An Overview of the Postgraduate Courses in Clinical Engineering Offered in Brazil

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Abstract. "Clinical Engineering" (EC) is an engineering specialty in which the primary role is to take care of the life cycle of medical equipment. Professional assignments cover activities ranging from planning the incorporation of new devices to managing the maintenance and disposal of systems in an appropriate destination. Engineers working in that field are commonly named Clinical Engineers. The first professionals with dedicated training in the field started in Brazil around four decades ago. However, despite the decades, Brazil's educational system still lacks standardization. Our goal in this paper was to investigate how these professionals act in the field and, more importantly, how they were trained. To accomplish that, we selected all 'Higher Education Institutions' (IES) in Brazil that currently offers recognized Clinical Engineering specialization. The number of thirteen IES met the established criteria. The institution's information was collected through an exploratory search on the official e-MEC portal and from their respective own electronic addresses. The data were statistically structured and further analyzed. The results could overview each EC specialization program's structure, highlighting abilities and skills developed. Our analysis supports government officials' standardization process and future candidate's decisions.

Keywords: Clinical Engineering · Clinical Engineer · Postgraduate Courses

1 Introduction

Even within "Health Care Facilities" (EAS), the work of EC is still little known. Clinical Engineering seeks to combine engineering and management knowledge by applying them to health technologies [1].

One of the best-known definitions of EC in Brazil is the definition made by the "Brazilian Association of Clinical Engineering" (ABEClin) which defines the Clinical Engineer as the professional who applies engineering techniques in the management of health equipment in order to ensure the traceability, usability, quality, efficacy, effectiveness, safety and performance of this equipment in order to promote patient safety [2].

According to the American College of Clinical Engineering (ACCE), Clinical Engineer is a supportive professional who promotes patient care by applying engineering and

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management skills to health technology. This engineering professional focuses on planning, evaluation, management, analysis, education, support, and regulatory compliance of healthcare technology [3].

The history of EC in Brazil begins in the early seventies. When in 1973, the 'Ministry of Health' pointed out the need for evaluation and quality of diagnostic products. This evaluation was made before authorizing its commercialization, according to Law nº 5,991 of 12/17/1973 [4–6].

In the 1980s, most of the medical equipment purchased in Brazil suffered malfunctions due to a lack of maintenance and/or spare parts. This scenario resulted from numerous variables, such as a lack of well-trained professionals, technical manuals, and other relevant documentation for maintenance and technology [1, 7].

In the following years, the activities of EC were restricted to carrying out corrective actions, delaying the consolidation of a broader and qualified process of hospital medical technology management (GTMH) [6, 8], and with the performance of corrective maintenance almost exclusively by manufacturers, it was clear the size of the waste of resources with the massive percentage of equipment failure, directly impacting the quality of health care services. This obstacle in maintaining hospital medical technology clearly showed the need to create EC departments throughout the country formally. Concomitantly, the federal government promoted the creation of training schools in EC [5].

In the early 1990s, precisely in the years 1993 and 1995 were created the first Lato sensu postgraduate courses in EC in Brazil. These courses were implemented at the universities UNICAMP (Campinas-SP), USP (São Paulo-SP), UFPB (João Pessoa-PB) and UFRS (Porto Alegre-RS). These courses were intended for Electrical Engineers who wanted to work in the area, within the hospital environment, to mitigate the losses accumulated by the lack of management of the technology park [5, 9].

Although the professionals have been working for at least forty years in Brazil, the profession of Clinical Engineer is not yet regulated, so there is no definition of which professional can perform this activity and its attributions [9, 10].

With the profession not regulated, professionals who work as clinical engineers face difficulties, such as proving their performance in the area and being absorbed by the labor market. The profession of Clinical Engineer does not compose the list of professions of the 'Brazilian Classification of Occupations' (CBO), a fact that makes it impossible for the professional to have his work card signed as a Clinical Engineer. However, even with the non-regulation of the profession, the area of EC has continued to expand. Over the years, more graduate courses have emerged in EC. It is possible to notice that the curricular matrix of these courses varies significantly according to the perception and experience of the coordinator who elaborates the course.

In the present study, exploratory research was carried out in the e-MEC portal of all the IES accredited by the MEC and currently offer the postgraduate course in EC in the national territory and information available in their respective electronic addresses [11–24].

Only thirteen IES met these two criteria and were selected for this study. These selected IES had their information collected through the e-MEC portal and in their electronic addresses. Data were collected on the total course load, course duration,

internship requirement and course completion work, and two IES quality measurement indices. The first was the 'General Index of Courses' (IGC) for the year 2019 (the last calculated index). Moreover finally, the level of teacher qualification was considered as an indirect measurement of the quality of the IES [25].

2 Method

The inclusion criteria assumed for this study were: (1) Official recognition of the program by MEC and (2) to be an active program in the current year of 2022.

Table 1. IES that offer the postgraduate course in EC, acronym of IES and year of start of offer

IES	Acronym	Beginning
Faculdade Unyleya	–	2019
Faculdade I. de C. S. Albert Einsten	FICSAE	2006
Faculdade Unimed	–	2020
Faculdade Estácio de Sá	UNESA	2017
Instituto Navigare	–	2021
Instituto Nacional de Telecomunicações	INATEL	2019
Instituto E-Class	–	2020
RTG Especialização	–	2020
Universidade de Fortaleza	UNIFOR	2010
Faculdade de Agudos	FAAG	2019
Faculdade Jardins	FACJARDINS	2020
Centro Universitário Internacional	UNINTER	2022
Senai Cimatec	SENAICIMATEC	2022

The data collection was conducted based on data available in the e-MEC portal and the official web pages of the respective programs, to verify the current offer and whether the information that was in the e-mail address of the IES corroborated the information contained in the platform of the MEC.

The e-MEC portal information collected were: IES region, teaching modality, year of the start of course offer, total workload, hours/classes per course, requirement of internship and 'Graduation thesis' (TCC), IGC and qualification of course coordinators [11–24]. Table 1 lists the IES selected for this study.

3 Results

Out of the thirteen IES selected in this study, 60% (8 in 13 program) are located in the Southeast region of the country (Minas Gerais, São Paulo and Rio de Janeiro), as it can be seen in Fig. 1, and others are spread across different states (Maranhão, Bahia, Sergipe, Ceará, Goiás and Paraná).

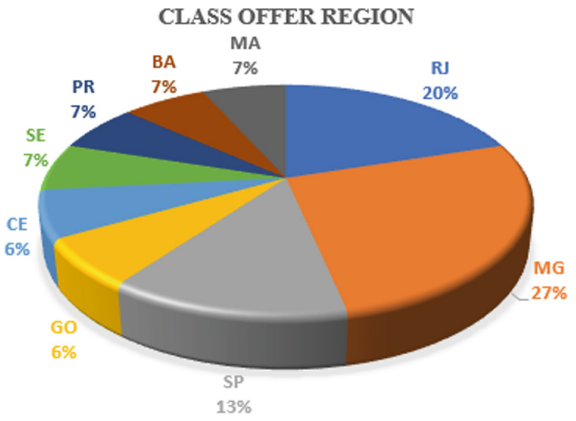

Fig. 1. Region of offer of postgraduate course in EC in The Brazilian territory

In Fig. 2, the distribution of programs workload is presented. The proportion of 38% of the IES analyzed offer the 360 h/class workload.

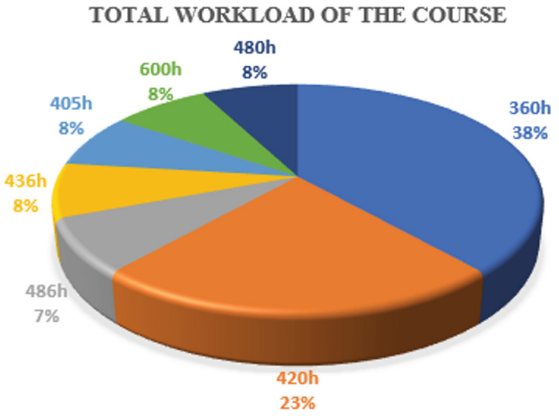

Fig. 2. Total workload of the postgraduate course in EC in hours/class

The arithmetic average total workload of the courses offered is 420.5 h/class, and the highest total workload of the postgraduate course in EC, is 600 h/class, offered by FACJARDINS. The same IES offers this course in the shortest time, in just 6 months [22].

Regarding the duration of the course, FACJARDINS offers its course in less time, of only 6 months. INATEL, UNIFOR and SENAI CIMATEC offer their courses in 24 months. The arithmetic mean duration of the course was 15.5 months. Figure 3 presents this distribution:

On the requirement of the mandatory internship, FICSAE determines 46 h of internship for fulfillment and UNIFOR determines 20 h of internship.

Fig. 3. Duration of the postgraduate course in EC in months.

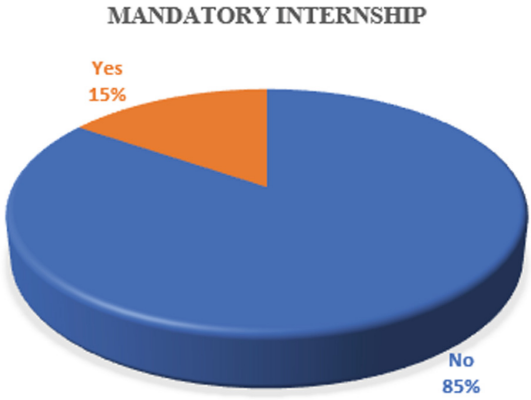

Fig. 4. Requirement of mandatory internship in the postgraduate course in EC.

These internship hours enter the total workload of the postgraduate course in EC. As shown in Fig. 4, the two IES mentioned above represent 15% of the total IES under study, and the rest of the IES (85%) does not have an internship requirement.

The CNE/CES 01 resolution of 04/06/2018 also made the TCC optional in all Lato sensu postgraduate courses. Even so, as seen in Fig. 5, the majority (62%) of the IES still require TCC as a mandatory activity for completing the Postgraduate course in EC [26].

The IGC attests the quality of all undergraduate and postgraduate courses of an IES. The calculation of the IGC is carried out by an average between the grades of the last 'Preliminary Course Concepts' (CPC) of the evaluated courses [27].

The calculated IGC is a continuous variable in the interval between 0 and 5, where indicators with levels above 3 are considered satisfactory, indicating quality.

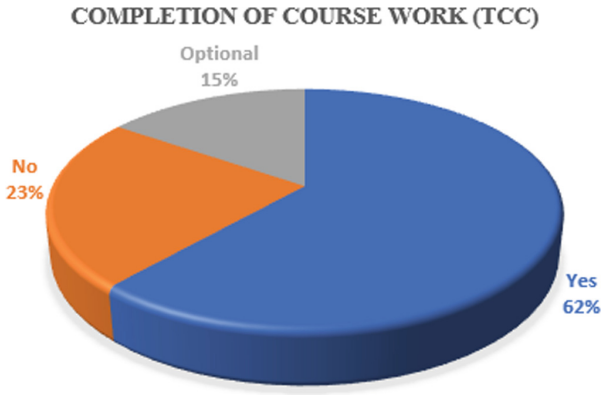

Fig. 5. Requirement of (TCC) in the Postgraduate Course in EC

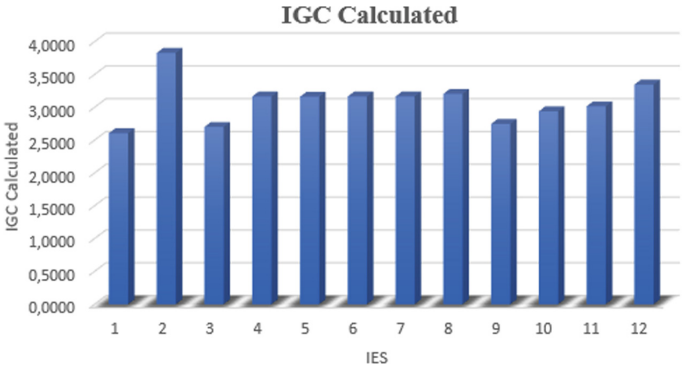

Fig. 6. IGC calculated from twelve IES selected for the study.

In the case of IES with grades between 1 and 2, they will be subject to a visit from INEP evaluators for *on-site* verification of the teaching conditions offered [27, 28].

The IGC of 12 selected IES were collected, except for Unimed College, because the calculated IGC value was not available for consultation in the e-MEC portal [11].

As shown in Fig. 6, the highest value of the calculated IGC was FICSAE, with 3.8290, and the lowest value was 2.6060, referring to Faculdade Unyleya.

The arithmetic mean of the IGC was 3.0872.

The level of teacher's qualification is part of the goals of the 'National Education Plan' (PNE), which aims to increase the number of teaching staff to 75% with masters and Ph.D., being at least 35% with Ph.D. [29].

The 'Census of Higher Education' is conducted annually by INEP. This census is the research instrument to evaluate the institutions offering higher education courses. The level of qualification of teachers is part of the calculation of quality indicators, such as CPC and IGC. [30].

As shown in Fig. 7, 42% of the teaching coordinators have the specialization, 42% have the master's degree, the remainder (16%) Ph.D. and postdoctoral.

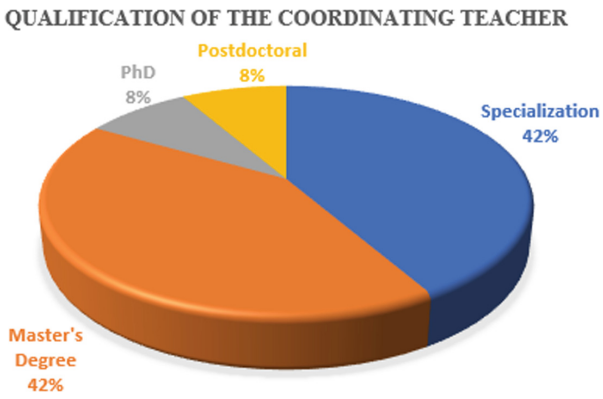

Fig. 7. Level of qualification of the teacher coordinator of postgraduate courses in EC

4 Discussion

The objective of this manuscript was to present an overview of the status of the EC postgraduate courses available in Brazil. Although the EC professionals have been acting in the country for at least four decades, the professional training programs still lack specific national legislation and professional recognition, which express no consensus regarding the professional duties of a clinical engineer and the absence of professional certification. The currently available programs vary along different parameters as the discipline's content, the number of subjects in the course, and the total workload.

Identifying national minimum requirements for Clinical Engineers who practice as health professionals have been a point of discussion globally since the 80's [31, 32].

Guaranteeing competency in their discipline by completing appropriate educational qualifications should be a common element for every global program. Therefore, standardizing the mandatory contents of the Postgraduate course in EC is necessary for Brazil.

The question regarding clinical engineering regulation and minimum curriculum has already been present in Brazilian society for at last 20 years [33]. However, more investments are needed.

As an example of EC professional definition and contradictions, the Vunesp Foundation published the EBSERH/HC-UFU (02/2019) Clinical Engineer Hire Program that required the following knowledge in its objective test: Electronics; operation of direct and indirect patient care equipment; hospital safety; management and acquisition of medical-hospital equipment, parts, and accessories; contract management; legislation and bidding [34]. This content does not superpose to the significant content covered in postgraduate courses in EC [35–37].

One of the challenges observed in this research was the collection of data through the web pages of the respective IES [12–24]. There was no course program on most web pages, or pre-registration was required to access more information about the course. Despite the challenges, our research demonstrated an asymmetrical geographic distribution of the courses offered. The southeast region is responsible for 60% of the current specializations offered. Although the demographic census conducted in 2010 by the

Brazilian Institute of Geography and Statistics (IBGE), considered a total of 80.364,410 inhabitants in the region, representing 42.1% of the Brazilian population.

The resolution CNE/CES 01 (04/06/2018) established that all Lato sensu postgraduate courses must meet a minimum workload of 360 h/class per course [26]. The total workload of the postgraduate course in EC ranged from 360 h/class up to 600 h/class. JACJARDINS offers its course in 600 h/class, with a completion time of only 6 months [22]. The average arithmetic duration of the postgraduate course in EC is 15.5 months. The majority of IES, around 85%, do not charge mandatory internships, but the majority (62%) still ask the TCC as a criterion for obtaining the 'Certificate of Completion of Course'.

The highest IGC value calculated was FICSAE, which is 3.8290 and the lowest value was that of Faculdade Unyleya with 2.6060. The indicator that indirectly attests to the quality of the IES is the degree of teacher qualification.

Miranda [25] carried out a mapping of variables that affect the academic performance of students in the business area. As a result, it was concluded that four variables of academic training significantly influence academic performances: exclusive dedication, Stricto sensu degree, relevant publications, and strategies or teaching and learning methods.

These results show that the education level of the teaching staff, the number of teachers per course, and the volume of courses offered by the IES have a significant impact on the performance of the students and the performance measurement index by the 'National Student Performance Exam' (ENADE) [25].

Thus, the level of training of the teaching staff is an indirect indicator of quality used by INEP, and this is part of the goals of the 'National Education Plan' (PNE) [30].

Figure 7 shows that teachers need to increase their qualifications. In the thirteen IES selected, there are only two coordinators with Ph.D. On the other hand, it is important to emphasize that there is little literature considering the essential knowledge for the Clinical Engineer's performance in Brazil. In this context, EC course instructors should have job experience in the EC. The content of some disciplines of the Postgraduate Course in EC would benefit from collected experiences in the EC job.

5 Conclusions

In this study, we presented data collection results of 13 officially recognized EC specialization courses in Brazil. All program information was publicly available and obtained on the MEC website. Despite the MEC recognition, our findings pointed out a poor standardization of the program's curriculums. The overall content covered by each postgraduate course varies among the requirements and workloads, and activities such as mandatory internships and graduation projects do not follow a common standard. All programs require tuition payment and are asymmetrically distributed among the country territory, with the offered courses centered in the country's Southeast region. In conclusion, our project demonstrates the current need to construct a standard national minimum curriculum.

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Conflict Interest
The authors declare that they have no conflict of interest.

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