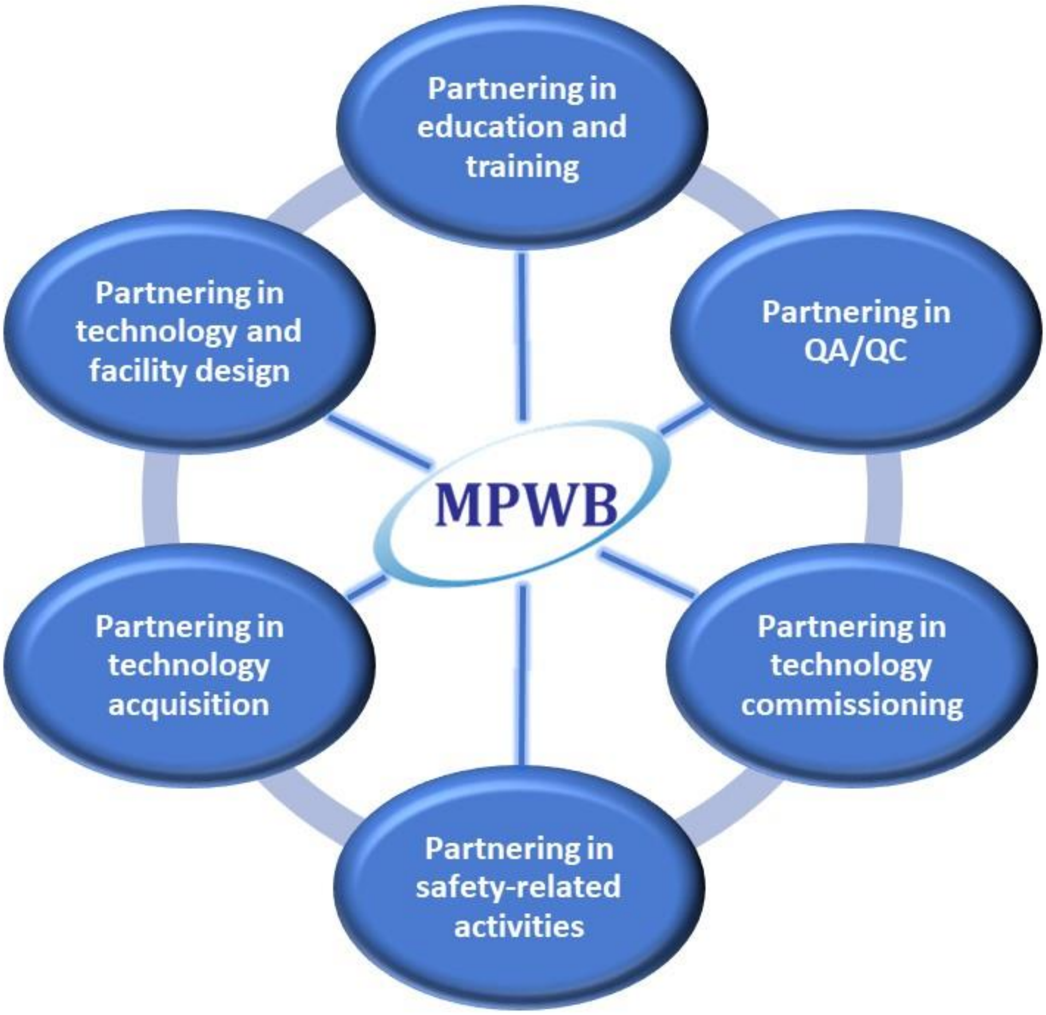

Fig. 11 Schematic diagram emphasizing the partnering relationship between MPWB and the individuals or institutions being supported by MPWB.

of physics and technologies in medicine through advising, training, demonstrating and/or participating in medical physics-related activities, especially in LMICs. Thus, its emphasis is on providing intellectual support through educating, training, mentoring and collaborating. As shown in Figure 1, the theme is “partnering” with a goal of having individuals and/or educational or healthcare institutions in both LMICs and HICs work together to meet well-defined needs. To help ensure sustainability, the intent is to provide support in those LMIC circumstances where basic infrastructure and staff already exist.

MPWB is a membership-driven organization with the formal membership application process having opened in June 2017. There are now over 150 registered Canadian, American, and International members, and a mailing list of over 800 individuals who have expressed an interest in MPWB activities. The Board meets electronically biweekly and addresses requests for assistance from LMICs that have come largely, although not exclusively, from Africa. In addition to projects specifically targeted towards addressing needs in a LMICs, broader activities related to training and implementation are also addressed by the Board. For example, a generous grant from Dr. Jack Cunningham to MPWB is being allocated largely towards training activities related to treatment planning. In this context, the MPWB Board members are open and welcome to similar initiatives.

Another project is the development of an “Open Syllabus” to support residency training. Recognizing that there is a wealth of on-line, educational resources for medical physics residency and clinical training, MPWB is connecting elements of the IAEA Medical Physics Clinical Training syllabus [6] with open-access resources that are readily accessible. In this context, the MPWB Board members would be pleased to receive information of any relevant, on-line resources for consideration and inclusion in the Open Syllabus. Multiple other projects are under discussion.

III. WHY INDEPENDENT OF EXISTING ORGANIZATIONS?

The question has been asked a number of times as to why MPWB does not function under the auspices of one of the major medical physics organizations such as the International Organization of Medical Physics (IOMP) [11] or the American Association of Physicists in Medicine (AAPM). The answer is that these bigger organizations have multiple priorities that go well beyond providing grass-roots support to individuals, to clinics or to educational institutions in LMICs. They have a broader mandate and more complex administrative structures such that charitable status, allowing tax-deductible donations, is often not available or appropriate. However, MPWB strives to work in close partnership with such organizations. Hence, MPWB has developed a memorandum of understanding with the AAPM, which helps clarify the communication and working relationship. For instance, if working on closely-related projects, MPWB and the AAPM agree to minimize the duplication of efforts and maximize potential benefits. MPWB is also in discussion about becoming an Affiliated International Organization of the IOMP.

MPWB is in frequent communication with the International Atomic Energy Agency (IAEA) about projects in LMIC environments. Indeed, at the recent IAEA International Conference on Advances in Radiation Oncology (ICARO2), the President of MPWB attended as representing MPWB as a non-government organization. MPWB is also working closely with the International Cancer Expert Corps (ICEC, www.ICECcancer.org) on various projects including meetings on developing robust, low cost radiation treatment technologies for challenging environments [12;13]. Two of the MPWB Board members are on the Advisory Board for ICEC. Furthermore, right from the outset, the President of MPWB has been in close communication with the Board Members of Physicien Médical Sans Frontières (PMSF, www.pmsf.asso.fr) who have a similar, although not identical, mandate to MPWB; however, they are not well recognized in the English-speaking world. PMSF has been very supportive of MPWB developing a sister organization. MPWB continues to maintain close contact to ensure collaborative efforts where appropriate and to avoid overlapping projects. In the 2017 Canadian Organization of Medical Physicists (COMP) Strategic Plan, under Strategic Priority 4, “Engage in strategically aligned international initiatives”, the following is included: “COMP is providing support for the newly launched Medical Physics for World Benefit.”

IV. WHAT ABOUT EQUIPMENT DONATIONS?

MPWB is often asked about new and used equipment donations. The MPWB mandate is to provide educational and training support where appropriate, and it defers equipment donations to other organizations. MPWB recognizes the limitations and potential pitfalls of donation of large, expensive, used equipment (e.g., linear accelerators, cobalt-60 machines, CT scanners, other major imaging devices). The success of such donations often fail due to inadequate needs assessment and lack of support for training, service and parts [14;15]. However, MPWB has been in close communication with the IOMP/AAPM Equipment Donation Subcommittee which is focused on small equipment donations. MPWB is supportive of providing training assistance for equipment such as dosimetry systems that have been fully refurbished, recalibrated and safe for use.

V. SUMMARY

In summary, MPWB is a young, not-for-profit, volunteer organization with the mandate of partnering to provide education, mentoring and training support to LMIC contexts. MPWB seeks the support of individuals who have a passion for reducing global health disparities, especially as related to medical physics. More information can be found on the MPWB website (www.mpwb.org).

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HOW-TO

X-RAY TUBE ARCING : MANIFESTATION AND DETECTION DURING QUALUTY CONTROL

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Abstract— **X-ray tube arcing is a dangerous rarely observed phenomenon, which may occur in all X-ray equipment. It may lead to artefacts and repetition of exposures, but also to costly defects of the X-ray equipment. An arcing X-ray tube should be immediately replaced. The paper presents unique images of X-ray tube arcing and discusses its cause. Several methods for early detection of X-ray tube arcing are presented as part of the Quality Control procedures in Diagnostic Radiology. The paper also aims to be used as a reference material for lecturing and training in X-ray Diagnostic Radiology Imaging.**

Keywords— **X-ray tube, Arcing, Heel Effect, Quality Control in Diagnostic Radiology.**

I. INTRODUCTION

Arcing may be expected in all high-voltage (HV) systems. It exists in all medical X-ray equipment. X-ray tube arcing is a phenomenon usually associated with tube ageing, but can be present also in new X-ray tubes.

Arcing is rarely a subject of direct observation, but is present and can lead to serious artefacts (hence repetition of exposures and increased patient dose) and also to significant technical problems with the equipment (arcing is one of the most frequent causes of X-ray tube failure). Routine Quality Control (QC) can often fail to detect the problem as it is with random manifestation. Occasionally radiographers could report hissing noise (or pops) from the X-ray tube during exposure, but this is not always reported to the medical physicists performing Quality Control surveys. Understanding the phenomenon and the methods to detect arcing is an important element of the QC tests.

II. WHAT CAUSES X-RAY TUBE ARCING

The high vacuum inside the X-ray tube (min 10^{-6} mbar) assures the undisturbed path of the thermal electrons (anode current, I_a) from the Cathode filament to the Anode target. Internal ionization of the X-ray tube leads to vacuum reduction and internal discharges (arcing sparks) between the two electrodes or between the tube envelope and one electrode (usually Cathode). There are two main types of arcing – in new tubes (or unused ones) and in old tubes.

Arcing in new (unused) X-ray tubes

During X-ray tube manufacturing the glass envelope is first vacuumed and then sealed. However with time the glass, and the other parts of the X-ray tube inside the vacuum, emit ions (cold emission). Special measures are taken for reducing this emission – such as polishing and degassing the glass and the metal electrode assemblies. However this treatment does not eliminate the problem entirely. The cold emission exists, causing internal ionization of the X-ray tube volume. This leads to discharges in the vacuum (small arcing sparks) what increases the current between Cathode and Anode (I_a plus ionization current). This is effectively a short-circuit, which is associated with disruption of the production of X-rays for short period of time. This may create artefacts or (rarely) damage the X-ray tube and Generator. Due to this reason new tubes and tubes, which have not been used for a long time (or have been stored for a long period) must be "degassed". The method includes slow warming with several low-power exposures before regular use - for more details see EMERALD materials website in Further Reading

Arcing in old (aged) X-ray tubes

The arcing inside old X-ray tubes is more powerful and more dangerous. It is most often observed in X-ray tubes with glass envelope, but can also be present in metal X-ray tubes. During each exposure the glass envelope is heated to very high temperature (due to the close proximity of the glass to the glowing-hot Anode - only several centimeters). This is followed by cooling to less than 100^0C temperature, and new heating during the next exposure, thus leading to thermal stress of the material, what causes microcracks in the glass after several years of work (depending on the power and frequency of exposures). This process increases the release of ions inside the tube. Additionally the evaporation of the Cathode filament and the Anode during the exposures leads to metallization of the glass, what further creates conditions for arcing inside the X-ray tube Fig.1 shows an old X-ray tube (after decommissioning) with many cracks on the glass surface.

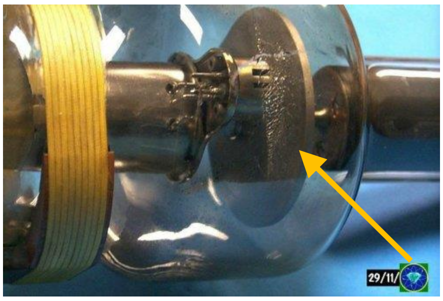

Fig.1 Decommissioned X-ray tube with severely cracked glass envelope (at the side opposite the cathode and anode).

There are various industry methods to decrease this “etching” of the glass of the tube envelope, but they do not eliminate the problem entirely - arcing exists and increases with the ageing of the X-ray tube. The arcing current between the high voltage electrodes of the X-ray tube can reach high values and can damage not only the X-ray tube, but also the X-ray Generator. Severe arcing may also lead to implosion of the X-ray tube. The manufacturers have special tests of the X-ray tube metal housings in order to assure patient safety in case of such dangerous situation.

III. X-RAY TUBE ARCING MANIFESTATION

There are several stages of X-ray tube arcing manifestation, which may have the following indicative separation. The first one is in case of very small occasional arcing, which can be detected only with an oscilloscope (see below). The second stage is occasional audible hissing noise from the X-ray tube during exposure. The third stage is associated with increased noise (cracking) from the X-ray tube and sometimes also unexpected high noise from the X-ray generator during the exposure (mostly in classical types of generators). The fourth stage may begin with the loud noises in third stage and continue with automatic switch off of the high voltage fuse during the X-ray exposure.

The noise made by moderate arcing inside the X-ray tube is weak, but audible. The random hissing/cracking noise (or pops) in the X-ray tube is associated with very brief arcing sparks, which quickly exhaust the existing ionization inside the X-ray tube, what leads to restoring the initial vacuum (until a sufficient number of new ions are produced by the effects described above and a new arc appears). The visual observation of this phenomenon is very difficult and usually requires industrial environment.

Figure 2 (on the next page) shows the visual appearance of a sequence of sparks inside an old X-ray tube. The images are made through frame-by-frame analysis of a two minutes video of the event. These unique images are extracted from a video of an open X-ray tube housing (see the Acknowledgements) and present a good visual of the manifestation of the arcing phenomenon inside the tube.

Fig.2a shows the normal work of the Anode (left, glowing hot) an the Cathode (right, only the profile of the filament is seen inside the Cathode cup). In front of these is the glass envelope (with a serial number). Fig.2b shows a small spark close to the Cathode (in the form of a bright dot marked with arrow), while Fig.2c shows the restored normal work of the X-ray tube immediately after the brief spark. These events are of the order of microseconds and only the after-glow of the discharge is recorded (in fact integrated) by the slow video recorder (one video frame lasts tens of msec).

Fig.2d shows another similar brief spark (at a different spot near the Cathode); this is immediately followed by a cluster of 3 small sparks in this area, seen on Fig.2e. Each of these events is usually associated with a very quick flash of light inside the X-ray tube. After these small sparks the vacuum could be restored (what is often the case), but also there is a high probability that the phenomenon could continue with increased strength and further clusters of sparks may appear - see Fig.2f. This produces a very bright flash of light inside the X-ray tube, associated with a strong “cracking noise” (sometimes even a noticeable “boom”). This creates significant mechanical stress inside the X-ray tube, what may further crack the glass and in turn - increase the ionization. This positive feedback creates further large cluster (a ball) of sparks – Fig.2g. This leads to the creation of a very strong arc inside the X-ray tube – Fig.2h. At this time the X-ray tube produces a burst of bright light associated with a loud sound (strong arcing, which could even lead to implosion of the tube). During this arc a very strong current passes through the tube electrodes, and further through the Rectifier and the HV Transformer of the X-ray Generator, what in turns activates the electrical safety circuit. This circuit senses the unusually strong I_a (and/or sudden decrease of the kV due to the short-circuit inside the X-ray tube). The safety circuit switches-off the High Voltage (HV) – see Fig.2i, which shows only the remaining after-glow of the cooling-down Anode. After a quick spark the system may restore the work of the Generator during the exposure, but the high current could also turn off the fuse of the equipment. If the sparking event is very fast and strong, and the safety circuit cannot react, it can damage both the X-ray tube and more importantly - the X-ray Generator.

IV. DETECTION OF THE X-RAY TUBE ARCING

Detection of arcing is very important, as its presence is an immediate sign for the urgent need of X-ray tube decommissioning and replacement. Otherwise artefacts and related repeat of exposures are imminent, and importantly, equipment damage is very likely to occur. There are two methods to asses arcing – Direct (Fig.3) and Indicative.

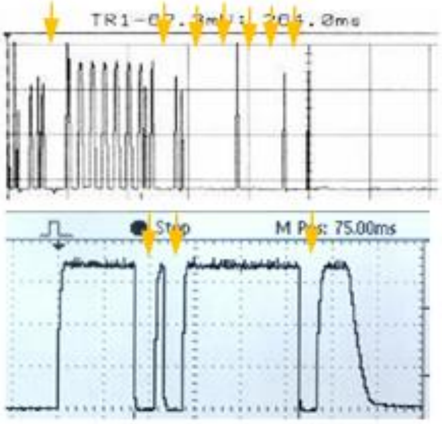

Fig.3 kVp oscillograms of X-ray tubes during arcing (see arrows)
-Above: arcing of tube with classical X-ray Generator - some kVp pulses are missing in clusters, as arcing is associated with these (the uneven kVp amplitudes are another sign of micro sparks).
-Below: arcing of tube with medium-frequency X-ray Generator -note the sharp drops (short-crciut) of the kVp line at 3 instances.
In both cases the arcing has been followed by self-recovery of the vacuum inside the X-ray tube (kVp recovers to its pre-arc value).

Direct detecting of arcing with kVp meter and oscilloscope

This is the most efficient way to detect X-ray tube arcing. It requires attaching an oscilloscope to the kVp meter. This direct recording of the kVp fluctuations detects even small arcing inside the X-ray tube. This is due to the fact that the spark between the Cathode and Anode is in fact a short-circuit, what causes a sudden drop of kVp (Fig.3). During this detection, it has to be insured that the kVp meter has sufficient bandwidth (see Annex). This is of special importance when assessing medium-frequency Generators. In case the kVp meter is not fast enough some sudden decreases in kV can remain undetected due to missed signal registration. This detection is a proof of the importance to use an oscilloscope and kVp meter with oscilloscope output for assessment of equipment performance during QC tests

This direct detection is the most reliable one, but it requires a good kVp meter and oscilloscope. If these are not available the arcing phenomenon cannot be observed, but an estimation of X-ray tube ageing (hence potential arcing) can be made.

Indirect estimation of the time when arcing may appear, using the X-ray tube specific dose output (mGy/mAs)

The indirect estimation of time when arcing may occur is only used for planning of X-ray tube replacement before potential strong arcing. This will require having a good record keeping of QC surveys, starting with the new X-ray tube. With the age of the X-ray tube its specific dose output decreases, what is an indication of its ageing – see Fig.4 on next page. In practice an X-ray tube will have to be replaced if its initial specific dose output (mGy/mAs) at specific kV (usually 80 kV for Radiographic equipment) is reduced below 60%. This reduction is due to the fact that with the ageing of the X-

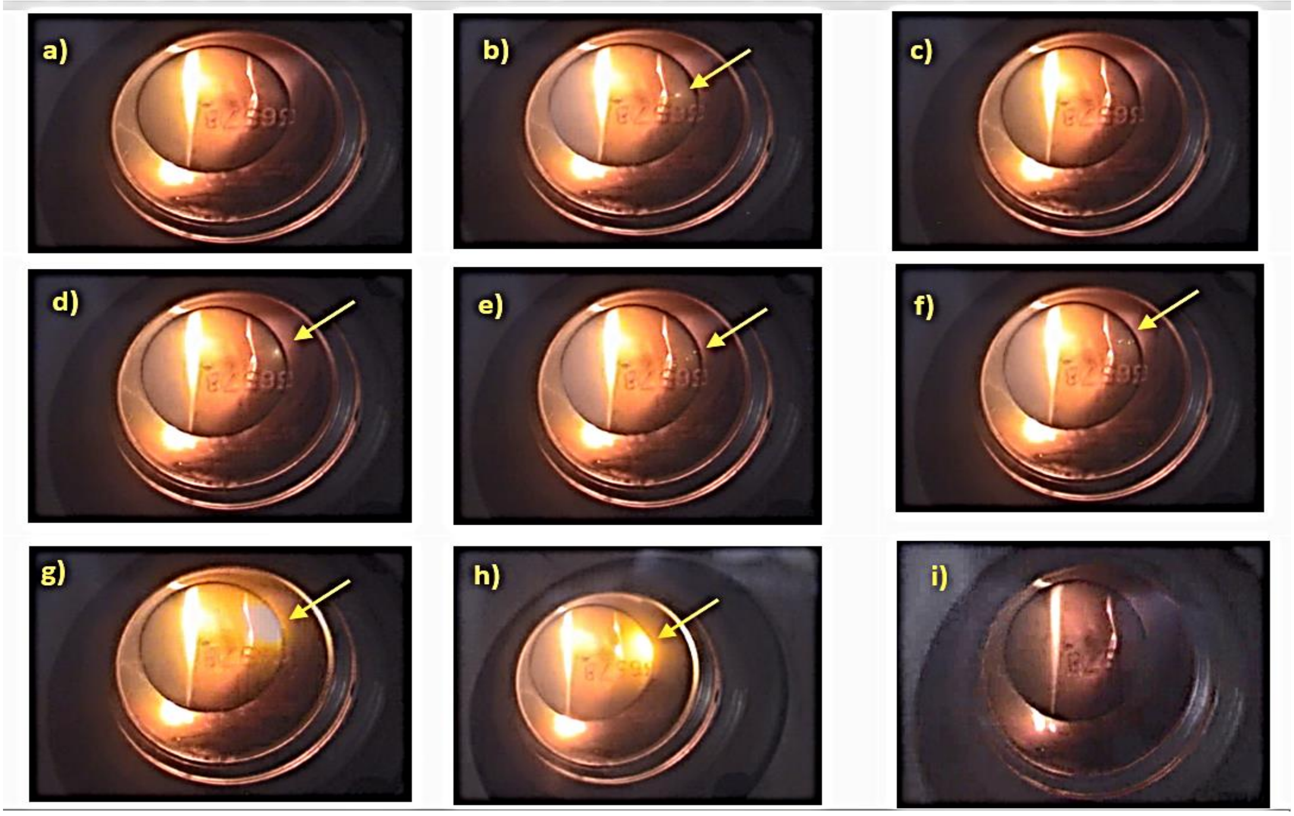

Fig.2 (a-i) Arcing - sequence of sparks inside an old X-ray tube with rotating Anode: a frame-by-frame analysis of a 2 minutes video through an open X-ray tube housing (the explanation of the images is inside the text of the paper); the filming of the video is described in the Acknowledgements ray tube the Anode target begins to crack due to the significant thermal stress after thousands of exposures (i.e. cycles of heating and cooling). The cracks not only decrease the life of the X-ray tube (damaging the anode), but also uneven the target surface. The cracked anode surface causes scattering or absorbing (inside the cracks) of some of the X-rays photons, hence decreases the tube output with time. The cracks increase the untreated surface of the materials leading to increased ion emission.

Indirect estimation of the time when arcing may appear using the Heel effect

Measuring the increased Heel effect, associated with the ageing of the X-ray tube is another indirect way to roughly estimate the time of expected X-ray tube arcing, hence tube replacement. Figure 4 shows the shifting of the maximum of the X-ray beam intensity from the central beam (15^0) toward the Cathode. This leads to further decrease of the already smaller beam intensity at the side of the Anode – i.e. more prominent Heel effect. The latter can be directly measured from a sufficiently long radiogram of a test object placed in parallel to the Anode-Cathode axis – Figure 5. However this will also require having the initial measurements of the Heel effect of a new X-ray tube, what is very rarely made. This method is even less accurate, as the Heel effect varies with different types of X-ray tubes and equipment.

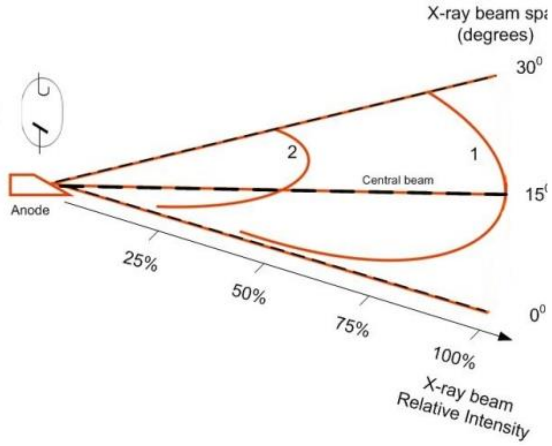

Fig.4 X-ray tube intensity spatial distribution for new X-ray tube (curve 1) and an old one (curve 2). The X-ray intensity is shown in relation to the maximum intensity (100%) at the middle of the central beam of a new X-ray tube. Note also the shifting of the maximum of the intensity from the central beam (15^0), what leads to significant decrease of the beam intensity at the side of the Anode – i.e. increased Heel effect.

V. CONCLUSION

The presence of arcing can be observed in any type of X-ray equipment – such as CT scanners (where the drop of the kVs during the scan time leads to lack of projections and line artefacts), Radiographic equipment (where the arcing directly underexposes the image or damages part of the image) or Fluoroscopy (where the image brightness and the dose may fluctuate). The article illustrates that arcing can be easily detected, hence avoided.

Quality Control (QC) of X-ray tubes and Generators requires detailed knowledge of the X-ray equipment function. The unique images of arcing manifestation, as well as methods for its detection, described in the article, can be used as teaching/training resources.

Enriching the routine QC surveys with such a knowledge will help to avoid artefacts (i.e. reducing the diagnostic value of the image), or repeated exposures (i.e. increased patient dose). It will also help to avoid increased servicing cost (or possible premature decommissioning). An arcing aged X-ray tube is a source of severe problems. It must be immediately withdrawn from service and replaced.

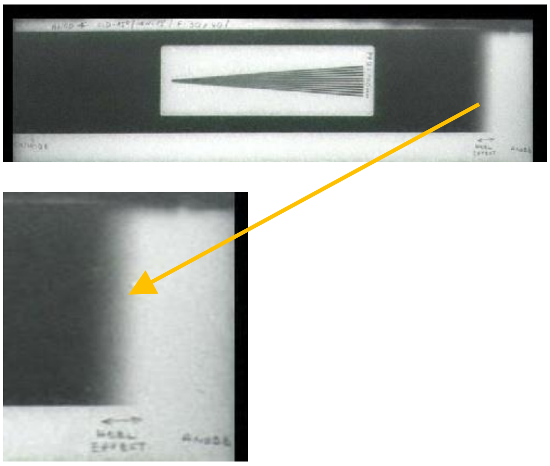

Fig.5 Illustration of Heel effect in old X-ray tube (gradual drop of optical density at the right side of radiograph). Note the zoom of the Heel effect zone (below), which is usually about 2-5 mm wide on the radiograph recording the effect.

VI. ACKNOWLEDGEMENTS

Most images/diagrams have been collected by the author and have been included in the EMITEL e-Encyclopedia of Medical Physics (www.emitel2.eu).

The video used for the frame-by-frame extraction of the arcing pictures has been made by Dipl. Ing. A Litchev and Dipl. Ing. G Tatarev from Medical University Plovdiv, Bulgaria. For this purpose the light-beam diaphragm (LBD) of the tube housing has been removed, as well as the inherent Aluminium filtration of the X-ray

tube. The video clip has been made with a small video camera directly attached in front of the radiolucent window of the X-ray tube – Fig.6. Before showing signs of arcing, the filmed X-ray tube has been intensively used for about 7 years, as part of an Digital Angiographic Equipment. The video has been shot during high-dose fluoroscopy mode. Immediately after this the tube has been replaced.

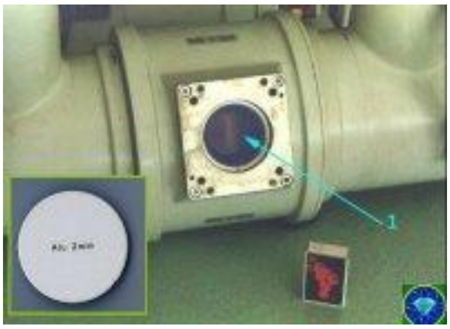

Fig.6 Outside view of an X-ray tube housing. The LBD and the inherent X-ray tube filtration have been removed (Al filtration plate is shown in the left segment of the image). Note that through 1 (the radiolucent window) the cathode and the anode disk can be observed (as in Fig.2), taking all radiation safety measures.

VII. ANNEX

The assessment of medium frequency X-ray Generators (as well as arcing) requires kVp meters, whose electronics is able to detect quick events. Some old kVp meters were based on low-cost electronic components with insufficient bandwidth. Due to this reason kVp waveforms and fast events were incorrectly presented (Fig.7). Soon after the introduction of the medium frequency Generators the author discussed the problem about misregistration of fast kVp changes with a leading manufacturer. This led to correction of the measuring equipment, but some of the old kVp meters are still available (as second hand equipment). Due to this reason the suitability of the measuring equipment should be checked before using it for arcing detection. Obviously kVp meters without an output for oscilloscope are not suitable for such detection.

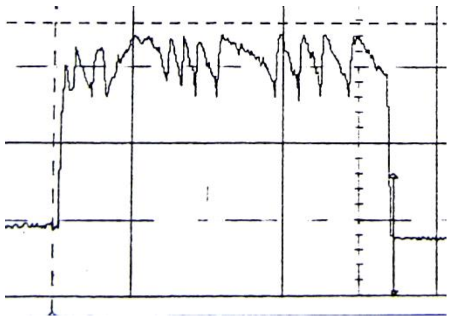

Fig.7 kVp waveform of a medium frequency Generator made with kVp meter with insufficient bandwidth. Note on the oscillogram the uneven kVp pulses due to lack of registration of the high frequency signals. Such kVp meter can miss (or present a false appearance) of the fast arcing events.

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INVITED PAPER

RADIATION EXPOSURE AND THE NEED FOR EFFECTIVE RISK COMMUNICATION: LESSONS FOLLOWING THE 2011 FUKUSHIMA NUCLEAR POWER PLANT ACCIDENT

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Abstract — **The communication of risk information following the Fukushima Daiichi Nuclear Power Plant accident in 2011 was often not transparent, timely, clear, nor factually correct. However, lessons related to risk communication have now been identified, and some of them have already been implemented in national and international emergency response programmes and strategies. As a result of risk and crisis communication failures during the accident, the world is now better prepared for effective communication related to nuclear and radiological emergencies than it was seven years ago. This article discusses the impact of risk communication, as applied during the Fukushima accident and the main lessons learned. It then identifies pathways for transparent, timely, clear, trusted and factually correct risk communication to be developed, practised and applied during future nuclear and radiological emergencies.**

Keywords- **Fukushima Daiichi Nuclear Power Plant, radiation exposure, crisis communication, risk communication, nuclear and radiological emergency.**

I. INTRODUCTION

On March 11, 2011, the world witnessed the unprecedented combined Great East Japan earthquake (magnitude of 9.0), tsunami and a nuclear power plant accident in Fukushima Prefecture, Japan. The nation was unprepared. From a communication perspective, the Japanese authorities, international regulatory authorities, radiation protection experts, mass media, local communities and the public were unprepared for such a triple-disaster event. Both the local Japanese and the international communicators were slow to provide clear, timely and unambiguous communication activities necessary to put the accident in its right context [1,2]. They were not prepared in advance nor trained in the state-of-the-art best practice in risk and crisis communication, resulting in a lack of a transparent, timely, trusted and understandable advice to best protect people and the environment.

II. RADIATION EXPOSURE: BENEFITS AND POTENTIAL HEALTH RISKS

The system of radiological protection is anchored in three fundamental principles: justification, optimisation of protection and dose limitations [3]. The application of the second principle - 'Doses should be kept as low as reasonably achievable (ALARA), taking into account economic and societal factors', is often fraught with difficulties, especially in an uncontrolled, emergency situation. Fig.1 depicts the intricate balance between radiation risk versus cost and benefits, and with other types of risk. The public and authorities (government, experts) have differing views on 'How safe is safe enough?' [4]. This depends on the context and the risks and benefits trade-off. However, we must be cognizant that there is uncertainty around our knowledge of both the risks (especially low-level radiation) and of the benefits [5].

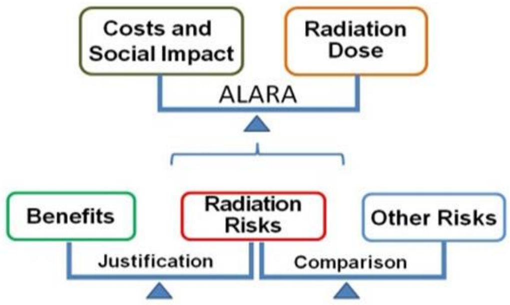

Fig. 1 The concept of ALARA, and the principles of balancing radiation risks with benefits and other forms of risks.

However, past experience of nuclear and radiological emergencies suggests that pressing issues of public concern were not necessarily those physical health problems directly related to radiation exposure, but rather the psychological and social effects which arise from the perceived adverse radiation risk. These perceived risks are highly susceptible to both amplification (over-emphasis) and attenuation (under-emphasis) through the complex processes of risk communication [6]. With the Fukushima accident, the additional implications of evacuation and long-term social displacement created severe health-related problems for the most vulnerable people in the Fukushima Prefecture, such as patients staying in hospitals and the elderly [7].

III. RISK COMMUNICATION: FOR CONTROLLED AND UNCONTROLLED EXPOSURES

Effective risk communication seeks to address the public and stakeholder perceptions of radiation, health and environmental risks in a planned and integrated manner. Best practice risk communication is to engage and have dialogue (multi-way exchange of information) with stakeholders of different perceptions of the risks to resolve their respective concerns [8]. Under crisis conditions, the demands for effective communication of risk become more intense and more urgent. A number of excellent references on risk and crisis communication are available [9-12].

Crisis communication takes place at a different stage of the risk communication life cycle, often it takes place under conditions such as natural disaster or nuclear emergency when it is very difficult to influence people's perceptions of risk [13]. Covello [14] has emphasized this as 'High Concern Low Trust' condition that requires a special mode of communication.

Fig.2 illustrates the inter-relationship of the three-fold objectives of risk communication, i.e. engaging to inform and educate; persuading and convincing those so engaged, and in building or repairing trust. Note that risk communication is a two-way process: the public may also inform, educate, convince and advise experts and others of their needs and concerns with own local knowledge. This important lesson is discussed further below.

Medical physicists are, by training, competent in radiological protection. Traditionally they have a good understanding of controlled exposures such as medical exposure in hospitals. There are various guidelines and procedures; such communication tends to be one-to-one and trusted. We could learn further from a systematic review of communicating cancer risk arising from radiological examinations [15].

When we explain how to do justification and optimisation in the case of medical exposure, we may refer to referral guidelines and diagnostic reference levels. Similarly, we could explain the justification and optimisation regarding nuclear regulations based on certain references consistently.

By contrast, uncontrolled exposures from accidents require a very different level of understanding and communication skills. This requires multi-dimensional techniques given the lack of trust in authorities, difficulty in handling exposure uncertainties, etc. [16] The deficit model attributes mistrust and public skepticism to science and technology due to a lack of understanding, a consequence of deficient in knowledge. This introduces very different sets of problems and challenges as became evident in the case of the Fukushima Daiichi Nuclear Power Plant accident.

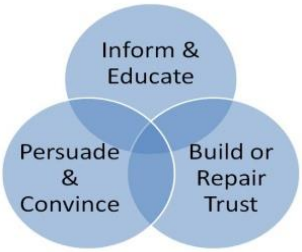

Fig.2 The inter-relationship of risk communication objectives

Contemporary risk communication research shows how non-traditional media has evolved into a multidirectional process whereby information is disseminated at an often uncoordinated and rapid pace and is able to easily reach all kinds of audiences, such as those affected, indirectly affected, or not affected by radiological risks [17]. This lack of control and uncertainty in the nature and effect of communication about radiological risks is perhaps the most challenging circumstance facing radiation protection and public health during emergency conditions in the modern world.

IV. FUKUSHIMA: WHAT HAPPENED

The Great East Japan catastrophe of combined earthquake and tsunami that devastated a large area of Tohoku region and took the lives of some 20,000 people was indeed a time of crisis. The major crisis issues included the uncertainties on decision making from the authorities and the failure of information flow. While radiation effects played a small part in the actual harm that occurred, perceptions of the danger from possible radiation exposure were extremely high – both in Japan and overseas.

As a result, there was a major challenge to both inform and advise citizens rapidly and clearly, but also to listen to and seek to assuage their concerns. Other issues that affected this difficult scenario include grey areas in regulatory authorities' roles and responsibilities, information about reactor design-bases, and stories about safety and food and environmental contamination. These issues are extremely complex and inter-related.

A number of comprehensive and authoritative reports of the Fukushima accident have been published, such as WHO [18], UNSCEAR [19] and IAEA [20].

We now have a better understanding of the communication errors that appear to have been made. These are mistrust of authority, confusing use of quantities and units for radiation exposure, inappropriate risk comparisons, lack of understanding of how risk perceptions affect responses, etc.

V. FUKUSHIMA: SOME LESSONS LEARNED

A. The need for transparency, trust and citizen-centred communication

Risk communication related to nuclear emergencies thus far has not engaged the affected citizens; this is now recognized as one of the biggest pitfalls of traditional approaches to communication [2,21]. Stakeholder engagement was often seen only as a one-way announcement from official experts to citizens, which led to a situation where the messages were the ones already framed and preferred by the authorities [22].

Risk communication related to nuclear emergencies should be developed and prepared in collaboration with various stakeholders [23]. That citizens should be invited into decision making is recognised as crucial for the recovery phase. In particular, citizen-centred communication should address socio-economic, political and ethical issues which arise from the perceived effects of radiation exposure.

The Fukushima experience demonstrated that citizen-centred communication using social media integration is essential for risk communication following nuclear or radiological emergencies in future.

B. Crisis communication should be prepared in advance

The Japanese authorities and regulatory authorities, as well as radiation protection experts, were not specifically trained and were unprepared to provide clear, transparent and timely communications to the affected population. For instance, they did not have ready templates for radiological risk communication to be used (e.g., responses to Frequently Asked Questions - FAQs), and they were not utilizing social media during the accident (e.g., they did not have Twitter accounts). The roles and responsibilities for internal communication were often unclear (e.g., among first respondents), and radiation protection experts were not trained for media or engaging in public communication [2, 24].

C. The communication gap between experts and the public should be narrowed

Risk communication aims to convey accurate information, such as the need to take adequate protection measures during emergencies and to make informed decisions about health and safety in the recovery phase. After the accident, the speed of information in the evacuation and shelter zones varied widely. The residents received no further explanation of the accident or evacuation directions or were unable to understand the messages received about the protective actions to be taken. Hence it is of utmost importance that the authorities and experts use clear language without jargon or excessive technical terms [25, 26]. Otherwise, necessary critical information is not understood, remembered or recalled.

Several studies have demonstrated that there was a huge communication gap between experts and the public about radiation risks, there was mutual misunderstanding [16, 27]. For instance, some research has confirmed that the use of a variety of units and technical jargon in public communication about Fukushima contributed to misunderstandings and confusion worldwide [26,27]. As a result, a number of mistakes and misrepresentations appeared in public communication. This included referring to non-existent ‘normal’ levels, as for example, comparing the radioactive levels for radionuclide content in seawater using a different ‘normal level’ without explaining what it meant [25].

D. Authorities to review and improve risk communication

As a result of the Fukushima accident, national and international authorities and non-governmental organizations worldwide, such as the International Atomic Energy Agency (IAEA), International Commission of Radiological Protection (ICRP) and International Radiation Protection Association (IRPA) reviewed risk communication plans and improved strategies for communication in nuclear and radiological emergency preparedness and response. Nuclear regulatory authorities have now acknowledged the need to include effective communication aspects in emergency preparedness exercises and training [2, 24]. Open-source, citizen-science-centred radiation mapping programmes were developed through collaborative innovation, and citizen science participated in radiation protection, for instance, in the case of ‘Safecast’ in Japan which assists residents in identifying radiological-contaminated hotspots in their vicinity [28].

E. Communication skills of key stakeholders, including medical physicists must be improved

Various key stakeholders provided inconsistent explanations regarding the risks associated with low-dose radiation, thus causing much confusion and mistrust of experts. To enable citizens to come to reasonable personal judgments, basic information about benefit and cost as well as risk needs to be conveyed to the public. This did not happen. The use of jargon did little to help explain the concept of radiation risk that the public did not understand. The magnitude of dose and terminology of risk are unfamiliar to the public (As for example, MBq, GBq, mSv, Sv, relative risk, risk coefficient, etc.) [29].

One critical component of effective communication is active listening and sympathizing with affected residents, and this was demonstrated by some during the post-accident phase [30].

The need to provide information quickly and accurately during a crisis makes social media an extremely valuable tool for regulatory authorities. It is increasingly taking on a crisis communication role.

Educational materials and training should be tested and prepared in advance, to be made easily available to the public and media on a general basis (e.g., Web sites of nuclear safety authorities), and communication channels should be readily implemented. Lessons from Fukushima should be used as a basis for developing communication materials, which should be monitored for effectiveness in future nuclear emergency exercises, preferably with a variety of different stakeholders. We should note that reaction time during a crisis is very short, and it is very difficult for authorities to respond quickly and accurately, so preparation is the key.

Fukushima lessons can also serve to inform experts' training in public speaking and justify investing in social media communication [17, 24] Effective risk/crisis communication is dependent upon the level of preparedness of the organizations involved. Not only does this include planning, training, and practising for public communication in emergency situation, it also depends on the strength of the overall communication program and on a culture of transparency within the organisations involved.

Of course, it is also unfortunate that much of the information on social media is likely to be incorrect or unverified - it can be classified as misinformation. Nevertheless, many users soon learned to figure out the reliable and trustworthy sources of information. Therefore, it is extremely important that the authorities responsible for communication learn to use social media effectively during normal day-to-day operation in order to develop those trusted connections and to perform well during an incident or emergency.

Along with the traditional media, the use of social media has become one of the most important communication channels for emergency conditions and it is no longer an option to be ignored, but to be embraced and enhanced.

VI. CONCLUSION

The Fukushima accident has taught the world community several important lessons, one of which is the need for effective risk and crisis communication during nuclear and radiological emergencies. We cannot overemphasize enough the need to invest in risk communication research and improvements in the organization of risk management before, during and after nuclear emergencies.

We need to empower our colleagues and our citizens to better understand information about radiological protection during nuclear and radiological emergencies to the best of our abilities. This means a more holistic approach to risk communication that embraces the challenges presented by social media so that decisions are informed not only by the best science, but also by human values and are based on our very best understanding of citizens' perceived concerns, their ability to engage and take action, and the likely nature of exposures both in the short and long-term. This means developing trusted communication experts and channels, training, and investment in the future.

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Introducing new IOMP ExCom members and Awardees

PHASE CONTRAST RADIOGRAPHY

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Abstract— **We briefly review the basic aspects of 2D radiography based on contrast generated by phase change of the X-ray wave passing through an object and around its boundary. Laboratory radiographies on test objects are shown for illustrating the principle of propagation based phase contrast imaging.**

Keywords— **X-rays, complex refractive index, radiography, phase contrast imaging.**

I. INTRODUCTION

For about 100 years, since Wilhelm Conrad Röntgen’s discovery in November 1895 [1], radiography has been based on the principle of X-ray attenuation in matter, i.e. the recording of an intensity map from differential absorption and scatter off atoms and molecules by incident X-ray photons along different ray paths. After Max von Laue in 1912 demonstrated the nature of X-rays as electromagnetic waves in analyzing the structure of crystals, with the prompt interpretation given by Lawrence Bragg in his well-known equation, the analysis of the transmitted hard X-ray beam through non-crystalline materials in radiography was restricted to the consideration of interactions by X-ray quanta (i.e. photoelectric absorption, Rayleigh scattering from atoms and Compton scattering from free electrons), rather than as transmission, reflection and refraction of the X-ray wave in matter. This might stem from the initial difficulties, experienced by Röntgen and later investigators, to produce refraction of X-rays by means of prisms of various materials. Indeed, in his experiments in 1916 on refraction of Br Kα X-rays by a KBr crystal, Charles Glover Barkla concluded that the refractive index at a wavelength of 0.5 Å differed from unity by less than 5×10^{-6} [2] (i.e. the refractive index decrement $\delta < 5\times10^{-6}$, where the complex refractive index of the material at wavelength λ is $n(\lambda) = 1 - \delta(\lambda) - i\beta(\lambda)$, with β the material’s absorption index). Note that for energies far away from atomic absorption edges, δ for compounds is directly proportional to the effective electron density, ϱ_e^{comp}, of the material: $\delta_{\text{comp}} = (r_e\ \lambda^2/2\pi)\ \varrho_e^{comp}$.

Due to its small cross section, small-angle Rayleigh scatter was essentially considered negligible for photon energy in the diagnostic range (10-150 keV), apart from X-ray mammography where average photon energies are in the range 15-20 keV, and Rayleigh scatter events represent less than 12% of all interactions in soft tissue below 30 keV. Compton scatter, on the other hand, has commonly been considered as a source of image blurring and degradation of the radiographic contrast in transmission projection radiography, with the common adoption of anti-scatter grids, air gaps or post-acquisition deconvolution algorithms as procedures able to reduce the scatter-to-primary ratio. Hence, traditionally, X-ray scatter has been considered as a negligible or detrimental contribution to the image quality in planar transmission radiography. On the other hand, wave phenomena in X-ray propagation in matter have a fundamental role in Physics, and Arthur Holly Compton, in December 1927, Nobel Prize in Physics "for his discovery of the effect named after him", in his Nobel Prize Lecture discussed “X-rays as a branch of Optics”.

Advancements in X-ray imaging techniques produced, in the last 20-25 years, a new type of radiography, based on the differential phase changes of a transmitted X-ray electromagnetic wave along different ray paths in the object: *phase contrast radiography*.

II. THE ORIGINS OF X-RAY PHASE CONTRAST IMAGING

In the years 1995 and 1996 an increasing number of scientific papers reported on a new technique for X-ray radiography of non-crystalline objects – developed by Russian physicists and already contained in 1991 and 1992 patents [4] – which investigated the slight changes in the X-ray wave front corresponding to phase changes of (pseudo)plane beams at the external boundary and at internal interfaces between internal structures of a non-homogeneous object [5]. All these initial observations and future additions and implementation introduced the so-called phase contrast X-ray imaging field. In 1995, a group at the Photon Factory in Tsukuba (Japan) reported in the journal “Academic Radiology” experiments carried out as early as in 1994 on imaging of metastatic liver cancerous lesions with synchrotron radiation, with cancer tissue contrast originating from phase contrast rather than from absorption contrast, concluding that “… X-ray phase-contrast imaging better differentiates tissues than does the absorption contrast imaging commonly used in radiology” [6]. In early 1996, the medical physics journal “Physica Medica” published an article on “phase dispersion radiography” [7], reporting applications of imaging optically-thin biological objects like e.g. small fishes, where subtle internal details where visible with high contrast in such low-attenuating (few-mm thick) biological objects. Indeed, the first observations of subtle changes in the wave front by objects inserted in the beam due to X-ray refraction were serendipitous: the observed intensity variations were discovered in X-ray diffraction topography investigations of crystalline objects, and found to be due to the undulations of the velvet fabric covering the crystal under investigation [5]. Additional investigations by this group on imaging vessel structures in living organisms and animal cadavers confirmed the promise of *in vivo* imaging of soft tissues without contrast agents [8].

The experimental setup for the X-ray optic system (Fig. 1) included usually a crystal analyzer for angular-resolved analysis of the diffraction pattern from objects irradiated with monochromatic pseudo-plane waves produced by an X-ray source and a single or double crystal monochromator [5]. Indeed, wave front deformations by phase gradients, $\partial\varphi/\partial x$, introduced by refractions at the object boundary and in the object, at the interface of materials with different index of refraction, introduce angular deviations, $\Delta\alpha$ (in the range of μrad), of the X-rays (wavelength, λ) with respect to the propagation direction, z, which can be sensed by this differential phase contrast methods, via:

$$\frac{\partial\varphi(x,y)}{\partial x} = -\frac{2\pi}{\lambda}\Delta\alpha\ . \qquad (1)$$

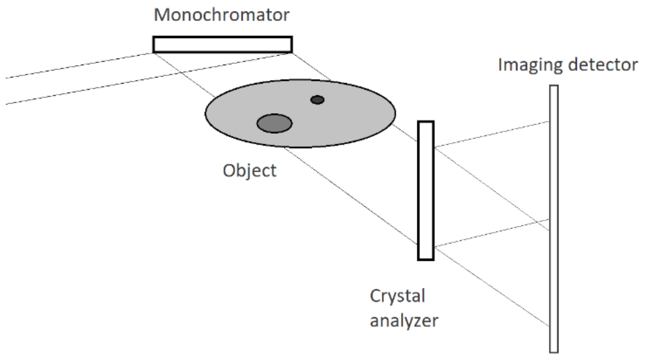


Fig. 1 Setup for analyzer based phase contrast imaging with a double-crystal Bragg-Laue optical scheme (adapted from ref. 2, fig. 1).

The retrieval of projected (z-integrated) phase shift maps $\varphi(x,y)$, e.g. from spatial integration of phase gradients $\frac{\partial\varphi}{\partial x}$ as in eq. 1, produces images in so-called *phase radiography*.

The analyzer based methods are simpler to implement than interferometric methods (e.g. with the Bonse-Hart crystal interferometer [9]), in which the transmitted X-ray wave front interferes with a (analogously coherent) reference beam and a 2D imaging detector records the interference fringe pattern (Fig. 2).

In the presence of a highly coherent, monochromatic X-ray beam from a synchrotron radiation source, a form of in-line holography was investigated at ESRF (Grenoble, France), now known as phase contrast propagation based imaging (PBI) [9]. In their experiments, a high resolution imaging detector placed at a distance up to 2 m behind the object (located at 40 m from the X-ray source) records the interference pattern produced by the superposition of the incident, quasi-parallel (spatially coherent), monochromatic beam with the beam scattered by the object.

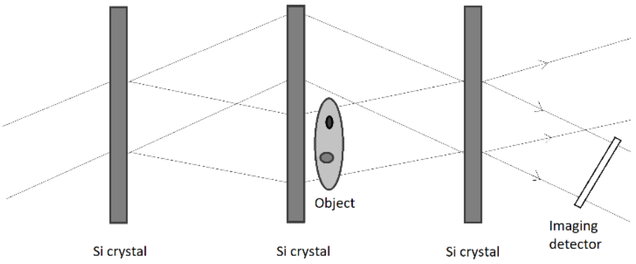


Fig. 2 Setup crystal interferometer based phase contrast imaging with a triple-crystal Laue optical scheme.

In PBI – an imaging technique which does not require any optics downstream of the object to analyze the transmitted beam – interference phenomena show up in the image signal as white and dark fringes at the boundary of the object and at any interface between internal structures of different index of refraction $n(\lambda)$. Low attenuation objects (e.g., 10-μm cellulose or beryllium fibers, or capillaries with 10-μm external diameter, in ref. [9]) are best suited to illustrate this phenomenon of X-ray refraction, due to spatial changes in the real part, $(1 - \delta)$, of the refractive index of the object. Note that δ may be three orders of magnitude greater than β (Fig. 3).

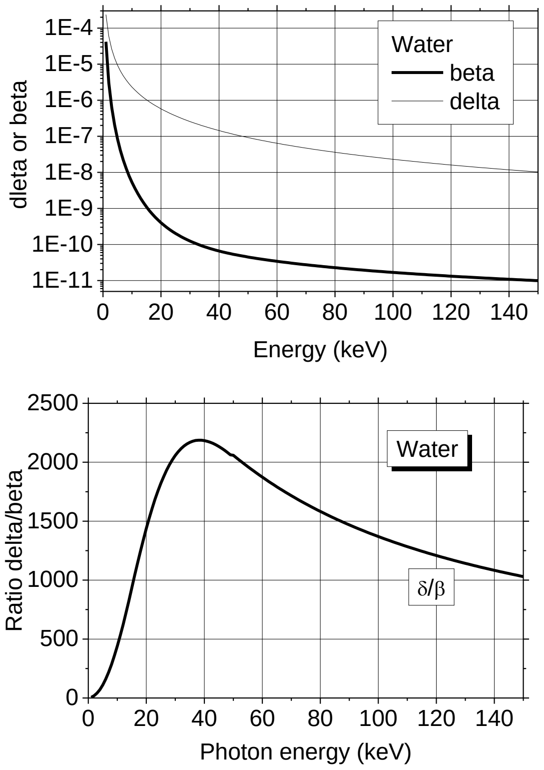


Fig. 3 (Top) The refractive index decrement, δ, and absorption index, β, for liquid water, in the range 1–150 keV. (Bottom) Ratio of δ to β for water.

The scheme for PBI is shown in Fig. 4. Under condition of the detail size $d^2 >> (\lambda z)$ – a condition easily realized for features micrometer-sized or larger, for hard X-rays and for propagation distances z realizable in the laboratory – the phase contrast signal on the detector is proportional to the transverse Laplacian $\nabla^2\varphi(x,y)$ of the wave front phase profile. Hence, registration of the transverse intensity profile in the imaging plane and a double spatial integration allows to derive the projected phase map of the object.

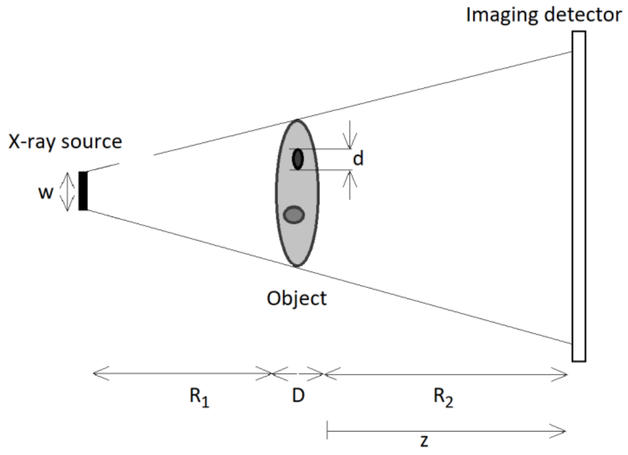


Fig. 4 Scheme of propagation based phase contrast imaging. The object size D is typically negligible with respect to the propagation distance $z = R_2$. Quasi parallel beam irradiation geometry occurs for large source-object distance, R_1. d is the size of the smallest resolvable detail in the object. Suitably large distances R_1 or small source size w (i.e. high spatial coherence) and suitably large R_2 between object and the high-resolution imaging detector, produce edge enhancement effects in the projected image at the boundary of the object and at internal interfaces between details of different refractive index decrement with respect to the surrounding material.

Following the phase retrieval algorithm for PBI developed by the CSIRO group in Australia [10], it can be shown [11] that the phase map can be recovered from a phase contrast image at a single distance R_2, as follows:

$$\varphi(x,y) = \frac{1}{2}\frac{\delta}{\beta}\cdot ln\left(F^{-1}\left\{\frac{F[I(x,y)/I_0(x,y)]}{1+\left[\frac{\lambda z\delta}{4\pi\beta}\right](u^2+v^2)}\right\}\right). \quad (2)$$

In eq. 2, F is the direct and F^{-1} the inverse Fourier transform operator, (u, v) are coordinates in the Fourier spatial frequency space conjugated to (x,y) in the spatial domain, I is the signal intensity map in the image plane with the object in the field and I_0 the intensity map without the object. Eq. 2 is valid in the near-field ($z << d^2/\lambda$) for objects with spatially uniform value of the ratio δ/β, and for a monochromatic source at large distance from the object (quasi parallel geometry).

Though the requirement of spatial (lateral) coherence of the incident X-ray beam is a condition for phase contrast imaging (with the coherence length $L_\perp = \lambda/\theta$, where θ is the angular width of the source from the observation point) it has soon been recognized that the requirement of temporal coherence (monochromaticity) is not strict: even using the polychromatic X-ray spectrum from an X-ray tube, the different spectral contributions may be expressed by an "average" wavelength $\bar{\lambda}$, and edge enhancement effects are still clearly visible as sharp white/black fringes at the boundary of zones of different thickness in the object or at interfaces between regions of different refractive index, in PBI. In a pioneering paper [12], the Australian group showed that the high spatial coherence could be achieved by a microfocus X-ray tube (having a focal spot size of 20 μm or less) with the focal spot at a distance, R_1, as close as ~0.5 m from the object, giving a lateral coherence length of $L_\perp \approx$ 1.5 μm at 20 keV effective energy: for comparison, $L_\perp \approx 9$ μm for the low-divergence (~1 mrad) synchrotron radiation experiments at 14 keV at ESRF [9]. The use of a (micro)focus X-ray tube for PBI gives promise of its clinical applicability, with respect to a synchrotron radiation source. However, the low output of microfocus X-ray tube due to low tube current (typically below 1 mA) and the divergence of the X-ray beam (20–40 deg) limit the X-ray flux on the detector plane, if the distance, R_2, from the object to the detector is too large (e.g. greater than 0.5–1 m). This is a major impediment to the application of the PBI technique with a microfocus source; a viable solution might be the increase of the tube voltage to increase the tube output [13,14]. Indeed, in PBI, the transmitted beam should propagate through sufficiently large distances behind the object for interference effects to develop. The quantity "shear length" has been introduced, $L_{shear} = \bar{\lambda}R_2/MD$, where R_1 is the source-object distance, $M = (R_1+R_2)/R_1$ is the image magnification and D is the minimum size of the target spatial non-uniformities in the object [15]. Hence, in PBI, phase contrast effects (e.g. edge enhancement) may be fully visible (independently of the X-ray wavelength) if the degree of spatial coherence in the incident and transmitted waves are such that $L_{shear} << L_\perp$, with only partial visibility occurring for $L_{shear} < L_\perp$.

The photoelectric absorption coefficient μ_a is related to the absorption coefficient via:

$$\mu_a = -\frac{4\pi}{\lambda}\beta, \quad (3)$$

while the wave phase shift $\Delta\varphi$ is related to the refractive index decrement δ and to the object thickness, D, via:

$$\Delta\varphi = -\frac{2\pi}{\lambda}\delta\cdot D. \quad (4)$$

The rate of phase change in the wave propagation in the material can be quite sizeable, in the order of tens of radians per mm in the diagnostic energy range (Fig. 5).

X-ray phase imaging via grating interferometry has been continuously developed in the last 15 years. It exploited the high sensitivity of the Talbot-Lau optical scheme for deriving phase maps by integration of the signal proportional to the phase gradient, combined with the use of the X-ray tube from a conventional radiographic unit (i.e. with large focal spots and high tube power), a key feature for clinical applicability [16,17]. Moreover, such grating interferometric methods allow also to derive the absorption map and a darkfield image of the sample.

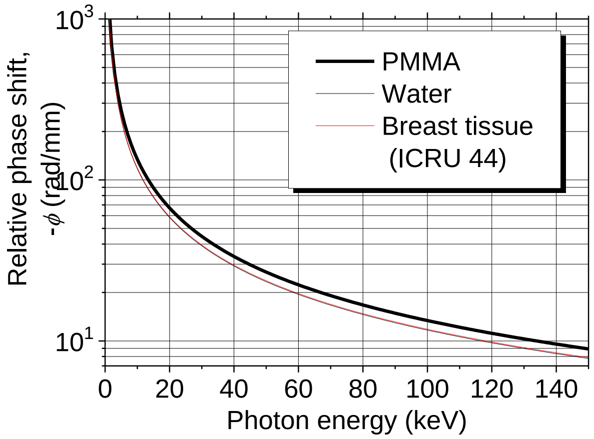


Fig. 5 Rate of change of the X-ray wave in the range 1–150 keV for plexiglas (PMMA), liquid water and breast tissue. The two last curves are almost coincident.

X-ray Talbot-Lau grating interferometers employ three (gold) transmission grating (amplitude grating G0, phase grating G1 acting as a beam-splitter of the first two diffraction orders, and amplitude grating G2 acting as an analyzer) placed, respectively, downstream of the source, downstream of the object and upstream of the detector (fig. 6) [16-18]. At each site of refraction, the object introduces a phase change and a slight refraction in each beamlet, which is proportional to the gradient of the phase shift, given by eq. 1.

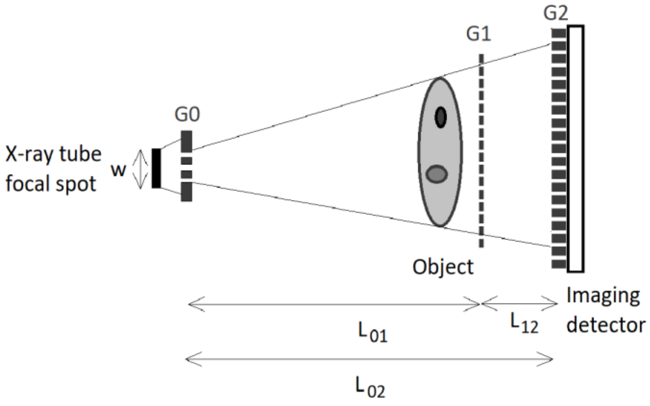
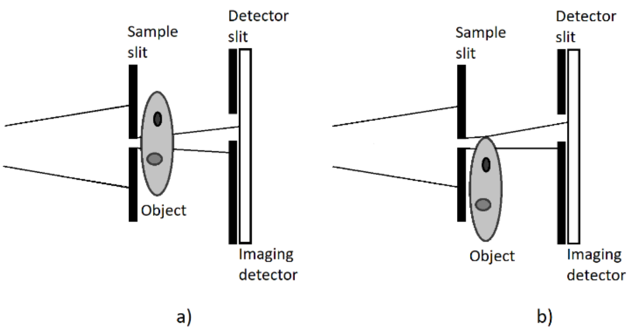


Fig. 6 Optical scheme of an X-ray Talbot-Lau grating interferometer for phase imaging (adapted from ref. 14, fig. 1).

The set of gratings G1 and G2 allows to record the differential phase changes introduced by the perturbation of the wave front by the object as lateral displacement of the fringe pattern and consequent changes of the local intensity on the detector, and a spatial integration along the direction x provides the map of phase changes in the object. Then, a so-called phase-stepping procedure is usually applied, which allows to distinguish intensity variations due to the phase shift introduce by the object, from other sources such as absorption in the object, uneven irradiation or defects in the gratings: this is done by scanning at high resolution one of the gratings in the lateral direction x so as to cover a distance of one period of the grating. The pitch of the gratings is in the order of micrometers and their open fraction is in the order of 1:2. The imaging spatial resolution is wL_{12}/L_{01}, where w is the size of the source. The grating G0 produces an array of period $p_0 = p_2 L_{01}/L_{12}$ of micrometer-sized "line sources" and determines high spatial coherence in the X-ray incident beamlets. G1 produces a periodic interference pattern of period p_1 (introducing a phase shift of $\pi/2$ or zero) whose intensity oscillations along the distance L_{12} have maxima at the periodic distances $L_{12\max}$. G2 consists of a periodic array of absorbing structures which transforms the changes in the interference fringe pattern produced by G1, into changes in X-ray intensity at the high-resolution detector plane. Its spatial period is $p_2 = p_1 L_{02}/L_{01}$.

Edge illumination is another form of X-ray phase-contrast imaging, first developed at ELETTRA synchrotron radiation facility in Trieste, Italy, and then at University College London, with non-stringent requirements for the temporal and spatial coherence of the X-ray beam, permitting to adopt table-top and clinically viable experimental setups with high-power (large focal spot size) X-ray tubes. Here, a slit (e.g., ~10 μm) upstream of the object ("sample slit") generates a thin transmitted beam which is analyzed by a second slit ("detector slit") in front of the detector, slightly misaligned with respect to the first slit (Fig. 7) [19]. The detector slit is precisely aligned with a row of pixels in the imaging detector. A part of the transmitted beam is stopped by the detector slit and the remaining part irradiates the detector.



a)

b)

Fig. 7 Scheme of the edge illumination technique for phase contrast imaging. The sample slit is slightly misaligned with respect to the detector slit. The incident beamlet on the object can be partially absorbed (as in *a*) and refracted (as in *b*), determining a change of the photon fluence on the detector. The object is translated across the beam to obtain an absorption and phase image (adapted from ref. 19, fig. 1).

The signal intensity on the detector is decreased by X-ray attenuation in the sample (Fig. 7a). On the other hand, refraction of the X-ray beam by the object (following eq. 1) also changes the total intensity reaching the detector through the detector slits (Fig. 7b), so that a differential phase map (superimposed on the absorption map) can be obtained by recording the transmitted image while scanning the object through the beam.

III. PROPAGATION BASED PHASE CONTRAST RADIOGRAPHY: EXAMPLES

In the following we show some radiographs, taken with a table-top micro-radiography system comprising a microfocus X-ray tube with a 7 μm focal spot size, a flat panel detector with 50 μm pixel pitch or a photon counting detector, and a source-to-image distance of less than 1 m, for the purpose of illustrating the effects of propagation based phase contrast radiography.

Fig. 8 shows the comparison of a conventional contact radiograph of a small flying insect, and a radiograph of the same sample acquired at magnification $M = 7$. For a detail spatial frequency of 10 lp/mm, one has $L_{\mathrm{shear}} / L_{\perp} = 0.06$ and the condition is fulfilled for a partial visibility of phase contrast effects. These show up as clear identification of the thinnest and very low contrast details like the wings of the insect, which show essentially null area contrast but well identified edges.

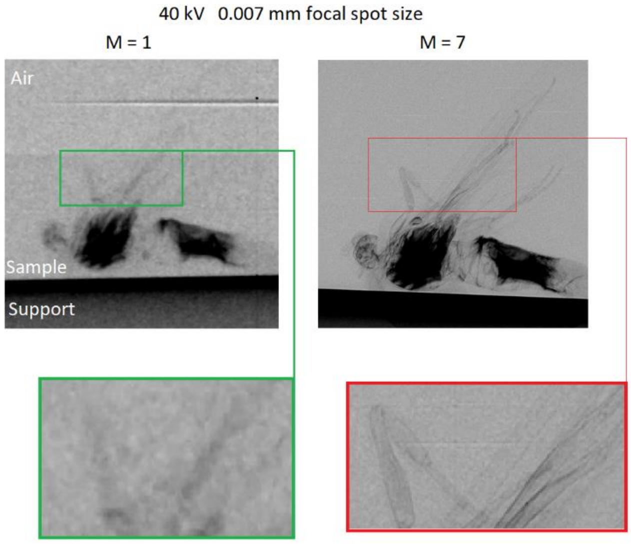


Fig. 8 (Left) Contact radiograph (image magnification factor $M = 1.01$, $R_1 = 715$ mm, $R_2 = 9$ mm) of a moth (a common flying insect, less than 2 cm long), taken at 40 kV with a high resolution flat panel detector (50 μm pixel pitch) and a microfocus X-ray tube with a 7 μm focal spot size. The low attenuation ($I/I_0 < 0.01$) gives low contrast for the thinnest body part, as for the wings shown in the zoomed image of the bottom panel. (Right) Phase contrast radiograph ($M = 7$) of the moth acquired at 40 kV with increased tube loading (mAs), but with $R_1 = 103$ mm, $R_2 = 621$ mm. The phase contrast image shows fine details of low contrast parts like the wings (see zoomed detail in the bottom panel on the right), thanks to the edge enhancement effect occurring at the boundary of the sample (adapted from ref. 20).

Fig. 9a shows a magnification radiograph of a beetle, acquired with the above microfocus X-ray imaging setup. With respect to the sample of Fig. 8, this represents a relatively high absorbing object, given the larger size and the presence of a thick exoskeleton of the red palm weevil. With $L_{\mathrm{shear}} / L_{\perp} \cong 0.05$, some limited edge enhancement effects can be observed (Fig. 9b), as low-amplitude undershoot and overshoot of the line profile across boundaries.

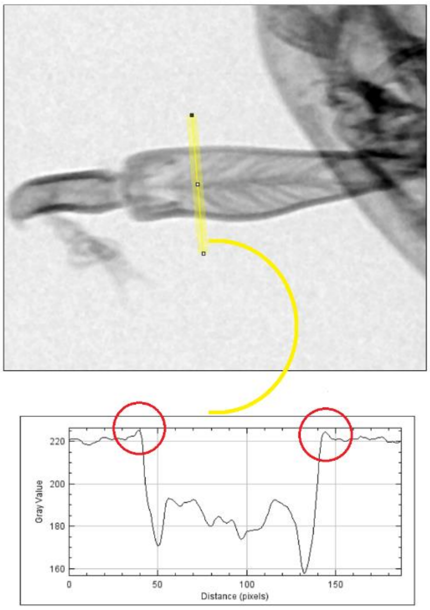


Fig. 9 (Top) Phase contrast radiography of a beetle “red palm weevil” (*Rhynchophorus ferrugineus*), taken at 80 kV with a microfocus X-ray tube (7 μm focal spot size) with a magnification $M \cong 4$, $R_1 \cong 250$ mm, $R_2 \cong 750$ mm. (Bottom) Detail of the left-side leg: a line profile across the leg shows some edge enhancement effect (overshoots circled in the line profile plot).

In Fig. 10, the use of a photon counting imaging detector (Medipix2 with Si pixel detector, 55 μm pitch, 256 × 256 pixels) allowed to improve the detector spatial resolution to 9.1 lp/mm and to increase the signal-to-noise ratio. Here, the focal spot size of the microfocus X-ray tube is set to 5 μm and the magnification is $M = 9.1$.

Fig. 10 Phase contrast radiograph of an ant taken at 40 kV, 20 mAs, with a microfocus X-ray tube (5 μm focal spot size) and with a magnification $M = 9.1$, $R_1 = 68$ mm, $R_2 = 552$ mm (from ref. 21). Important edge enhancement effects are visible, which permit to clearly delineate the silhouette of all low-absorption details of the insect.

IV. CONCLUSIONS

Phase contrast radiography exploits X-ray wave refraction when crossing interface between regions of different values of the refractive index decrement δ, for generating contrast. Then, phase retrieval algorithm may provide phase radiographs of weekly or moderately attenuating objects, the phase map being proportional to the local effective electron density of the object. Various fields are under investigation for application of such techniques in the clinical practice, including e.g. lung imaging and 2D mammography. 3D tomographic techniques based on these X-ray wave phenomena are also well advanced. Its potential for improving the image contrast is large, at radiation dose levels not largely differing from those of attenuation based radiography. The role of the various phase contrast and phase imaging techniques (interferometric, propagation based etc.) in the clinic is still to be disclosed, with medical physicists leading the edge of this frontier research.

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MEDICAL PHYSICS EDUCATION AND SCOPE FOR IMPROVEMENT

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INTRODUCTION

Medical physics is a branch of applied physics, pursued by medical physicists, who use physics principles, methods and techniques in practice, in the clinical environment and in research, for the prevention, diagnosis and treatment of human diseases with the specific goal of improving human health and well-being [1].It encompasses radiation oncology physics, medical health physics, imaging and nuclear medicine physics. Medical Physicists are also involved in research, development and teaching. The job of medical physicists is multidisciplinary involving wellbeing of patient as well as general public in context of radiation safety.

Medical physics is a fast growing area needing high degree of knowledge and professional competency due to the rise in complexity of treatment procedures, increasing access to medical technology and the requirement of coordination between medicine, physics and biomedical engineering areas. The unprecedented surge in medical physics competency in the last 2- 3 decades is due to implementation of specialized physics intensive procedures such as particle therapy, image guided & intra operative radiotherapy ,advanced imaging and nuclear medicine techniques. In this scenario to handle this new technology era the quantity of qualified medical physicist needs to be in consonance with the competency needed. There is a special requirement for education and training of medical physicists which lead to opening of numerous educational programme around the world.

DEFINING MEDICAL PHYSICISTS

According to the definition of the International Basic Safety Standards (BSS) [2], a medical physicist working in a clinical environment is: "*a health professional, with specialist education and training in the concepts and techniques of applying physics in medicine, and competent to practise independently in one or more of the subfields (specialties) of medical physics*."

Further IOMP has defines medical physics profession [3] as "*Medical Physics is a branch of Applied Physics, pursued by medical physicists, that uses physics principles, methods and techniques in practice and research for the prevention, diagnosis and treatment of human diseases with a specific goal of improving human health and well-being*"

Looking to needs and to maintain minimum standards in medical physics education across the globe, IAEA has published their updated suggestions related to roles, responsibilities, education and training requirements for clinically qualified medical physicists [3].The goal of the publication is to establish criteria that support the harmonization of education and clinical training worldwide, as well as to promote the recognition and professionalism of medical physics as a profession internationally. It suggests that after receiving the proper under graduate program in physical or engineering services, the medical physicist students should undergo 1-3 years of academic education of post graduate level and also recommends the academic training at the postgraduate level which must be followed by at least two additional years of structured practical training in a clinical environment, in one or more specialties of medical physics. Overall, the academic education and clinical training should extend over a minimum period of, typically, seven years.

It suggests that medical physics programme should be recognized by an international or national accreditation body in order to enhance their independent work ability and their professional competence. Further Medical physics is not a static field and it's rapidly growing, changing as a dynamic scientific profession and therefore to keep updated the practicing medical physicists should undergo continuous professional development [CPD] by organizing and participating in the workshops, symposium, national & international conferences and also they should be regularly updated by consulting relevant scientific journals and literature.

In addition, the Task Group reports by American Association of physicists in medicine has continuously published reports on essential and guidelines for hospital based medical physics residency training programs [4][5][6] since 1990.The first AAPM report (No-36) on essential and guidelines for hospital based medical physics residency training program was published on 1990 [4]. The residency programs was aimed, both educating and providing practical experience so that an individual would be ready to be examined for certification and practice in a hospital setting. They are conceptually different than the academic programs and post-doctoral fellowships, where the aim is primarily research. Following that in 1993, AAPM report (No-44) on academic program for Master of Science degree in medical physics was published in 1993 [7]. This committee has collected a set of topics that provides the minimum level of training an M.S. graduate would be expected to have. This report was further revised in 2002, 2009 [8] [9] which concentrated on the clinical and professional knowledge needed to function independently as a practicing medical physicist in the areas of radiation oncology, diagnostic imaging, and nuclear medicine.

In 2008, AAPM Task Group 133 published the report "Alternative Clinical Training Pathways for Medical Physicists [10]. The focus of this report was to describe different training pathways to achieve clinical competency and to outline potential mechanisms for the creation of a suitable number of clinical residency positions. In doing so, this report introduced two initiatives that would become accredited alternative training procedures: a professional degree, the Doctorate in Medical Physics (DMP), which contains both didactic and clinical training, and the certificate program, which provides core didactic elements of a graduate degree in medical physics for students with a PhD from a related field. The first certificate program was accredited by CAMPEP in 2011, and as of March 2017 there were 24 such programs. This latest report recommends structure and conduct of medical physics program. Following the appropriate didactic training, a clinical training period of at least two years is required. The first goal in these two years should be to provide the trainee with a broad experience in clinical medical physics in the subfield in which the residency program specializes. This provides the foundation for the physicist to manage the broad range of medical physics tasks involved in caring for patients in diagnostic and interventional radiology, nuclear medicine, or radiation oncology. Next, training should build on this clinical foundation in terms of both level of responsibility and coverage of topics such as specification, commissioning and acceptance testing, quality assurance, special procedures, and patient safety measures. After two years of clinical training, residents are expected to have sufficient competence to function independently and safely as medical physicists in a clinical environment. Some residency programs may choose to require more than two years of training, allowing residents time to obtain further supervised experience. It is important to note that portions of clinical training may take place at affiliated institutions. They also recommended essential medical physics didactic elements for physicists entering through an alternate pathway.

ACCREDITATION OF MEDICAL PHYSICS PROGRAMME

In addition, the American Association of Physicists in Medicine (AAPM) have a well-recognized system for accreditation of residency programs in Medical Physics, the Commission on Accreditation of Medical Physics Education Programs, CAMPEP [11] and recently created a Memorandum of Understanding (MOU) with other institutions to promote the unification and harmonization of certification programs of these professionals. The International Medical Physics Certification Board (IMPCB) was created by IOMP to provide guidance and support to medical physics organizations across the globe for the establishment of national medical physics certification boards and to conduct board examinations for certifying medical physicists [12]. IOMP collaborates with IMPCB providing international accreditation for MSc courses and other educational/training activities (initiated in 2016).

PROGRAMME FOR ENHANCEMENT OF MEDICAL PHYSICS CURRICULUM

In European Community, for several decades, medical physics teachers and researchers worked for producing teaching materials compatible with the different training areas in Medical Physics. The EMERALD and EMIT educational programs are good examples (Tabakov, 2008) [13]. Tabakov also mentioned that to fulfill the educational requirement for profession within two year of post-graduation, students should be specialized in one field. (e.g. Radiotherapy) ,which will educate the students very well in one sub specialty. But it may impact the overall medical physics knowledge and employment opportunity in different fields. Such initiatives demonstrate the intense effort that the international community has been doing to ensure the qualification of these professionals at a high quality education level. It must also be emphasize that the recently WHO/IAEA proposed "Bonn: Call for Actions" document [14] [15], which establish a proposal for priorities for stakeholders regarding radiation protection in medicine for the next decade, present the "strengthen radiation protection education and training of health professionals" in the Action 4[14] [15]. Some universities already open under-graduate (BSc) courses on medical physics in order to accommodate the increased volume of professional knowledge. As all other recommendations, the IOMP Model Curriculum refers to the level of education as a post-graduate (MSc) type education – a typical pattern followed almost everywhere. Recently a new MSc Curriculum was introduced in the UK National Health System (NHS) requiring the MSc-education in a specific sub-field of Medical Physics to be tripled – e.g. Radiotherapy Physics to be expanded from 15 credits to 45 credits. The same requirements were placed to the education of the sub-specialties of Radiation Safety, Imaging with Ionizing Radiation and Imaging with Non-ionizing Radiation. The problem of including the large volume of Medical Physics education into a limited number of Post-graduate contact hours needs special discussion by the whole profession. One possible outcome is opening of Under-graduate (BSc-level) Education in Medical Physics.

CURRENT STATUS

Medical physicists working as health professionals shall demonstrate competency in their discipline by obtaining the appropriate educational qualification and clinical competency training in one or more subfields of medical physics. The current requirements for the qualification of medical physicists vary largely throughout the world. This variation has recently been confirmed by the results of two large scale surveys undertaken by the EFOMP in 2006 [16] and the IAEA in 2010–2011, which together included responses from 77 countries from five continents. The minimum 'academic education and clinical training' time frame for employment as a medical physicist at a hospital varies between three to nine years, the average being about six years. The requirements for the fraction of time spent in basic, postgraduate and clinical training varies enormously, ranging from a basic three year degree without any clinical training to nine years including all three components. Basic physics studies of approximately four years are the most common modality for over 90% of the respondents, and for countries with a postgraduate system, one or two year programmes are most frequent. The largest discrepancy found in the analysis corresponds to the clinical training programmes across different countries. Their duration varies from non-existent to a four year requirement. They also have rather different formats; for example, among the formally structured programmes, 20% have a residency system or on the job training for the first year, 29% have it as a component of the postgraduate programmes and 51% do not have structured clinical training. The assessment of the skills acquired during the clinical training also shows rather different patterns, ranging from a formal examination (57%) to continuous assessment (9%) or a combination of the two (23%); 11% of the responses were unspecified. It is worth noting that a significant number of countries having formal clinical training have their trainees remunerated as staff members, and that some countries have their trainees employed automatically upon completion of the training programmes , whereas others do not guarantee employment.

To cater to the ever increasing need and easy affordable access to the educational material in the field of medical physics development and availability e-learning material has already found its presence in the field of medical engineering and physics. At present large number of e learning programmes are available such as the AAPM virtual library, the IAEA training materials and website, the EMERALD and EMIT to upgrade the medical physics knowledge

MEDICAL PHYSICS COURSE IN INDIAN SCENARIO

As a case study I will explain the growth of Medical Physics education in India. In India, two different types of medical physics courses are conducted, namely (a) Post Master of Science (M. Sc.) Diploma in Radiological / Medical Physics (Post M. Sc. Dip RP/Dip MP), and (b) M. Sc. Degree in Medical Physics (M. Sc. [Medical Physics]). In Post M. Sc. Dip RP/Dip MP course, the entry level qualification of the candidate is M. Sc. Degree in Physics whereas in M. Sc. (Medical Physics) course the entry level qualification is Bachelor of Science Degree majoring in physics. As the majority of the medical physicists trained in India work in the discipline of radiation oncology medical physics (ROMP), the entry level qualifications are based on the eligibility criteria prescribed by the Atomic Energy Regulatory Board (AERB) for medical physicist and radiological safety officer (RSO)[17]. The curriculum of the Post M. Sc. Dip RP course, conducted by Bhabha Atomic Research Centre (BARC) since 1962, has been adopted by the AERB indicating it to be one of the best courses in the country with its well organized modality. In the recent past, over 24 universities/institutions have started either Post M. Sc. DipRP / DipMP or M. Sc. (Medical Physics) courses to cater to increasing demand for medical physicists.

At present, more than 200 medical physicists are graduating per annum from the education and training programs conducted at different universities/institutions in India.

INTERNSHIP COURSE - A MANDATORY FOR QUALIFYING MEDICAL PHYSICS

As per revised AERB safety code minimum 12 months internship in a recognized well-equipped radiation therapy department has been specified as a mandatory requirement for a qualified Medical Physicist and Radiological Safety Officer. To fulfil this requirement, all the Medical Physics students passing out from different academic courses in the country need to undergo one year internship/residency under the supervision of a qualified and sufficiently experienced Medical Physicist at a recognized well-equipped radiotherapy centers in the country.

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MY JOURNEY TO MEDICAL PHYSICS

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Abstract— **many people, including me, wonder how physics and its theories apply to our daily life. I have never thought that I will be using physics in my profession until I had meet the Director of Medical Physics Program at Wayne State University at that time, Dr. Colin Orton, who introduced me to Medical Physics.**

Keywords— **Medical Physics, Education and Training, Radiation Therapy.**

I. INTRODUCTION

The first day statement of my high school physics teacher was: *"You can find physics in all aspects in our life"*. Of course everybody in class laughed out loud and each one of us started challenging the teacher with many things in our life we thought had nothing to do with physics. The confident teacher will answer all inquiries and questions and trace it back to physical phenomena. That was the astonishing moment where all students started to like the class and wait eagerly to discover and learn about physics and its application in our life.

II. SCHOOL DAYS

During my intermediate school days, back in 1980's, my dad assigned me to teach my younger brother physics subject because he didn't like to study it at all, arguing about the need of physics in our life, in which I did not have an answer for that. I was so intense and I used to treat him very badly even punching him with pencils on his hands because he refused to do homework. My younger brother ended up hating physics and schools in general and he was the only one out of five other brothers who did not have a university degree. I felt and till now guilty because I misused teaching physics in the wrong way.

When I was in high school, my friends used to come over our house to teach them physics and math; it gave me a respectful image among my friends unlike my competitor in class who used to have his knowledge for himself and never shared it with anybody, so the class used to look at him inferiorly. I then realized the value of sharing information and teaching it.

I finished my BS degree in Biology at the American University of Beirut (AUB) in 1995; I decided to continue perusing a Teaching Diploma degree for the sake of teaching career in physics. While I was still doing on-class observation and training in 9th Grade Physics Class at the American Community School (ASC), I had an opportunity to take over the class since the home teacher had a break-down and she quit from teaching due to students' behavior in the class. I remembered my mistakes with my younger brother; change the gear of teaching Physics, make it fun and interesting! I continued teaching in this class and students' behavior has changed; **"we never thought Physics is fun until you taught us"**; a goodbye note from the class at the end of the year.

III. JOURNY TO THE USA

My parents encouraged me to join a medical school and to become a physician like my eldest brother, however, medicine was not fully my interest. In 1996, I moved to the States, and by coincidence while continuing a post degree in Industrial Engineering at Wayne State University (WSU) in Michigan, USA, I meet an AUB physics Graduate who introduced me to a new profession called **Medical Physicist**. The term made me enthusiastic and eager to find out more about this profession. Fortunately, WSU offers this program at the medical school. So, I contacted the head of the department **Dr. Colin Orton** and he showed me what a medical physics does as a profession and how to apply the principles of radiation physics in the diagnosis and treatment of cancer patients. So, I decided to transfer to this program instead. Eighteen years later, I am still happy I saw one of AUBits physics guy who changed my career life.

I have joined the master program in Medical Physics which above the clinical and technical duties, there are teaching and training duties assigned to this profession and that was the reason I choose it. An essential part of my career is teaching and training technologists, nurses, physicians and other professions about the good use of radiation in diagnosis and treatment of diseases and guide them on the ways to protect them from the risks of radiation exposures. Upon completion of my degree and residency, I have worked in three hospitals consequently till 2004.

When I came back to Lebanon in 2004, establishing the Radiation Oncology Department at Rafik Hariri University Hospital, I had difficulties finding Radiotherapy Technologists, thus I hired Radiology Technologists and I had to teach and train the staff on a daily basis until they become professional in their duties. In 2013, I suggested to the Faculty of Medicine at the Lebanese University in Saida to incorporate a couple courses of Radiotherapy Physics Principles and Radiotherapy Treatment Application Courses in the Radiologic Technological BS Degree to fill the gap in this degree especially that there are 11 Radiotherapy Centers in Lebanon and there is a high demand for these technologists to have the proper education and training before treating cancer patients. The program started in 2014 and many of my students are finding Radiotherapy jobs easy and worth it.

I learned that medical physics is not only a profession to work in a hospital or to teach at a university, it is a way of seeing and experiencing life. *" We do not teach you only how to use radiation in diagnosis or treatment of cancer, we also teach you to be the problem solvers in anything you encounter in your life";* Professor **Colin Orton**, my advisor and the head of Medical Physics Department at WSU. And this is what physics really is; my secretary always calls me to fix her printer or copier machine before calling in services, she knows that I always fix it long before they showed up.

IV. CONCLUSIONS

Now, that I am involved with the International Organization of Medical Physics (www.iomp.org) and recently I was elected as a member of the ExCom and as the Treasurer, I am eager to establish a Master Program in Medical Physics in Lebanon so that to be the top in the region. We have now many skilled and the experienced Medical Physicists here and abroad to run the program. Holding the President of the Middle East Federations of Organizations of Medical Physics (www.mefomop.org) for two terms from 2009 till 2015, many students from our Arab Countries are seeking to pursue a postgraduate degree in medical physics, and I am hoping to channel them to this new Medical Physics Program in Lebanon.

ACKNOWLEDGMENT

I would like to thank Prof. Colin Orton for his encouragement to join his MP program back in 1996 at WSU. Also, I would like to thank Prof. Slavik Tabakov for his invitation to write about my Journey to Medical Physics so that to shine a light for students who are looking to pursue a Medical Physics career in their life. .

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KWAN HOONG NG AWARDED
THE MARIE SKLODOWSKA-CURIE AWARD OF IOMP, 2018

The Marie Sklodowska-Curie Award is one of the highest awards given by the International Organization for Medical Physics. It was established to honour scientists who have distinguished themselves by their contributions to education and training, advancement of medical physics knowledge based upon independent original research and/or advancement of the medical physics profession.

Dr Ng is a Professor at the Department of Biomedical Imaging, University of Malaya, Kuala Lumpur, Malaysia. His journey in academia began when he received his M.Sc. (Medical Physics) from the University of Aberdeen and Ph.D. (Medical Physics) from the University of Malaya (1995). He is certified by the American Board of Medical Physics (1999). He is a Fellow of the Institute of Physics, UK (IoP) (2008), the International Organization for Medical Physics (IOMP) (2013), and the Academy of Sciences Malaysia (2014). He is also a member of the Academy of Medicine Malaysia (2003).

While a visiting scientist at the University of Wisconsin, Madison (1995-97) Dr Ng had the opportunity to work with great physicists such as the late Prof. John Cameron who was the inventor of bone densitometry and thermoluminescent dosimetry. His visit resulted in many fruitful collaborations and lasting friendship.

Dr Ng established and headed up the Master of Medical Physics Programme, University of Malaya in 1998, providing an opportunity for those who shared his passion to study locally in S E Asia and launch their professional careers. More than 120 students, from both Malaysia and overseas, have graduated from this programme. In 2002, he was responsible for obtaining the UK's Institute of Physics and Engineering in Medicine (IPEM) accreditation for the Master of Medical Physics programme, which currently is the only programme so accredited outside the British Isles. Dr Ng has also contributed greatly to the teaching and training of radiology and clinical oncology residents.

Dr Ng has contributed extensively to the IOMP for over two decades: having served as member in several committees; chairman, International Advisory Board (2003-2006); and chairman, Publication Committee (2003-2006). In 2013 the IOMP honoured him as one of the top 50 medical physicists for outstanding contributions to the field. In 2016 he received the International Day of Medical Physics (IDMP) Award.

Dr Ng is renowned for his breast density research and its clinical applications in predicting breast cancer. His other research contributions are in breast imaging, radiological protection, radiation dosimetry and medical physics education. He has long time collaborated with Prof. Lai Meng Looi and Prof. David Bradley on physical characterization of breast tissues since his PhD. He is actively collaborating with Dr Ray Kemp on risk communication and public understanding of radiation; Dr U Rajendra Acharya on image processing, artificial intelligence and radiomics; and Prof. Wilfred Peh on radiology and scientific publishing.

Dr Ng has authored/coauthored more than 230 peer-reviewed journal papers, 80 conference papers, 30 book chapters and co-edited seven books. He has presented more than 550 scientific papers, with over 300 of them being invited lectures. He is a member of the editorial and advisory board of more than 12 journals, and has served as one of the series editors for the “Series on Medical Physics and Biomedical Engineering” published by Taylor and Francis for over ten years.

Dr Ng has held several visiting professorships, such as Jinan University, China; Chang Gung University, Taiwan; Chulalongkorn University, Thailand; University of Sydney, Australia; and most recently at the University of São Paolo, Brazil.

As a consultant and expert with the International Atomic Energy Agency (IAEA), he has participated in numerous expert missions, conference lectures, and in drafting and reviewing standards, guidelines, chapters and reports. Some notable contributions are: “Diagnostic Radiology Physics - A Handbook for Teachers and Students”, “Clinical Training of Clinical Medical Physicists Specializing in Diagnostic Radiology”, “The Fukushima Daiichi Accident”, and “Advanced Medical Physics Learning Environment”.

Dr Ng was a member of the International Advisory Committee on EMF of the World Health Organization. He has also served as a consulting expert for the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

On the regional scene, Dr Ng is the Founding President of the South East Asian Federation of Organizations for Medical Physics (SEAFOMP), serving from 2000-06 before being appointed as the President Emeritus in 2014. He instituted the celebrated John Cameron Memorial Lecture. Further, he became one of the founding members of the Asia Oceania Federation of Organizations for Medical Physics (AFOMP), serving as its President from 2010-12. In 2014, he founded the ASEAN College of Medical Physics, which conducts regular medical physics education and training workshops.

In 2017, he started an international leadership and mentoring programme for medical physicists, collaborating with Prof. Robert Jeraj, Prof. Tomas Kron and Prof. Eva Bezak as fellow mentors. Those being mentored come from Brazil, Cambodia, Hong Kong, Indonesia, Japan, Malaysia. Peru and Vietnam.

Throughout his career, in addition to his contributions through basic research, Dr Ng has been a passionate educator and communicator in a field which many would otherwise approach with trepidation. He has particularly sought to build skills and capacity in South East Asia and developing nations. Away from his busy scientific and professional commitments, Dr Ng and his wife Suan devote much time in church activities and related charitable work.

Dr Kwan Hoong Ng C.V. is available at
https://umexpert.um.edu.my/ngkh

Professor Dr Anchali Krisanachinda

ELISEO VAÑO AWARDED THE IUPESM AWARD OF MERIT, 2018

Professor Eliseo Vano: A dear friend, a mentor, a person to derive motivation from

I had the pleasure of meeting Professor Eliseo Vano in 2001 in the First International Conference on Radiation Protection of Patients held at Malaga, Spain, even though I had been reading his publications in the area of medical radiation protection. I must say Eliseo is a doyen of medical radiation protection with unparalleled similarity in contributions the world over. He has a knack of picking up the problems that one faces in day-to-day practice, investigating them scientifically and publishing the data generated for the benefit of professionals all over the world. There has been a tendency among many medical physicists to confine to work that involves working alone or among medical physics colleagues as it is hard to work together with radiologists and clinical colleagues. Cooperative efforts have their own level of complexity and require a skill of "being useful to others" which Eliseo has mastered. Most of his publications prove how successful he has been in achieving the collaboration with clinical colleagues like cardiologists, electrophysiologists, orthopedic surgeons, urologists, just to name a few. I wonder if he had not taken the lead in working with clinical colleagues and producing excellent research papers, things would not have been the same in the world as we have today. He is the person behind many actions in medical radiation protection that are common today.

The amount of outputs achieved by him and response time to communication indicate that he hardly sleeps few hours. Just send him an email at midnight or early morning and you can be assured of his response right immediately. The number of travels he makes is more than anyone amongst us and yet his efficiency is unbeatable. I have no hesitation in accepting that he is role model and I have loved to derive motivation from him and taking him as my role model.

I joined the International Atomic Energy Agency (IAEA) in late 2001 and during my 11+ years of work at the IAEA I felt that Professor Vano (I will refer to him as Eliseo, being such a good friend) is the best expert in every project or action that I initiated in fluoroscopic guided interventional procedures, digital imaging, education and training, regulatory framework, radiation and cataract and the list can go on. It was his preoccupation and non-availability that prevented me to utilize his services in some, much as I tried in to have him in every case. He is an excellent contributor in meetings and his comments are practical and pragmatic. When we were driving the radiation protection actions almost exclusively towards patient protection, I found in him a champion of occupational protection. He has been Chair of the Working Party MED of Article 31 of European Commission for several years and has contributed actively to the revision of European Basic Safety Standards.

He was appointed as Chair of the Committee 3 of the International Commission on Radiological Protection (ICRP) in 2009 and he asked me act as Secretary of the Committee. I had the pleasure of working actively for 8 years with him and enjoyed his cooperative spirit besides professional excellence.

He has been advisor to the Spanish Ministry of Health for radiation protection in medical exposures.

Eliseo has been nominated by the Spanish Ministry of Health as an expert to represent Spain on several International Committees, such as IAEA, WHO and UNSCEAR.

Wonder if there is anyone in the world who has published as much as Eliseo in the area of medical radiation protection.

I salute Eliseo on his commendable success and we in IOMP and IUPESM family are proud of his achievements.

Madan M. Rehani, PhD
Vice President, IOMP
Massachusetts General Hospital, Harvard Medical School, Boston, USA

ANCHALI KRISANACHINDA AWARDED THE HAROLD JOHNS MEDAL, 2018

In recognition of her exceptional achievements in international education and training in medical physics and outstanding contributions in promoting international development of the medical physics profession, the IOMP has awarded Professor Anchali Krisanachinda the Harold Johns Medal, one of the highest honours of the Organization.

Professor Anchali Krisanachinda is from the Department of Radiology, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand.

Professor Krisanachinda has been very much involved in promoting the development of medical physics in Asia, particularly in the South East Asian Countries. She was one of the Founding Officers of AFOMP and SEAFOMP. She was elected AFOMP Treasurer in year 2000 and was elected SEAFOMP Vice President in 2001 and became President in 2005. Under her leadership, Thailand hosted the first AFOMP congress, the 1st AOCMP in conjunction with the 2nd SEACOMP in Bangkok in 2001 and the 9th AOCMP in conjunction with the 7th SEACOMP in Chiang Mai in 2009. She was the congress chairperson of these major Asian international medical physics congresses. She also organized and chaired the 22nd IOMP International Conference of Medical Physics (ICMP) in Bangkok in 2016. In her own personal capacity as well as her official capacity of AFOMP and SEAFOMP, Professor Krisanachinda has helped medical physicists in Brunei, Cambodia, Laos, Myanmar and Vietnam in establishing their own national medical physics organizations and contributed to the development of medical physics in these countries.

Professor Krisanachinda has been serving as IAEA National Project Coordinator for Thailand under the Regional Cooperative Agreement (RCA) for the Asian Region (RAS) and has completed several projects since 1985. The projects included IAEA programmes in QA/QC, DAT and DATOL (Distance Assisted Training On Line) in nuclear medicine, and Strengthening Medical Physics through Education and Training in Asia and Pacific where a structured clinical training programme for medical physicists was initiated in Thailand. This was an IAEA residency training programme (initially started as a pilot programme in 2007 and now a regular one) for medical physicists practicing in diagnostic radiology medical physics, radiation oncology medical physics and nuclear medicine medical physics in Thailand and was organized under Thai Medical Physicist Society and Chualalongkorn University. Professor Krisanachinda has been a principal investigator of the IAEA Coordinated Research Project on Quantitative PET/CT, SPECT/CT since 2008. She has also been appointed as IAEA expert and consultant in the field of nuclear medicine and medical physics since 2005 and has taken a number of IAEA missions to a number of South East Asian countries.

In recognition of her achievements in global development of medical physics and her outstanding contributions to the services and activities of IOMP, AFOMP, SEACOMP and the IAEA, Professor Krisanachinda was named as one of the Fifty Outstanding Medical Physicists for the Past 50 Years at ICMP 2013 held in Brighton, UK. At the World Congress in Toronto, 2015 Prof. Anchali Krisanachinda was made Fellow of IOMP.

Let us congratulate Professor Krisanachinda for her outstanding achievements and her award of the Harold Johns Medal 2018. She truly deserves the honour.

Kin Yin Cheung, PhD
Past IOMP President and IUPESM President

SALLY HAWKING – HONORARY MEMBER INTERNATIONAL ORGANIZATION FOR MEDICAL PHYSICS (2018)

I met Mrs Sally Hawking in early 2012, when I was still IOMP Treasurer, since this time she has been one of the most dedicated members of the IOMP team, caring for many of our administrative and finance activities. Currently Mrs Sally Hawking is External and International Services Manager in IPEM, UK specifically dealing with the activities of IOMP.

Sally has graduated Communication and Media Studies at Sheffield Hallam University, UK and further specialised Project Management. She joined the UK Institute of Physics and Engineering in Medicine (IPEM) in 2012. Since this time she works as Administrative Secretary of IOMP. In this period of time she also supported the work of EFOMP and IUPESM. Her activities for these 6 years were outstanding. She not only delivered an exceptional service of Administrative Secretary, helping directly the Treasurer, the Secretary General, the President, and all ExCom, taking also active role in some vital moments for the development of the Organisation.

Sally arranged the electronic banking of IOMP and all tax-related issues of the Organisation. Most importantly she took a very active role in the incorporation of IOMP. Mrs Sally Hawking, Prof. Stephen Keevil and myself worked several years on this very important, but also very difficult task, which led to the establishment of the legal status of IOMP. As lead of the Work Group dealing with the IOMP incorporation, I witnessed Sally's very diplomatic role in dealing with the Law and Finances Firms, which were moving our case through the quite unknown process of incorporating of an international organisation. The results achieved last year are a milestone for IOMP – arranging our status as a legal body; strengthening the international position of IOMP; supporting its status as NGO to WHO; potentially opening ways for external project funding, etc. The legal and business hand of IOMP – the IOMP Company was registered in the UK at the end of December 2017 and started its activities in January 2018. Just in the first month of its incorporation, IOMP was already benefitting from this action – re-confirming its NGO status with WHO.

Alongside the many administrative and financial activities in IOMP, Sally took also an active role in the work of the IOMP Finance Sub-Committee, IOMP Women Sub-Committee, IOMP Web Sub-Committee. Her professional, constructive and gentle way of dealing with urgent situations, and also with everyday tasks, was of great help to our IOMP ExCom members, volunteering their time for the global development of medical physics. The impact of Sally in IOMP is a real example of the important inter-professional skills, necessary for our profession.

The activities of Mrs Sally Hawking in the IOMP were far above the work of an Administrative Secretary. In her diplomatic and highly competent way of work, she played pivotal role in some of the most important organisational aspects of IOMP, thus making significant contributions to the objectives of IOMP and indirectly helping thousands of medical physicists. I was very happy that the IOMP Awards and Honours Committee, headed by Dr Simone Kodlulovich-Renha unanimously approved Mrs Sally Hawking as IOMP Honorary Member - the special IOMP Honour, recognising significant contributions to the objectives of IOMP by persons who are not Medical Physicists.

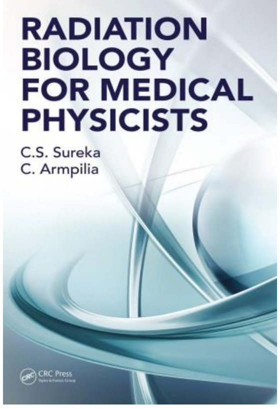
I am very grateful to Mrs Hawking for her relentless help in the activities of IOMP and its incorporation. On behalf of the IOMP Executive Committee, I am happy to sincerely congratulate her for this well-deserved Honour.

Prof. Slavik Tabakov, President IOMP

Mrs Sally Hawking with the IPEM CEO Rosemary Cook, CBE and the Presidents of IOMP and IPEM (S Tabakov and M Tooley) at the installation of the IOMP Company Registration Plaque, IPEM, York, April, 2018

BOOK REVIEW

A BOOK REVIEW
RADIATION BIOLOGY FOR MEDICAL PHYSICISTS
BY C.S. SUREKA, C. ARMPILIA



Introduction and purpose

This book has the goal of providing an introduction and overview of radiation biology, as applied from medical physicists to radiation oncology. The book aims at encouraging medical physics students to choose radiobiological carrier and clinical medical physicists to enrich their job with radiobiological research.

Audience

In the preface, the editors state that the book is intended as an introductory learning guide for more medical physics students and clinical medical physicists. The support of Bharathiar University, International Centre of Theoretical Physics (ICTP) and Aretaieion University Hospital of Athens has been highlighted in the acknowledgment paragraph.

Content/Features/Assessment

The book is organized into ten parts — from the “cell biology”, “a brief introduction of cancer”, to “biological effects of radiation”, “radiobiological models”, “biological basis of radiotherapy” and “biological dosimetry”. Most radiobiology textbooks are aimed at a broad audience, biologists, radiation oncologists, medical physicists whose academic training and working experience emphasizes different aspects of the subject. A most wanted addition to the literature, the book by Sureka and Armpilia is tailored to the needs of the medical physicists working in the clinic on plan optimization both in external beam radiotherapy and brachytherapy. The relevant aspects of cell and cancer biology and of the manifold effects of ionizing radiation on living tissues are covered in a terse and precise manner. Radiobiological models both at cell- and patient- level are subsequently illustrated with all the formalisms most often used in the clinical workflow. Mainly parameters considered the fulcrum of radiobiology such as Biological Equivalent Dose are presented and discussed, while the most commonly used TCP/NTCP models are summarized. A questionnaire at the end of each chapter to test the acquired knowledge makes the textbook suitable for self-study. A final chapter on biological dosimetry provides the background for further research.

The book can be fruitful used to support MSc programmes in medical physics or also professionals from different disciplines (engineering, radiation protection, medical instruments design, ..) who can find in it what is necessary to approach the radiobiology topics and increase their capability to handle effectively biological effects of ionizing radiation. Finally, this book could represent a must-have in the library of any researcher, teacher, professional that need a quick and easy way to go deep in the radiobiology.

Reviewed by Lidia Strigari, Ph.D., M.Sc.

Lidia Strigari is the head of Laboratory of Medical Physics and Expert Systems of IRCCS Regina Elena National Cancer Institute (IFO). Her research interests are in radiobiology, modelling and dosimetry.

INFORMATION FOR AUTHORS

PUBLICATION OF DOCTORAL THESIS AND DISSERTATION ABSTRACTS

A special feature of Medical Physics International (on line at www.mpijournal.org) is the publication of thesis and dissertation abstracts for recent graduates, specifically those receiving doctoral degrees in medical physics or closely related fields in 2010 or later. This is an opportunity for recent graduates to inform the global medical physics community about their research and special interests.

Abstracts should be submitted by the author along with a letter/message requesting and giving permission for publication, stating the field of study, the degree that was received, and the date of graduation. The abstracts must be in English and no longer than 2 pages (using the MPI manuscript template) and can include color images and illustrations. The abstract document should contain the thesis title, author's name, and the institution granting the degree.

Complete information on manuscript preparation is available in the INSTRUCTIONS FOR AUTHORS section of the online journal: www.mpijournal.org.

For publication in the next edition abstracts must be submitted not later than /august 1, 2014.

INSTRUCTIONS FOR AUTHORS

The goal of the new IOMP Journal Medical Physics International (http://mpijournal.org) is to publish manuscripts that will enhance medical physics education and professional development on a global basis. There is a special emphasis on general review articles, reports on specific educational methods, programs, and resources. In general, this will be limited to resources that are available at no cost to medical physicists and related professionals in all countries of the world. Information on commercial educational products and services can be published as paid advertisements. Research reports are not published unless the subject is educational methodology or activities relating to professional development. High-quality review articles that are comprehensive and describe significant developments in medical physics and related technology are encouraged. These will become part of a series providing a record of the history and heritage of the medical physics profession.

A special feature of the IOMP MPI Journal will be the publication of thesis and dissertation abstracts for will be the publication of thesis and dissertation abstracts for recent doctoral graduates, specifically those receiving their doctoral degrees in medical physics (or closely related fields) in 2010 or later.

MANUSCRIPT STYLE

Manuscripts shall be in English and submitted in WORD. Either American or British spelling can be used but it must be the same throughout the manuscript. Authors for whom English is not their first language are encouraged to have their manuscripts edited and checked for appropriate grammar and spelling. Manuscripts can be up to 10 journal pages (approximately 8000 words reduced by the space occupied by tables and illustrations) and should include an unstructured abstract of no more than 100 words.

The style should follow the template that can be downloaded from the website at:

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Illustrations can be inserted into the manuscript for the review process but must be submitted as individual files when a manuscript is accepted for publication.

The use of high-quality color visuals is encouraged. Any published visuals will be available to readers to use in their educational activities without additional approvals.

REFERENCE WEBSITES

Websites that relate to the manuscript topic and are sources for additional supporting information should be included and linked from within the article or as references.

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Only persons who have made substantial contributions to the manuscript or the work described in the manuscript shall be listed as authors. All persons who have contributed to the preparation of the manuscript or the work through technical assistance, writing assistance, financial support shall be listed in an acknowledgements section.

CONFLICT OF INTEREST

When they submit a manuscript, whether an article or a letter, authors are responsible for recognizing and disclosing financial and other conflicts of interest that might bias their work. They should acknowledge in the manuscript all financial support for the work and other financial or personal connections to the work.

All submitted manuscripts must be supported by a document (form provided by MPI) that:

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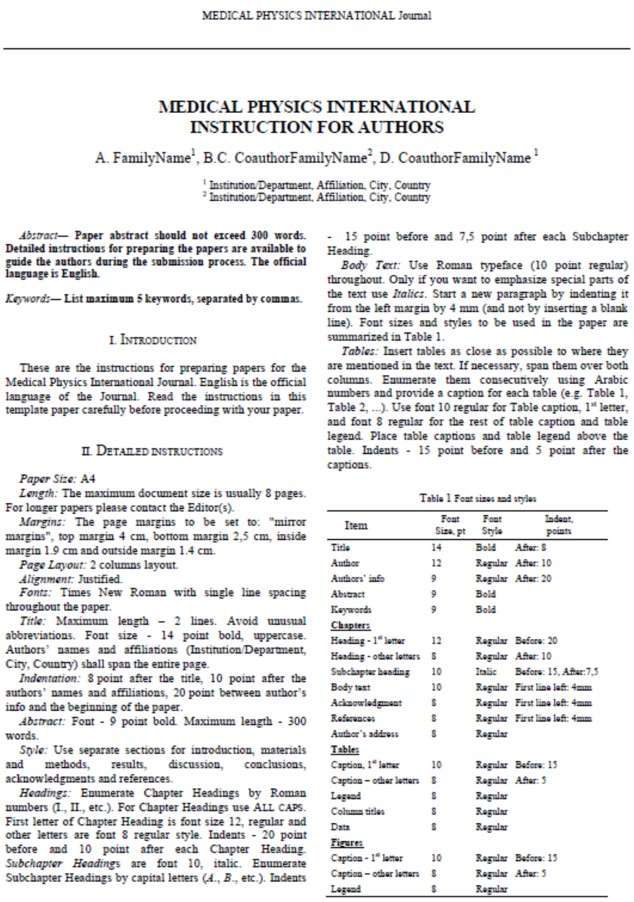

MEDICAL PHYSICS INTERNATIONAL Journal

MEDICAL PHYSICS INTERNATIONAL INSTRUCTION FOR AUTHORS

A. FamilyName[1], B.C. CoauthorFamilyName[2], D. CoauthorFamilyName [1]

[1] Institution/Department, Affiliation, City, Country
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Abstract— **Paper abstract should not exceed 300 words. Detailed instructions for preparing the papers are available to guide the authors during the submission process. The official language is English.**

Keywords— **List maximum 5 keywords, separated by commas.**

I. INTRODUCTION

These are the instructions for preparing papers for the Medical Physics International Journal. English is the official language of the Journal. Read the instructions in this template paper carefully before proceeding with your paper.

II. DETAILED INSTRUCTIONS

Paper Size: A4

Length: The maximum document size is usually 8 pages. For longer papers please contact the Editor(s).

Margins: The page margins to be set to: "mirror margins", top margin 4 cm, bottom margin 2,5 cm, inside margin 1.9 cm and outside margin 1.4 cm.

Page Layout: 2 columns layout.

Alignment: Justified.

Fonts: Times New Roman with single line spacing throughout the paper.

Title: Maximum length – 2 lines. Avoid unusual abbreviations. Font size - 14 point bold, uppercase. Authors' names and affiliations (Institution/Department, City, Country) shall span the entire page.

Indentation: 8 point after the title, 10 point after the authors' names and affiliations, 20 point between author's info and the beginning of the paper.

Abstract: Font - 9 point bold. Maximum length - 300 words.

Style: Use separate sections for introduction, materials and methods, results, discussion, conclusions, acknowledgments and references.

Headings: Enumerate Chapter Headings by Roman numbers (I., II., etc.). For Chapter Headings use ALL CAPS. First letter of Chapter Heading is font size 12, regular and other letters are font 8 regular style. Indents - 20 point before and 10 point after each Chapter Heading. *Subchapter Headings* are font 10, italic. Enumerate Subchapter Headings by capital letters (*A.*, *B.*, etc.). Indents - 15 point before and 7,5 point after each Subchapter Heading.

Body Text: Use Roman typeface (10 point regular) throughout. Only if you want to emphasize special parts of the text use *Italics*. Start a new paragraph by indenting it from the left margin by 4 mm (and not by inserting a blank line). Font sizes and styles to be used in the paper are summarized in Table 1.

Tables: Insert tables as close as possible to where they are mentioned in the text. If necessary, span them over both columns. Enumerate them consecutively using Arabic numbers and provide a caption for each table (e.g. Table 1, Table 2, ...). Use font 10 regular for Table caption, 1st letter, and font 8 regular for the rest of table caption and table legend. Place table captions and table legend above the table. Indents - 15 point before and 5 point after the captions.

Table 1 Font sizes and styles

Item	Font Size, pt	Font Style	Indent, points
Title	14	Bold	After: 8
Author	12	Regular	After: 10
Authors' info	9	Regular	After: 20
Abstract	9	Bold	
Keywords	9	Bold	
Chapters			
Heading - 1st letter	12	Regular	Before: 20
Heading - other letters	8	Regular	After: 10
Subchapter heading	10	Italic	Before: 15, After:7,5
Body text	10	Regular	First line left: 4mm
Acknowledgment	8	Regular	First line left: 4mm
References	8	Regular	First line left: 4mm
Author's address	8	Regular	
Tables			
Caption, 1st letter	10	Regular	Before: 15
Caption – other letters	8	Regular	After: 5
Legend	8	Regular	
Column titles	8	Regular	
Data	8	Regular	
Figures			
Caption - 1st letter	10	Regular	Before: 15
Caption – other letters	8	Regular	After: 5
Legend	8	Regular	

SUBMISSION OF MANUSCRIPTS

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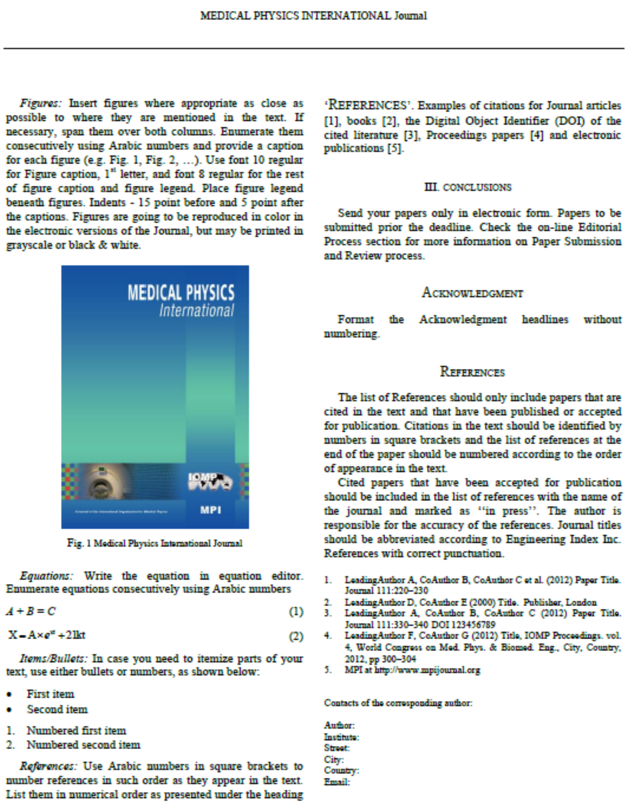
MANUSCRIPT PROPOSALS

Authors considering the development of a manuscript for a Review Article can first submit a brief proposal to the editors. This should include the title, list of authors, an abstract, and other supporting information that is appropriate. After review of the proposal the editors will consider issuing an invitation for a manuscript. When the manuscript is received it will go through the usual peer-review process.



MEDICAL PHYSICS INTERNATIONAL Journal

Figures: Insert figures where appropriate as close as possible to where they are mentioned in the text. If necessary, span them over both columns. Enumerate them consecutively using Arabic numbers and provide a caption for each figure (e.g. Fig. 1, Fig. 2, …). Use font 10 regular for Figure caption, 1st letter, and font 8 regular for the rest of figure caption and figure legend. Place figure legend beneath figures. Indents - 15 point before and 5 point after the captions. Figures are going to be reproduced in color in the electronic versions of the Journal, but may be printed in grayscale or black & white.

Fig. 1 Medical Physics International Journal

Equations: Write the equation in equation editor. Enumerate equations consecutively using Arabic numbers

$$A + B = C \quad (1)$$

$$X = A \times e^{st} + 2lkt \quad (2)$$

Items/Bullets: In case you need to itemize parts of your text, use either bullets or numbers, as shown below:

- First item
- Second item

1. Numbered first item
2. Numbered second item

References: Use Arabic numbers in square brackets to number references in such order as they appear in the text. List them in numerical order as presented under the heading 'REFERENCES'. Examples of citations for Journal articles [1], books [2], the Digital Object Identifier (DOI) of the cited literature [3], Proceedings papers [4] and electronic publications [5].

III. CONCLUSIONS

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ACKNOWLEDGMENT

Format the Acknowledgment headlines without numbering.

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5. MPI at http://www.mpijournal.org

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IUPESM 2018 World Congress

IOMP SCHOOL

Editing: John Damilakis, Magdalena Stoeva

SESSION ON IOMP PROJECT “HISTORY OF MEDICAL PHYSICS”

Moderators: Slavik Tabakov, IOMP President; Perry Sprawls, USA; KY Cheung, IOMP History Sub-Com Chair; John Damilakis, IOMP ETC Chair, Magdalena Stoeva, IOMP MPWB Chair

During 2016 IOMP launched a large project “History of Medical Physics” aiming to show the creation and the evolution of different equipment and methods, as well as their clinical application; the overall development of the profession and the main contributors in the various topics in medical physics. The project will be developed over a number of years by independent teams. The first results of the project are being published as Special Issues of the IOMP Journal Medical Physics International.

The aim of the session is to present the current progress of the project – in particular the development of the volume related to Diagnostic Radiology and the volume(s) related to Professional development and Education and Training development. The session will present the current progress of the surveys developed and assessed in collaboration with the 6 Regional Organisations of IOMP (covering Asia, S-E Asia, Middle East, Africa, Europe, Latin America and North America).

The session will also form future teams for the development of the further volumes of the History (related to the professional sub-fields of the profession – Imaging, radiation Safety, Radiotherapy, etc).

CT DOSES AND RISKS

John Damilakis
University of Crete, Faculty of Medicine, Greece

CT is a valuable imaging method that can be used to examine organs and tissues, detect abnormalities and guide procedures. However, radiation dose associated with CT examinations and the potential of developing cancer due to radiation is an issue of concern. This presentation will provide an overview of the doses and the radiation-induced cancer risks from CT examinations. Specific groups of patients may be at greater risk from CT exposure and radiogenic risk should be considered carefully in these patients. The increasing use of CT has resulted in an increase in requests for imaging during pregnancy. Conceptus doses and associated risks from most CT examinations are very low especially if the unborn child is not exposed primarily to X-ray beam. The use of paediatric CT has been increasing rapidly. Children and adolescents are more radiosensitive than adults and they have long expected lifetime. CT has been used for screening of asymptomatic individuals. In lung cancer screening, individuals who have a high risk of developing lung cancer undergo low-dose CT examinations. CT colonography (CTC) has also been used as a method to screen for colorectal tumors as well as for large colorectal polyps. Patient dose from a low-dose chest CT examination is about 1 mSv and from CTC ranges from about 3 mSv for modern CT scanners to about 9 mSv. The ICRP and the BEIR committee have provided estimates of cancer mortality risks per unit dose. A single low-dose CTC would result in about a 0.01% lifetime cancer risk i.e. 1 in 10000 for a typical patient cohort. A novel method for the estimation of patient organ doses and risks from chest CT is currently being developed in the University of Crete as part of the MEDIRAD project. Results of this research effort will be presented during this lecture.

DOSE OPTIMIZATION STRATEGIES

Mahadevappa Mahesh
Johns Hopkins University School of Medicine

Radiation dose is of concern for patients undergoing medical x-ray imaging procedures. In order to ensure radiation burden is kept minimum, the approach of dose optimization is more holistic and effective than simple dose reduction. Dose optimization in medical imaging consists of not only keeping radiation burden as low as possible (ALARA principle) but at the same time maintain optimal image quality to ensure proper diagnosis. In this presentation, various dose reduction strategies will be discussed. Since among the medical x-ray imaging procedures, CT studies contributes the most radiation burden, hence dose optimization strategies with focus on CT will be discussed. Tube current modulation, tube voltage selection, limiting scan volume, patient positioning, use of iterative reconstruction methods are among the many dose optimization tools that will be discussed in this session.

DOSIMETRIC CHALLENGES OF PHOTON BRACHYTHERAPY IN TERMS OF ABSORBED DOSE TO WATER

Golam Abu Zakaria[1], Ulrich Quast[2] Theodor Kaulich[3]

[1]Department of Medical Radiation Physics, Klinikum Oberberg, Gummersbach Hospital, Academic Teaching Hospital of the University of Cologne, Gummersbach, Germany

[2]Clinical Radiation Physics, University Hospital, Radiology Center, Essen, Germany

[3]Department of Medical Physics, University Hospital for Radiooncology, Tuebingen, Germany

About 10% of all radiotherapy cancer treatments are performed by brachytherapy (BT). For BT with beta radiation, the ISO 21439:2009 *Clinical dosimetry – Beta radiation sources for brachytherapy* gives guidance. But for photon radiation-BT a corresponding recommendation is missing. Detailed recommendations have been prepared by the AAPM TG-43. Their recommendation to perform the calibration of photon radiation BT-sources in terms of the reference air kerma rate is still used world-wide. But, as the BT-dose is prescribed in terms of the biologically relevant quantity absorbed dose to water, it is the task of medical physicists to convert the data by using the AAPM TG-43 formalism. Recently different primary standards have been developed in several national metrological institutes for high-energetic (HE) BT-photon sources, like ^{192}Ir and ^{60}Co, as well as for low-energetic (LE) BT-photon sources, like ^{125}I and ^{103}Pd. Known transfer standards, such as well chambers, calibrated in terms of absorbed dose to water in water for every model of photon-BT-sources to be used, can be utilized for traceability to a primary standard. Secondary standards are still missing.

Photon-BT dosimetry measurements are really challenging as the response R of dosimetry detectors depends on several influence quantities. R can be described as product of the detector-to-water-dose-ratio and the intrinsic response, describing the conversion of the detector absorbed dose to a measurement indication, both dependent on the mean photon energy $\overline{E}$. Instead of complicated Monte-Carlo simulation calculations, $\bar{E}$ can precisely be determined from the BT-photon radiation quality index, the ratio of the primary dose at r = 2 cm to that at r = 1 cm (in water on the transverse plane of the source), easily derived from published attenuation coefficients and primary-and-scatter-separated (PSS-) dose data. Such source reference data for all commercially available photon-BT sources are published e.g. at (http://www.physics.carleton.ca/clrp/seed_database/).

OVERVIEW OF RADIATION SAFETY CULTURE IN HEALTHCARE

Madan Rehani
Harvard Medical School and Massachusetts General Hospital, Boston, USA; Ex-IAEA, Vienna

Transitioning from individual actions on radiation safety to a culture of safety is a long process that requires concerted actions. Further, there are requirements in international Basic Safety Standards on radiation safety culture. There is a need to educate professionals on difference between radiation safety and radiation safety culture, create awareness about actions ongoing as a joint activity of IOMP with international organizations [World Health Organization (WHO), International Radiation Protection Association (IRPA) and International Atomic Energy Agency (IAEA)], inform about requirements, need to integrate actions with patient safety and to discuss how individuals and organizations can contribute.

QUALITY CONTROL FOR CBCT DEVICES ACCORDING TO EFOMP-ESTRO-IAEA

Hugo de las Heras Gala, Jonas Andersson
Science and communication, Munich, Germany

The course covers the contents of the recent guideline published by a collaboration of EFOMP, ESTRO, IAEA and EURADOS, with authors from more than 19 countries. It is available for free online since October 2017. The document focuses on measurements of radiation output and objective image quality parameters, which are required to check CBCT devices, including applications in dental radiology; interventional and guided surgery; and guidance systems of linear accelerators for radiotherapy.

In particular, we will describe why and how to perform the measurements of uniformity, geometrical precision, voxel values (or Hounsfield units), noise, low contrast resolution and spatial (high contrast) resolution. We will also indicate how to use different phantoms, as well as examples of commercial and free software. A special section is devoted to measurements of radiation output, either using a kerma-area product meter or a conventional solid state dosemeter attached to the flat panel.

After the explanation of the theory, if time permits, we will simulate a practical application of the whole protocol and discuss recent developemts regarding patient dosimetry.

Participants who bring a USB stick may take with them a digital copy of the guideline and the article appeared in Physica Medica.

BREAST TOMOSYNTHESIS: WHERE ARE WE AND WHERE ARE WE GOING?

Ioannis Sechopoulos
LRCB, Dutch Expert Centre for Screening, Nijmegen, The Netherlands

The introduction of digital tomosynthesis for breast imaging has brought about many questions, regarding its optimal clinical application, dosimetry, artifacts, image quality, and quality control, among others. Given that breast tomosynthesis seems ideally suited for screening, its optimization for population-based screening implementation is an especially important topic of interest. The appropriate number of views to acquire, number of readings to perform, its use along real mammograms or synthetic mammograms, are all open questions that need to be addressed. However, the optimal combination of these parameters are most probably dependent on the manufacturer of the system in question. Furthermore, these issues will have a direct impact on the dose involved in screening tomosynthesis.

We will review the current state of digital breast tomosynthesis technology, its clinical applications and the challenges being faced with this modality. Current research and future developments, and how these might impact the use of this modality in the realm of breast cancer care will be discussed.

Conflicts of interest: Research agreement, Siemens Healthcare

PET/CT VS PET/MRI: QUO VADIS

Habib Zaidi

PET Instrumentation & Neuroimaging Laboratory (PINLab), Geneva University Hospital, Geneva, Switzerland

During the last few decades, PET-based molecular imaging has advanced elegantly and steadily gained importance in the clinical and research arenas. However, the lack of structural information provided by this imaging modality motivated its correlation with structural imaging techniques such as x-ray CT or MRI, which are well established in clinical setting. The advent by academia of combined PET/CT and PET/MRI systems, their commercial introduction and the fast and wide acceptance of the former in the clinic has had a significant impact on patient management and clinical research. However, the latter is still an “embryonic” technology having the potential to become a powerful tool and likely to play a pivotal role in clinical diagnosis and research. The additional capability of simultaneous acquisition of PET and MRI data bridges the gap between molecular and morphologic diagnosis. Since diagnostic imaging methods evolve from the anatomic to the molecular level, the mission of multimodal and multiparametric imaging becomes ever more essential. Whole-body hybrid PET/MR imaging is, since 2010, being investigated in clinical setting for clinical diagnosis and staging, treatment response monitoring and radiation therapy treatment planning of a wide range of malignancies. However, quantitative PET/MRI is still challenged by the lack of accurate and robust attenuation and motion compensation strategies to enable the production of artifact-free and quantitative PET images. This talk briefly summarizes the historical development of PET/CT and PET/MRI and then gives an overview of state-of-the-art and recent advances in the design and construction of clinical systems and discusses the challenges facing multimodality imaging.

MULTI-ENERGY (SPECTRAL) CT

Cynthia H. McCollough
Mayo Clinic, Rochester, MN, USA

In x-ray computed tomography (CT), materials with different effective atomic numbers can have the same CT number (in HU), depending on the density of the materials and the energy of the x-ray beam. Discriminating between different tissue types or contrast materials is therefore very challenging. In dual-energy CT (DECT), a second attenuation measurement is acquired at a second energy (e.g., a second x-ray tube potential), allowing discrimination between the two materials. Clinical DECT systems are now available using two x-ray sources and detectors, sequential acquisitions of low- and high-tube potential scans, fast tube-potential switching, or dual detector layers. The use of photon-counting detectors, which can resolve individual photon energies and hence acquire data at more than two energy levels, is currently undergoing evaluation on research systems. Thus, dual- or multi-energy CT data, collectively referred to as spectral CT, can be acquired using a number of different approaches. Once the dual- or multi-energy data are collected, material decomposition algorithms are used to identify materials according to their effective atomic number and/or to quantify their mass density. These algorithms can be applied to either projection or image data. A number of different applications have been developed for clinical application, including those that automatically 1) remove bone and/or calcified plaque signal; 2) map out and/or quantify the concentration of iodine in contrast-enhanced CT images; 3) create virtual non-contrast images from contrast-enhanced scans; 4) identify perfused blood volume in the lung or myocardium; and 5) characterize materials according to their effective atomic number, which is useful for differentiating between uric-acid and non-uric-acid kidney stones or uric acid (gout) and non-uric-acid (calcium pyrophosphate) crystals in joints and surrounding tissues. In this presentation, the physical principles of spectral CT will be reviewed and current technical approaches described. In addition, current clinical applications will be introduced.

CHM: Research grant, Siemens Healthcare GmbH

FLAT PANEL DETECTOR FLUOROSCOPY

Mahadevappa Mahesh
Johns Hopkins University School of Medicine

Interventional and fluoroscopic imaging procedures are becoming more prevalent because of less-invasive nature of these procedures compared to alternatives such as surgery. Flat-panel x-ray detectors (FPD) are replacing conventional image intensifiers in fluoroscopy. There are two approaches to produce digital x-rays. One is based on indirect conversion of x-rays to light (using CsI scintillators) and then to proportional conversion to electrical charge/signal (using amorphous-silicone (a-Si) based thin film transistors). Second approach is the direct conversion of x-rays to electrical charge/signal (amorphous-Selenium (a-Se) based thin film transistors). Flat panel detector fluoroscopy systems mostly use the indirect digital conversion approach (a-Si based thin-film-transistor with CsI scintillator). Both of the approaches will be discussed in this session. The advantages of FPD system such as lower radiation dose burden with higher magnification modes compared to II, lesser geometric distortions, larger field of view, less geometric foot-print, improved detective quantum efficiency that allows radiation dose reduction will be discussed in this session.

NEW ASPECTS OF MEDICAL PHYSICS IN RADIATION ONCOLOGY AND IMAGING

Golam Abu Zakaria, Ph.D

Department of Medical Radiation Physics, Klinikum Oberberg, Gummersbach Hospital, Academic Teaching Hospital of the University of Cologne, Gummersbach, Germany

Medical Physics is the application of physics concepts, theories and methods to medicine and health care. Medical physicists play a vital and often leading role for any medical research team. Their activities cover some key areas such as cancer, heart diseases and mental illnesses. In cancer treatment, they primarily work on issues involving imaging and radiation oncology. Thus the medical physicists play a mandatory role in every radiation oncology team.

The capability of controlling the growth of any cancer with radiation dose is always associated with the unavoidable normal tissue damage. Accordingly, many physical-technical developments in radiotherapy facilities are aimed to give a maximum radiation dose to tumour cells and – at the same time – minimize the dose to the surrounding normal tissue.

For that reason, after the development of the 60-Co Irradiation Units in the 50ties medical Linear Accelerators were developed in the following decades. Advanced Linear Accelerators, Helical Tomotherapy and Cyber Knife machines have been developed over the past two decades. Last but not least, Neutrons, Protons and even heavier Ions have also been applied. At the same time, treatment calculation and delivery methods have been continuously improved from conventional multi-beam techniques to tumour shape conformal methods such as 3D- Conformal Radiotherapy (3DCRT), Radio Surgery, Intensity Modulated Radiotherapy (IMRT), Image Guided Radiotherapy (IGRT), Stereotactic Body Radiation Therapy (SBRT) and Adaptive Radiotherapy (ART).

The concentration of dose to tumour requires precise information on the shape and the anatomical geometry of the tumour within the body. The techniques providing such pieces of information in a visible form is summarized by the term of “Imaging”. X-ray has played a dominant role almost from the time of its discovery in 1895. Up to now, the use of x-rays has been extended to tomographic imaging with Computer Tomography (CT) and other imaging modalities like Ultrasound (US), Magnetic Resonance Imaging (MRI) or Positron Emission Tomography (PET) which have been developed over the last decades. By their combined use, the required information level on the clinical tumour target volume for radiotherapy has been tremendously raised.

The physical and technical development of radiation oncology and imaging are discussed in this talk covering aspects in biology as well.

SURVEY OF SITUATION IN 67 COUNTRIES AND WAY FORWARD

Madan Rehani
Harvard Medical School and Massachusetts General Hospital, Boston, USA; Ex-IAEA, Vienna

The Statement in the side event of the World Health Assembly 2016 on “Are we making the right investments for Caner control” stated: It is estimated that 22,000 Medical Physicists will be required in LMICs by 2035 to provide equal access to radiation therapy. The total number of medical physicists in 2016 is around this number, of which approximately only 1/3rd are in LMICs. There is an urgent need to strengthen actions to address this demand.

The figures were drawn from an article in Lancet Oncology in September 2015.

The shortage of medical physicists has been recognized globally not only in radiotherapy but also in diagnostic radiology, more so in developing countries. There is a need to assess the situation, do cause analysis, assess implications and develop solutions.

TEACHING OF MEDICAL PHYSICS TO RADIOLOGY RESIDENT: EUROPEAN SITUATION AND SUGGESTED SOLUTIONS

Carmel J. Caruana
Medical Physics Department, University of Malta, Malta

A Medical Physics component is integral to the curricula of all Radiology resident programmes in Europe. However, breadth and depth vary between one country and another leading to loss of harmonization across European states. The European Training Curriculum for Radiology should go a long way in addressing this issue. This presentation will describe and discuss the physics component of this curriculum.

IOMP/IUPAP WORKSHOP ON MEDICAL PHYSICS PARTNERING WITH THE DEVELOPING WORLD

Moderators: Slavik Tabakov, IOMP President; Yakov Pipman, IOMP PRC Chair; Fridtjof Nuesslin, IUPAP AC4 Chair; Libor Judas, Co-President WC2018

The aim of this regular IOMP/IUPAP Workshop is to support the medical physics capacity building in the Low-and-Middle-Income countries (LMIC). Special attention will be given to the activities necessary to address the expected tripling of the profession in the coming 20 years.

This extended IOMP Workshop is expected to attract about 100 participants. It is made on purpose as a satellite activity to the large World Congress of Medical Physics WC2018, which will attract approx. 2000 specialists from almost all 86 IOMP national member societies. This event will include various plenary and public lectures.

The Workshop attendees will benefit from these lectures, and all state-of-the-art presentations, and also from networking with senior specialists, aiming to boost the future expansion of the profession. IOMP expects significant impact from the Workshop, what is based on our very positive experience from the previous Workshop in Toronto, as well as similar Workshops in Eastern Europe and Asia.

The Workshop session will consist of presentations from the representatives of the main IOMP Regional Organisations (Federations in Asia, S-E Asia, Middle-East, Africa, Latin-America and Europe) followed by Panel discussion and drafting a Working plan.

Workshop opening and address from IUPAP – Prof. Fridtjof Nuesslin (Chair IUPAP AC4)
-Aims of the Workshop – Dr Yakov Pipman (IOMP PRC Chair)
-Challenges to the profession – Prof. Slavik Tabakov (President IOMP 2015-2018)
-Status of Medical Physics and Activities to Boost the Professional Development in the AFOMP Region – Prof. Arun Chougule (India, Vice-President AFOMP)
-Status of Medical Physics and Activities to Boost the Professional Development in the SEAFOMP Region – Prof. Anchali Krisanachinda (Thailand, Past-President SEAFOMP)
-Status of Medical Physics and Activities to Boost the Professional Development in the MEFOMP Region – Mr Nabil Iqeilan (Jordan, Chair ETC of MEFOMP)
-Status of Medical Physics and Activities to Boost the Professional Development in the EFOMP Region – Dr Hrvoje Hrsak (Croatia, nominated by EFOMP President)
- Status of Medical Physics and Activities to Boost the Professional Development in the FAMPO Region – Dr Taofeeq Ige (Nigeria, President FAMPO)
- Status of Medical Physics and Activities to Boost the Professional Development in the ALFIM Region – Dr Rodolfo Alfonso (Cuba, President ALFIM)
IAEA activities towards Capacity Building in LMI countries – Dr Harry Delis
WHO activities towards Capacity Building in LMI countries – Dr Maria Perez, Dr Adriana Velazquez
Open discussion and Way Forward

STATUS OF MEDICAL PHYSICS AND ACTIVITIES TO BOOST THE PROFESSIONAL DEVELOPMENT IN THE AFOMP REGION

Arun Chougule, Ph.D.
Vice President AFOMP

Asia-Oceania Federation of Organizations for Medical Physics (AFOMP) is founded in July 2000 and today 21 countries national medical physicist associations (NMPO) with over 5000 medical physicists in Asia-Oceania region are members of AFOMP. If we look at socio-economic & educational status of AFOMP countries we found huge diversity and therefore task of AFOMP to homogenies the medical Physics education and profession is quite challenging.

To cater to the needs of the medical physicists and their education, AFOMP has created three main following committees to work on number of important tasks.

1. Professional development committee (PDC)
2. Education and training Committee (ETC)
3. Scientific Committee (SC)

These committees have drafted policy statements to deal with minimum level of education and training of medical physics, continuous professional development and career progression for clinical medical physicist in AFOMP countries.

Medical physicist is a health profession recognized by International Labour Organization (ILO) needs high level of professional competency and therefore medical physicist working in clinical environment must have undergone structured training program which is, 3 year undergraduate in science plus 2 year masters in medical physics followed by minimum of 1 year residency under experienced medical physicist in recognized institution. To access the present medical physics education, training and professional status in AFOMP member countries, a survey was undertaken by sending questionnaire to all AFOMP NMPO's. The questions were framed to get information such as, medical physics education program with their duration and the eligibility level education to pursue the medical physics education program etc.

Though officially we received responses from only four NMOP's however from personal contacts and understanding we compiled the information and observed that only few countries have master level medical physics education programme with proper residency and accreditation. The detail outcome of the survey and possible remedies to make it compatible with IAEA recommendations, teaching & education structural requirements are suggested.

AFOMP works in many areas to enhance medical physics by organizing various scientific activities, conferences and officially publishes & endorses various journals & newsletter. Also promotes students & young professional through various grants.

One of the most important scientific events organized by AFOMP every year is Asia-Oceania congress of Medical Physics (AOCMP). This congress gives a strong platform to AFOMP region medical physics communities to unite, exchange their scientific research & expertise and discuss professional issues.

Official publication of AFOMP includes Australian Journal of Physics and Engineering Sciences in Medicine (APESM) and AFOMP newsletter. Apart from this AFOMP officially endorses two journals i.e. the Biomedical Imaging and Interventional Journal (BIIJ), Radiological Physics and Technology (RPT). In December 2017 MOU between AFOMP & MFOMP is signed to enhance collaboration and exchange of science between AFOMP & MEFOMP countries. The "AOCMP 2019" is being organized in conjunction with MEFOMP meeting in Kuwait to enhance the collaboration.

AFOMP is playing a lead role in scientific and professional development of medical physics communities in Asia-Oceania region. Due to its continuous efforts in subsequent years surely the status of medical physics and physicist has increased but still there is long way to go ahead to reach its goals.

STATUS OF MEDICAL PHYSICS AND ACTIVITIES TO BOOST THE PROFESSIONAL DEVELOPMENT IN THE SEAFOMP REGION

Anchali Krisanachinda
President, Thai Medical Physicist Society, Past-President SEAFOMP

ASEAN is an organization comprising of 10 nations located in Southeast Asia. The organization was formed on 8 August 1967 by its five original member countries, i.e. Indonesia, Malaysia, Philippines, Singapore and Thailand. Over the years, the organization grew when Brunei Darussalam joined in as the sixth member on 8 January 1984, Vietnam on 28 July 1995, Laos and Myanmar on 23 July 1997 and Cambodia on 30 April 1999. Its objectives include the acceleration of economic growth, social progress and cultural development among its members, as well as to promote regional peace. (ASEAN Secretariat, 2007). The idea of setting up an organization for South-east Asian medical physics societies was first mooted in 1996. During the International Organization of Medical Physics (IOMP) World Congress at Nice, the formation of SEAFOMP was endorsed by member countries. The South East Asian Federation of Organizations for Medical Physics (SEAFOMP) was officially accepted as a regional chapter of the IOMP at the World Congress in Chicago in 2000 with five member countries. Indonesia, Malaysia, Philippines, Singapore and Thailand. At that time, the founding members of SEAFOMP were Anchali Krisanachinda and Ratana Pirabul from Thailand, Kwan-Hoong Ng from Malaysia, Agnette Peralta from the Philippines, Djarwani S Soejoko from Indonesia and Toh-Jui Wong from Singapore. Three other countries joined subsequently: Brunei (2002), Vietnam (2005) and Myanmar (2016). The objectives of SEAFOMP are to promote (i) co-operation and communication between medical physics organizations in the region; (ii) medical physics and related activities in the region; (iii) the advancement in status and standard of practice of the medical physics profession; (iv) to organize and/or sponsor international and regional conferences, meetings or courses; (v) to collaborate or affiliate with other scientific organizations. SEAFOMP has a complementary and synergistic relationship with AFOMP in moving medical physics forward in the region. SEACOMP has initiated the tradition of awarding the best student presentation awards and this has stimulated much interest among the students. The students were given awards for best student presentations, both oral and poster, to encourage excellence in this field. Book prizes were generously donated by Medical Physics Publishing.

The abstracts and full papers were published in Proceedings, in hard and soft copies, and distributed to all the participants.

Medical physics profession was first started in Thailand in 1959 while the medical physics education was started in 1972, followed by Philippines, Malaysia, Indonesia and Vietnam. The IAEA structured program on clinical training in radiation oncology was piloted in 2007 in Thailand. Diagnostic radiology clinical training was started in 2008 in Philippines and in nuclear medicine in Thailand in 2010. Those who completed the program become Clinically Qualified Medical Physicist. In 2016, Thailand piloted the IAEA e-learning of medical physics clinical training which the residents from Vietnam and Myanmar could practice at their own department and obtain the on-line supervision from Thailand. AMPLE (Advance medical physics leaning environment) platform had been demonstrated and become available in all branches of medical physics in SEAFOMP country members. The activities are cooperated by national professional societies and university hospitals. Certification of medical physics will be available within a couple of years in south-east Asian region. The establishment of ASEAN College of Medical Physics is well supported at the annual congress- SEACOMP which the venue of the College/Congress is rotating among SEAFOMP country members.

STATUS OF MEDICAL PHYSICS AND ACTIVITIES TO BOOST PROFESSIONAL DEVELOPMENT IN THE MEFOMP REGION NABIL

Iqeilan, Huda Al Naemi
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Middle East Federation of Organizations of Medical Physics (MEFOMP) was born in 2009 as one of regional organizations of Medical Physics in the world. There are twelve (12) countries involved, namely Qatar, Oman, Iraq, Syria, Jordan, Kuwait, Lebanon, Saudi Arabia, Palestine, Bahrain, United Arab Emirates and Yemen. The process of activities for establishing local Medical Physics Societies varies among the 12 countries, and this creates a wide divergence among medical physics programs in the Middle East. Most of the medical physics programs have succeeded since its establishment; whereas others have not due to the conditions beyond the control of medical physicists; although, a few are still trying to survive.

In spite of the instability in the region, there are enormous efforts and achievements from fellow medical physicists who continuously work and support for the development of the Medical Physics Profession in the Middle East. It is vital that such efforts be sustained to further accelerate the growth of Medical Physics profession in the region.

Although the number of Medical Physicist in the Middle East has been constantly increasing, there is a continuous demand for more qualified medical physicist. It is also good to note that the local authorities started to realize its importance in the medical practice. However, it is a challenge to acquire qualified medical physicists due the following: 1) limited number of universities offering this specialty; 2) limited awareness on how vital this profession is within the medical practice and within the society in general; and 3) absence of, or under-recognition of the profession by the local authorities.

In view of this, there is a strong need to establish and formulate new rules, guidelines and standard specific to this field. Improvement of professional recognition which would promote interest within the new generation of professionals is essential. A Medical Physicist Education System and Certification Board in the region would further establish the profession, and this can be made possible through a collaborative effort between the MEFOMP and local/regional authorities.

The need for education and training of clinical medical physicists is fundamental in defining role, responsibilities and status; hence, it is important that senior academic positions of medical physics at universities should be established in every country; in such a manner that they should have dual responsibilities in the faculty of Medical Physics and hospitals.

STATUS OF MEDICAL PHYSICS AND ACTIVITIES TO BOOST THE PROFESSIONAL DEVELOPMENT IN THE EFOMP REGION

Hrvoje Hrsak

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Introduction: In most of the European countries, Medical Physics is a well-defined profession. However, differences in the status, level of development and harmonisation of the Medical Physics profession across Europe are still considerable, especially for lower-middle-income (LMI) countries. For those countries, the status is ranging from the unrecognised profession without appropriate qualification framework to fully recognised independent profession. A short survey was conducted to get an insight into the status of profession and activities needed to boost the professional development of Medical Physics in the European LMI countries.

Methods and materials: A questionnaire was prepared and sent to the National Member Organisation (NMO) for Medical Physics of each LMI country member of European Federation of Medical Physics (EFOMP). Those country members are Bosnia and Herzegovina, Bulgaria, Croatia, Macedonia, Moldova, Romania, Russian Federation and Serbia. 5 out of 8 country members responded (Bosnia and Herzegovina, Bulgaria, Croatia, Moldova and Serbia). The questionnaire was divided into six parts: General, Requirements to enter Medical Physics education, Training and education programme, National requirements and position of Medical Physicists, Medical Physicists registration and Medical Physics profession management.

Results: In all countries that responded to this questionnaire, the number of Medical Physicists was significantly increased in the last ten years (by 40% to 230%). The basic educational requirement to enter Medical Physics is a university degree. National training and education program in Medical Physics exists in two countries (Bulgaria and Serbia), resulting in the qualification “Medical Physics Specialist”. However, the program is approved at the national level only in Bulgaria. Only Bulgarian program follows the recommendations given in the European Guidelines for Medical Physics Experts and EFOMP Policy Statement No. 12.1. In three countries this program is in the status of the ongoing project (Bosnia and Herzegovina, Croatia, Moldova). In all countries except Moldova, there are legal requirements for Medical Physicist involvement in medical procedures. However, only in Bulgaria and Serbia Medical Physics is recognised as an independent profession. National legislation is harmonised with the EU Directive EURATOM 2013/59 in Bulgaria, Bosnia and Herzegovina and Croatia. There is an organised Register for Medical Physicists only in Serbia, while in Bulgaria it is being developed. A formal Continuing Professional Development programme (CPD) exist only in Bulgaria.

Conclusions: There is a significant increase in the number of Medical Physicists in the European LMI countries (on average more than 100% in last ten years) due to the high demands of the national healthcare and modern technologies in medicine. It is expected that this number will continue to increase at the even steeper rate. However, the current status of profession and level of development are not following that trend. Therefore, there is an urgent need for close cooperation between Medical Physics societies, hospitals and national policy stakeholders in healthcare to boost the development of Medical Physics profession.

STATUS OF MEDICAL PHYSICS AND ACTIVITIES TO BOOST THE PROFESSIONAL DEVELOPMENT IN THE FAMPO REGION.

Taofeeq A. IGE
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FAMPO President

FAMPO as the youngest regional federation of the IOMP was created on 12th December 2009 and got its charter in May 2010. It currently has membership from 30 member states in the region and those with national member organization (NMO's) are Algeria, Cameroon, Egypt, Ghana, Libya, Morocco, Niger, Nigeria, South-Africa, Sudan and Tunisia. The remaining countries at present do not have the critical mass to establish NMOs and they include Angola, Burkina Faso, Cote D'Ivoire, Ethiopia, Gabon, Kenya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Namibia, Rwanda, Senegal, Sierra Leone, Uganda, Tanzania, Zambia and Zimbabwe.

Training and recognition of medical physicists in Africa faced a number of challenges and through IAEA and AFRA, three publications on E&T of MPs in Africa have been produced.

FAMPO has been tasked to form the axis for medical physics activities in Africa through the 3 committees (education and training, professional and scientific) with E&T looking at development of academic education and training materials, Professional – accreditation, recognition and CPD, Scientific – endorsements of documents, promotion of research, exchange of scientific information and matters with membership.

FAMPO has created a basic database of medical physicists in Africa to facilitate communication. This can be used for surveys of activities, e.g. infrastructure, trainers,

Professional Development Committee (PDC) of FAMPO is further mandated to establish regional mechanism by which CQMPs can be recognized through formal process of certification and registration. Working closely with E&T Committee to help increase the number of accredited academic training programmes and establish accredited clinical training programmes in the region. This is necessary for development of MP profession in the Africa region, ensuring that trained MPs from accredited institutions automatically receive registration from FAMPO.

Moving forward, FAMPO's role is key to achieving harmonized and high standard of education and training programmes in Africa, which leads to improved quality and quantity of trained MPs who would readily be in position to practice competently and independently, thereby improving medical imaging and radiotherapy treatment delivery in the region.

STATUS OF MEDICAL PHYSICS AND ACTIVITIES TO BOOST THE PROFESSIONAL DEVELOPMENT IN THE ALFIM REGION

Dr Rodolfo Alfonso
Cuba, President ALFIM

During the last decade, Latin America has witnessed an accelerate development in the available radiation medicine technologies, both for diagnosis and therapeutic purposes. In several countries of the region, governments have promoted investment in high-end technologies for increasing the coverage of Radiotherapy and Nuclear Medicine public services. So currently, although large inequities in distribution and accessibility still prevail, the access to advanced diagnosis and treatment radiation facilities is continuously growing. In parallel, the private health sector is also introducing very sophisticated radiation technologies, even in low-income countries. While in 1990 there were about 400 MV units (25% linacs, 75% Cobalt machines) and 260 medical physicists (MPs) in Latin America (0.65 MPs/MV machine), 25 years later the numbers grew to 1000 machines (75% linacs and 25% Cobalt) and 650 MPs. Therefore, although the proportion MPs/MV did not changed, the significant increase in complexity of technology and sophistication of procedures means that the gap in demand of MPs has broaden.

This boom has pushed forward the demand of highly qualified medical physicists in the region, stimulating universities to establish academic training programs; in 2017 there were 19 master programs in medical physics, and even 16 programs at bachelor level (which is not the approach supported by ALFIM). Most of the academic programs do not have enough hours of supervised clinical practice to be able to meet the minimum training requirements required for the clinically qualified MP. Recognition of the MP as a health professional is still an issue in most of the countries; this could be partly the cause of the shortage of residency type, clinical training programs. In general, clinical institutions, even university hospitals or national cancer institutes are not prone to hire medical physics residents. Consequently, there is not balance between the number of graduates from academic programs and the availability of positions for clinical training. Recently, some universities have started an intermediate solution, the so-called professional master, which combined the academic and the clinical training in the same program. Regarding certification, in many countries this process has been fulfilled by the national nuclear regulatory bodies, which requires a minimum education and training for providing the corresponding license for working in radiation medicine practices.

The Latin American Association of Medical Physics (ALFIM) is working jointly with the Latin American Association of Therapeutic Radiation Oncology (ALATRO) and the Latin American Association of Societies of Biology and Nuclear Medicine (ALASBIMN), in order to gain support from our medical counterparts, for the recognition of the MP as a health professional, as well as understanding the role of MP resident in corresponding departments.

ALFIM is promoting a network of educational programs in medical physics in the region, using as starting point the existing Latin American Network for Education of Nuclear Technologies (LANENT) and the Latin American Network for Radiation Protection in Medicine (LAPRAM). ALFIM which to promote, in coordination with IOMP and the IMPCB, the accreditation of a regional certification body and its recognition by national regulatory and health authorities.

MRI-GUIDED RADIATION THERAPY

Colin Orton

The latest versions of commercial treatment planning systems include the option to employ radiobiological optimization. We will review the basic principles involved in both conventional and radiobiological optimization and discuss why biological optimization might lead to better plans. Topics presented will include volume effect modeling, equivalent uniform dose (EUD), tumor control probability (TCP), normal tissue complication probability (NTCP), bioeffect dose relationships, and the linear quadratic model. A review of the specific algorithms available in various commercial treatment planning systems will be presented.

AN INTRODUCTION BY THE INTERNATIONAL SOCIETY OF RADIOLOGY (GLOBAL PERSPECTIVE)

Guy Frija, Donald Frush
International Society Of Radiology

The mission of the International Society of Radiology (ISR) is 'to facilitate the global endeavours of its member organisations to improve patient care and population health through medical imaging'. To this end, the ISR formally established the Quality and Safety Alliance (ISRQSA) in 2016.

The ISRQSA is co-chaired by Drs Guy Frija (EuroSafe Imaging Chair of the European Society of Radiology) and Donald Frush (Image Gently Alliance Chair). Current members of ISRQSA are: AFROSAFE (E-Afrosafe and F-Afrosafe), ArabSafe, Canada Safe Imaging, EuroSafe Imaging, Image Gently, Image Wisely, Japan Safe Imaging, and LatinSafe. These are independent professional organisations lead primarily by radiologists and supported by their regional societies of radiology. Most of them are also multi-stakeholder organisations, having on board medical physicists and radiographers.

The ISRQSA acts as a convener and facilitator for continental, regional and national quality and safety campaigns in radiation protection and drives the ISR’s quality and safety agenda. The ISR is a non-state actor in official relations with the World Health Organization (WHO) and is also collaborating with the International Atomic Energy Agency (IAEA). The ISRQSA manages the relations with these international organisations.

CLINICAL DRLS FOR ADULTS: A NOVEL APPROACH

Guy Frija
International Society Of Radiology

Diagnostic reference levels (DRLs) are an important tool for optimisation. With the new Basic Safety Standards Directive (Council Directive 2013/59/Euratom) DRLs have been included in European legislation. The BSS Directive defines DRLs as “dose levels in medical radiodiagnostic or interventional radiology practices, or, in the case of radio-pharmaceuticals, levels of activity, for typical examinations for groups of standard-sized patients or standard phantoms for broadly defined types of equipment".

Usually, DRLs are specified in relation to the body region without specification of the clinical indication. However, different clinical tasks of the same anatomical area do not require the same image quality. For example, a chest CT can have different clinical indications, different protocols and different exposures. Thus, EuroSafe Imaging, the European Society of Radiology’s radiation protection campaign, is promoting the concept of clinical DRLs. Exposure protocols should rather be based on clinical indications and not on anatomical locations, which means that DRLs should also be established for clinical indications.

EuroSafe Imaging launched a working group dedicated to clinical DRLs in 2016, which prepared a preliminary list of clinical indications, which are proposed for the establishment of clinical DRLs. In addition, the European Commission launched the 33 month-tender project "European Study on Clinical Diagnostic Reference Levels for X-ray Medical Imaging" (EUCLID) in 2017, which is carried out by the ESR and supported by the EuroSafe Imaging campaign. In the course of this project, a list of clinical indications for CT and interventional radiology for which adult data from selected European facilities will be collected has been set up. In further consequence, data will be analysed to specify up-to-date clinical DRLs for Europe.

EUCLID – A EUROPEAN COMMISSION FUNDED EUROPEAN STUDY ON CLINICAL DRLS

John Damilakis
University of Crete, Faculty of Medicine, Greece

The European Commission (EC) has launched the ‘European study on clinical diagnostic reference levels for x-ray medical imaging’ (Abbreviation: EUCLID) project to provide up-to-date clinical dose reference levels (DRLs). The main objectives of the project are to a) conduct a European survey to collect data needed for the establishment of DRLs for the most important, from the radiation protection perspective, x-ray imaging tasks in Europe and b) specify up-to-date DRLs for these clinical tasks. EUCLID started in August 1, 2017. During the first months of the project, a comprehensive review was carried out to identify the status of existing clinical DRLs for CT, interventional radiology and radiography in Europe and beyond by analysing recent studies and publications. Information about existing clinical DRLs has also been collected from national competent authorities and other organisations involved in the project. A few national radiation protection authorities, only, have defined a limited number of DRLs for CT clinical indications and interventional radiology procedures, so far. Although a large number of studies on doses from x-ray imaging are available, there is very limited information about clinical-indication specific DRLs. A survey has been developed for collection of data needed for DRLs determination. To establish clinical DRLs, EUCLID will collect information from European hospitals for specific CT clinical indications and fluoroscopically guided interventional procedures. This presentation will provide a brief update on EUCLID project.

E-LEARNING EXPERIENCE: BUILDING EDUCATIONAL MODULES IN MEDICAL PHYSICS AND ENGINEERING WITH MOODLE VLE

Dr Vassilka Tabakova
King's College London, UK

The session will illustrate a practical solution of eLearning in Medical Physics and Engineering based on the free e-Learning VLE platform Moodle.

It will be of interest to educators in all fields related to Medical Physics and Engineering. No prior knowledge of Moodle and no advance preparation is needed.

The session will consist of a brief overview of e-Learning in Medical Physics, after which there will be an illustration of the application of the free e-Learning platform Moodle in the profession.

In the first part of the session the types and effectiveness of e-Learning will be discussed. A brief overview of e-Learning in Medical Physics based on the projects EMERALD, EMIT, EMITEL and others will be given, followed by a review of e-Learning platforms and an introduction to the Moodle platform.

The second part will illustrate the development of an educational e-module on Moodle step by step (based mainly on the example of a module on Physics of Medical Imaging). The roles of a Manager, Teacher and Student and their functions will be discussed. The symposium will deal also with Formatting and settings and an illustration of building a complete module will be given (with lectures, coursework, quizzes etc.). It will be discussed how to gather effectively information from Moodle (student participation, grade information, etc.)

The Session will highlight the advantages of e-Learning and focus on the prerequisites for its successful introduction in the teaching of Medical Physics and Engineering.

The Session is based on the author's own experience of e-Learning in the field of Medical Physics and Engineering since the mid-1990-ies and of applying Moodle in the past 7 years in the MSc programmes in Medical Physics and Engineering at King's College London, UK and other courses.

SESSION ON MEDICAL PHYSICS E-ENCYCLOPAEDIA AND DICTIONARY UPDATE

Moderators: Slavik Tabakov, IOMP President; Perry Sprawls, USA; Franco Milano, Italy; Magdalena Stoeva, IOMP MPWB Chair; Sameer Tipnis, USA, Tracy Underwood, UK

Since its launch at the World Congress in Munich (2009) the EMITEL on-line Encyclopaedia of Medical Physics and Multilingual Dictionary of terms established itself as a very useful reference source for the profession. Currently this large reference has about 5,000 users per month.

EMITEL (www.emitel2.eu) includes about 3100 articles with over 2000 illustrations (with volume about 2100 pages). During 2013 it was published on paper by CRC Press.

Currently EMITEL has a contract for Second editing of the Encyclopaedia to be completed by 2020. This will include update of the Dictionary as well.

The aim of the session will be to present to the colleagues the Update project and to discuss additional terms to be included both in the Encyclopaedia and the Dictionary. Special attention will be given to the feedback from current users of these large Reference materials. Colleagues from Low-and-Middle-Income countries will be asked for additional topics to be included aiming to support their education and training needs.

EXERCISES IN STRATEGIC MEDICAL PHYSICS LEADERSHIP - CASE STUDIES FROM THE TRENCHES

Carmel J. Caruana

Medical Physics Department, University of Malta, Malta

The EUTEMPE-EFOMP module Leadership in Medical Physics, development of the profession and the challenges for the Medical Physics Expert (D&IR) is perhaps the most comprehensive module on medical physics leadership worldwide. One of the very attractive features of the module is the discussion of case studies of real world issues faced by medical physicists in clinical practice. Two examples are shown below. We will together discuss possible ways of tackling these case studies.

Case study 1: There are 5 chest radiography rooms in your hospital each run by a different team of radiographers. You have noticed that one of the rooms is repeatedly exceeding the local DRLs which you have established. How would you tackle it? You know that the team of radiographers don’t like people investigating their techniques.

Case Study 2: Consider a particular Medical Physics department. With respect to D&IR: (a) Describe the present situation of the department (b) Describe a future vision: how should the department to be in 10 years time? (c) List 3 gaps between the present situation and future vision (d) List the Strengths and Weaknesses of the department with respect to the vision (e) List the external Opportunities available and Threats it faces with respect to the vision (f) Give ideas on how to reduce each gap using the SWOT methodology.

No conflicts of interest.

HOW IAEA SUPPORTS EFFORTS TO INCREASE THE NUMBER OF QUALIFIED MEDICAL PHYSICISTS WORLDWIDE

H. Delis, K. Christaki, J. Izewska, G. Loreti, G.L. Poli, S. Sarasanandarajah, P. Toroi, D. van der Merwe

Dosimetry and Medical Radiation Physics Section, Division of Human Health, Department of Nuclear Sciences and Applications, International Atomic Energy Agency

The International Atomic Energy Agency has been working to increase capacities of Member States in medical physics, aiming to enhance safe and effective use of radiation in medicine. The role of the medical physicist as a member of the multidisciplinary team of clinical professionals is underlined in all IAEA publications, starting from the International Basic Safety Standards.

Important activities, such as dosimetry, quality assurance and clinical computing are only some of the elements necessary for safe and effective use of radiation medicine that requires the competencies of adequately qualified medical physicists. However, there is an important shortage of medical physicists in most countries.

Recognizing the difficulty of stakeholders to understand the benefits that a new professional team member can bring to long established practices, especially in medical imaging, the IAEA organizes awareness activities to introduce the roles and responsibilities of the medical physicist in radiation medicine. These activities include development of awareness material, organization of high level meetings and publication of IAEA guidelines. The appreciation of the medical physics roles and responsibilities is a vital step to facilitate professional recognition that is also lacking in many Member States, although medical physics has been recognized as a profession by the International Labour Organization since 2008.

Direct support to Member States to develop capacities is also provided, either through individual training, to support emerging needs, or through assistance in developing National education and training schemes that will ensure sustainability.

Additionally, the IAEA has been one of the main stakeholders that support the Master of Advanced Studies in Medical Physics (MMP) programme, together with the Abdus Salam International Centre for Theoretical Physics (ICTP) and the University of Trieste. The contribution of the programme to medical physics capacities is noticeable, since 87 students, from 48 countries have participated since its establishment in 2013.

Although a lot has been achieved in support of Member States to increase medical physics capacities, more work is required by all relevant stakeholders, as these efforts will have a direct impact on the quality and safety of radiation medicine services delivered.

MRI-GUIDED RADIATION THERAPY

Geoffrey S. Ibbott
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The history and benefits of image-guidance in radiation therapy will be covered very briefly, to lead into a description of the potential benefits of MRI-guided RT. The installation, commissioning and initial experience with the Elekta MR-Linac will be discussed. Issues that arise when using dosimetry equipment in magnetic fields will be covered, and our experience and developments in calibration and performing QA measurements will be described.

MEDICAL PHYSICS INTERNATIONAL – THE IOMP JOURNAL

Slavik Tabakov and Perry Sprawls
MPI Journal Co-Editors-in-Chief

The IOMP Journal Medical Physics International (MPI) successfully completed its first term in 2017. During this time the IOMP Journal that is dedicated to educational and professional issues published more than 650 pages of reviewed papers and c. 1300 pages with abstracts of IOMP- supported Conferences. A number of the papers in the first 10 issues were downloaded more than 5,000 times each.

The success of the MPI Journal proved the need of a forum for discussion of our educational, professional and other related issues. This is especially important for topics related to e-Learning (e-L), as often e-L materials have short period of life and require quick dissemination and use. Behind the establishment of the Journal was the necessity of an e-L forum. This was identified in the Special Issue on "e-Learning in Medical Engineering and Physics", published by the Journal Medical Engineering and Physics (Guest-Editor S Tabakov, 2005). The IOMP ExCom approved the idea of Journal establishment in 2012 and by the end of the year the foundations of MPI were laid down: the name was suggested by W. Hendee; an ISSN number was obtained (2306-4609), a web site was made by M Stoeva (www.mpijournal.org), and an Editorial Board was formed including colleagues from IOMP ExCom and representatives of the IOMP Regional Organizations (Federations).

Special Gratitude should be expressed to all Founding members of the MPI Editorial team: KY Cheung; Madan Rehani; William Hendee; Tae Suk Suh; John Damilakis; Virginia Tsapaki; Raymond Wu; Simone Kodlulovich-Renha; Anchali Krisanachinda; Taofeeq Ige; Technical Editors: Magdalena Stoeva and Asen Cvetkov; Editorial Assistant: Vassilka Tabakova.

MPI Journal is also specially grateful to the authors of all papers submitted and published in the MPI Journal. It was mainly due to them that the Journal had such a successful start and continues to engage an ever growing number of readers and authors.

The official statistics from the server of MPI Journal includes not only the readers, but also the geographical spread of the Journal usage and the most frequently read papers. For example only in one randomly selected day (10 Sep 2017) there have been between 10 and 50 readers per hour. The MPI server statistics during the period covering August 2017 to April 2018 shows more than 11,000 visits per month, while their geographical spread indicates that more than 50% of readers are from LMI countries.

At the IOMP ExCom meeting in Jaipur (Nov 2017), the Founding MPI Editors-in-Chief (S Tabakov and P Sprawls) were approved to continue leading the Journal for another period of 4 years and additional members were included in the Editorial Board. The new period of the MPI Journal started with the first Special Issue of MPI, dedicated to the large IOMP Project "History of Medical Physics". This Special Issue is available for free download from: www.mpijournal.org/pdf/2018-SI-01/MPI-2018-SI-01.pdf It includes the first chapters of the History of the profession, related to X-ray Tubes, Radiographic Receptors and e-Learning. Apart from the refereeing papers, the new current issue includes abstracts from the IOMP School during WC2018. We are looking forward to the further success of the MPI – the IOMP Journal dedicated to education, training and professional issues.

IOMP MEDICAL PHYSICS WORLD

Magdalena Stoeva
Chair IOMP Medical Physics World Board; Department of Diagnostic Imaging, Medical University – Plovdiv, Bulgaria

Medical Physics World (MPW) has been the official bulletin of the International Organization for Medical Physics for over 30 years. The first issue of the bulletin was published in 1982 presenting a challenge to the IOMP and the medical physics societies around the world: "… to make 'Medical Physics World' worthy of its title".

The last several years mark a great progress in Medical Physics World. The new style and layout introduced in 2012 increased the interest towards MPW not only among our professional society, but also among corporate members and professionals from other disciplines. MPW is now regularly distributed on all major professional events – AAPM meetings, RPM, ICMP, many regional events.

Medical Physics World has always been in-line with IOMP's initiatives and hot topics. Besides providing the regular organizational reports, we have actively supported some of the IOMP's most successful activities – IOMP's 50th anniversary, the foundation of the Medical Physics International Journal (MPI), the International Day of Medical Physics (IDMP) and the formation of the IOMP Women subcommittee (IOMP-W). MPW successfully conducted a dissemination campaign that resulted in MPW's wide recognition among world's leading institutions. The journal is now regularly delivered to the European Congress of Radiology (ECR), the UNESCO International Center for Theoretical Physics (ICTP) and to the US Library of Congress. The latest achievement of MPW's editorial team is including Medical Physics World in the International Standard Serial Number registrar. With all the contemporary technology our world turned into an electronic world, so did Medical Physics World. We often call it eMPW now, but we are still devoted to the very first promise "… to make 'Medical Physics World' worthy of its title".

www.mpijournal.org

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