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How many physicists do we need? An institutional point of view

De quantos físicos precisamos? Um ponto de vista institucional

Karina W. Boccaletti, Adriana A. Flosi, Ana P. V. Cunha, Cassio Q. Tannous, Jeam H. O. Barbosa, Amanda B. Rech

Departamento de Radioterapia, A.C.Camargo Cancer Center, São Paulo, Brasil

Abstract

In Brazil the hiring of medical physics in radiation therapy (RT) departments follows the guidelines of the regulatory agencies, considering only the number of patients treated. With the rise of new technologies, treatment techniques become more complex, requiring a greater amount of time and staff qualifications. International organizations solved this problem with a method for assessing personnel levels and determining the quantity of professionals required for a specific RT department. In this work, we adapted this strategy to our clinical reality and derived calculations of the time per task multiplied by the expected number of tasks. The task requirements were described in detail and the amounts of time required to perform each task over a one-year period were determined. The sum of task times were related to a suitable full-time equivalence (FTE), considering a team only of medical physicists. We thus determined that our clinic should have approximately 13 FTE personnel, evidencing a need for hiring. The use of a personnel justification grid enables the demonstration of professional staffing insufficiencies in clinics, a condition that hinders the development of RT departments, including the scope of teaching and research.
Keywords: medical physics; radiation therapy; staff calculation; full-time equivalence.

Resumo

A contratação de físicos em radioterapia no Brasil segue as diretrizes das agências reguladoras, que consideram apenas a quantidade de pacientes tratados. Com o advento de novas tecnologias as técnicas de tratamento se tornam mais complexas, demandando maior quantidade de tempo e qualificação de pessoal. Tal problemática foi resolvida por organizações internacionais, mediante método para avaliar os níveis de pessoal da física e determinar a quantidade de profissionais necessários para um serviço específico de radioterapia. Neste trabalho personalizamos um estudo internacional para nossa realidade clínica, derivando o tempo por tarefa multiplicado pelo número previsto destas tarefas. As tarefas foram detalhadas e relatado o tempo necessário para a realização da tarefa no período de um ano. Com o agrupamento do tempo de tarefas foi feita a relação com o número de FTE (Full Time Equivalent) necessário, considerando apenas físicos na equipe. A quantidade encontrada para nossa clínica foi de aproximadamente 13 FTE, evidenciando a necessidade de mais contratações. A utilização da grade de justificação de pessoal é indispensável para evidenciar a lacuna de profissionais nas clínicas para além da rotina tradicional, condição que atrapalha o desenvolvimento da radioterapia brasileira, inclusive no âmbito de ensino e pesquisa.
Palavras-chave: *física médica; radioterapia; cálculo de pessoal, FTE.*

1. Introduction

Given rising demands on the time needed to implement new technologies, developing a personnel justification grid for medical physics clinics is an unpredictable and dynamic task. Furthermore, there is a lack of guidance as how to equate clinical needs with required staffing levels and competencies.

When heads of radiation therapy (RT) services negotiate staffing requests with their institutions' administrations, whether they are at small clinics or large cancer hospitals, they are often guided by the rules of the National Nuclear Energy Commission (Comissão Nacional de Energia Nuclear, CNEN)[1], or regulations of the Brazilian Health Regulatory Agency (Agência Nacional de Vigilância Sanitária, Anvisa)[2], or international protocols, such as those of the American College of Radiology[3]. However, these publications do not offer suggestions for the minimum staff needed to cover all areas within RT departments. In general, they are simplistic documents that are susceptible to misinterpretation. Moreover, the organizations that produced them had not adapted their rules and regulations to increasingly complex emergent activities. The institution's leadership needs to find studies conducted by medical physicists' associations that deal directly with these activities and can provide greater detail about the number of professionals needed. In 2015, a study performed by the American College of Physical Medicine (ACPM) and the American Academy of Physical Medicine and Rehabilitation (AAPM&R), known as the Abt study, presented data from 2003, 2007, and 2014 from research that examined the hourly load for each medical physicist activity in RT[4]. The Abt study provides a report which describes about labor needs, including details about the time needed per activity (in hours). However, none of the aforementioned documents provide information regarding the level of staff qualification.

We question how the same rules established by a specific group[1] can be applied to completely different RT services. We also question how it is possible to expect that the same number of medical physicists needed for machines that treat patients with only conventional techniques would be appropriate for delivering more advanced therapies [e.g. volumetric-modulated arc therapy (VMAT), cone-beam computed tomography (CBCT), and respiratory gating] that demand much more of the physicist's time in all aspects. Instead, physicists are usually asked the simple question, "How long does it take to execute clinical medical physics tasks?", the final result is often insufficient and/or presents lack of experience to complex and heavy tasks.

Mills et al. (2000)[5] published a deep examination of the medical physics situation, linking efforts with billing codes. However, using a pure cost analysis to justify budgets is risky because billing codes and reimbursement amounts can change, and often without justification and/or unfairly.

The European Society for Radiotherapy & Oncology (ESTRO) and European Federation of Organizations for Medical Physics (EFOMP) used a valuable complete method to evaluate medical physicist staffing levels[6] and the International Atomic Energy Agency (IAEA) provided a generic staff calculator spreadsheet to RT departments[7]. Their findings led to the development of organizational directives for the education and training of RT physicists. The aim of the present study was to develop a personnel justification grid that relates clinical needs directly to the quantity and quality of personnel required to run a complex RT service within a Brazilian institution, which could also serve as a useful reference for various other Latin American institutions.

2. Methodology

2.1. Time Needed for Tasks

We used the Abt study approach[4], adapted for our clinical reality, to derive the product of the time per task multiplied by the predicted number of such tasks. The personnel justification included the time needed to execute the tasks and took into consideration time allocated for education and administration.

However, conservatively, we did not include holidays, leave time, or time spent in meetings. These times were already accounted for by the physicist team itself and not passed back to the hospital. All tasks were detailed as specifically as possible and, subsequently, we reported the total time related to the specified tasks over the course of a year. Time per task estimates were extracted from the Abt study values[4] and based on our institution experiences, which owns four linear accelerators, a CT-simulator, a brachytherapy (BT), and a simulator. In some cases, was considered a smaller time or value of a task, for conservative reasons, partially because our experience level.

2.2. Translation of Task Time to Staffing Level

When completing the step of collecting the hours required to execute tasks, the sum of specific tasks evolved to consolidate the grid for administrative review. For example, tasks related to BT, in its totality, were up to 2,080 hours, which represents 1.0 full-time equivalent (FTE) professionals, given a conversion of 2,080 hours per FTE[8].

2.3. Mapping of Experience

Following the time analysis, tasks were mapped based on the level of competence and experience needed. For example, tasks were mapped by the commitment level of teaching staff. A high level of experience and specialization may be needed for technically complicated tasks related to intensity-modulated RT (IMRT) and image-guided RT. Meanwhile, routine tasks, such as basic machine quality assurance (QA), can be performed by less experienced staff. In addition, the team being studied consisted almost entirely of people who were not equivalent to one FTE. For example, physicist "X" works part time each day would be 0.5 FTE.

2.4. Other Personnel

Other staffs with peripheral involvement in medical physics tasks, such as therapists, nurses, dosimetrists, residents, engineers, information technology support, and administrative personnel, were not included in the medical physicist's team or budget. The medical physics residency program is financed by the Ministry of Health, however the training and mentoring of residents does take up the physicist team time, so these efforts were accounted for.

The flow chart shown in Figure 1 describes the general sequence of task examination steps and attributions that contributed to the generation of the personnel justification in terms of quantity and skill.

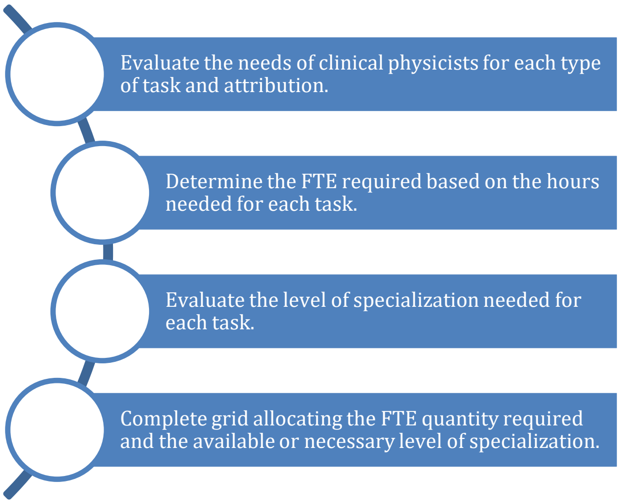

Figure 1. Task analysis and attributions needed to generate personnel justification.

3. Results

The sections and tables below list the attribution of values for the time needed for external beam radiation therapy (EBRT) activities, BT, quality assurance, special procedures, imaging, IMRT, education, administrative support, computing assistance, development time, Intrabeam®, and comparison of the values required by CNEN and ANVISA. The values were based on the institution's activities for the year of 2018. Some of the time values were obtained from the Abt study[4], while others were derived by consensus of the physicist team. Billable activities generate the number of events for most tasks.

3.1. EBRT

3.1.1. EBRT Tasks Routine

Table 1 shows the hours spent on performing routine general tasks, based on the 2,347 patients treated with conformal 3D radiotherapy (3DCRT) in 2018.

3.1.2. Non-programmed Consultations

Non-programmed consultation efforts were found to take a total of 587 hours annually. Special consultations by the medical physicist (which were not already part of a special procedure so as not to duplicate the count) were summarized, and the time spent for each one was estimated. For instance, each pacemaker inquiry involving dosimetric evaluation consumed 5 hours. Other examples include a peripheral dose evaluation (5 hours), investigation for pregnant patients (25 hours), and surface dose evaluation (2.5 hours).

3.1.3. Construction and/or Verification of Specific Devices for Bolus, Immobilization, or Compensators

This effort took a total of 80 hours annually.

3.1.4. Renovation of Rooms and Equipment Specifications

Renovation and specification efforts took a total of approximately 200 hours annually.

3.2. BT

The institution's BT service is one of the most important and comprehensive in Brazil, covering the various procedures detailed below.

3.2.1. High-dose-rate (HDR) BT

On average, 6 hours per patient is spent considering the process of BT, of which 122 were gynecological patients. This effort took a total of 732 hours annually to cover the HDR BT procedures. The main tasks include daily QA, plan review, the transfer of data, cases, and research.

3.2.2. Ophthalmic BT

On average, ophthalmic BT takes 6 hours per patient; there are, on average, 52 cases per year. Thus, this effort consumes some 312 hours per year to cover 52 procedures, with the hours being mainly attributed to planning, re-planning, and attending cases (including in the patients rooms hospitalized for radiometric survey of the area and radiation protection instructions).

3.2.3. Prostate Implants

Prostate implant-related efforts took a total of 18 hours annually, encompassing four low-dose-rate (LDR) procedures and five HDR procedures. Other activities associated with this work include pre-planning, requests for radioactive seeds, trials, preparation, technical assistance, patient instruction, and post-planning.

3.2.4. Maintenance of the BT Inventory

This maintenance effort was found to take a total of 260 hours annually and to consist of the coordination of 15 requests and/or dispatches of sources. Even though this is not a medical physicist activity, in our institution is an assigned task.

3.2.5. Radiation Safety

Radiation safety efforts took a total of 208 hours annually, mainly for the continuing education of therapists, nurses, residents, and all persons involved with radiation safety.

3.2.6. Additional Hours for BT

The total hours spent on evaluation and specification of equipment, room and shielding projects, and dosimetry calibration and maintenance equipment was found to be 550 hours per year. In total, 2,080 hours were used for BT service within the examined year, covering 780 procedures, mainly treatment of surface lesions. This work equals a coverage need of approximately 1 FTE for the 780 procedures. *3.3. QA*

QA efforts took a total of 96 hours of annual QA work, 297 hours of quarterly QA, 180 hours of monthly QA, 306 hours of weekly QA, and 697 hours of daily QA; resulting in 1,576 hours of QA per year. These values were based on time estimates for QA per day, week, month, trimester, and year in addition to annual reviews performed on our accelerators and simulators, as well as maintenance and calibration of all the dosimetry measurement equipment.

Table 1. Tasks and time needed for routine EBRT.

Task	Task time, h	No. events/year	Total hour/year
File review	0.2	2,347 x 5 (weeks per patient) = 11,735	2,347
Monitor units verification	0.1	7,393	739
Conventional treament	0.4	1,905	762
Complex treatment	1.0	684	684
Journal club	0.2	12	2.4
Special consultation	2.5	235	587
Special dosimetry measurements	1.0	26 (TBI) + 34 (Intrabeam) + 4 (Intraop) = 64	64
		Total hours	5,185.4

3.4. Special Procedures for EBRT

The overall total time per year for special procedures was 2,116 hours, as showed below.

3.4.1. Radiosurgery

A total of 2,020 hours for patient support was attributed to radiosurgery, for which there are 202 predicted patients per year. This annual total was based on 10 hours per case to perform the planning, review of the plan, the execution of treatment and care for each part.

3.4.2. Total Body Irradiation (TBI)

In 2018, 24 patients undergo TBI, with 4 hours needed per case (the Abt study**Erro! Indicador não definido.** estimates 5.2 hours per patient). This effort took a total of 96 hours per year.

3.5. Imaging

*3.5.1. Imaging Service to Support Treatment Plannin*g

Planning-indicated imaging includes ultrasonography, conventional simulators, and dedicated tomography systems. This effort was found to require a total of 850 hours per year. Most of this time was attributed to equipment support and procedures for developing training and research.

3.5.2. Imaging Service for Treatment Location

Localization-related imaging efforts took up a total of 850 hours annually and involved various devices such as electronic portal imaging, low-energy X-ray images, and video imaging devices. Most of this time was spent on the quality assurance of equipment and procedures, attending cases, training, evaluation and implementation of the providers equipment and software.

3.6. IMRT/VMAT Patient Activities

A total of 336 patients per year, including 5 new patients per week, require IMRT/VMAT activities. Each patient requires around 9 hours of the physicist's time (the Abt study[4] estimated 12.6 hours per patient). This effort took up a total of 3,000 hours annually. These activities included review of plans, creation of QA plans, review of QA performed, and review of the parameters used for treatment.

3.7. Education

The institution where the study took place has teaching programs for medical residents, physicist residents, therapists, and students and visitors.

3.7.1. Training and Continuing Education

Training and continuing education efforts took some 874 hours per year, which is equivalent to 0.42 FTE. Most of these efforts involved services and ongoing education for technical staff.

3.7.2. Teaching

Classroom activities took up a total of 240 hours per year, which equates to 0.12 FTE. An additional 0.38 FTE was spent on mentoring, and informal training required 0.5 FTE for teaching and education.

3.8. Administrative Support

The medical physics team elected a joint representative to management, and this individual performs certain administrative duties, which consumed 1,404 hours, or 0.70 FTE, annually. The administrative duties included tasks such as teaching staff development and evaluation, scheduling and organization, and meetings with teaching staff and departmental directors.

3.9. Computing Support

Computing support efforts took up a total of 624 hours per year, including 416 hours for 3DCRT, and 208 hours for IMRT and VMAT. These tasks involve organization, planning, and execution related to the institution's management system.

3.10. Development Time

An important point to consider, taking into consideration scientific development, would be the appropriation of 20% of the work time of each member of the teaching staff for development. Ideally, this expectation could be agreed upon with the goal that the teaching body would have dedicated time to develop new clinical procedures and to work on implementing new equipment, not applied yet.

3.11. Intrabeam®

Medical physicists spend approximately 4 hours per Intrabeam® procedure (the Abt survey[4] estimated 8 hours per patient). Intrabeam® efforts took up to 136 hours per year to cover 34 implants. Tasks included calibration of x-ray tubes, pre-treatment QA, mounting, and procedure tracking.

3.12. Comparison of CNEN and Anvisa Values

A total of 22,931 hours were spent within a year on EBRT services (including planning, conventional and QA services, special procedures, IMRT/VMAT, imaging, IT support, radiosurgery, BT, and Intrabeam®) in support of 2,589 patients treated with 3DCRT, 336 patients treated with IMRT/VMAT, as well as 19 TBIs, and 118 radiosurgeries. Altogether, 3,062 patients with complete planning accounts for 5 FTE according to CNEN (600 news patients per year = 1 FTE)[1] and 4 FTE according to Anvisa (3 hours work per new patient = 1FTE)[2].

FTE attributions, calculated by hours and divided by task, are shown in Table 2. The final grid produced based on activities in 2018 is shown in Table 3. FTE values were attributed to tasks, taking into consideration the appropriate experience level for the tasks.

Because our appointments are academic, specialization levels increase from resident to professor (assistant to full). For example, one physicist at the full professor level may spend 30% of his time on IMRT and 20% on planning-related images. Meanwhile, another physicist may spend 30% of her time on conventional EBRT and 30% on BT.

Table 2. Attribution of FTE hours to tasks.

Task	Hours	FTE
EBRT	6,052	3.03
BT	2,080	1.00
QA	1,576	0.79
Special procedures	2,116	1.06
Imaging	1,700	0.85
IMRT/VMAT	3,000	1.50
Education	1,114	0.56
Administrative support	1,404	0.70
Computing support	624	0.31
Development time	-	2.20
Intrabeam®	212	0.11
Radiosurgery	1,488	0.74
TOTAL	**23,789**	**12.85**

As an example of the breakdown of tasks, the IMRT service is covered by 2.5 FTEs by members of the teaching staff. Covering this need may involve three physicists who dedicate most of their time to IMRT, with IMRT tasks for these physicists distributed as follows:

- Experienced physicist (0.3 FTE): The primary responsibility of this person is to commission and supervise a specific plan system and to deliver IMRT. In addition, this person provides coverage for at least 1 day/week for IMRT planning and advising residents in the review and approval of completed plans.
- New physicist (0.25 FTE): This person offers coverage for at least 1 day/week for IMRT planning and helps residents with the final review and approval of completed plans. This person takes primary responsibility for QA management for IMRT, assuring that IMRT measurements are performed as surveyed.
- Instructor (0.35 FTE): This person provides coverage for at least 1 day/week for the IMRT planning service, advising residents on the final review and approval of completed plans. This person also executes most QA plans for subsequent comparison with treatment planning system-provided measurements.

Other physicists provide coverage for IMRT plan review, QA, and commissioning.

4. Discussion

Based only on the CNEN[1] and Anvisa[2] regulation, our institution would need only 4 FTEs, without considering specialization level. The 9.5 FTE value we obtained here does not include time for activities related to education (0.56), administration (0.70), and development (2.20) (an additional of 3.4 FTEs), activities which are encompassed in the CNEN and Anvisa values. Hence, the requirements of CNEN and Anvisa for FTE level would leave us with approximately 9 fewer FTEs than would the ACPM/AAPM proposed model.

The personnel justification grid yields strong documentation for recommending and defending an increase in the number of medical physics professionals at the institution to match the level employed at international institutions such that it can serve as reference. Essentially, the need for IMRT/VMAT staff doubled from 1.5 FTE to 3 FTE (a 1.5-FTE increase), while the need for 3DCRT showed a 0.75-FTE increase. In addition, everyday localization procedures have increased dramatically with the introduction of new systems (AlignRT®, Calypso®, CBCT, and related imaging modalities), increasing the need by an additional 0.25 FTE.

Therefore, with 3 FTE currently working, the institution needs a total increase of at least 2.5 FTE to reach 5.5 FTE, though the actual value needed to meet all current demands of the technological schema would be more than 9 FTE. Standardization of the medical physics situation would make it possible to perform teaching and referral research activities like those performed by US and Canadian institutions.

As IMRT procedures become more routine, the time needed for them can be distributed based on experience. However, imaging magnification for treatment should be carried out by more experienced physicists. In Table 4, we show how FTE personnel could be increased and redistributed based on these changes.

Table 3. Mapping example of FTE attributions to tasks in RT service.

Task	S1*	S2**	S3***	S4****	J5*****	Total FTEs
EBRT	1.00	0.63	0.60	0.40	0.40	3.03
BT	0.45	0.22	0.20	0.09	0.04	1.00
QA	0.30	0.30	0.30	0.67	0.30	0.79
Special procedures	0.60	0.20	0.20	0.03	0.03	1.06
Imaging	0.25	0.20	0.20	0.10	0.10	0.85
IMRT/VMAT	0.45	0.25	0.25	0.25	0.25	1.50
Education	0.09	0.04	0.25	0.09	0.09	0.56
Administrative support	0.50	0.20				0.70
Computing support	0.11	0.08	0.04	0.04	0.04	0.31
Development time	0.20	0.20	0.20	0.80	0.80	2.20
Intrabeam®	0.23	0.13	0.13	0.12	0.12	0.74
Radiosurgery	0.01	0.05		0.05		0.11
TOTAL	4.19	2.50	2.62	2.64	2.18	**12.85 (14.13)**
Current situation	*1.00*	*0.57*	*0.53*	*0.40*	*0.53*	***3.03***

S denotes senior staff denominations; J, junior staff. *S1, 47 hours/week = 1 FTE. **S2: 27 hours/week = 0.57 FTE. ***S3: 25 hours/week = 0.53 FTE.****S4: 19 hours/week = 0.4 FTE. *****J5: 25 hours/week = 0.5 FTE. 1 FTE = 2,080 hours

Table 4. Grid of team levels for medical physicists and their experience levels.

Task	Medical physiscist							Total
	1	2	3	4	5	6	7	
EBRT	0.20	0.15	0.15	0.10	0.10	0.15	0.15	1.00
BT	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.70
QA	0.02	0.05	0.02	0.20	0.05	0.10	0.10	0.55
Special procedures	0.15	0.05	0.05	-	-	-	-	0.25
Imaging	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.15
IMRT/VMAT	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.35
Education	0.10	0.1	0.15	0.05	0.05	0.05	0.05	0.55
Administrative support	0.12	0.03	-	-	-	-	-	0.40
Computing support	0.10	0.05	0.05	0.05	0.05	-	-	0.30
Development time	0.07	0.07	0.07	0.15	0.15	0.07	0.07	0.65
Intrabeam®	0.06	0.04	0.03	0.03	0.03	0.03	0.03	0.25
Radiosurgery	0.05	0.15	-	0.15	-	-	-	0.35
TOTAL	**1.00**	**0.57**	**0.53**	**0.40**	**1.00**	**1.00**	**1.00**	**5.50**

At present, the service has four linear accelerators (two providing VMAT) and BT. The department has a CT-simulator, and treatment-guiding images are made by portal imaging (average of 3 portals per patient) in accelerators with sufficient capacity and/or in digital radiography. Our team also performs special procedures, such as TBI, stereotactic body RT and Intrabeam®. Because we are a teaching institution, we have a strong medical physics residency program with a total of 6 residents (3 first-year and 3 second-year residents), which is also under the responsibility of the medical physics team.

In a major-scale RT service, there is always demand for the development of cutting-edge research that can motivate and even direct new projects across the institution. Currently, our institution is not at the level of international referral institutions. One reason for this lack of research is the over-imposition of tasks and work overload making scientific development impossible.

As a justification for personnel, we emphasize strongly that a high level of specialization is needed for specific tasks. We must guarantee that the physicists assigned to these tasks are competent. Therefore, we use a robust cross-training program. For example, to provide coverage for a stereotactic radiosurgery operation, there must be another experienced person accompanying a new physicist during his or her first cases, and that physicist must also demonstrate proficiency with emergency procedures and the ability to work independently and ensure quality. Similar mentoring must occur for BT and IMRT coverage. In addition, if there is a gap in clinical activity (e.g., if the physicist takes a long time to see a minimum number of radiosurgery cases over the course of a year), retraining is necessary. Finally, if new procedures or equipment are introduced, formal and mandatory training must be provided.

This methodology can be replicated for others radiotherapy centers, changing the values according to the demand of each institution and the experience of the hired physicists. This is a suggestion for the Brazilian regulatory agencies and heads of radiotherapy departments, to take into account all the complexity and diversity among the existing services. Thus, we would have a more real and customized value for the different radiotherapy centers.

5. Conclusion

We have described a workload-driven methodology to analyze medical physics staffing to levels that would enable the activities needed for a large-scale Brazilian institution to be performed as referral international institutions.

Although the example grid presented here is for a large academic department, the methodology could be extended to a non-academic and smaller-scale settings. This grid method matches needs with numbers of staff, and generates a staffing budget based on the type of personnel needed. The grid can be adapted easily when there are changes to the clinical environment and increased needs for specific procedures.

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Contato:

Karina Waiswol Boccaletti
A.C.Camargo Cancer Center
Rua Professor Antônio Prudente, 211
Liberdade, São Paulo
São Paulo – Brasil
karina.boccaletti@accamargo.org.br