MEDICAL PHYSICS EDUCATION AND TRAINING IN BRAZIL: CURRENT SITUATION AND FUTURE DEVELOPMENT

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Abstract — **The evolution of technologic applications in Medicine has been guided by concepts and methods of Physics and Engineering in the last century. The constant interaction among Physics professionals has been reinforced in activities related to health sciences, that is a characteristic of the Medical Physicist. The Medical Physics area in Brazil has been experiencing a period of growth and development, due to the increasing access to medical technology and its importance to diagnostic and treatment procedures. The Brazilian Health Authorities at the National Cancer Institute (INCA) estimate that approximately 600,000 new cancer cases will be diagnosed in 2016 – 2017 in Brazil. Therefore, the growing importance of early diagnostic and treatment of diseases such as cancer raises the need for qualified Medical Physicists. These professionals assist to ensure the quality of the facilities, equipment and treatment plans used in the health systems. In recent years, Brazil had the initiative to expand Medical Physics graduate and undergraduate programs and clinical training. Moreover, the government is investing in new equipment and creating regulatory standards for minimum quality maintenance of health services in the country. In the present work, an analysis of the Medical Physics status in Brazil was performed. It included the education, the Diagnostic Imaging equipment, training programs, the current mandatory national standards and perspectives for the development of the Medical Physics profession in Brazil.**

Keywords — **Medical Physics, Education, Training, Professional qualification.**

I. INTRODUCTION

The Brazilian territory is geographically divided in five regions (North, Northeast, Midwest, Southeast and South) with 26 States and one Federal District where the capital is situated, Brasília (Figure 1)[1]. The country has an area of 8,515.767.049 km², a population of 24.66 people per square kilometer (62 per square mile)[1,2] and present a 1.774.72 billion of Gross Domestic Product (GDP)[3].

The National Cancer Institute (INCA) estimates approximately 600,000 new cancer cases will be diagnosed in 2016-2017 in Brazil[4]. Therefore, it is evident the importance of early diagnoses and treatment, which consequently, raises the need for qualified Medical Physicists to assist on the quality improvement of the diagnostic facilities and treatment centers[5].

Figure 1: The five regions and 26 states and one Federal District of Brazil[6].

An important step in this direction was the approval of Brazilian 11.129/2005 bill and the 1077/2009 regulation, which created the multidisciplinary residences in the professional field of health. As a consequence, new sites for training in different Medical Physics areas have been opened. In addition, the Ministry of Health recently announced the acquisition of 80 linear accelerators that would be distributed to attend the population of 63 cities around the country[7].

Hence, the need for qualified Medical Physicists has been growing in some areas in recent years. Consequently, the Brazilian education system has expanded as well as the Medical Physics career opportunities.

The aim of this study was to analyze the status of the education and training programs in Medical Physics in Brazil. In addition, the current mandatory national standards, the approximate number of Diagnostic Imaging equipment and perspectives for the development of the Medical Physics profession in Brazil are presented.

II. EDUCATION AND TRAINING PROGRAMS

Costa P.R[8] previously published a data survey regarding undergraduate, graduate, and clinical training levels in Medical Physics up to 2012. The present work will show a summary of these results and some updated information.

Undergraduate courses

The first undergraduate Medical Physics course established in Brazil started its activities in 1990. Eleven undergraduate programs were found in operation in the country up to 2012 and an estimated offer of 400 enrollment admissions per year[8].

The formal average duration of these undergraduation programs is 4.5± 0.5 years and the compulsory internship (practical/clinical training activities) differ between 0 to 720h[8]. This data is still representative, since the total number of undergraduate programs in Brazil remained eleven, as shown in Table 1, and no major changes have been identified in their curriculum grid.

Table 1: Universities with Medical Physics undergraduate courses in Brazil

Universities with Medical Physics undergraduate courses	Region	Initial Year
Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS)	South	1990
Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto (USPRP)	Southeast	2000
Centro Universitário Franciscano (UNIFRA)	South	2000
Universidade Federal de Sergipe (UFS)	Northeast	2001
Universidade Federal do Rio de Janeiro (UFRJ)	Southeast	2002
Universidade Estadual de Campinas (UNICAMP)	Southeast	2003
Universidade Estadual Paulista "Júlio de Mesquita Filho" - Campus de Botucatu (UNESP)	Southeast	2003
Centro Universitário da Fundação Educacional de Barretos (UNIFEB)	Southeast	2008
Universidade Federal de Uberlândia (UFU)	Southeast	2010
Universidade Federal de Goiás (UFG)	Midwest	2013
Universidade Federal de Ciências da Saúde de Porto Alegre (UFCSPA)	South	2014

Graduate courses

Thirteen Institutions with graduate programs in Physics with areas of concentration in Medical Physics or related fields were found in the previously published work corresponding to 140 opportunities for MSc, 93 to PhD and 23 direct-PhD[8]. The data on postgraduate studies remains uncertain nowadays, due to the lack of programs dedicated to Medical Physics, researches go into correlated areas such as Nuclear or Solid State Physics, even in other areas such as engineering and applied science to obtain their MSc and PhD titles.

The only significant novelty in this category of professional qualification since 2012 was the creation of the first Medical Physics professional master's degree at State University of Rio de Janeiro (UERJ). This program aims at training physicists in the Radiotherapy area[9].

Clinical Training programs

In Brazil, these programs are named "Residency Programs" and it has a minimum of 1152 hours of in classroom didactical instruction and at least 4608 hours of practical training determined by law. Nowadays, these programs offered 23 positions per year in the Radiotherapy area (RT), 2 positions in Nuclear Medicine (NM) and 9 positions in Diagnostic Radiology (RD), with 65% concentrated in the southeast region of the country.

There are other similar programs named "Professional Development Programs" with less hours of didactical instruction (~522 hours[8]) and practical training (~3396 hours[8]). These programs provided 3 positions in the Radiotherapy area and 1 in Nuclear Medicine, each position located in three different regions of the country (Northeast, southeast and Midwest).

III. CERTIFICATION IN MEDICAL PHYSICS AREA AND PROFESSIONAL CAREER

There are currently two categories of certifications for Medical Physicists in Brazil: (1) **Radiation Protection Supervisor - RPS** provided by the National Commission of Nuclear Energy (CNEN) and (2) **Specialist Certificate** provide by the Brazilian Association of Medical Physics (ABFM).

The recommendations for obtaining the Radiation Protection Supervisor certificate follow the regulation established in CNEN NN 7.01[10]. In order to be able to apply for the examination to become a SPR, the candidate must demonstrate at least 350 hours of experience in Radiotherapy and 200 hours in the area of Nuclear Medicine[10]. There is a total of 739 certified RPSs (295 in Nuclear Medicine and 444 in Radiotherapy) currently in Brazil, as shown in Figures 2 and 3[11]. It was possible to observe that the southeast region is the region with the highest number of supervisors (273 for RT and 165 for NM).

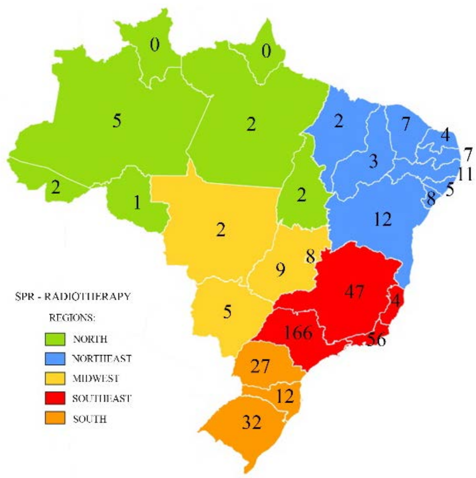

Figure 2: Regional distribution of Radiotherapy RPS [11].

Figure 3: Regional distribution of Nuclear Medicine RPS [11].

Nowadays, it is necessary a minimum experience of 3800 hours in the chosen area (initiated after the undergraduate program be concluded) in order to comply to the ABFM specialist certificate[12]. Currently, according to ABFM[12], there are 306 specialists in RT, 82 in RD and 42 in NM, distributed over the geographical regions of the country (Figure 4). It can be highlighted the predominance of certified physicists in the southeast region.

The Brazilian Association of Medical Physics (ABFM) was founded in 1969 by approximately 9 physicists and since then the number of members has increased considerably. The emergence of other undergraduate courses in medical physics, national congresses and specialist certification, the average membership increased from 8 per year until 1990 to 30 (up to 2001) and 54 (up to 2016). Currently, ABFM officially has 1345 active members. The temporal growth of ABFM members is shown in Figure 5.

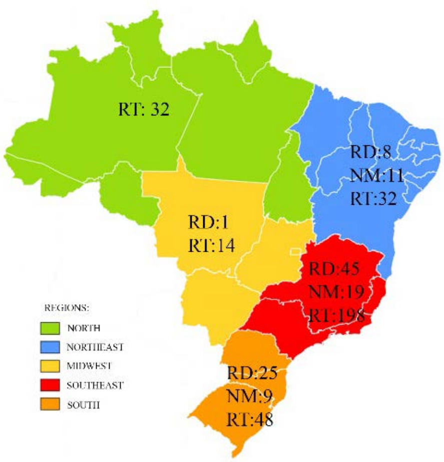

Figure 4: Regional distribution of ABFM Certified Medical Physicists[12].

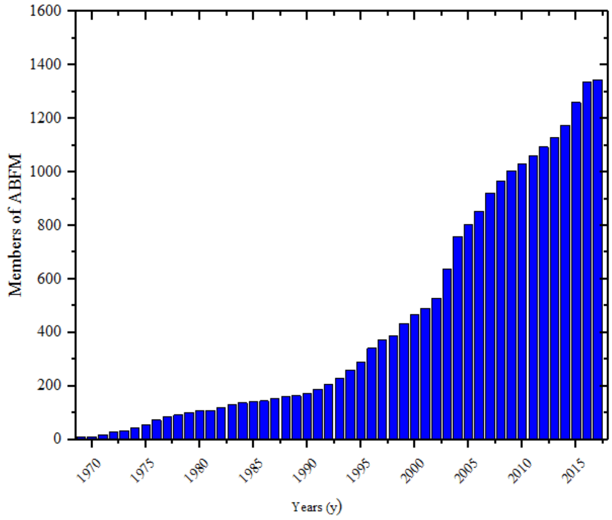

Figure 5: Temporal growth of ABFM members between 1969 to 2017.

Completing undergraduate, residency/training programs and certifications, the professional career can initiate in hospitals, clinics, and companies. Except for Radiotherapy, the recruitment of medical physicists as hospital staff is not a common practice, but over the past few years some vacancies have been opened in public hospitals for certified physicists, It is a common practice Medical Physicists create their own company and provide services to hospitals and clinics in the RT, RD and MN area. Otherwise, there are also vacancies in multinational companies for Medical Physicist positions that can diversify a lot, such as in software development, clinical applications support, product sales, product manager and others. Students of Medical Physics and/or Physics who continued their studies in postgraduate courses normally pursuit an opportunity in academic career.

IV.EQUIPMENTS IN BRAZIL

The technological base in Brazil has approximately 175000 Diagnostic Imaging equipment (data from private and public hospitals), being 89% in activity and 11% still without operational requirements (Annex A)[13]. Among the active equipment, 71% are in the private sector reflecting the greater investment of the private sector over the years. The percentage of no operational equipment in the public sector is approximately 5% and may be due to the installation cost of new equipment purchased or donated and maintenance of the broken devices.

The Southeast region concentrate 45% of the total equipment in use. This data highlights the great technological base of the southeast region and justifies the high concentration of Medical Physics specialists in this area.

In addition to the officially registered equipment data, shown in Table 2, there are no official numbers available of treatment equipment in 236 radiotherapy facilities and 432 nuclear medicine facilities authorized by CNEN across the country[14].

It is important to emphasize that most of metropolitan areas it is possible to find updated technologies for diagnostic and treatment (DR, tomosynthesis, dual energy CT, IGRT, IMRT, radiosurgery, SPECT, PET-CT and PET-RM). Investigative technology, such as non-invasive biopsies with a 7T magnetic resonance imaging and a micro-PET imaging for the non-invasive, quantitative and repetitive imaging of biological function in living animals have also been used[15].

V. NATIONAL STANDARDS

The quality of installations and equipment in Brazilian health system and the safety of patient and workers are assured by the compliance of mandatory national standards. These standards were published by the National Commission of Atomic Energy (CNEN), the Ministry of Health (MS), the Department of Health Surveillance (SVS), the Ministry of Labour (ML), and the National Health Surveillance Agency (ANVISA).

The CNEN is responsible for establishing standards and regulations in radioprotection and regulating, licensing and supervising the production and use of nuclear energy in Brazil. The current regulations in the country cover the topic about Radiation Protection, Licensing of Radiating Facilities, Transport of Radioactive Materials, Requirements for Registration of Individuals for the Preparation, Use and Handling of Radioactive Sources and Management of Radioactive Rejection[16].

The MS/ANVISA created a National Guidelines for Radiation Protection in Medical and Dental Diagnostic Radiology (453/1998 regulation)[17] and a National Quality Program in Mammography (PNQM)[18].

The ML has a standard covering Safety and Health at work in health services. Ensuring those who work with Ionizing Radiation must have the proper training and monitoring.

In spite of several published national standards, there is a lack of more complete guides for quality control tests and respective reference levels. Therefore, it is a common practice Brazilian Medical Physicists base their quantitative evaluation of quality and dosimetric data on consult IAEA, ICRP, NCRP and AAPM publications.

VI. PERSPECTIVES OF THE DEVELOPMENT OF THE MEDICAL PHYSICIST PROFESSION AND NEEDS FOR THE NEXT 20 YEARS

The authors invited experienced Medical Physicists, all ABFM ex-presidents, to manifest their opinions regarding their point-of view regarding the perspectives of the development of the Medical Physics profession and the need in this field for the next 20 years. Ten professionals have replied to this request. The next paragraphs reflect a summary of these important opinions.

The recent classification of Medical Physics as a health profession by the MS was highlighted as a milestone according to the contributors. This classification allowed introduction of new residences programs in Medical Physics around the country. Many of these programs are nowadays supported and recognized by the Ministry of Health and Ministry of Education. Consequently, education and training has been improved and the number of certified medical physicists increased.

The Medical Physicists certification conducted by CNEN and ABFM are well-established processes, and they represent a fundamental stage for the professional development in Medical Physics. Additionally, the compulsory incorporation of certified radiotherapy and nuclear medicine professionals also reinforce the radiation protection culture. Although, ABFM certification be not mandatory, it have demonstrated be a differential qualification in the professional careers.

The contributors also highlighted that the country has an important technological base. It ensure the access to state-of-art technologies available in the major health facilities in the world. Therefore, the country is a reference in Latin America, in special in radiotherapy. In addition, recent investments in new linear accelerators equipment represents a positive perspective to the consolidation of Medical Physics profession. IAEA cooperative projects and training programs offered by manufacturers on new technologies also encourage the fortification of the profession.

The introduction of undergraduate and graduate Medical Physics courses and the consolidation of the residence programs allowed a satisfactory number of professionals in different working areas. Some of the contributors understand that the number of trained professionals currently meets the market requirement, and the number of new jobs may be lower than the number of the graduated/certified professionals in the next few years. It is difficult to consider all economical, educational and strategic aspects in order to balance adequately these numbers.

VI.CONCLUSIONS

The educational programs and equipment are concentrated in the Southeast region of the country, leading to a greater concentration certified Medical Physicists in this region. This demonstrates a need for investment in educational structure and health systems in order to decentralize these programs in the future, providing better access to medical physics education and professional distribution across the country.

The need of trained and experienced professional led to the consolidation of Residence Programs, as a consequence of the incorporation of the medical Physics as a health profession. Additionally, the certification processes annually offered by recognized institutions reinforces the need of highly qualified personal.

Dedicated Medical Physics graduate programs are not usual in the country few, which hinders entry and discourages students from initiating specific research in this area. This may be slowing major national developments in Medical Physics due to the lack of staff and laboratories dedicated to medical physics research.

The technology base of the country is diverse and contains state-of-art technologies. However, it also has a high concentration in the Southeast region. Quality control and preventive maintenance are deficit in some regions, especially out of the metropolitan centers. The causes widely vary, but the lack of qualified professionals, public policies and investments in these areas aggravate this scenario.

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ANNEX A
Technology Park of Brazil in the area of Imaging Diagnostic

Equipment	Region of Brasil																			
	North				Northeast				Midwest				South				Southeast			
	Private		SUS		Private		SUS		Private		SUS		Private		SUS		Private		SUS	
	Total	In Use	Total	In Use	Total	In Use	Total	In Use	Total	In Use	Total	In Use	Total	In Use	Total	In Use	Total	In Use	Total	In Use
Computed Mammography	50	49	35	34	175	172	140	138	81	81	42	42	105	103	74	72	269	266	138	136
Mammography (Stereotaxia)	50	46	28	24	205	197	97	91	85	81	25	24	146	143	71	70	391	368	150	138
Mammography	181	164	102	90	858	816	497	468	316	308	131	127	603	586	338	328	1955	1882	782	749
Film Processor	139	134	114	109	681	668	551	541	192	189	159	156	445	442	393	390	1049	1021	821	800
Computed Tomography	220	206	105	99	755	723	438	416	413	399	170	163	742	719	438	424	2000	1953	830	808
Hemodynamic	42	39	23	20	146	138	87	80	77	76	31	30	154	148	85	82	436	428	201	195
Bone Densitometry scanner	82	80	34	33	406	393	192	185	182	174	51	49	344	340	139	136	1050	1036	297	296
Fluoroscopy	42	38	26	23	180	171	114	108	95	84	54	44	293	283	202	195	998	852	467	439
Dental X-Rays	1860	1765	529	486	7720	7380	1985	1842	3472	3318	616	564	10764	8485	1215	1136	25740	24682	4156	3823
X-Rays	1244	1165	811	747	4547	4332	3057	2894	2120	2007	1286	1209	3578	3443	2308	2229	11713	5710	6057	5724
Ultrasound scanner	1253	1196	699	668	5340	5146	3131	3020	1799	1731	843	807	3647	3504	1872	1792	9453	4487	3735	3534
Color Doppler Ultrasound	626	602	246	236	2638	2575	1044	1005	1197	1165	365	352	2309	2237	909	867	6895	6640	2123	2065
Magnetic Resonance Imaging	107	99	57	52	340	328	191	182	178	170	57	54	400	391	222	214	1086	1066	373	366
Gamma camera scanner	53	50	28	27	163	161	93	91	99	96	38	35	150	146	81	79	468	448	210	204
PET/CT	0	0	0	0	7	7	6	6	3	2	2	1	12	12	11	11	20	20	13	13
TOTAL	**5949**	**5633**	**2837**	**2648**	**24161**	**23207**	**11623**	**11067**	**10309**	**9881**	**3870**	**3657**	**23692**	**20982**	**8358**	**8025**	**63523**	**50859**	**20353**	**19290**