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Radiological Protection and Nuclear Medicine subjects of the Brazilian federal undergraduate disciplines in Technology in Radiology

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Abstract: In Brazil, the undergraduate programs in Technology in Radiology (Curso Superior de Tecnologia em Radiologia – CSTR in Portuguese) have been gaining space as an academic education, requiring improvement of the curriculum of educational institutions. In the year 2000, the country had five active CSTR and in 2023 this number increased to two hundred and thirteen. In a similar scenario, the Brazilian Nuclear Medicine (NM) has been expanding strongly, demanding qualified training of professionals to manage work processes and comply with the principles of Radiological Protection (RP). This work analyzed the lecture plans of the CSTR of Brazilian federal educational institutions dealing with the themes "Radiological Protection" and "Nuclear Medicine". The aim was to verify the homogeneity (or not) of the curricular matrices and the alignment to the growing demand of the job market. Seven federal undergraduate programs currently active were analyzed. Respective curricular matrices were obtained from the official institution's websites. The study allowed the identification of eight disciplines dealing with RP and eleven dealing with NM. A comparative analysis of workloads, contents and curricular period in which they are offered was performed. Results revealed that all the analyzed CSTR offer disciplines in the themes RP and NM, which evidences the qualification of the professional Technologist in Radiology to work in NM Services.

Keywords: Radiology Technology; Radiological Protection; Nuclear Medicine.

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Disciplinas de Proteção Radiológica e Medicina Nuclear dos cursos federais brasileiros de graduação em Tecnologia em Radiologia

Resumo: No Brasil, os cursos de graduação em Tecnologia em Radiologia (CSTR) vem ganhando espaço como formação acadêmica, exigindo aprimoramento do currículo das instituições de ensino. No ano de 2000, o país contava com cinco CSTR ativos e em 2023 esse número aumentou para duzentos e treze. Em cenário semelhante, a Medicina Nuclear (MN) brasileira vem se expandindo fortemente, exigindo formação qualificada de profissionais para gerenciar processos de trabalho e cumprir as normas e princípios de Proteção Radiológica (PR). Este trabalho analisou os planos de disciplinas do CSTR de instituições de ensino federais brasileiras que tratam dos temas "Proteção Radiológica" e "Medicina Nuclear". O objetivo foi verificar a homogeneidade (ou não) das matrizes curriculares e o alinhamento à crescente demanda do mercado de trabalho. Foram analisados sete cursos federais de graduação atualmente em atividade. As respectivas matrizes curriculares foram obtidas nos sites oficiais da instituição. O estudo permitiu a identificação de oito disciplinas que tratam de PR e onze que tratam de MN. Foi realizada uma análise comparativa de cargas horárias, conteúdos e período curricular em que são oferecidos. Os resultados revelaram que todos os CSTR analisados oferecem disciplinas nas temáticas PR e MN, o que evidencia a qualificação do profissional Tecnólogo em Radiologia para atuar nos Serviços de MN.

Palavras-chave: Tecnologia em Radiologia; Proteção Radiológica; Medicina Nuclear.

SBPR

1. INTRODUCTION

In Brazil, the first undergraduate program of Technology in Radiology (*Curso Superior de Tecnologia em Radiologia* - CSTR) was created in 1990 [1]. Since then, CSTR has been growing as an academic training, demanding improvements in the teaching schedule of institutions across the country. In 2000, the country had 5 active CSTR and in 2023 this number increased to 213 [1], equivalent to an increase of more than 4.000 %.

In a similar scenario, Nuclear Medicine (NM) Services in Brazil has been expanding strongly with more than 3 million procedures performed per year [2], demanding qualified training of staffs to manage work processes and comply with the principles of Radiological Protection (RP).

The National Nuclear Energy Commission (*Comissão Nacional de Energia Nuclear - CNEN*) is a federal agency linked to the Ministry of Science, Technology and Innovation (*Ministério de Ciência, Tecnologia e Inovação (MCTI) in Portuguese*), created in 1956. CNEN is the highest planning, guidance and inspection body in the country, establishing norms and regulations in radiological protection, being responsible for regulating, licensing and inspecting the production and use of nuclear energy [3]. CNEN has published 09 groups of regulatory standards, with group 03 dedicated to Radiological Protection. The Standard CNEN 3.01 establishes the basic requirements of radiological protection for people in relation to exposure to ionizing radiation, among other requirements. Contacts and practices involving ionizing radiation necessitate the establishment of radiation protection standards. Therefore, teaching on the topic of radiological protection must be essential, mandatory and in-depth for the training of radiology professionals and other professionals who carry out activities involving radioactive sources.

CNEN certifies the qualifications of the Radiological Protection Supervisor (*Supervisor de Proteção Radiológica - SPR*) in 23 different areas of activity, including the area of Nuclear Medicine. To be qualified to perform this role, the candidate must have a higher education diploma (bachelor's degree, postgraduate degree or technologist) and be approved the CNEN certification exam [3]. Curricular project for CSTR presents content relevant to the SPR routine and, therefore, to the CNEN qualification exams [4].

In this context, this work analyzes the lecture plans of the disciplines of the CSTR offered by Brazilian federal education institutions dealing with the subjects "Radiological Protection" and "Nuclear Medicine". The aim of this study was to learn preliminary about the training in Radiological Protection and Nuclear Medicine offered by undergraduate programs in Technology in Radiology in Brazil. For this first step, a quality analysis of the homogeneity (or not) of the curricular matrices of the CSTRs was carried out, since the disciplines offered reflect on the future qualification of the professional. It is important to emphasize that the focus of this work was the professional who wants to become and act as a SPR in Nuclear Medicine.

2. THEORETICAL REFERENCE

2.1. Historical Context

After the discovery of X rays by the German physicist Wilhelm Conrad Roentgen in 1895, the French physicist Antoine Henri Becquerel reported in 1896 the discovery of a new form of radiant energy to the French Academy of Sciences [5]. This work was recognized by Marie Curie as the main influence on the direction of her thesis, which led to the isolation of radium and introduction of the term "radioactivity" [6]. After the discovery of the radium element and radioactivity, Marie Curie, with the help of the French government, created the Radium Institute, paving the way for current Nuclear Medicine. Radium was used for years to treat various dermatological diseases and cancers, which gave rise to Radiotherapy treatments [7].

In 1923, the Hungarian physical chemist George Charles de Hevesy began his investigations using isotopes in plant and animal tissues, which provided dynamic relationships between organs [8]. Hevesy, considered the “Father” of Nuclear Medicine, described the application of 38 different radionuclides in mammal animals and 14 in humans. Thus, since then, in the last hundred years, the expansion of Nuclear Medicine enabled the development of new radiopharmaceuticals for the diagnosis and treatment of diseases [8]. Today, according the ANVISA (*Agência Nacional de Vigilância Sanitária*), Nuclear Medicine is the medical specialty that uses radiopharmaceuticals, in the form of unsealed sources, for administration to patients for diagnostic and therapeutic purposes [9].

2.2. History of Radiology in Brazil

The use of ionizing radiation generating equipment in Brazil began in 1897 when physician José Carlos Ferreira Pires installed the first X ray device in the city of Formiga, in Minas Gerais [10]. Thus, the use of radiological techniques started in the country, requiring trained professionals to deal with this new technology. The first course for training Radiology Technicians in Brazil was created on June 15, 1916, practically two decades after the arrival of the first X ray equipment [10]. Almost 60 years after the creation of Radiology Technician courses, Brazilian law 7.394 of 1985 regulated the profession of Radiology Technicians. Until the 1970s, the development and incorporation of the field of Radiology and its applications in the health sector in Brazil have occurred slowly, gradually accelerating after this period [10].

2.3. Nuclear Medicine and Multidisciplinary Team

In the health area, particularly in Nuclear Medicine, it is required that professionals are qualified with technological, biological and radiological knowledge [11]. In this context, the CSTRs emerged in Brazil as a response from the educational sector to the specific demands of the health sector inserting a professional into the services who will carry out practices with radiological safety. For this, in addition to the holder of the installation, the technician in charge and the nuclear physician, it is essential to have a SPR and enough duly qualified professionals is necessary to carry out their duties [11].

The SPR is the member of the radiology team who must assume responsibility for actions relating to radiation protection. The SPR conducts specific safety programs for the team and the public and performs work involving radioactive sources and is responsible for drawing up the Radiological Protection Plan for the facility [12].

Currently, there are 462 Nuclear Medicine services licensed by CNEN [13] in Brazil and 333 professionals certified as SPR in Nuclear Medicine to work in these services [3]. These numbers draw attention to the fact that there are fewer professionals certified to act as Supervisors of Radiation Protection in Nuclear Medicine than the number of Nuclear Medicine facilities licensed by CNEN.

2.4. Regulation of Undergraduate Technological Education in Brazil

Undergraduate education in the Technological modality emerged in Brazil in the 60s, and nowadays, the profession of Radiology Technologist is still not regulated. However, Project Law 3661/2012, currently on discussion in the Legislative Chamber, proposes changes to Law 7394 of 1985 aimed at regulating the exercise of the professions of Radiology Technician, Radiology Technologist and Bachelor of Radiological Sciences [14]. For meanwhile, the performance of the undergraduate professional called Radiology Technologist is supported by the Resolution Nº 02/2012 of the National Council of Radiology Technicians (*Conselho Nacional de Técnicos em Radiologia* - CONTER). The Ministry of Education (MEC), with the aim of improving Undergraduate Technological Courses, periodically updates the National Catalog of Undergraduate Technological Courses (*Catálogo Nacional de Cursos Superiores de Tecnologia* -CNST) [15]. This catalog is essential to ensure that the offer of these courses and the training of technologists follow the demand of the productive sector and society. The undergraduate programs in Technology in Radiology (CSTR) is presented in this catalog in the Environment and Health area, and there is a description of the professional profile, field of activity, etc.

3. MATERIALS AND METHODS

The federal CSTRs were the object of study in this work. The choice of this kind of course was because federal courses obtained the maximum grade in ENADE[1] 2019 (4 and 5) unlike private courses, the majority of which obtained a grade less than or equal to 4.

CSTR survey of Brazilian federal institutions was carried out in 02 distinct stages. The first stage consisted of a search on the e-MEC website [16] aiming to know the list of active CSTRs in the country, offered by federal institutions. The search used the following filters available on the website:

Search for: Undergraduate Course;
Course: Radiology;
Public Course: Yes;
Modality: Technological;
Status: Active.

In the second stage of this work, consultations were carried out on the websites of the institutions selected in the previous stage. The purpose of these consultations was to obtain the pedagogical projects, curriculum and description for the course subjects. After collected material, descriptive and comparative analyzes were carried out of the contents offered by each discipline, about training in Radiological Protection and Nuclear Medicine subjects.

[1] ENADE - (Exame Nacional de Desempenho dos Estudantes in Portuguese) is the Higher Education Quality Indicator that evaluates courses through student performance.

4. RESULTS AND DISCUSSIONS

The e-MEC website search reported all the active CSTRs offered by federal educational institutions in Brazil. In 2024, there are 9 public CSTRs, of which 2 were excluded because they were not offered by federal educational institutions. Currently, there are 7 federal CSTRs, as shown in Table 1.

Figure 1 presents the geographic distribution of federal public CSTRs in Brazil. This Figure reveals that the courses are concentrated in the Northeast, Southeast and South regions of Brazil, with no federal CSTR in the North and Midwest regions.

Table 1 : List of active Federal CSTRs in Brazil.

	Undergraduate Education Institution	Acronym	Act of Creation	Start of Operation	Uptime (Years)
I	*Universidade Tecnológica Federal do Paraná*	UTFPR	23/08/1999	20/09/1999	24
II	*Instituto Federal de Educação, Ciência e Tecnologia de Santa Catarina*	IFSC	12/12/2002	02/04/2003	20
III	*Instituto Federal de Educação, Ciência e Tecnologia de Pernambuco*	IFPE	01/10/2002	07/10/2004	19
IV	*Instituto Federal de Educação, Ciência e Tecnologia do Piauí*	IFPI	31/03/2000	02/03/2005	18
V	*Universidade Federal de São Paulo*	UNIFESP	09/05/2007	03/03/2008	15
VI	*Instituto Federal de Educação, Ciência e Tecnologia da Bahia*	IFBA	18/10/2007	02/03/2009	14
VII	*Universidade Federal de Minas Gerais*	UFMG	25/10/2007	01/03/2010	13

Source: https://emec.mec.gov.br, (2024).

Figure 1: Geographic distribution of federal CSTRs in Brazil

Source : the authors, from Table 1

4.1. ENADE 2019 results

Table 2 presents the ENADE grades for the federal CSTRs.

Table 2: Active Federal CSTRs results in ENADE

Institution	Acronym	ENADE 2019 Result
I	UTFPR	5
II	IFSC	4
III	IFPE	4
IV	IFPI	4
V	UNIFESP	5
VI	IFBA	5
VII	UFMG	5

Source: https://inep.gov.br, (2024)

4.2. CSTR Training in Radiological Protection

Considering the Radiological Protection content, curricular analysis revealed that 6 of the 7 courses offer a single discipline dealing with the subject meanwhile a single course offers two disciplines, as detailed in Table 3.

Analysis revealed a significant variation in the workload devoted to the topic, which ranged from 48 hours to 144 hours. It was also revealed that six institutions offer the discipline in the 1st half of the course (2nd to 4th periods) and one institution offers the discipline in the 2nd half of the course (5th period). It is important to consider that theoretical knowledge in Radiological Protection is fundamental for practical action (mandatory internship) involving exposure to ionizing radiation.

Table 3: Active Federal CSTRs results in ENADE

Institution	Period	Workload	Discipline Name [Portuguese / English]
I	3°	48h	Proteção Radiológica / Radiological Protection
II	3°	80h	Proteção Radiológica / Radiological Protection
III	3°	72h	Introdução à Higiene Proteção das Radiações / Introduction to Hygiene Radiation Protection
	5°	72h	Higiene Proteção das Radiações / Hygiene Radiation Protection
IV	4°	60h	Proteção Radiológica / Radiological Protection
V	3°	52h	Proteção Radiológica / Radiological Protection
VI	2°	90h	Proteção Radiológica / Radiological Protection
VII	2°	60h	Radiobiologia e Proteção Radiológica / Radiobiology and Radiological Protection

Source: Data from the websites of institutions I, II, III, IV, V, VI, VII - elaborated by authors

Considering the contents of the disciplines related to Radiological Protection, the analysis revealed a relevant non-homogeneity, showed in Table 4.

Table 4: Disciplines content related to Radiological Protection

Content (Portuguese/English)	**Institution**						
	I	II	III	IV	V	VI	VII
Interação da radiação com a matéria /Interaction of radiation with matter	•		•				•
Princípios de proteção radiológica /Principles of radiological protection	•	•	•	•	•	•	•
Cálculos de blindagem /Shielding calculations	•	•	•		•	•	•
Limitação de dose / Dose limitation	•	•	•	•	•	•	•
Normas nacionais e internacionais /National and international standards	•	•	•		•	•	
Efeitos biológicos / Biological effects	•		•	•	•		•
Unidades, medidas e terminologias /Units, measurements and terminologies	•		•	•	•	•	•
Dosimetria / Dosimetry		•	•				•
Instrumentação para medidas de radiação / Instrumentation for radiation measurements					•	•	•
Elaboração de plano e/ou memorial descritivo / Elaboration of plan and/or descriptive memorial		•			•	•	•
Manuseio de materiais e rejeitos radioativos / Handling of radioactive materials and waste	•					•	•

Source: Data from the websites of institutions I, II, III, IV, V, VI, VII - elaborated by authors

Basic Principles of Radiological Protection and Dose Limitation contents are found in all the schedule analyzed while Interaction of Radiation with Matter, Dosimetry, Instrumentation for Radiation Measurements and Handling of Materials and Radioactive Waste contents were found in only 3 of the CSTR.

4.3. CSTR Training in Nuclear Medicine

Curricular analysis revealed for the Nuclear Medicine content that 6 of the 7 courses offer a single discipline dealing with the subject, meanwhile a single course offers four disciplines, as listed in Table 5.

Table 5: Disciplines related to training in Nuclear Medicine

Institution	Period	Workload	Discipline Name [Portuguese / English]
I	6°	64h	Medicina Nuclear / Nuclear Medicine
II	6°	80h	Medicina Nuclear / Nuclear Medicine
III	5°	144h	Técnicas de Medicina Nuclear / Nuclear Medicine Techniques
IV	5°	60h	Medicina Nuclear / Nuclear Medicine
V	3°	42h	Medicina Nuclear / Nuclear Medicine
VI	4°	90h	Medicina Nuclear / Nuclear Medicine
VII	4°	30h	Meios de Contraste e Radiofármacos / Contrast Agents and Radiopharmaceuticals
	5°	30h	Anatomia Funcional em Medicina Nuclear / Functional Anatomy in Nuclear Medicine
	6°	30h	Tecnologia em Medicina Nuclear I / Technology in Nuclear Medicine I
		30h	Tecnologia em PET/CT / Technology in PET/CT
	7°	90h	Tecnologia em Medicina Nuclear II / Technology in Nuclear Medicine II

Source: Data from the websites of institutions I, II, III, IV, V, VI, VII - elaborated by the authors

Table 5 revealed a significant variation in the number of hours devoted to the topic, which ranged from 42 hours to 205 hours. It was also revealed that all institutions offer disciplines that address the topic in the second half of the course. This fact is possibly justified by the complexity inherent to the Nuclear Medicine and the need for prior fundamental knowledge. It was revealed that six institutions offer one discipline dealing with Nuclear Medicine while one institution offers five disciplines about the topic.

Content analysis of disciplines related to Nuclear Medicine revealed a non-homogeneity between the CSTRs, as showed in Table 6.

Table 6: Disciplines content related to Nuclear Medicine

Content (Portuguese/English)	Institution						
	I	II	III	IV	V	VI	VII
História da Medicina Nuclear / History of Nuclear Medicine	•	•	•	•		•	
Equipamentos / Equipments		•	•	•	•	•	•
Radiofarmácia / Radiopharmacy	•	•	•	•	•	•	•
Controle de Qualidade / Quality Control	•		•		•	•	•
Normas e Legislação / Standards and Legislation			•		•	•	
Protocolos clínicos / Clinical Protocols		•	•	•		•	•
Dosimetria / Dosimetry	•	•	•	•	•	•	
Instrumentação / Instrumentation	•	•	•		•	•	•
Formação e Reconstrução das Imagens / Formation and Reconstruction of Images	•	•	•	•	•	•	•
Manuseio e Gerenciamento de fontes radioativas / Handling and Management of Radioactive Sources	•	•	•		•	•	
Artefatos / Artifacts							•

Source: Data from the websites of institutions I, II, III, IV, V, VI, VII - elaborated by the authors

Radiopharmacy and Formation and Reconstruction of Images contents are found in all analyzed courses, while the Quality Control content was found in 5 of the 7 analyzed CSTRs. Artifacts content was found in just one CSTR.

It is important to point out that the contents mentioned in Tables 3 and 5 do not exhaust the knowledge in the referred disciplines, therefore, contents not listed may (or may not) be worked on by other disciplines, mandatory and/or elective. Considering that this work presents an initial analysis of the CSTRs, its continuity is suggested in order to subsidize and/or contribute to a potential National Curricular Guideline for Technology in Radiology undergraduate programs.

5. CONCLUSIONS

This work revealed that all federal courses in Technology in Radiology in Brazil include the Radiological Protection and Nuclear Medicine contents, which demonstrates the qualification of the professional Radiology Technologist to work in Nuclear Medicine Services. The analysis of the training offered by the courses revealed a significant attention to these subjects.

An additional statistical analysis is necessary to verify the correspondence between the curricular matrices of the CSTRs and the schedule of the MN SPR exams of the CNEN. This analysis is the object of study in another work, in progress, by this group of authors and will allow categorizing the training offered by the CSTRs as sufficient or not for the Qualification Certification of Radiation Protection Supervisor in Nuclear Medicine.

This preliminary work made it possible to know the training of the professional Technologist in Radiology offered by the Brazilian federal CSTRs in the areas of Radiological Protection and Nuclear Medicine, revealing important similarities and differences qualitative between the analyzed courses.

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