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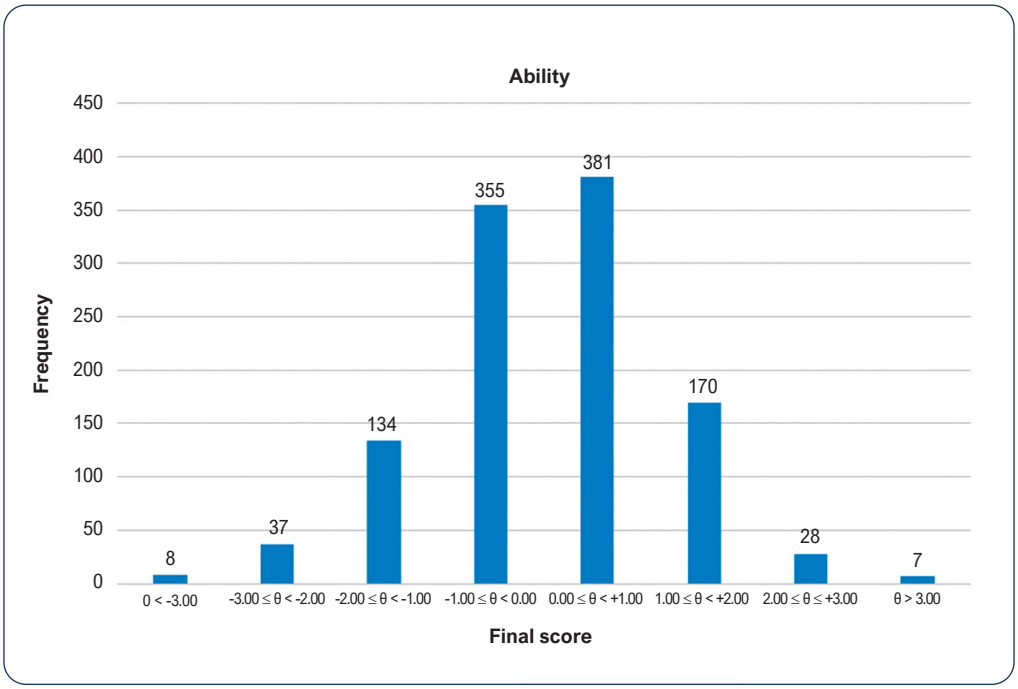

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Challenges and Opportunities for the Development of Medical Education Research

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The year was 1747. The doctor on board the Salisbury, Dr. James Lindt, upset with the high number of deaths by scurvy among the mariners, planned and conducted a study comparing different therapeutic approaches. Described in his "Treatise of the Scurvy", published in Edinburgh in 1753, his study is considered to be the first controlled clinical trial in the modern era.[1] But the history goes even further. Clearly, without the requirements of a controlled clinical trial, the experiment, conducted during the reign of King Nebuchadnezzar in the years of 500 BC in Babylonia, is cited as the first record of a medical study that guided a public health decision. A "herbivorous" diet was authorized when, contradicting what the King believed, it showed more benefits than the preferred "carnivorous" alternative.[1]

The year was 1926. The *Journal of the Association of American Medical Colleges (known today as Academic Medicine) was launched described* at that time by Fred Zapffe, its editor, as "the only scientific publication of its type in the world – a journal dedicated to medical education and pedagogy." Three decades later, the first departments of medical education emerged in American universities, which many believe to be the origins of medical research.[2] In view of the long history of clinical research, medical education research can be seen as newborn. In its few years of life, its development has been quite remarkable. The number of journals on medical education have multiplied. The *Science Citation Index* offers 19 publications, and the list continues to grow each year. The number of scientific article submissions to these journals has also increased significantly. For example, in the first 5 years since its foundation in 1996, *Advances in Health Sciences Education* had received a total of 78 submissions. In 2019 alone, the number of submissions reached 750.[2]

There have also been advances that are more difficult to quantify. There appears to be a change in mentality taking place. Some time ago – and, in fact, still today in many places – the educational decisions in medical schools, as regards the adoption of a teaching method, for example, were made based on the opinion of department heads who had greater power of persuasion, often under the influence of fads or political positions. No one spoke of evidence. The view that prevailed was that common sense was enough to guide decisions. Over the years, and with the evolution in medical education research, it has become clear that this is not true. Ideas that seemed reasonable and were adopted, often in large scale and for decisions as important as certification exams, were subsequently abandoned because they were unable to survive the test of empirical evidence.[3] This is a good sign. The abandonment of ideas that are proven to have no empirical support, or the change in focus of research over time, are clear signs of the life of scientific production in the field. For this to occur, evidence has to "accumulate". I speak of evidence here in the broader sense, an accumulation of empirical evidence about a specific topic, and not merely "proof" that a given intervention "worked". It represents a change in mentality in the sense of assuming that, much like the clinical decision, the educational decisions also require an empirical basis, in this broader sense. Even if in its incipient stage, it opens doors to the development of research in education.

How to promote this development is a recurring theme of debate in international medical journals. As expected, there are different perspectives, different views on the problem.[4-6] The following discussion is partly guided by this literature, but it represents a personal position on the conditions that seem to me to be more important to promoting scientific progress in our field, along with some ideas about how this can be made possible.

One first critical condition necessary to advance on the issue concerns the purpose and the type of research to which it is necessary to give priority. Universities with departments dedicated to medical education research have stood out in reviews of scientific production.[7] These departments have researchers and doctoral students dedicated to the medical education field, many from areas outside of medicine, which gives space for the exchange of theories, models, and methods from different disciplines.[3,8] These are departments with a strong research support structure and a long tradition of scientific production. But this type of department is clearly the exception and not the rule. Most medical education research is conducted by professors from basic sciences or from clinics who are motivated by their interests in education and/or scientific production for academic promotion. These professors have limited formal training in education research, when they have any; a limited acquaintance with of the literature in the area; and little time available to invest in overcoming these limitations. The tendency is, therefore, to conduct occasional studies about their own work. A professor who introduced a new way to teach a specific topic, for

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Education, Medical/trends; Biomedical Research/trends; Research Design; Empirical Research; Data Collection; Research Promotion.

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example, may wish to investigate if this new method "works". All of this is quite valid, but it is important for this type of investigation to begin with the study of the existing literature, to have a theoretical basis, and to be inserted in a conceptual structure. This is essential not only to avoid wasting time and effort, for example, when a person repeats what has already been done, but also to advance knowledge in the medical education field. Discoveries that have the potential to produce changes are rarely the result of an isolated study. What is important is a series of interconnected studies that "talk" with previous studies and build upon them so that progress can be made in understanding a given theme. It is important to connect observational studies (for example, the description of a new educational intervention) and studies that seek to test hypotheses and models or understand how and why they work (or not) in order to expand our understanding of the teaching-learning process and direct not only the practice, but also research in education.[3,4,8] These series of studies are always the result of a collective effort from a diversity of groups and centers over time. There will always be specific local questions that are worth investigating; however, comprehending how this study fits within the collective effort is essential to making it truly worth the effort.

A second essential condition is that of commitment to the methodological quality of medical education research. And here I avoid referring to "improvements", because I think, as many do, that there is high-quality research being conducted in the area.[9,10] However, criticism of the research methodological quality is common, usually based on the assumption that it uses methods that would be "inferior" to those used in clinical research.[5,11] For instance, if randomized controlled trials are considered the gold standard in research for the evaluation of a therapeutic intervention, then we should be conducting similar trials to evaluate the effectiveness of a new course or a new program. This position, from my point of view, does not recognize that medical education research has its own characteristics that differentiate it from clinical research.[6,9,10] While there is, for example, a reasonable degree of certainty about the use of a medicine (or a placebo) in a clinical trial, if (or how much, or how) the "treatment" was administered to the student is something basically impossible to control. The "doses" of the course cannot be standardized. Each course consists, in fact, of various elements, conducted by a wide range of teachers, each with his/her own characteristics and skills. It is not by accident that this type of large-scale experiment to evaluate full curricula have become known, in the parody of the acronym in English, as RCT - "*Results Confounded and Trivial*".[12] The complexity inherent to the process and, consequently, to educational research, does not imply that experimental research has no place in medical education. In fact, it plays a crucial role. The knowledge we have today in many areas of medical education was produced over the years through the accumulation of small-scale experimental studies, built upon a theoretical foundation about that specific theme – highly controlled, usually conducted under laboratory conditions, and replicated many times to reach a systematic variation of the factors involved.[2-4] What is of utmost importance, I believe, is understanding that a high methodological quality does not mean adhering to a specific type of study, but rather to search for methods that are more appropriate to examine the phenomenon in question and to assume the responsibility with their careful application. It is highly probable that the investigation of a complex phenomenon, as educational phenomena commonly are, demands a combination of different research methods, often brought from different disciplines. Whatever the most appropriate study design and method may be, we need to ensure that they comply with the highest of standards when putting them into practice.

Directing our efforts to conducting this type of research – research founded on a theoretical basis and oriented towards its expansion and with high level methodological quality – is seen by many as crucial to scientific development in the field. It is not easy to make this type of research possible. It requires a substantial mastery of the literature on a given theme so as to take advantage of the conceptual structures and identify gaps, questions that require investigation. It is important to master the study designs and methods that allow one to treat such questions. It is likely that only a few of those who are interested in medical education research within our universities will actually opt to dedicate the time and effort needed to acquire such mastery. Combining two lines of action can, I believe, help. The first would be to give researchers interested in dedicating themselves intensely to medical education research the opportunity to develop the necessary expertise, constructing, over time, a research group that can guide, support, and ensure the quality of the research in its context. The second would be to expand the support available to a much larger groups of faculty members who are interested in conducting research in the field of education, but not as the main focus of their professional work.

Reports of international experiences suggest some initiatives that can help in both directions.[3] A key word seems to be "cooperation". Connecting with universities that have accredited Masters and Ph.D. programs in medical education, with a well-recognized scientific production, is essential in order to enable the education of teachers who choose to dedicate themselves to research in the area as their main professional activity. A formal, more advanced training is necessary to create a "critical mass of scientists", whose experience has proven to be a critical factor in the development of the field.[13] Many universities currently offer high-quality programs, even in hybrid formats, which can potentially be made possible using the existing schemes for post-graduation support. At the local level, the interaction with other colleges and research centers in the university itself can help to open the door to the possibility of attracting other professionals from other disciplines, such as from the social sciences, with knowledge and experience regarding research methods that may be lacking within one's own faculty.[8] The cooperation between several institutions, both at the local and international levels, can also help to expand the research support structure, adding efforts and resources, including shorter-term courses for a larger group of faculty members. To conclude, this laudable initiative of this supplement of the journal *Arquivos Brasileiros de Cardiologia* (ABC Cardiol) calls attention to

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the role that medical societies can play in this process. The credibility and influence in the professional community and in society itself qualify these societies for this. Highly successful initiatives already exist in which a medical society became an important partner in the effort to boost research skills in the field.[14] Defending the importance of medical education research, fostering the debate on strategies for its development, and formulating cooperation among a wide range of institutions, in both the national and the international contexts, can help expand existing research skills and clearly contribute to promoting scientific progress in the field.

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Medical Education: Interlocutor of Science and Society

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Scientific progress in Cardiology is unquestionable.[1,2] We must have in mind, however, that the propelling of this development lies on *education sciences*, which transform the world by mobilizing people to knowledge. Despite the debate on what types of knowledge are related to them, according to Kant,[3] education sciences enable individuals to reach autonomy and freedom to live in society.

Traditional science produces knowledge from experiment and observation, using rational methods that guarantee the validity of the results. Nevertheless, these assumptions favor the separation between the *subject* and the *object* of study, resulting in a technical-scientific culture that often ignores philosophical thinking, which drives individual's desire for knowledge.[4]

Science for a long time has no longer been a method detached from social issues, but rather, has served the needs of the community.[5] The COVID-19 pandemic, started in Brazil in 2020,[6] exemplifies this and will contribute to accelerate this process. The pandemic posed challenges to scientific research, which was required to provide fast responses to halt the advance of the disease, bringing the academic world closer to society. Augusti[5] supports that it is necessary to think about a science committed to social practices, that encourages the production of collective teaching and learnings.[5]

At this point it is important the contribution of education sciences as an interlocutor between scientific knowledge and philosophy, the latter contributing to determine the purposes. Therefore, the different functions of the educational process are highlighted, which should be dedicated to individual's professionalization without neglecting individual's growth as a *person*, in terms of affective, cultural, ethical and political dimensions.[7]

Thus, despite the importance of technical-scientifical knowledge in professional formation, it is not sufficient to meet the demands of the contemporary world. The 1988 Constitution establishes health as a universal right, and the Brazilian Unified Health System (Sistema Único de Saúde, *SUS*) as the centerpiece of the health care model in the country. The SUS assumes a change from a predominantly biomedical perspective of health care to a model that incorporates a biopsychosocial perspective, interdisciplinarity, and shared responsibility.[8] There are still challenges in incorporating these professional competencies, requiring a debate on education in health and the formation of teachers in all spheres of medical education.[8]

In general, a good part of the discussion about medical training concerns to the undergraduate period, with little debate about postgraduate study, usually carried out in hospitals and medical specialty societies. Considering the importance of "lifelong learning", medical education is a topic that should be addressed in these institutions, to foster research and teacher professionalization.[9]

Just as medical professional activity should incorporate the best scientific evidence for decision making, instructional strategies developed by institutions responsible for medical training should also be guided by scientific studies. Cardiology societies in the whole world have established criteria for certification of specialties and work areas; however, part of them have been determined by specialist consensus and not by research in education. There is hence the need to widen the discussion on medical education to all the community involved in medical training programs.[10]

Medical education is an internationally renowned field of scientific investigation involving a large academic community and specialized peer-review journals.[11] Confusion still exists regarding the terms "Medical Education" and "Continuing Education". Medical education is a field of knowledge dedicated to developing studies on the teaching-learning process, while continuing education focuses on knowledge acquisition and update.[12] Medical societies are generally more involved in continuing education activities, as those developed in congresses, seminars, courses etc.

Despite their importance, publications on education have been rarely covered my specialized medical journals, but rather published in health education journals. Therefore, many of these publications have been concentrated in the undergraduate program, although professional formation extends for life.

Allred et al.[11] quantified the number of publications on education in cardiology and the number of cardiologists participating in education research and estimated the priority level of medical education studies in cardiology journals. The results were disappointing – of 26 cardiology journals included and 6645 articles screened, only four were on education. Ten general medical journals and 15 medical education journals were included, and of 6810 articles screened, only seven addressed cardiology-specific education and all have been published in medical education journals. It is of note that none of the authors of these seven articles were trained cardiologists. Regarding the percentage of cardiologists dedicated to medical education research, only 2.3% (n=128) out of 5584 researchers were cardiologists. Finally, the authors also assessed

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Education, Medical; Learning; Cardiology/education; Scientific Research and Technological Development; Faculty, Medicine

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the cardiology journal mission statements and found that, of 1036 total words included, the term "educational" appeared only once, in the European Heart Journal.

Data of the present study highlight the little attention paid to medical education by cardiology journals. However, both cardiology societies and institutions for cardiology training have promoted teaching activities, and thus many cardiologists are involved in educational activities. Probably there has been no incentive to the development and publication of studies on medical education. In fact, it is difficult to publish studies about this topic in medical journals, due to the low priority given to these subjects.

The Brazilian Cardiology Society (SBC) is a scientific entity involved in medical knowledge production in Brazil. SBC has been renowned for its high-quality productions and innovations over the years. Its group of collaborators is composed of highly experienced specialists and researchers, who, in general, develop teaching activities at undergraduate and postgraduate levels, in addition to healthcare work. It is worth pointing out the important educational activities carried out by SBC, such as the *Universidade do Coração* (the Heart University), the preparatory course for certification in cardiology, and the relevant works conducted by the Judging Committee for the Cardiologist Title.

Although "Medical Education" appears to be a new topic, probably successful educational activities have already been performed by many in their work settings and not shared with the academic community. Therefore, the development of a supplement focusing medical education in cardiology would be an opportunity for teachers and researchers to share their findings and thereby foster the growth of a new area of professional activity and knowledge for cardiologists, the Medical Education.

Once again, corroborating its mission for innovative and contemporary actions, the SBC, specifically by members of the scientific board and the editorial board of the Arquivos Brasileiros de Cardiologia, led by the Editor-in-Chief Dr. Carlos Eduardo Rochitte, takes a step forward in offering strong support to research about education in cardiology, which is embodied in this Supplement. The space for high-quality publications on education in cardiology is guaranteed in the ABC Cardiol.

Medical education encompasses a variety of themes that may be within the SBC journals' scopes, like teaching of clinical reasoning, the physician-patient relationship, curriculum development, teaching-research integration, teaching-community integration, teacher development, learning theories, assessment of the teaching-learning process, among others. Researchers involved in medical education in cardiology will be able to share the results of their works. By doing so, it is expected to encourage studies on this subject and the formation of study groups in medical education in the SBC, and to contribute for professionalization of teaching and preceptorship in cardiology in Brazil.

To invest in education and teacher training is an excellent way to form highly qualified professionals, capable to understand and meet social needs, seeking to improve people's quality of life.

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Psychometric Evaluation of the Cardiology Certification Exam of the Brazilian Society of Cardiology

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Abstract

Background: **The Cardiology Certification Exam is issued annually by the Brazilian Cardiology Society and set and applied by the Judging Committee for the Cardiologist Title (CJTEC). The psychometric analysis of the exam items using the Item Response Theory (IRT) may provide robust data that can help in the continuous improvement of this instrument.**

Objectives: **To evaluate the psychometric properties of the 2019 Cardiology Certification Exam in relation to the IR parameters.**

Methods: **This was an observational study, with psychometric analysis of the 120 questions of the exam taken by 1,120 candidates for the title of Cardiologist in 2019.**

Results: **The IRT analysis revealed that 32.2% of the items had a "high" or "very high" discriminating power, 49.2% were categorized as "easy" or "very easy", and 41.5% showed a high probability of a correct guessing. Sixty-nine deficient items in terms of the IRT parameters were identified, which were then considered poorly effective in evaluating the candidate's ability.**

Conclusions: **The psychometric analysis of the 2019 Cardiology Certification Exam by the IRT revealed a high percentage of easy questions, with nearly two thirds of the items with a high probability of correct guessing. These data may serve as a basis for a series of discussions and proposals for the elaboration of future certificate exams in Cardiology.**

Keywords: **Specialization; Cardiology; Psychometrics.**

Introduction

The title of specialist has become a constant goal among Brazilian physicians. The reasons range from knowledge gain, prerequisite to participate in public calls, to becoming a member of medical cooperatives in the labor market, evidencing that medical titles enhance both professional status and the prestige of the specialty.

The Cardiology Certification Exam (CCE) has been issued by the Brazilian Cardiology Society (SBC) since 1968, but was legalized only in 1989 by the Brazilian Medical Association (AMB) and the Federal Council of Medicine (CFM) by the 1286/89 resolution. In this context, in 1992, the Judging Committee for the Cardiologist title (CJTEC) was created.[1]

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The CCE consists of 120 multiple-choice questions with five choices with one correct answer each. There is a concern regarding the difficulty level of the questions, and in this respect, the CJTEC classify them as highly, moderately or little difficult. However, this classification has been done subjectively, *i.e.*, according to the opinion of the CJTEC members, without the use of a psychometric methodology that evaluates the degree of difficulty faced by the applicants.[2]

The item response theory (IRT) has been recently used as a psychometric method for the analysis and interpretation of the results in different scenarios of exams and public calls.[2]

So far, the CCE has not undergone a psychometric test, and considering the importance of this exam, it is essential to know whether this method of evaluation provides a reliable and coherent measure from the technical point of view. Based on this, this study aimed to assess the psychometric properties of the 2019 CCE in relation to the IRT.

Methods

Study design

This was an observational study, with psychometric analysis of 120 questions of the CCE taken by 1,120 applicants to obtain the title of cardiologist. The CCE was administered on October 27, 2019, from 13h to 18h at the Universidade Privada de São Paulo.

Inclusion and exclusion criteria

All the answer keys delivered by the candidates who applied for the CCE in 2019 were included. After the appealing phase, two questions and one exam from an applicant who answered only two questions of the test were excluded.

Sample

After the exclusion of two questions in the appealing phase, the sample consisted of answer keys of 118 questions, answered by physicians who applied for the CCE in 2019.

Data Collection

Data were collected from the database of the agency responsible for elaborating the exam (Segmento Farma Editores Ltda., with the help of Simples Detalhe Assessoria, Planejamento e organização de Eventos Ltda. and Picsis informática indústria e comércio Ltda.) and plotted in Excel spreadsheets.

Separate spreadsheets were then generated, with identification data and exam scores. The names of the candidates were deleted from the spreadsheets for the sake of confidentiality, and the applicants were identified by numbers.

Ethical aspects

Informed consent was waived since secondary databases were used, *i.e.* without participants' identification. However, to construct the database, a consent form for the use of the data was signed, which was first sent to the SBC and then to the ethics committee (approval number 4.030.702).

Statistical analysis

We performed a psychometric assessment of the 2019 CCE, offered by the SBC, using the IRT. The IRT aims to determine the applicant's ability level (latent trait, theta [θ]), and the probability that a person with a given ability level will answer correctly a set of items according to their difficulty level.

For analysis of the latent trait, the IRT assesses the following parameters:

a) Item Discrimination (a): performance of the item in differentiating between individuals possessing different levels of ability;

b) Item Difficulty (b): minimum ability that a respondent must possess to be very likely to answer correctly;

c) Guessing (ci): probability of a low-proficient respondent answering correctly an item.

Therefore, the IRT attempts to measure unobservable variables (latent trait) that may influence the answers given to the items, by measuring observed variables (responses). Thus, IRT establishes a relationship or the respondent's ability and the item parameters with the probability of endorsing the correct answer for an item. The higher the person's ability, the higher the respondent's probability of answering correctly the instrument's items.

Two important assumptions of the IRT are Unidimensionality, that assumes that there is only one latent trait (θ) affecting the responses observed for the items in the measure, and Local Independence, that assumes that the individual's performance in separate items is mutually independent, since each answer is given according to the dominant ability (θ) to that item.

In Brazil, the most widely used IRT model is the unidimensional three-parameter logistic model. The unidimensional models with one or two parameters are not suitable for the analysis in the present study, since the results obtained from the three-parameter model revealed a great variation in the guessing item between the 120 questions of the exam applied in 2019.

IRT calculation methods:

Unidimensional three-parameter logistic model

$$P(U_{ij} = 1 \mid \theta_j) = c_i + (1 - c_i) \frac{1}{1 + e^{-Da_i(\theta_j - b_i)}}$$

with i = 1, 2, ..., I and j = 1, 2, ..., n, where:

- $\mathbf{U_{ij}}$ is a dichotomous variable that corresponds to 1, when the respondent j answers correctly the item i, or 0 when the respondent does not answer the item i correctly.
- $\boldsymbol{\theta_j}$ represents the ability (latent trait) of the respondent number j.
- $\mathbf{P(U_{ij}=1 \mid \theta_j)}$ is the probability of the individual j with a θj ability to answer correctly the item i, and is called Item Response Function (IRF).
- $\mathbf{b_i}$ is the difficulty (or position) parameter, measured on the same scale as ability.
- $\mathbf{a_i}$ is the discrimination (or inclination) parameter of the item i, which is proportional to the inclination of the item characteristic curve (ICC) in the point bi
- $\mathbf{c_i}$ is the parameter that represents the probability of low-ability individuals answering correctly the item i by chance (often referred as the correct guessing probability)
- **D** is a scale factor, constant (=1).

Values of the *a*, *b* and *c* parameters are calculated by pre-testing (calibration) using the maximum likelihood (**L**) method, which works with derivatives and is defined as:

$$L(u_{1s}, u_{2s}, \ldots, u_{ns} \mid \theta) = \prod_{i=1}^{n} Pi\ (\theta s)^{u_{si}}\ Qi\ (\theta s)^{1-u_{si}}$$

The maximum likelihood (**L**) works with derivatives.

Where:

- **i** = 1, 2, ..., n items
- $\mathbf{u}_{is}$ = response of the individual to each item (1 = correct, 0 = wrong)

To calculate the ability/ proficiency of the applicant, we have first to determine the maximum value of the function above. First, the probability of correct responses [(Pi(θ)] of each item is determined using one of the three IRT models – 1PL, 2PL or 3PL. In the present study, the three-parameter model (3PL) was used. Then, θ is empirically substituted with values ranging from -5 to +5 (-5,00 ≤ θ ≤ +5,00, usually -3,00 ≤ θ ≤ +3,00), or the Newton-Raphson iteration algorithm is used to calculate the maximum of the L function. Based on the θ, this maximum represents the applicant's ability/proficiency.

Item characteristic curve (ICC)

The mathematical model that defines IRT is a probability function. Therefore, it will always be visualized within the interval [0,1]. The number $U_{ij}=1 \mid \theta_j)$ can be identified by the proportion of correct answers to the item I in the group of individuals with ability θj. This ability is described as a sigmoid curve, where the horizontal axis represents the ability level and the vertical axis the probability of the individual with ability θj to give a correct response to the item i. Two horizontal asymptotes can be highlighted, and three parameters can be seen with some accuracy.

Item information curve – I(θ)

Informatics accuracy is the degree of accuracy in which the item represents what it intends to measure. In this context, accuracy means how well the item predicts the criterion or represents the latent trait (θ). Thus, the IRT information function follows the calculation of the estimation error, that is, how much the score obtained by an individual in a test differs from the real score. The concept of information function itself is the reciprocal of variance, *i.e.*, $I = 1/S^2$. The information function corresponds to the concept of factorial load of the item of the factorial analysis, from the latent trait model perspective, since the factorial load represents the covariance between the item (behavioral representation) and the latent trait (theta). The test information curve depicts the amount of information yielded by the test at any ability level; it presents the amplitude of theta to which the test provides reliable information, and out of which the test provides more erroneous than correct information about theta. Thus, the information curve has an interface to both test parameters, i.e., validity and accuracy, but is not cofounded by any of them. Representation of the information item resemble a normal-type (bell-shape) curve.

In the present analysis, a rate of correct guessing ≥ 25% in an item of the exam was considered unsatisfactory. Then, of the 1,120 exams, 5% of correct guessing higher than the expected rate (20%) is considered very high, and thus the item evaluated has some problem in its formulation or in the answer choices. The correct guessing can be seen by the lack of coherence of the candidate in answering incorrectly easy questions or, in contrast, answering correctly difficult questions, with no ability for it.

Results

We present the results obtained from the psychometric analysis of 118 items of the exam the candidates applying for the CCE in 2019, using a three-parameter unidimensional logistic model of IRT: discrimination (a), difficulty (b) and guessing (c).

In the analysis, one item (question number 110) revealed a negative level for the *discrimination* parameter (*a* = - 0.174), suggesting that the higher the respondent's knowledge level, the lower the probability of correct answer, which is inconsistent with the objective of the parameter. For this reason, this item was not included in the final analysis.

Table 1 presents the distribution of the 118 items of the exam by their discriminating power. Of these items, 18.7% showed a very low or low discriminating power (a ≤ 0.65); 49.1% showed moderate discriminating power (0.651 < a ≤ 1.350) and 32.2% showed high or very high discriminating power (a ≥ 1.351).

Table 2 presents the distribution of the 118 items of the exam according to the *difficulty* parameter. Of these items, 49.2% were classified as easy or very easy (b < -0,52); 22.0% were moderately difficult (-0.51 ≤ b ≤ 0.51); and 28.8% were classified as difficult or very difficult (b ≥ 0.52).

Table 3 presents the distribution of the 118 items of the exam according to the *guessing* parameter. Of these, 41.5% of the items showed a high probability of guessing correctly according to the IRT methodology.

According to the ICC and the information curve, 58.5% and 78.8% of the items, respectively, were considered unsatisfactory (Table 4).

Individual analysis of the exam items by the IRT identified 69 deficient items in relation to the three parameters, that were then considered to have a low probability of providing information about the latent trait (θ), which evaluates the ability of the candidate. Thus, the other 49 items were analyzed by the IRT and compared with the initial model composed of 118 items.

Figure 1 shows the ICC considering the 118 items by the IRT method. The results showed that the higher the applicant's ability (θ), the higher the number of correct answers. It is expected that a medium-ability respondent answers approximately 80 (out of 118, 67.8%) items correctly. In addition, a very low-ability candidate (θ < -4.0) is expected to answer at least 36 (out of 118, 30.5%) items correctly.

The information curve (Figure 2) for the 118 items showed that the maximum amount of information about the logical reasoning of the candidate was near the median ability, *i.e.*, θ near zero. Besides, for the extreme values of θ, the exam produces more information error than legitimate information, and the maximum information generated by the exam is within θ values between -3.2 and +3.1.

Figure 3 shows the ICC for the 49 items remaining after the items with problems related to the IRT were excluded.

Table 1 – Distribution of the exam items by the item response theory (IRT) *discrimination* parameter

Classification of the discriminating power (a)	Frequency (n)	%
≤ 0,35 (very low)	12	10.2
0.351 - 0.650 (low)	10	8.5
0.651 - 1.350 (moderate)	58	49.1
1.351 - 1.700 (high)	25	21.2
> 1.700 (very high)	13	11.0
Total	118	100.0

Database: 1,120 candidates. Note: Two items cancelled (items 23 and 46)

Table 2 – Distribution of the exam items by the item response theory (IRT) *difficulty* parameter

Classification of the difficulty parameter (b)	Frequency (n)	%
≤ -1.28 (very easy)	31	26.3
-1.27 – -0.52 (easy)	27	22.9
-0.51 - 0.51 (moderate)	26	22.0
0.52 – 1.27 (difficult)	19	16.1
≥ 1.28 (very difficult)	15	12.7
Total	118	100.0

Source: The authors; database: 1,120 candidates. Note: Two items cancelled (items 23 and 46).

Table 3 – Distribution of the exam items by the percentage of *correct guessing* according to the item response theory (IRT)

Percentage of correct guessing (c)	Frequency (n)	%
≤ 10.0%	48	40.7
10.1 - 25.0%	21	17.8
25.1 - 40.0%	20	16.9
40.1 - 60.0%	19	16.1
> 60.0%	10	8.5
Total	118	100.0

Source: The authors; database: 1,120 candidates. Note: Two items cancelled (items 23 and 46).

Table 4 – Distribution of the exam items according to the item characteristic curve and the information curve of the item response theory

Item characteristic curve	Frequency (n)	%
Satisfactory	49	41.5
Unsatisfactory	69	58.5
Information curve	**Frequency (n)**	**%**
Satisfactory	93	78.8
Unsatisfactory	25	21.2

Source: The authors; database: 1,120 candidates. Note: Two items cancelled (items 23 and 46).

The result shows that the higher the ability (θ) the higher the number of correct responses. Thus, it is expected that a 0-ability candidate (θ = 0 – median ability, -1 < θ < +1) answers approximately 32 questions (out of 49, 65.3%) correctly, and a very low-ability candidate (θ < -4.0) answers at least four (out of 49, 8.2%) correctly. Therefore, considering the IRT data for the 49 items, the candidates will require a higher ability level (θ) than that required for the 118 exam items.

The information curve (Figure 4) for the 49 items showed that the maximum amount of information about the logical reasoning of the candidate was also near the median ability, i.e., θ near zero. Besides, for the extreme values of θ, the exam produces more information error than legitimate information, and the maximum information generated by the exam is within θ values between -4.0 and +3.2.

Figure 5 depicts the results of ability generated by the IRT, considering the 49 items excluded from the exam initially applied. As can be seen, the mean ability level of the candidates shows a normal distribution, illustrated by a Gaussian pattern of data distribution.

Discussion

The aim of the present study was to analyze the items of the 2019 CCE regarding the psychometric parameters using the IRT. So far, the only known parameter was the degree of difficulty of the questions, categorized as easy, moderately difficult, or difficult, based on the knowledge and experience of the CJTEC members, who participated in the test formulation. However, this method of evaluation is subjective and lacks validity.

Regarding the *discrimination* parameter, only 32.2% of the items showed a "high" or "very high" discriminating power. This is a relevant information, since the discrimination of an item is related to its capacity to identify candidates with different ability levels, as the parameter measures the probability of individuals with different ability levels to answer an item correctly. Similar data were observed in the Brazilian National Exam for the Assessment of Student Performance (ENADE, *Exame Nacional de Desempenho dos Estudantes*) applied in 2010, 2011 and 2012. Psychometric analysis of these exams identified several questions with low discriminating power, providing technical contributions for the formulation of new items for the following exams.[3,4]

With respect to the *difficulty* parameter, 49.2% of the items were categorized by the IRT as "easy" or "very easy", and only 22% as "moderately difficult". This indicates that the CCE was unbalanced in terms of psychometry, which recommends the following proportion of the items by difficulty level – very easy (10%), easy (20%), moderately difficulty (40%), difficult (20%) and very difficult (10%).[4] The proportion of "difficult"

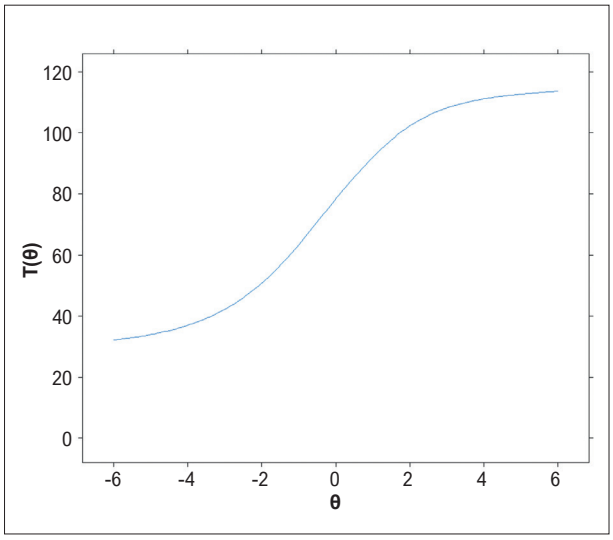

Figure 1 – *Score: T(θ) – of each respondent, estimated by the item response theory (IRT) considering a total of 118 exam items, according to the candidate's ability (θ).*

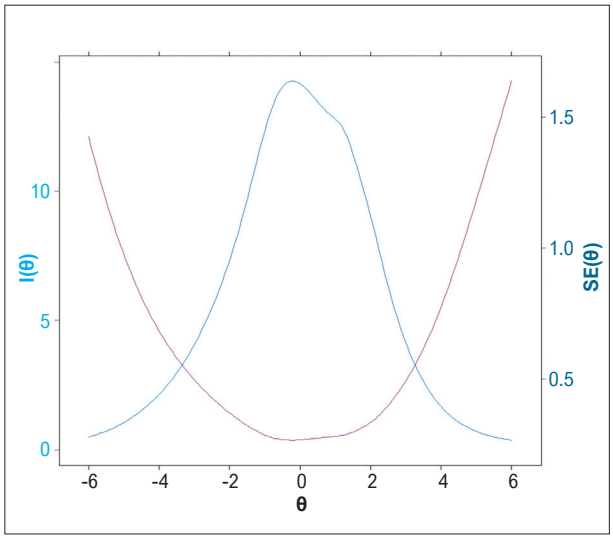

Figure 2 – *Information curve: I(θ) – and standard error of each candidate, generated by the item response theory, according to the respondent's ability (θ).*

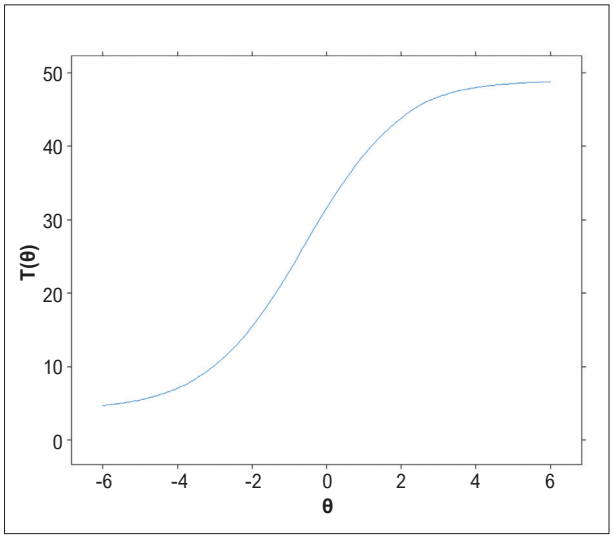

Figure 3 – *Score: T(θ) – of each respondent, estimated by the item response theory (IRT) considering a total of 118 exam items, according to the candidate's ability (θ).*

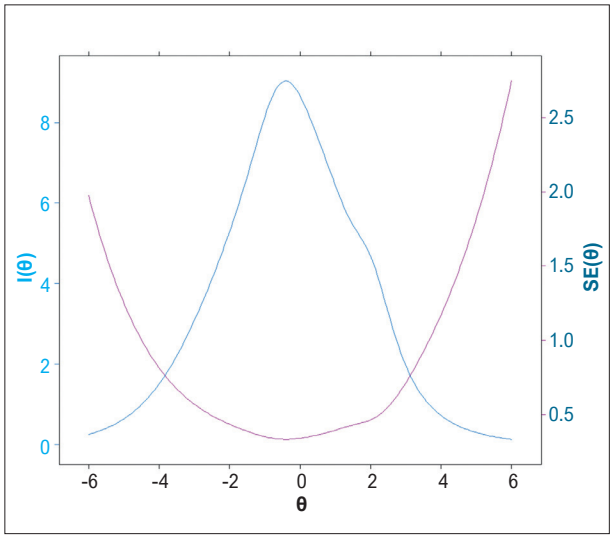

Figure 4 – *Information curve: I(θ) – and standard error generated by the item response theory, considering the 49 exam items.*

and "very difficult" items was adequate. It is of note that the 2019 CCE was predominantly composed of "easy" items.

As for the *guessing* parameter, 41.5% of the CCE items had high probability of correct guessing. This is a high percentage considering the importance of the CCE. The ICC was unsatisfactory for 58.5% of the items and the information curve was satisfactory for 78.8% of the items, which indicates that answering correctly the items did not have a good correlation with the respondents' ability, although it was able to measure the latent trait.

Individual analysis of the exam items identified 69 items with problems related to the IRT parameters and that were then considered to have a low probability of providing information about the candidates' latent trait. Despite that, ICC was consistent regarding the candidate's ability and the number of correct answers, *i.e.*, the higher the candidate's ability, the higher the number of correct answers. Nevertheless, the ICC also revealed that low-ability respondents were able to answer up to 30.5% of the questions correctly. Similar result had been found in the 2016 Brazilian Mathematical Olympiad of Public Schools, in which 11 out of its 20 questions were deficient considering the classical test theory criteria.[3]

When the deficient items were removed from the original exam, the remaining 49 items were assessed as an "alternative

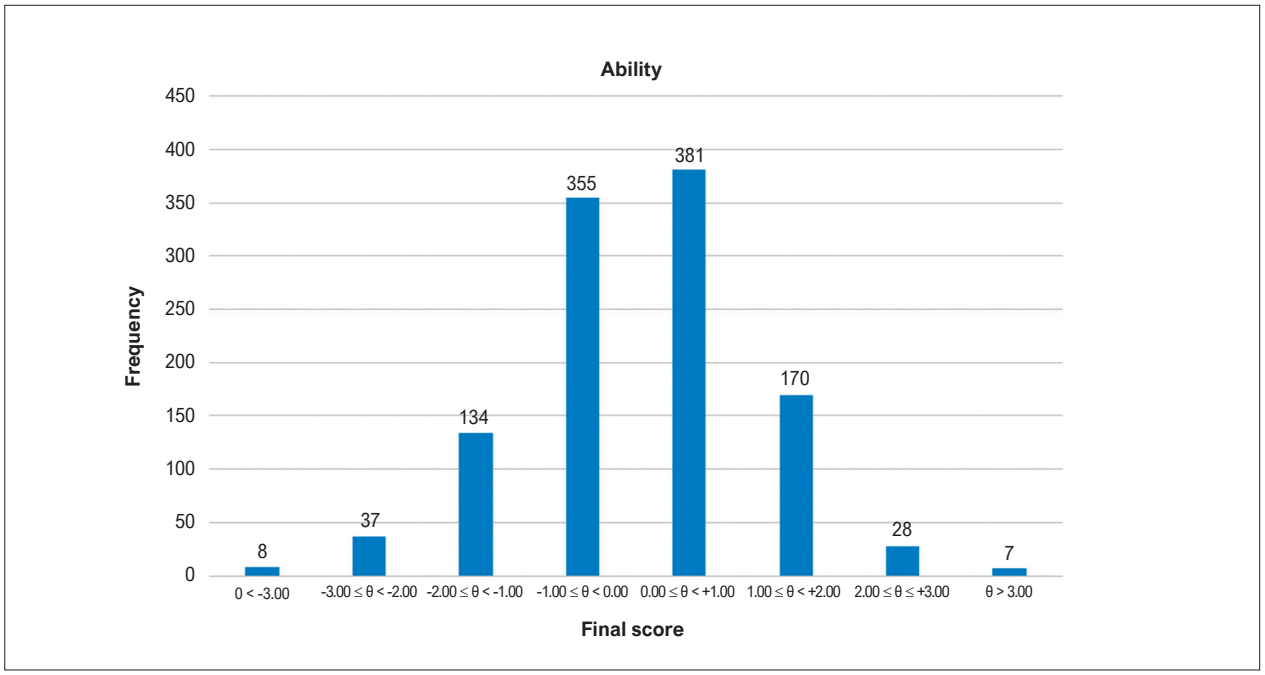

Figure 5 – *Results of ability generated by the item response theory. Source: The authors.*

model" of exam and maintained the same psychometric characteristics of the ICC of the original test and a normal distribution with the mean ability level of the candidates. However, with this model, the percentage of low-ability candidates who would answer the items correctly reduced from 30.5% to 8.2%. This significant reduction is attributed to a decrease in the percentage of correct guessing, which is a relevant result of the "alternative model" of exam, obtained by the IRT.

Therefore, psychometric parameters have mathematical measures, and their analysis in certification exams allows the improvement and construction of more "calibrated" instruments.

To the best of our knowledge, this is the first study to evaluate the psychometric characteristics of a specialist certification exam of the AMB, and the results will contribute to ideas and enhancement of this instrument. For this reason, we did not identify references of other medical societies or specialties to compare our results, although there are publications in other scenarios.

The present study opens the discussion about the current model of elaboration of the CCE. In this model, the items are constructed by a heterogeneous group of people, who do not discuss the exam as a unique instrument. Also, the annual exams do not have similar psychometric characteristics, which precludes their comparability over time.

In addition, our data contribute for the CJTEC to analyze the adequate number of questions of the CCE, since the IRT showed that an adjusted model of 49 items yielded the same certifying results. The possible reduction of the number of questions, when guided by psychometric methods, can produce an instrument able to discriminate, with greater accuracy, the candidates who are qualified for the title of cardiologist. Also, the exam would be less exhaustive, favoring a better performance of the candidates. Thus, the likelihood of passing the CCE due to a high percentage of correct answers by chance would be reduced, optimizing the identification of proficient professionals, able to give coherent answers in terms of the parameters evaluated.

Based on our findings and on the trends observed in other institutions where the IRT has been used for the selection of their exams' items,[4] this method can strongly impact the quality of the AMB specialty certification exams, contributing to the identification of candidates with the competencies expected for their practice.

The SBC supported this study, demonstrating its commitment in improving its professional certifying instrument, the CCE. The results of this unprecedented study are important for the technical improvement of the CCE items and will serve as a reference to other AMB specialty societies.

Limitations and perspectives

The present study has some limitations. First, better results of the IRT can be obtained if a database with previously calibrated items is used. However, this was not possible in our study, since this is the first one to evaluate the CCE, and probably the first to evaluate an AMB medical specialty certificate examination. Another limitation is related to the database used in the study. Although we have analyzed the CCE applied in 2019, all previous editions were independent despite having been elaborated using the same method. Thus, we cannot affirm that the results obtained from the present study can be extrapolated to previous years' editions. However, we do believe that the

study provides important contributions for the SBC and the AMB to make improvements in their exams.

Conclusion

This study allowed to determine the psychometric characteristics of the 2019 CCE by the IRT. The exam showed a high percentage of easy questions, with nearly one third of the questions with a high discriminating power and two thirds requiring improvements, as they had a high probability of correct guessing. The study suggests that an exam with a lower number of questions would show the same psychometric characteristics of the initial instrument, but with the potential to reduce the probability of guessing the answers correctly. These results contribute to the improvement of the CCE, an important certificate examination for the title of cardiologist in Brazil.

Author Contributions

Conception and design of the research, Acquisition of data, Analysis and interpretation of the data, Statistical analysis, Obtaining financing and Writing of the manuscript: Marinho GEM; Critical revision of the manuscript for important intellectual content: Marinho GEM, Peixoto JM, Knopfholz J, Andrade MVS.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

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Study Association

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thics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

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Teaching of Clinical Reasoning Guided by Illness Script Theory

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Abstract

Background: **Teaching of clinical reasoning (CR) can be facilitated by educational strategies guided by illness script theory.**

Objective: **To evaluate the effects of an educational strategy guided by illness script theory on the diagnostic accuracy of chest pain in medical students.**

Methods: **Experimental study in 3 phases, with 18 third-year medical students completing phase 3. Phases 1 and 2 had 27 students. In phase 1, each participant solved 8 clinical cases (6 of chest pain and 2 distractors). In phase 2, participants were divided into 2 groups, which distinctly trained 3 of the chest pain diagnoses from phase 1. In phase 3, after 1 week, each participant solved 8 new cases, with the same diagnoses as phase 1. Case resolution time and diagnostic accuracy were evaluated. The significance level adopted for statistical analysis was $p < 0.05$.**

Results: **In phase 3, both groups showed improved diagnostic accuracy and reduced case resolution time for the trained diagnoses, with no transfer of learning. For these diagnoses, the diagnostic accuracy scores in phases 1 and 3 were: group 1 = 1.00, IQR [0.00 to 1.00] versus 2.00, IQR [2.00 to 2.50], $p = 0.017$ and group 2 = 1.00, IQR [0.66 to 1.17] versus 3.00, IQR [1.33 to 3.00], $p = 0.006$. Case resolution times in seconds were: group 1: 485, IQR [450 to 583] versus 318, IQR [284 to 418], $p = 0.027$ and group 2: 655, IQR [543 to 740] versus 408, IQR [337 to 569], $p = 0.010$.**

Conclusion: **The proposed strategy seems to contribute to improved diagnostic accuracy, and it may be considered for teaching CR.**

Keywords: **Cardiovascular Diseases; Education,Medical; Learning; Decision Making; Clinical Decision Making; Students, Medical.**

Introduction

Clinical reasoning (CR) is a determining element of professional competence.[1] During the undergraduate course, it is not possible to control the variability of clinical cases that students will face or the teaching methods of CR.[2] It is believed that students should learn to distinguish more than 700 types of illnesses.[3] CR depends on the level of specific knowledge organized as illness scripts in long-term memory.[4]

Illness scripts are a system of concepts that organize knowledge in relation to a diagnosis. Faced with a clinical case, illness scripts are activated in an attempt to relate them to the current case. For routine diagnoses, the process occurs automatically, with good accuracy and little cognitive effort. Faced with uncommon diseases, there will be greater mental effort, as the information will be evaluated individually. Diagnostic expertise is related to the variability and quality of illness scripts acquired.[1]

The formation of illness scripts occurs in stages. Initially, students learn specific knowledge about illnesses.[4] When initiating care activities, they begin to relate clinical manifestations to biomedical knowledge, which will with practice be "encapsulated" in patterns organized as illness scripts.[4-7] Strategies for the development of illness scripts have been studied, such as structured reflection, self-explanation, agreement scripts, study of example cases, and others.[5] Studies on the effectiveness of these interventions are limited, and there is still no standardization for teaching CR.[6,7]

Given that strategies guided by illness script theory contribute to the development of CR,[8] this study evaluated a methodology that sought to imitate the stages of illness script development. The study also tested whether training for illnesses that share clinical presentations would improve diagnostic accuracy for illnesses with the same manifestation that were not trained.

Methods

This was an experimental study with 3 phases (Figure 1). Students from the fifth period of Medicine at the UNIFENAS University in Belo Horizonte, Minas Gerais,

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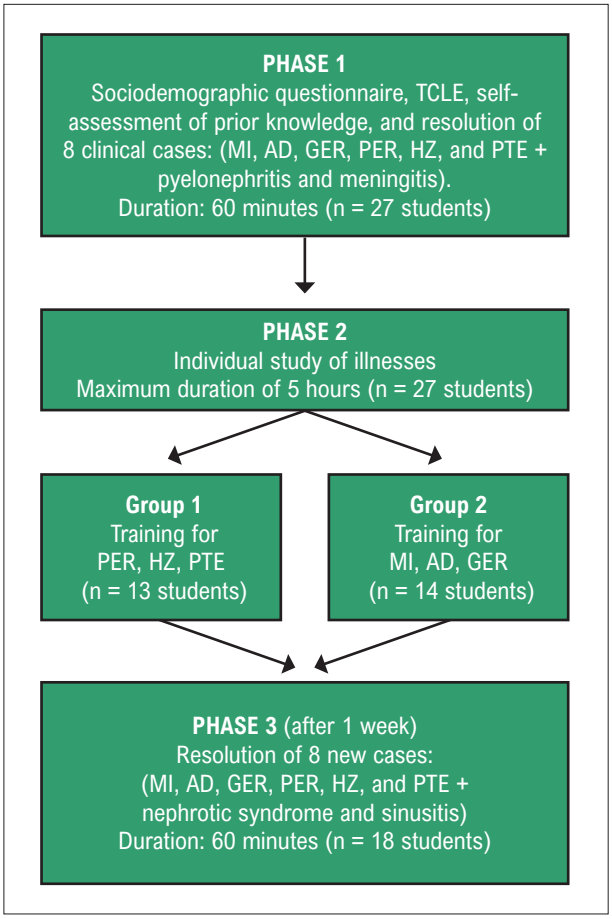

Figure 1 – *Study design. Source: Designed by the authors. Note: AD: aortic dissection; FICF: free and informed consent form; GER: gastroesophageal reflux; HZ: herpes zoster; MI: myocardial infarction; PER: pericarditis; PTE: pulmonary thromboembolism.*

Brazil (80 students) were invited in the second semester of 2017, at the end of the Pediatrics unit, before starting the Cardiology, Pulmonology, and Gastroenterology units. These students were chosen because they had not yet been exposed to knowledge of the illnesses that would be part of the study. The study included students who signed the free and informed consent form, who participated in all phases of the study, and who had not completed the fifth period. They were guaranteed confidentiality of information.

Instructional methodology

With the objective of reproducing the stages of development of illness scripts, it was postulated that students should initially be exposed to the specific knowledge of the illnesses that would be part of the study: epidemiology, pathophysiology, clinical manifestations, and clinical workup. Subsequently, through structured reflection, they would contrast their discriminatory characteristics.[2] Afterwards, they would practice exercises to identify, associate, and categorize the illnesses. Finally, they would organize the concepts studied into mind maps.[9]

Instruments

The study used 2 sets of 8 clinical cases, one for phase 1 and another for phase 3. The cases were presented in brochures in a variable sequence to avoid presentation bias. The material contained instructions and an example case. The cases addressed 6 diagnoses of chest pain, containing approximately 250 words that informed the clinical history, physical examination, and clinical workup for the following diseases: myocardial infarction (MI), aortic dissection (AD), gastroesophageal reflux (GER), pericarditis (PER), herpes zoster (HZ), and pulmonary thromboembolism (PTE). The cases were elaborated based on real cases, and they were validated by 3 experts. Two diagnoses that were not part of the study were inserted to reduce the effect of recurrence of clinical presentation (pyelonephritis and meningitis in phase 1; sinusitis and nephrotic syndrome in phase 3).

Procedures

Participants' self-assessment of prior knowledge

After signing the free and informed consent form and answering the sociodemographic questionnaire, participants completed a self-assessment of their knowledge of the illnesses in the study using a 5-point scale, in which 1 = I have never studied or seen patients with this illness and 5 = I have studied or frequently seen patients with this illness. In this instrument, the illnesses in the study were listed among others, to avoid association with the diagnoses that would be used.

Phase 1 (initial assessment)

In this phase, after reading each case, the students freely provided 1 main diagnosis and 2 differential diagnoses. Before beginning to solve each case, they were instructed to write down the numbers that appeared on a stopwatch projected at the front of the room and, at the end, write down the numbers on the stopwatch again. In this manner, case resolution times (CRT) were measured.

Phase 2 (training)

Students were randomly divided into group 1 (G1) and group 2 (G2), sequentially selecting the first and last student from the attendance list. The groups were allocated in separate rooms, where G1 trained diagnoses of PER, PTE, and HZ, and G2 trained MI, AD, and GER.

Individual study (duration: 60 minutes)

Initially, students were exposed to the components of the illness scripts for the diagnoses that would be trained (epidemiology, pathophysiology, and clinical and laboratory manifestations), through individual study of a handout prepared by the researchers based on an internal medicine book.[10]

Structured reflection (duration: 60 minutes)

Following individual study, the students compared the studied illnesses using structured reflection. To do this, they received a chart where they had to identify the discriminatory

factors of these illnesses, using the information from the handout, which could be consulted. The students were instructed to fill in the table horizontally, favoring comparison of the illnesses (Chart 1).

Identification and association exercises (duration: 60 minutes)

Subsequently, the students received material that randomly presented the elements of the illness scripts of the diagnoses studied. They were instructed to indicate, in a reserved space, to which diagnosis(es) each piece of data was related. Intentionally, data that did not belong to the illnesses studied were included (Chart 2).

Mind maps (duration: 60 minutes)

In this phase, students constructed mind maps for the trained illnesses. In the center of the map, the diagnosis was placed, and, from that point, branches corresponding to the elements of the illness scripts were developed. In each branch, there was an area where students should describe the characteristics related to the diagnosis (Figure 2).

Chart 1 – Structured reflection exercise

Defining and discriminatory factors	Illness 1	Illness 2	Illness 3
Epidemiology			
Clinical history			
Physical examination			
Physiopathology			
Complementary exams			

Source: Designed by the authors .

Application to the resolution of clinical cases (duration: 60 minutes)

Finally, the students reviewed the vignettes from phase 1, again providing the main and differential diagnoses. The study materials could be consulted.

Phase 3 (late assessment)

After 1 week, participants resolved 8 new cases, with the diagnoses from phase 1 and 2 new distractors. After reading each vignette, they provided 1 main diagnosis and 2 differential diagnoses. The CRT was measured using the same procedure as phase 1.

Ethical aspects

This study received approval from the Research Ethics Committee of UNIFENAS, under opinion number: 1.877.200 (CAAE: 60865316.8.0000.5143).

Data analysis

Scoring of the answers

To measure diagnostic accuracy, the main diagnoses provided in phases 1 and 3 were listed and scored independently by 3 clinicians. A 3-point system assigned scores as follows: 1 point for correct diagnosis; 0.5 points if the diagnosis was not listed, but a component was mentioned (e.g., ischemia in a case of MI); and 0 points for incorrect diagnosis.

Statistical analysis

For each participant, the average score for each diagnosis was calculated, obtaining 2 variables: diagnostic accuracy in phases 1 and 3. As the groups worked on different diagnoses, analysis was carried out by blocks of illnesses: block 1 (HZ,

Chart 2 – Identification and association exercises referring to the epidemiology for the illnesses thromboembolism, herpes zoster, and pericarditis

Common in hospitalized patients	[___, ___,___]	Chronic obstructive pulmonary disease	[___, ___,___]
Related to aging	[___, ___,___]	Exposure to the sun	[___, ___,___]
Benign illness	[___, ___,___]	Common after orthopedic surgery	[___, ___,___]
Contact with water from a river	[___, ___,___]	AIDS	[___, ___,___]
Arterial hypertension	[___, ___,___]	Cause of great morbidity	[___, ___,___]
Suffering from pain	[___, ___,___]	Contraceptive use	[___, ___,___]
Self-limited disease	[___, ___,___]	Extended travel	[___, ___,___]
Cause of death on admission	[___, ___,___]	Recurrence is not common	[___, ___,___]
Common in young adults	[___, ___,___]	Obesity	[___, ___,___]
Stroke	[___, ___,___]	May occur do to non-viral illness	[___, ___,___]
Ingrown nail	[___, ___,___]	Complication in patients with cancer	[___, ___,___]
Common during the postoperative period	[___, ___,___]	Related to viral infection	[___, ___,___]

Source: Designed by the authors. Note: Students were instructed to write, in front of each piece of data, the letter(s) corresponding to the illness(es) to which they relate. In this case: H: herpes zoster; P: pericarditis; T: thromboembolism.

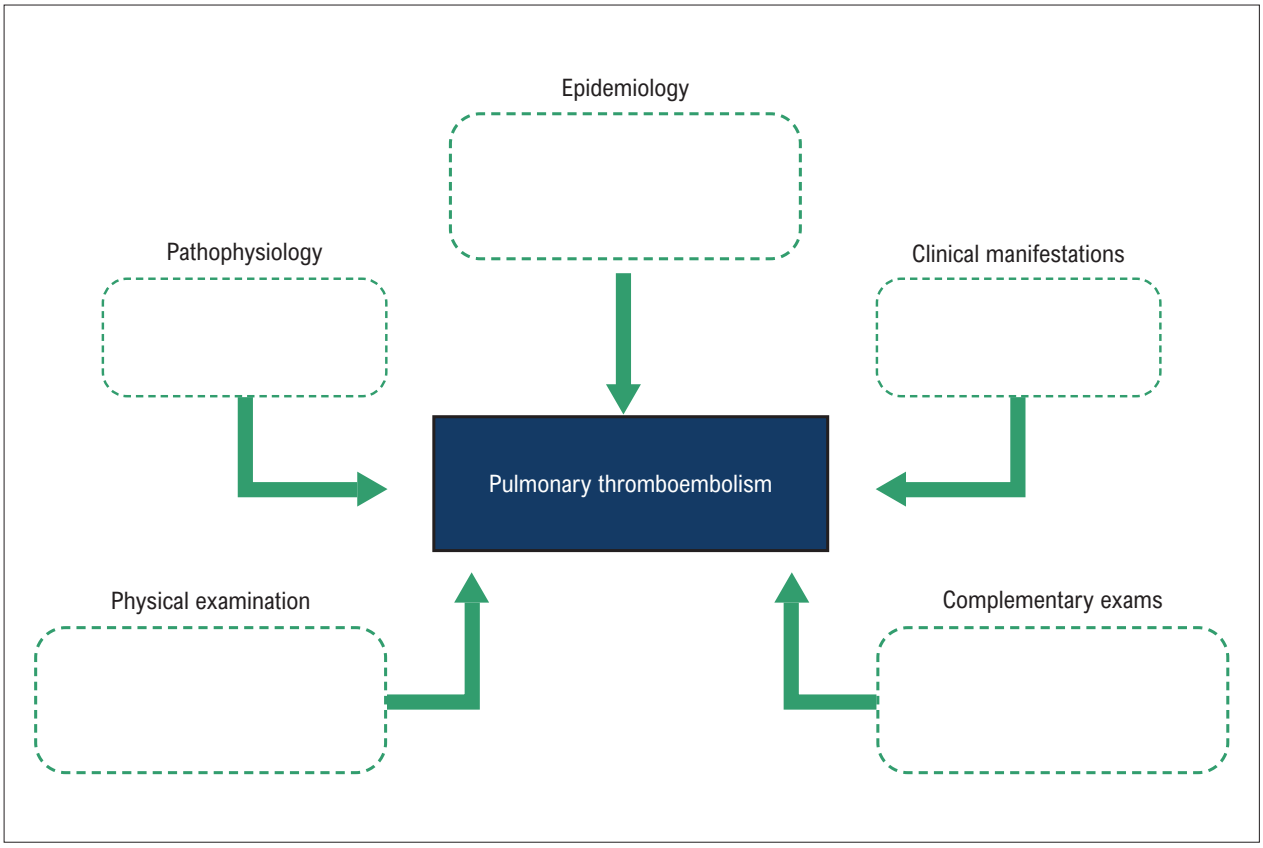

Figure 2 – *Mind map for diagnosis of pulmonary thromboembolism. Source: Designed by the authors.*

PTE, and PER), block 2 (MI, GER, and AD), and block 3 (HZ, PTE, PER, MI, GER, and AD). Categorical variables are presented as numbers and percentages. Continuous variables without normal distribution are presented as median and interquartile range (IQR). To verify the normality of the data, the Shapiro-Wilk test was used. Since the normality of the data was not confirmed, the non-parametric Mann-Whitney tests for independent samples and the Wilcoxon tests for paired samples were used. Comparison of participants in terms of age and self-assessment of prior knowledge was performed using the Mann-Whitney test; comparison in terms of sex used Fisher's exact test. To assess the effect of the intervention in each group, the Mann-Whitney test was used. The effectiveness of the proposed strategy in relation to the scores between the phases was evaluated using the Wilcoxon test. Results with probability of significance < 5% were considered significant. Statistical analysis was performed using SPSS software, version 17.0.

Results

Sociodemographic characteristics

Initially, 27 students volunteered in the study. In phase 2, 13 students were allocated to G1 and 14 to G2. For phase 3, 18 students returned, constituting the group considered for data analysis, with 7 students from G1 and 11 from G2. The median age in years was similar between the groups: G1 = 21, IQR [20 to 26] versus G2 = 21, IQR [20 to 60]; p = 0.96. G1 included 5 women (71.4%), and G2 included 6 (60%); p = 1.00. The medians for self-assessment of prior knowledge did not differ between groups: G1 = 2.67, IQR [1.83 to 3.00] and G2 = 3.00, IQR [2.50 to 3.67]; p = 0.24.

Diagnostic accuracy in phase 1

There was no difference between the median scores obtained between the groups in relation to each of the blocks of illnesses in phase 1 (Table 1).

Diagnostic accuracy in phase 3

Table 1 shows that differences were observed between groups regarding the diagnostic accuracy score obtained in phase 3. G1, which trained the illnesses in block 1, obtained a higher score for these cases in phase 3, compared to G2. The opposite occurred in G2, which trained the diseases in block 2. For block 3, there was no difference between groups.

When analyzing the diagnostic accuracy between phases 1 and 3 by group and block of illnesses (Table 2), in G1, the median for diagnoses in block 1 was higher in phase 3, with no difference in block 2. In G2, the median for diagnoses in block 2 was higher in phase 3, with no difference in block 1.

Table 1 – Comparative analysis of diagnostic accuracy between groups 1 and 2, by phase and block of illnesses

Blocks of illnesses and phase	Group 1 (n=7)	Group 2 (n=11)	p
Phase 1	**Diagnostic accuracy**	**Diagnostic accuracy**	
Block 1 HZ, PTE, PER	1.00 [0.00-1.00]	1.00 [0.00-1.00]	0.961
Block 2 MI, GER, AD	1.00 [0.33-1.83]	1.00 [0.66-1.17]	0.747
Block 3 HZ, PTE, PER, MI, GER, AD	1.83 [1.00-2.00]	1.66 [1.00-3.00]	0.819
Phase 3	**Diagnostic accuracy**	**Diagnostic accuracy**	
Block 1 HZ, PTE, PER	2.00 [2.00-2.50]	1.00 [0.00-1.00]	0.004
Block 2 MI, GER, AD	1.00 [1.00-2.83]	3.00 [1.33-3.00]	0.041
Block 3 HZ, PTE, PER, MI, GER, AD	3.00 [2.00-4.83]	4.00 [1.33-4.00]	0.791

Source: Study data. Note: Database: 18 students; p: Mann-Whitney test; numerical variables: median [interquartile range]; AD: aortic dissection; GER: gastroesophageal reflux; HZ: herpes zoster; MI: myocardial infarction; n: number of students; PER: pericarditis; PTE: pulmonary thromboembolism; score variation: blocks 1 and 2 (0 to 3); block 3 (0 to 6).

Table 2 – Comparative analysis of diagnostic accuracy between phases 1 and 3, by group and block of illnesses

Blocks of illnesses by group	Phase 1	Phase 3	p
Phase 1	**Diagnostic accuracy**	**Diagnostic accuracy**	
Group 1 (n=7)			
Block 1 HZ, PTE, PER	1.00 [0.00-1.00]	2.00 [2.00-2.50]	0.017
Block 2 MI, GER, AD	1.00 [0.33-1.83]	1.00 [1.00-2.83]	0.450
Block 3 HZ, PTE, PER, MI, GER, AD	1.83 [1.00-2.00]	3.00 [2.00-4.83]	0.027
Group 2 (n=11)	**Diagnostic accuracy**	**Diagnostic accuracy**	
Block 1 HZ, PTE, PER	1.00 [0.00-1.00]	1.00 [0.00-1.00]	0.854
Block 2 MI, GER, AD	1.00 [0.66-1.17]	3.00 [1.33-3.00]	0.006
Block 3 HZ, PTE, PER, MI, GER, AD	1.66 [1.00-3.00]	4.00 [1.33-4.00]	0.006

Source: Study data. Note: Database: 18 students; p: Wilcoxon test; numerical variables: median [interquartile range]; AD: aortic dissection; GER: gastroesophageal reflux; HZ: herpes zoster; MI: myocardial infarction; n: number of students; PER: pericarditis; PTE: pulmonary thromboembolism; score variation: blocks 1 and 2 (0 to 3); block 3 (0 to 6).

Case resolution time

Table 3 shows that, in G1, which trained the cases in block 1, there was a reduction in the CRT for all blocks in phase 3. In G2, which trained the cases in block 2, there was a reduction in the CRT for blocks 2 and 3 in phase 3.

Discussion

This study evaluated the effect of an instructional approach guided by illness script theory on diagnostic accuracy for cases of chest pain, in medical students. The results confirmed that the methodology improved the students' diagnostic accuracy and decreased the CRT, suggesting acquisition of mental representation for the illnesses trained, in accordance with illness script theory.[11] However, transfer of learning to a group of illnesses with the same clinical presentation that were not trained was not confirmed.

Other studies have been guided by illness script theory; however, this is one of the first to imitate the stages of its development. Moghadami et al.[12] compared the teaching of CR, guided by illness scripts, to the traditional teaching

Table 3 – Time spent solving the cases between study phase, by group and block of illnesses

Blocks of illnesses by group	Phase 1	Phase 3	p
Group 1 (n=6)	**Time in seconds**	**Time in seconds**	
Block 1 HZ, PTE, PER	485 [450-583]	318 [284-418]	0.027
Block 2 MI, GER, AD	558 [400-1,067]	495 [181-646]	0.046
Block 3 HZ, PTE, PER, MI, GER, AD	1,059 [874-1,744]	812 [466-1,064]	0.028
Group 2 (n=11)	**Time in seconds**	**Time in seconds**	
Block 1 HZ, PTE, PER	501 [485-588]	421 [290-576]	0.328
Block 2 MI, GER, AD	655 [543-740]	408 [337-569]	0.010
Block 3 HZ, PTE, PER, MI, GER, AD	1,131 [1,020-1,317]	872 [698-1,062]	0.026

Source: Study data. Database: 17 students (1 case without information); p: Wilcoxon test; numerical variables: median in seconds [interquartile range]; AD: aortic dissection; GER: gastroesophageal reflux; HZ: herpes zoster; MI: myocardial infarction; n: number of students; PER: pericarditis; PTE: pulmonary thromboembolism.

of fourth-year students. The intervention group, after reading a clinical case, was instructed to identify the mental representation of the problem and compare the components of the illness script for 3 differential diagnoses, while the control group attended a lecture on the illnesses in the study and had a small-group discussion. The activity lasted 7 hours, and they found that both groups improved diagnostic accuracy, but the intervention group outperformed the control.

In our study, the participants were less experienced; they were in the beginning of the third year of studies, and they had not started the clinical cycle. It would probably be difficult for these students to identify the mental representation of a problem, as this requires inference abilities and, therefore, greater knowledge about illnesses. Perhaps, in a pre-clinical phase, a methodology that guides cognitive operations for the elaboration of the illness script would be more adequate, and one guided for mental representation of problems could be implemented in subsequent years. These questions may be evaluated in future studies.

In another study guided by illness script theory,[13] 15 fourth-year and 12 sixth-year medical students participated in a class on illness script theory. Subsequently, the fourth-year students, after reading clinical cases that shared differential diagnoses, informed the common and discriminatory clinical characteristics of each case. Sixth-year students were asked to inform 2 diagnoses, the clinical characteristics of the diagnoses, and the degree of prediction of the clinical characteristics informed. Students received feedback during the activity, which lasted 3 hours.

The results showed that there was an improvement in the ability of sixth-year students to identify new clinical characteristics of the illnesses, with no improvement in diagnostic accuracy and recognition of discriminatory clinical characteristics. Among the fourth-year students, the activity did not demonstrate any benefit.[13] Unlike our study, the activity was aimed at identifying the clinical characteristics of the diseases, with improved diagnostic accuracy in more advanced students. Perhaps, for less experienced students, a methodology that provides more support, such as the one developed in our study, would have more impact. These considerations may be evaluated in future studies.

Other studies not guided by illness script theory obtained satisfactory results, such as the one carried out by Diemers et al.[14] who developed a CR course that lasted 10 weeks. In this study, the students explained the pathophysiology aloud, while analyzing 4 cases (2 from the course and 2 from a transfer). Similar to our findings, an improvement in the students' diagnostic accuracy was observed, with a reduction in CRT, but the learning was not transferred to cases that were not trained. An advantage of the strategy proposed in the present study is the maximum duration of 5 hours, making it feasible in educational environments.

Keemink et al.[15] investigated the transfer of learning of CR in a course based on clinical cases. After explaining aloud the pathophysiology, predisposing factors, clinical characteristics, workup, and management of 15 diseases (5 from the course), the students analyzed 12 clinical vignettes, 4 with diagnoses trained in the course. Similar to our data, there was an improvement in diagnostic accuracy only for the illnesses that were trained. The debate about the transfer of learning from one context to another is not new.[16] Transfer of learning is understood to refer to the use of learned abilities to a new situation, which requires the recontextualization of knowledge. This is one of the final stages of learning.[17]

As mentioned, CR occurs through the recognition of illness scripts, which contain the discriminatory clinical characteristics of the diseases.[4] Studies on analogical transfer suggest that clinical characteristics have both superficial and profound elements. The profound elements relate to the rules that determine a diagnosis, and the superficial elements to the clinical manifestations. For transfer of learning, it is necessary to identify the profound elements; however, the superficial ones are the most noticeable.[17] In our study, this fact may have prevented the transfer of learning to illnesses that were not trained, because, although they share clinical manifestations, the diagnoses had different clinical characteristics in relation to epidemiology, pathophysiology, and workup. Therefore, the students were not able to arrive at a correct diagnosis, because the specific (in-depth) knowledge of these illnesses was not available. In Medicine, there is no general ability to solve all tasks, given that they have specific contents.[17]

To reproduce the stages of illness script development, this study used suggested educational strategies for teaching CR.[5] Structured reflection is based on experiential learning that involves perception, description, analysis, and synthesis. It requires that students intentionally search for evidence that supports their learning.[18] In teaching CR, structured reflection favors the comparison of disease characteristics, contributing to the acquisition of mental representation of them.[19] Another strategy used was cognitive training, which aimed to exercise some thinking skills,[20,21] such as attention, perception, coding, memory, reasoning, and creativity. Favorable results like this methodology have already been reported for surgical abilities.[20,21] This is one of the first studies to use this methodology in teaching CR, an area that warrants further investigation.

In the end, the students constructed mind maps of the trained diagnoses, which facilitate the visualization of how the information is related, improving memorization of the content.[9] Kalyanasundaram et al.[22] demonstrated that mind maps improve information recall 1 week after an instructional activity. Mind maps have been little tested in teaching of CR, but we believe that they may have favored the visualization of the mental representation of illnesses, since their construction considered the components of the illness script.

This study highlights the importance of a structured activity for the development of CR. The results are encouraging, as the literature emphasizes the need for real contact with patients to acquire the illness script.[15] Our results have shown that, even before beginning clinical activities, students benefit from a CR program, which can serve as a bridge to the beginning of the clinical cycle.

The proposed methodology showed satisfactory results for the teaching of CR. It also allowed exercise of varied diagnoses and manipulation of the components of the illness scripts, which is a relevant fact for the acquisition of an illness script network.[1,4] The activity has an appropriate duration for educational environments, and its incorporation into computing platforms would contribute to greater interaction and feedback. Initiatives with this aim have been developed, such as Clinical Key,[23] NEJM Healer,[24] and Paciente 360.[25]

This study has some limitations. This is the only study in this format, with a small number of participants in the final phase. As the study was designed to start before the specialties units, the activities took place concurrently with the final exams in Pediatrics, which precede these units, and this contributed to sample loss. Thus, replication of this study with a greater number of participants would contribute to confirming the results. As the method was tested for the diagnosis of chest pain, it is necessary to evaluate its use for other conditions.

It is not possible to identify the contribution of each strategy used in an isolated manner. It could be argued that the improvement in performance was due to an overall effect of the effort invested in the activity, rather than a specific result attributed to the methodology. Although students dedicated effort to the activity, what matters is that the skill for which they were trained was acquired and that the format may be more attractive in relation to commonly used traditional methods. Work with clinical cases is representative of students' future practice, and it may favor the development of CR. The feedback received from students was stimulating, as they requested new sessions for other diagnoses.

Conclusion

The proposed instructional approach improved students' diagnostic accuracy for chest pain. However, the improvement occurred only for the illnesses trained, and transfer of learning was not observed. The strategy is easy to implement, and it can be considered for the development of CR.

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Author Contributions

Conception and design of the research: Oliveira JCV, Peixoto JM; Acquisition of data: Oliveira JCV; Analysis and interpretation of the data, Writing of the manuscript and Critical revision of the manuscript for important intellectual content: Oliveira JCV, Peixoto AB, Marinho GEM, Peixoto JM; Statistical analysis: Peixoto JM.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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Effectiveness of an Active Methodology for Learning ECG during the Internal Medicine Internship

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Abstract

Background: Studies have shown a low accuracy of urgent care physicians in interpreting electrocardiogram (ECG) in severe cardiovascular conditions.

Objective: To evaluate the effectiveness of an ECG learning method in internal medicine internships and to know the perception of interns regarding learning before and after the methodology.

Methods: This study used a database with the results of an ECG pre- and post-test of the classes in the internal medicine internship from 2017 to 2022. A qualitative questionnaire was sent with questions for self-assessment of perception of learning.

Results: The study included a total of 227 students, 161 of whom (70.9%) were female. The mean age was 26.4 ± 4.2 years old. The pre-test mean was 3.75 ± 2.0 points, and the post-test mean was 8.48 ± 1.5 points, showing a statistically significant difference, even after stratification by sex, age, and course period ($p < 0.001$ for all comparisons). Sixty-nine (30%) of the students responded to the qualitative questionnaire. The three predominant feelings prior to learning were despair, fear, and insecurity. After the Club, the predominant feelings were security, tranquility, and confidence.

Conclusion: The level of prior knowledge regarding ECG was low among students in the medical internship, and the proposed methodology was effective for learning ECG, regardless of age, sex, or course period. It was possible to transform negative beliefs regarding ECG learning and make learning meaningful and enjoyable. A more incisive look at medical courses for learning the ECG in a more practical and contextualized way can improve this scenario.

Keywords: Electrocardiography; Problem-Based Learning; Education, Medical.

Introduction

Cardiovascular urgencies and emergencies correspond to up to 10% of consultations,[1] and they are the second most common reason for adults seeking emergency clinics in the United States.[2] Therefore, the importance of knowledge of electrocardiography in clinical urgencies is unquestionable. Studies have shown a low accuracy of emergency physicians in interpreting electrocardiograms (ECG) of serious diseases, such as infarction, ventricular arrhythmias, and advanced atrioventricular blocks.[3-5] Many students who graduate from medical school report that they are insecure in caring for cardiac patients with the content learned during their course of studies. However, there is a lack of studies that evaluate the effectiveness of methodologies for teaching ECG at this stage of medical training, the practical cycle of internship, which precedes their training as doctors.

The objectives of this study were to evaluate the effectiveness of an ECG teaching method in the internal medicine internship for students from the ninth to the twelfth period, in a private university center, using an innovative technique, with active methodology, which has previously been described, and to know the self-assessment of students regarding their knowledge before and after the application of the technique.[6]

Methods

Study type

This was a before-and-after quantitative observational study of the results of interns' evaluations in internal medicine, with qualitative analysis of the interns' perceptions before and after.

Study population

The study included students from the ninth to the twelfth period of medicine at a private university center in the city of Recife, Pernambuco, Brazil, with sample size and selection by convenience.

Study period

March 2017 to May 2022.

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Methodology of the ECG Club

The institution's internal medicine rotation lasts for 12 weeks, and it takes place in 3 medium-sized centers. The ECG Club is part of the theoretical content of the rotation, and it occurs throughout the 12 weeks, with weekly 2-hour meetings. The preceptor responsible for guiding the ECG Club is the local coordinator of the rotation, cardiologists, and the same methodology is followed.

The methodology used for teaching ECG has been described in a publication in the *Revista da Associação Brasileira de Ensino Médico*,[6] and it consists of 8 meetings distributed in the following manner: 2 lecture classes with dialogue that introduce the Portuguese mnemonic devices, REFASA or RIFEMOS, as we currently call it. Initially, the mnemonic was REFASA, which stood for rhythm, axis, heart rate, morphological changes of P, Pri and QRS, S, ST, and T. The last A of the mnemonic stood for "other changes" including analysis of other pathological changes, such as the Q wave. We currently use RIFEMOS, as we reversed the order of analysis with axis after heart rate, following the interns' perception that it was more important to see the heart rate for definition of supraventricular tachyarrhythmias. In RIFEMOS, RI = rhythm, F = heart rate, E = cardiac axis, MO = morphological analysis of P, Pri, and QRS waves, S = ST segment and T wave. After understanding the method, the interns were divided into 6 small groups, and each week, 1 group was responsible for presenting the interpretation of a number of tracings sent during the previous week to the entire group, using the mnemonic. The preceptor provided the clinical context after the presentation of each tracing and corrected possible misunderstandings. All students were expected to have their tracings printed in A4 size, and they were encouraged to actively participate regarding their doubts. Each ECG Club meeting was identified as Club 1, 2, 3, 4, 5, and 6, corresponding to a specific theme, as follows: 1 = intraventricular conduction disorders; 2 = chamber overloads; 3 = atrioventricular conduction disorders; 4 = ST-T changes; 5 = regular supraventricular tachyarrhythmias; 6 = irregular supraventricular tachyarrhythmias and ventricular tachycardia.

The study used the database with pre- and post-test scores of internal medicine interns from 2 of the 3 institutions where interns perform their internal medicine training. The pre-test consisted of questions from clinical cases of urgent and emergency cardiology, where ECG diagnosis is the basis for clinical management. It was applied in the second week of the rotation and reapplied as a post-test in the final week. The score obtained on the post-test was included as part of the theoretical grade for the rotation.

Research methodology

During the retrospective stage, a search was carried out in the database of the results of the pre- and post-tests of the classes from 2017 to 2022, in addition to information such as age, sex, and period when they were enrolled in internal medicine.

During the prospective stage, a qualitative questionnaire was sent to all participants, with the following questions:

Do you consider that the learning experience in the ECG Club: was useful, was necessary, was unnecessary for rotation and your practice, was useless for your practice, interfered with your learning of internal medicine, contributed to your learning of clinical medicine, demystified your learning of ECG, contributed to your belief that ECG is difficult, made ECG easier and simpler?

In a single sentence, describe how you felt before the Club when receiving an ECG in your hands.

In a single sentence, describe how you feel today when receiving an ECG in your hands.

Statistical analysis of quantitative data

Categorical data were summarized using absolute and relative frequencies. Numerical data were summarized using mean and standard deviation, as the data had a normal distribution (Shapiro test). Comparison between pre- and post-test means was performed using Student's T test for paired samples. In all tests, a significance level (p value) of 0.05 and 95% confidence interval (CI) were adopted. Data were analyzed using the Stata 12.0 program (Stata, College Station, Texas, USA).

Qualitative analysis

Qualitative analysis was performed using the technique of speech content analysis regarding the perception of ECG learning.

Results

The quantitative analysis included all students who completed the internal medicine rotation during the study period, a total of 227 students, 161 of whom (70.9%) were female. The mean age was 26.4 ± 4.2 years old. Table 1 exhibits the general characteristics of the research participants.

Regarding pre-test scores, 84.5% (192) were below 6.0 points, with an overall average of 3.75 ± 2.0 points. The pre-test averages did not show statistically significant differences regarding sex, age, or period enrolled in the internship when participating in the ECG Club.

Table 1 – Characteristics of the study participants

Characteristics	Number (%)
Age (minimum to maximum)	22 to 44 years
Age range	
24 years and younger	76 (33.5%)
From 25 to 29 years	110 (48.5%)
30 years and older	41 (18.0%)
Period	
Ninth	51 (23.8%)
Tenth	60 (26.4%)
Eleventh	70 (30.9%)
Twelfth	43 (18.9%)

Regarding post-test scores, 68.5% (155) were above 8.0 points, and 84% (190) were above 7.0 points. The average increment from the pre-test score was 4.73 points (95% CI 4.46 – 4.99), and there were no statistically significant differences in the results regarding sex, age, or period enrolled in the internship when participating in the ECG Club.

The difference between pre- and post-test scores was statistically significant, even after stratification by sex, age, and course period ($p < 0.001$ for all comparisons). The average post-test score gain was similar for all participants, with no statistically significant differences when comparing by sex, age, or course period. Table 2 exhibits the results of the comparisons of pre- and post-test scores for all participants and stratification by age, sex, and course period.

Of the 227 participants, 69 (30.5%) responded to the qualitative research questionnaire. The mean age of respondents was 25.6 ± 3.5 years, and 49 (71%) were female. There were no statistically significant differences for the characteristics of age and sex between respondents and the total study sample, or between the pre- and post-test means (3.28 ± 1.8 and 8.45 ± 2.2, respectively).

To the closed question ("*Do you consider that the learning experience in the ECG Club*"), 60 (86.9%) answered that it was useful, 55 (79.7%) that it contributed to the learning of internal medicine, 61 (88.4%) that it made learning ECG easier and simpler, and 64 (92.7%) that the method demystified ECG learning.

For the open-ended question, "*In a single sentence, describe how you felt before the Club when receiving an ECG in your hands*", the 3 predominant feelings were despair, fear, and insecurity. For the second open-ended question, "*In a single sentence, describe how you feel today when receiving an ECG in your hands*", the predominant feelings were security, tranquility, and confidence. Table 3 exhibits the categories extracted from the speeches of the interns in the open-ended questions.

Discussion

This research has shown a low level of knowledge of ECG by students, regardless of whether it was their first contact with the internship (students in the ninth period) or they were already close to graduating (twelfth period), with an average score below 5.0 for both groups (3.53 versus 4.02 points). This finding corroborates the findings of a study carried out in 2003 at UNIFESO[7] with students in the eighth period of medicine at the university, where this period precedes entry into the medical internship cycle. No Brazilian or international study has evaluated students in the internship cycle regarding their level of knowledge about ECG.

The learning result demonstrated by the RIFEMOS methodology in the post-test average (8.48 ± 1.5 points), with a significant average increase, regardless of students' age or period, of 4.73 points (95% CI 4.46 to 4.99) demonstrates how important it is to consider the inclusion of this learning model in the internship, when students have a more developed clinical-care perspective than during undergraduate studies. No study was found in the Brazilian or international literature that performed a similar comparison in medical interns.

Table 2 – Comparison of ECG pre- and post-test scores

Characteristics	Pre-test (mean ± SD)	Post-test (mean ± SD)	Mean score gain on the post-test (95% CI)	p value
General	3.75 ± 2.0	8.48 ± 1.5	4.73 (4.46 – 4.99)	<0.001
Sex				
Female	3.76 ± 2.0	8.53 ± 1.5	4.77 (4.45 – 5.09)	<0.001
Male	3.73 ± 1.8	8.37 ± 1.3	4.63 (4.16 – 5.10)	<0.001
p value	0.865	0.479	0.640	-
Age range				
24 years and younger	3.68 ± 1.8	8.55 ± 1.5	4.87 (4.48 – 5.26)	<0.001
From 25 to 29 years	3.80 ± 2.1	8.58 ± 1.4	4.79 (4.36 – 5.21)	<0.001
30 years and older	3.75 ± 2.1	8.07 ± 1.6	4.32 (3.72 – 4.92)	<0.001
p value	0.924	0.134	0.346	-
Period				
Ninth	3.53 ± 1.9	8.45 ± 1.8	4.91 (4.29 – 5.54)	<0.001
Tenth	3.73 ± 1.9	8.33 ± 1.4	4.59 (4.13 – 5.07)	<0.001
Eleventh	3.77 ± 2.0	8.56 ± 1.4	4.79 (4.30 – 5.27)	<0.001
Twelfth	4.02 ± 2.1	8.60 ± 1.9	4.58 (3.98 – 5.19)	<0.001
p value	0.686	0.767	0.807	-

CI: confidence interval; SD: standard deviation.

Table 3 – Categories after analysis of students' speech about their perception of learning ECG before and after the Club

Before the Club	After the Club
Despair	Confidence
I felt panic about not knowing how to interpret it	More tranquility
Fear of making a mistake	I still have a lot to learn, but I feel confident
Affliction	I discovered that I know how to look at an ECG
Nervousness and insecurity	More security for interpretation and clinical reasoning for patients
Despair and sadness	Enthusiasm
Fear and worry	I overcame the fear of ECG
I didn't understand ECG	Greater security to diagnose the main ECG changes in the intensive care unit and emergency environment
Terror	Happy to be able to discuss ECG
ECG is difficult	ECG is easy
I'm never going to learn	Security to read ECG and identify changes
Incompetence	I can interpret ECG clearly
Insecurity	More security
I felt unable and lost	I am excited to interpret. The challenge has become very good!
Despair and anguish	I feel less distressed and today I am able to understand what is not right on the ECG
I felt unable and lost	More security in diagnosis and treatment
I felt nervous because I couldn't interpret it	I feel able to analyze and identify important changes
I didn't feel prepared to be a doctor	Relief to be able to read an ECG and save lives!

ECG: electrocardiogram.

Considering the students' feelings about the exam and making them aware of these feelings was the first step to making it possible for them to modify their own reality. Thus, it was possible to help them feel confident and enjoy studying ECG, promoting independence for permanent, lifelong learning. The change in students' perception after the ECG Club was evident in all speeches. The combination of learning based on real ECG cases with clinical problems common in emergencies brought the extrinsic motivation for learning to the reality of the internal medicine rotation and of their future practice as urgent care workers. The result of the pre-test activated each student's internal motivation. This result is similar to that found by Zhao et al. in teaching the interpretation and approach of thyroid diseases, with fourth year students and clinical residents in China.[8] According to the authors, this learning model increases motivation to learn, understanding, student-professor interaction, final exam results, communication skills, clinical thinking skills, self-learning skills, teamwork skills, and knowledge absorption. These skills are extremely necessary for medical practice, especially in clinical emergencies.

The paradigm regarding ECG learning has existed for a long time, and it permeates the medical training of many of the current professors and cardiologists in medical schools. However, it is necessary to demystify the learning of this highly valuable, simple, and low-cost method, which is widely available in emergencies. Therefore, it is urgent to review medical schools regarding the methodology applied in teaching during undergraduate studies or even internships.

The study limitations include the observational and retrospective nature of the quantitative study, the smaller sample size for the qualitative analysis, and the fact that the study was carried out in a single university center.

More studies in the area of ECG teaching should be encouraged by academic and medical societies, with the aim of expanding the knowledge of students graduating from medical courses on this exam, which is highly essential in medical urgencies and emergencies.

Conclusion

This study found a low level of ECG learning among students in the medical internship, and it demonstrated the effectiveness of the proposed methodology regarding learning to interpret ECG, regardless of age, sex, or course period. It is possible, in a short time, with a simple methodology, to modify students' beliefs about ECG and convert them into learning that is solid, contextualized, and useful for medical practice.

Author Contributions

Conception and design of the research, Statistical analysis and Writing of the manuscript: Silva MCA; Acquisition of data, Analysis and interpretation of the data and Critical revision of the manuscript for important intellectual content: Silva MCA, Assunção MELSM.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

This study is not associated with any thesis or dissertation work.

Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

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Deduction, Induction and the Art of Clinical Reasoning in Medical Education: Systematic Review and Bayesian Proposal

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Abstract

Background: Clinical reasoning is at the core of medical practice and entangled in a conceptual confusion. The duality theory in probability allows to evaluate its objective and subjective aspects.

Objectives: To conduct a systematic review of the literature about clinical reasoning in decision making in medical education and to propose a "reasoning based on the Bayesian rule" (RBBR).

Methods: A systematic review on PubMed was conducted (until February 27, 2022), following a strict methodology, by a researcher experienced in systematic review. The RBBR, presented in the discussion section, was constructed in his undergraduate dissertation in Philosophy at Minas Gerais Federal University. Heart failure was used as example.

Results: Of 3,340 articles retrieved, 154 were included: 24 discussing the uncertainty condition, 87 on vague concepts (case discussion, heuristics, list of cognitive biases, choosing wisely) subsumed under the term "art", and 43 discussing the general idea of inductive or deductive reasoning. RBBR provides coherence and reproducibility rules, inference under uncertainty, and learning rule, and can incorporate those vague terms classified as "art", arguments and evidence, from a subjective perspective about probability.

Conclusions: This systematic review shows that reasoning is grounded in uncertainty, predominantly probabilistic, and reviews possible errors of the hypothetico-deductive reasoning. RBBR is a two-step probabilistic reasoning that can be taught. The Bayes theorem is a linguistic tool, a general rule of reasoning, diagnosis, scientific communication and review of medical knowledge according to new evidence.

Keywords: Education, Medical; Problem Solving; Learning; Clinical Decision-Making; Systematic Review; Bayes Theorem; Evidence Based Medicine.

Introduction

Reasoning is at the core of medical practice, spread in several disciplines and traditions.[1] Reasoning occurs through biochemical, electrical and magnetic processes that are not well understood despite advances in neuroscience, since it is pre-linguistic.[2] By means of linguistic expression, we can teach several types of reasonings: logical, mathematical, and probabilistic reasoning, including the "reasoning based on the Bayesian rule" (RBBR).

"Evidence-based medicine" (EBM) describes a movement against an excessive dependence on clinical judgement and experience in treatment decision-making.[3] EBM is the conscious, explicit and careful use of the best available evidence in the decision making about individual patient care.[4] Under a dual perspective of probability, EBM would be a version that values the frequencies in clinical trials, and medical reasoning would be the coherent formation of "degrees of belief",[5] governed by the subjective theory of probability and the RBBR. This incorporates evidence into a previous context, so that a clinical trial alone is not able to overcome it.

Logical reasoning tends to be deductive and deterministic, and thus, different from probabilistic reasoning which is inductive and based on uncertainty (non-deterministic). We will carry out an attack against the abusive use of deductive reasoning and isolated evidence. Both evidence and deductive and argumentative reasonings can be incorporated into RBBR. The motivation of this work was a philosophical research[5-8] about reasoning conducted by a physician experienced in teaching and research in health. The objective was to conduct a systematic review of the literature about reasoning and decision making in medical education, and to propose an explanation and arguments in favor of RBBR, a specific type of probabilistic reasoning.

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Methods

The systematic review was performed following PRISMA guidelines.[9] In the MeSH (Medical Subject Headings) thesaurus, 'clinical reasoning' is a subheading of 'diagnosis', and 'decision making' is a subheading of 'mental processes'. In this descriptor, 'decision making' is defined as "the process of making a selective intellectual judgment when presented with several complex alternatives consisting of several variables, and usually defining a course of action or an idea". 'Medical education' was the main question of interest and thus the following reproducible search was carried out:

((("Education, Medical"[Majr]) AND (("Clinical Reasoning"[Majr]) OR "Decision Making"[Majr]))) AND (("1952/02/27"[Date - Entry]: "2022/02/27"[Date - Entry]))

The references of the articles were also used. Inclusion criteria were articles written in English, German, Portuguese, and Spanish; all types of publications focusing on education for clinical reasoning, decision making, methods of thinking, case studies. Exclusion criteria were articles on decision-making on choices in the medical career, medical marketing, healthcare, and other aspects not related to reasoning. Comparisons using questionnaires for specialists, questionnaires for students, results of structured cases, schemes or serious games were only included if arguments about general rules of reasoning were discussed in the study.

The critical assessment of medical literature included the use of the RBBR,[10] as this was an "a priori" proposal. After screening the articles based on their titles and abstracts using the RAYYAN application,[11] articles were selected after the first reading of full text. Since the main interest lay on the authors' arguments in favor of clinical reasoning, all articles were read for a second time for analysis of the arguments and were divided into three groups defined *a posteriori*: 1- uncertainty; 2- vague concepts subsumed under the term "art"; and 3- general idea of reasoning. Although this last group was of the greatest interest, the other two were considered for providing relevant arguments.

The RBBR proposal was elaborated by a physician researcher in his undergraduate dissertation in Philosophy, supervised by an experienced science philosopher. In this work, this physician evaluated the work by Ian Hacking[5,8] and Donald Gillies[7] about the philosophical theories about probability and the Bayes' theorem. This is a conditional probability of a posterior hypothesis due to evidence, i.e., it is a revision of existing probabilities given new evidence or information. The theorem is expressed as:

$$Pr(H|E) = \frac{Pr(H)Pr(E|H)}{Pr(H)Pr(E|H) + Pr(\sim H)Pr(E|\sim H)}$$

Or as: "***post-test odds = likelihood ratio x pre-test odds***". Sensitivity, specificity and likelihood ratio are alternatives to accuracy measurement.[12] Pr(E|H) stands for sensitivity and Pr(E|~H) = (1 – specificity). Pr(H|E) is the revision of the hypothesis (post-test probability or probability of posterior scenery) considering the base rate (Pr(H)) of the previous probability (pre-test probability) and the accuracy of the new evidence or information. Posterior probability is determined by prior probability (base rate) and accuracy (also a probability) of the new evidence or information. This is a conditional combination of probabilities in two temporally integrated steps. Based on the subjective theory of probability, the physician's state of belief is updated based on information collected from medical history taking, clinical examination, complementary tests and from medical literature (which may provide less subjective measures). In the discussion section, heart failure is used to illustrate possible uses of RBBR in the diagnosis, prognosis, and therapeutic choices.

Results

Figure 1 illustrates the flowchart of article selection. Of 3,340 references analyzed, 154 articles were included: 24 discussing uncertainty, 87 on concepts subsumed in the term "art", and 43 discussing the general ideal of reasoning. These three groups of articles will be presented in three sections. Due to lack of space, it would be unfeasible to cite 154 references in this article; for this reason, an appendix with a brief explanation about the classification and division of the articles into groups is provided (https://bit.ly/3EMx5sp).

Section 1: Uncertainty

There were 24 articles on the concept that medical students and physicians should learn how to deal with 'uncertainty' (Table 1). The meaning of the word "uncertainty" includes from diagnostic uncertainty to uncertainty about physician's knowledge and the scientific literature itself. These articles were grouped to form the epistemic basis of RBBR. Uncertainty is a human condition for contingent reasoning. Instead of rejecting it, physicians should understand and learn to deal with uncertainty, by means of arguments and evidence, in a hierarchy that will be presented in the final proposal.

Section 2: Art

'Art' was the term chosen for inclusion of 87 articles. It is the most common teaching method used by medical teachers. The method is mainly based on case discussions and learning of the art of medicine in specific contexts, without a general rule, but rather with several small contingent rules. These clinical cases may be either real or imaginary, and electronic games or platforms may also be used. Medical students and physicians should be educated to appreciate the relevance of narratives of disease in the care process.[13]

Twelve articles were classified within the term "heuristic". Heuristics allow us to be involved in decision making in missing data situations, by a process that may also requires a deliberate disposal of data. For the clinician, the process based on heuristic refers to an intuitive integration of clinical findings. This description is analogous to an intuitive characterization of a scenario, to which a subjective probability that would be inserted to RBBR may be attributed.

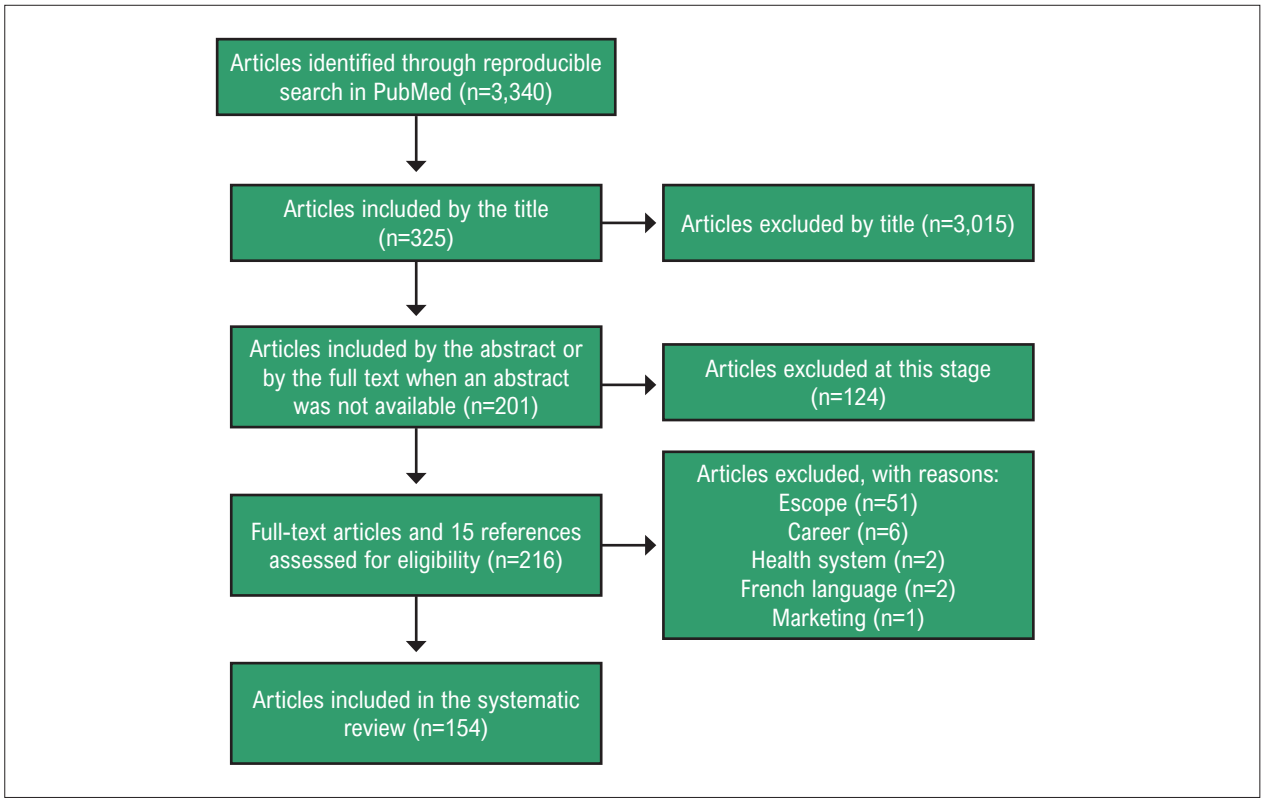

Figure 1 – *Flowchart of study selection.*

The art of this "standard recognition" or "similarities" is largely unconscious, effortless and, despite usually associated with availability and confirmation biases, it is considered efficient.[14] Several thinking dimensions are considered, including emotions. This "art" contributes to humanization in medical practice, forcing physicians to also think in non-technical terms. In this "standard recognition", we must go beyond the "vague distinction between System 1 and System 2 towards more precise models of diagnostic decision making."[15] In general, physicians have been learning to think from prior experiences in similar cases. Therefore, this is a type of inductive reasoning, that does not guarantee the truth of conclusion and may be translated into a Bayesian language, as described in the Discussion section. Table 2 shows the main terms in these articles used to characterize reasoning, but not to establish reasoning rules.

Section 3: General rule of reasoning

These 43 articles were grouped for expressing more general ideas with some reasoning rules. In this section, two types of reasoning processes needed to critical thinking are discussed: the inductive and deductive processes; these are different processes, appropriate to different types of tasks.[16] Only three articles presented a more explicit defense of the deductive thinking (hypothetic-deductive, by which the data obtained generate hypothesis that are tested in search of confirmation or falsification). Two articles make qualitative[16] or quantitative comparisons (in relation to validity and similarity)[17] between deduction and induction.

On the other hand, 13 articles present a more explicit defense of an inductive and probabilistic thinking, applying the RBBR in the decision making. This way of thinking is applied not only to diagnosis, but also to interpretation of clinical trials' results,[18] as this is a general form of reasoning.[19]

Twelve articles were grouped in the EBM category. We consider that EBM is the clinical judgement that involves knowledge of methodological notion about study design, and especially about probabilistic notion about the difference between relative and absolute values, clinical relevance degree, intervention impact (effect size), interpretation of confidence intervals of a study results rather than isolated values of statistical significance (p-value), therapeutic decision making based on NNT (number of individuals needed to treat to prevent a relevant outcome) and survival gain, cost-effectiveness analysis, interpretation of meta-analyses, in addition to basic notions of article search mechanisms and methodological quality criteria. Incorporation of this information into RBBR, with higher or lower probability, requires the inclusion of these knowledges of EBM into decision making. They act as knowledges that evaluate, in a probabilistic and inductive way, the decision scenario that is modified by each new piece of information. New evidence is then incorporated into RBBR as new information.

Among the 12 remaining studies, five were classified as "inductive schemes", one as "score methods for reasoning comparison" and seven classified as "others" that address issues related to the importance of the context (which is a method to evaluate the initial scenario), epistemological assumptions, or

Table 1 – Main arguments or ideas described in the 24 articles on uncertainty

Author, Year	Type of publication	Main argument
Whitehorn, 1963	Expert's opinion	Against determinism, in favor of probability and values.
Elstein, 1982	Editorial	A proposal to deal with uncertainty: "More time is spent on the computation and interpretation of chi-squares, T-tests, and other inferential techniques than on the statistics of opinion revision and decision making – the so-called Bayesian approach – though the latter is more relevant to the daily work of clinical practice (…). Clinical practitioners are properly more concerned with the soundness of decisions made in particular circumstances than with the soundness of general inferences. For this purpose, the Bayesian outlook will be more helpful, and instruction in the logic of clinical decisions should incorporate it."
Gunderman, 2005	Expert's opinion	A dialogic proposal to deal with uncertainty.
Nevalainen et al., 2009	22 students' reflective learning diaries	Reflective writing as a proposal to express and deal with uncertainty.
Blanch et al., 2009	147 interactions between medical students and patients	The authors found a negative perception of medical students who expressed uncertainty to patients. Types of sentences were analyzed.
Charlin et al., 2010	Panel with experts, residents and students	Standardization methods to compare scores of individual examiners with those of a reference panel to deal with uncertainty.
Schwartz, 2011	Expert's opinion	A proposal to teach decision making as the main question in medicine.
Hamui-Sutton et al., 2015	128 Residents: interview and expert's opinion	A comprehensive evaluation of several types of uncertainty in medical practice.
Niedermier, 2016	Letter to the editor	Points to the negative effects of uncertainty and the need to deal with it.
Simpkin et al., 2016	Expert's opinion	Speak about "hypotheses" rather than "diagnoses", embracing uncertainty as an attitude.
Cooke et al., 2017	594 trainees	Uncertainty stress and reluctance in communicating uncertainty.
Cooke et al., 2017	Expert's opinion	A proposal to embrace uncertainty and accept more than one solution to a problem.
Oferta, 2017	Expert's opinion	Literature, music, art and humanities to learn to deal with uncertainty.
Kim et al., 2018	Review	Proposal of strategies to manage uncertainty.
Simpkin et al., 2018	86 Interviews with residents and expert's opinion	High levels of uncertainty stress and low levels of resilience seem to be associated with depression and burnout.
Tonelli et al., 2019	Expert's opinion	Philosophical approach of uncertainty, including metaphysics, fallibilism, and epistemological reasoning.
Davidson, 2019	Editorial	A set of recommendations to deal with uncertainty in medical science: "Authors should be appropriately tempered in their conclusions, using language that acknowledges uncertainty where appropriate. The conclusions should be influenced by not only the P value but also the effect size and bounds of the 95% confidence intervals."
Ying et al., 2019	70 residents	The study suggested that individuals that are more comfortable with uncertainty can experience greater satisfaction at work.
Stephens et al., 2020	Qualitative study with 608 students	Motivate medical educators to incorporate aspects of tolerance to uncertainty in academic and learning environments.
Beck et al., 2020	Expert's opinion	A dialogic proposal to deal with uncertainty.
Lee, 2020	Editorial	A call for articles on uncertainty motivated by the COVID-19 pandemic.
McCarthy et al., 2020	Randomized trial comparing communication strategies in disclosing diagnostic uncertainty	Educational intervention for clear communication about diagnostic uncertainty to improve quality of care at the emergency department.
Papanagnou et al., 2021	Observational cross-sectional study with third-year medical students	The students were surveyed for the development of trainings to deal with uncertainty.
Romiti et al., 2021	Expert's opinion	The authors argued that the COVID-19 pandemic intensified our conflicting relationship with uncertainty.

Table 2 – Keywords of articles that discuss clinical reasoning as "art":

Case-based learning; Heuristic; Information processing; List of cognitive biases; List of abilities; Memorization; Philosophical perspective; Role models; Serious games; Values; Ambiguity; Asking for help; Choosing wisely; Clinical education track; Costs; Emotions; Encapsulated theory; General perceptions; Urgent priority degree; Gut feelings; Use of non-medical literature; Prevention; Realistic theater; Salient clinical findings; Familiarity and similarity; Reflection time

tools for characterization of information or discussions about reasoning, not categorized neither as inductive nor deductive, named by the authors as "analytical methods", "polyphony", "histories and trends", "decision analysis".

Discussion

In this section, we will make a brief discussion about the results of this review and present the RBBR proposal. The review suggests that uncertainty is ubiquitous in medicine, and case-based learning is predominant (induction). There was a higher frequency of inductive, probabilistic reasoning and especially RBBR for decision making as compared with the hypothetico-deductive approach.

Both deductive logic (scarcely found in the literature) and inductive reasoning (widely defended in this review) are linguistic expressions, manipulations of signs. Usual deductive signs lead to categorical thinking (e.g.: T or F, 0 or 1) and our proposal is to use values between 0 and 1, which can be taught. The motivation for the construction of formal logical languages was the differentiation of good *versus* bad arguments; however, it is possible that logic has nothing to do with mental processes.[6] For feasibility reasons, this review was restricted to MeSH descriptors as the main topics ([majr]) in the reproductive research, which makes it more restrictive and less sensitive. Nevertheless, as a meta-analysis was not performed, this literature sample can be considered satisfactory for a critical analysis of the theme.

Inductive reasoning involves information processing in a bottom-up approach, *i.e.*, from evidence to theory. The strategy of data processing is driven by data (validated, appropriate, unstructured). This is an exploratory pathway to get to a conclusion, collecting evidence of cases and constructing a general principle. In the inductive thinking, a conclusion may be false even when all premises are true (*i.e.*, does not guarantee the truth of the conclusion). It is necessary to recognize patterns and connections to formulate hypotheses and theories.[16] Deductive reasoning, in turn, occurs in a top-down approach, i.e., from hypotheses (or theories) to evidence: from theoretical knowledge about a syndrome, to examine the patient for signs and symptoms. Alternatively, when deduction does not occur from hypotheses to evidence, it occurs from one hypothesis to another one, as implication of the own hypotheses. From diagnostic suspicion, signs and symptoms are sought to confirm the hypothesis. In deduction, a conclusion cannot be false if premises are true, in attempt to predict the consequences not from observational data, but rather from the hypotheses.[16]

One study suggests that training physicians and specialists eventually generate diagnostic hypotheses in the beginning of the investigation and, therefore, it is likely that the collection and subsequent interpretation of clinical signs are guided by these early hypotheses. This is an important source of errors in the hypothetico-deductive reasoning. It represents a challenge to medical educators and researchers to develop studies or interventions aimed at reducing errors.[20]

The RBBR proposal about probability and the Bayesian theorem, based on the review of philosophical literature[5,7,8] and corroborated by the systematic review, allows a unified language. As illustrated in Figure 2, from a subjective perspective (degree of belief) of probability, RBBR considers both the prior scenario and the result of current investigation to estimate the likelihood of the scenario be more appropriately interpreted after such investigation.

RBBR can condition the interpretation of new information on the prior scenario. Thus, the Bayes theorem consist of an inductive inference with two temporally articulated steps.[21] In the characterization of the initial scenario, all aspects are considered, and the theories related to medical formation can be influent. However, it is paramount to observe: first the medical history, then clinical examination, followed by complementary tests focusing on patients' problems. The risk of naive use the deductive hypothetical thinking is that, during the initial steps of the investigation, the physician starts to search for confirmation of things that are going on in their heads (a type of confirmation bias). The risk of naive use the RBBR is to believe that beliefs or the observed frequencies will guarantee the conclusion.

For example, heart failure is a syndrome that is difficult to be diagnosed in its mild forms or in case of pulmonary comorbidities. During examination of a patient with mild heart failure, it is not known whether the patient has or not the disease. We start the investigation without this information; therefore, this knowledge is not the ground of the diagnosis, whose foundation is the "not knowing", the uncertainty, and whose construction is guided by the initial scenario (focused on signs and symptoms rather than on prior hypothesis) and revised by complementary tests (generating post-tests scenarios). Hypothetical-deductive reasoning may be useful, but its risk lies in using a very limited set of hypotheses, without considering alternative ones. Symptoms reported and signs observed are the initial basis, the pre-test scenario of reasoning during consultation.

A counterargument to this hypothesis may be that the theory of heart failure provides a model analogous to the models and structures of deductive logic, and that the diagnostic criteria would be similar to deduction, evaluating whether propositions and inferences would satisfy the model (typical standard of deductive reasoning). However, clinical reasoning occurs from contingent individuals in their contexts to hypotheses or to the theory. Symptoms and signs in addition to the series of tests should guide hypothesis formulation, and not the hypotheses per se guide the reasoning process. Evidence obtained from clinical examination and information obtained from medical history lead the physician to an inductive rather than deductive reasoning. From these "hints" (symptoms, signs, tests), the physician makes hypotheses, not only of heart failure in this example, but also other possibilities to explain the hints. An astute physician must think about alternative hypotheses, constructed from data observed in the patient and not from a

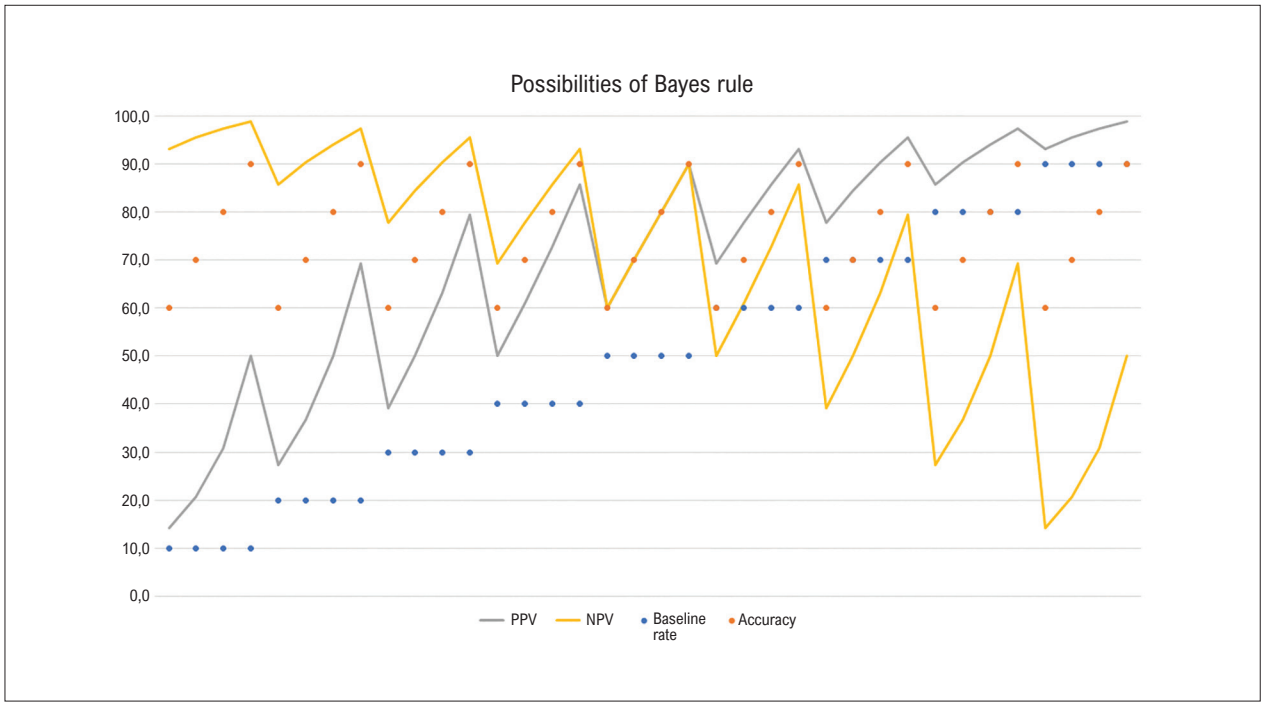

Figure 2 – *Probability of results in the Bayes theorem based on the degree of belief; percentage in the y-axis; PPV: predictive value of a positive result of the new information; NPV: predictive value of a negative result of the new information; the Bayesian reasoning is based on the baseline rate of the prior scenario and on the accuracy of the new information or evidence. Subjectively, the degree of belief is estimated and, objectively, good-quality evidence is searched. In the intuitive reasoning, in the estimates of either very low or very high degree of belief, the baseline rate is determinant of reasoning. In the estimates of intermediate baseline rate, the accuracy is determinant of the reasoning result. The explanation is available at https://youtu.be/EVqfyUNe-bU*

list of differential diagnoses from a book that does not consider individual contexts.

The same works with prognosis: physicians should estimate it based on patient's condition and context. Even enlightened by studies, physicians must analyze patient's individual data to decide the type of study or population subgroup that the patient should be included. The same works for treatment: patient's clinical profile, patient's context, and stage of the disease spectrum should be evaluated to decide which evidence from therapeutic studies best fit the patient. Guidelines should not be applied uncritically, but rather, patient's clinical spectrum should be scrutinized to determine where it better fits into the guidelines.

When seeking for solutions to patient's problems, values and preferences, the use of medical literature should follow the same rule: the tools described in the EBM language should prioritize quantitative and absolute (not relative) estimates of diagnostic, prognostic or therapeutic interventions, based on empirical (and not merely theoretical) data, for the construction of a Bayesian hierarchy. Only one study or one evidence is not enough. There is a whole framework that supports the decision making. A decision is made under some degree of residual uncertainty, based on the highest subjective probability, that incorporates objective data from the studies. In the RBBR, "likely" is taken as "likely to be a more accurate, more useful knowledge"; there is a hierarchical sequence, as described in Table 3.

In the RBBR, there is always residual uncertainty, but uncertainty reduces with increasing contexts, scenarios and evidence. Each piece of information of this hierarchy is aggregated into the context, as new information with certain accuracy incorporated into a previous probability. A diagnosis, a prognosis or a treatment can be seen as probabilistic or as hypotheses rather than as "truth". The most appropriate linguistic discourse in patient communication should be based on what seems to be the most likely considering the available data at that moment. The principle of bivalence of classical logic, of "true or false", is insufficient to explain residual uncertainty. RBBR deals with uncertainty without falling into relativism.

Conclusion

This literature review demonstrated that: 1) uncertainty is an epistemic condition of reasoning; 2) for this reason, probability is predominantly applied; 3) there is considerable conceptual confusion about the subject. RBBR, here proposed, and strongly supported by the literature review, is a two-step probabilistic reasoning that can be taught. Bayes theorem is a linguistic tool, a general rule of reasoning, diagnosis, scientific communication and review of medical knowledge according to new evidence. Characterization of the initial scenario is an art that involves multiple aspects, some of them subjective, but that can be inserted into the RBBR, under the light of the subjective theory of probability.

Author Contributions

Conception and design of the research, Acquisition of data and Statistical analysis: de Sousa MR; Analysis and

Table 3 – Bayesian hierarchy in the Bayesian reasoning

1- An expert opinion is more likely than a non-expert opinion.
2- Opinion is less likely than argument.
3- An expert argument is more likely than a non-expert argument.
4- Argument is less likely than evidence.
5- Evidence with a reliable method is more likely than evidence with a less reliable method.
6- Evidence with a reliable method produced by individuals with less conflict of interest is more likely than evidence produced by individuals with more conflict of interest.
7- Step 6 is more likely if checked using the same method by investigators other than those of the step 6.

interpretation of the data, Writing of the manuscript and Critical revision of the manuscript for important intellectual content: de Sousa MR, Aguiar TRX.

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Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

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Learning: New Strategy for Humanized Digital Medical Education and Training in Cardiology

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Abstract

Background: **The consolidation of new educational paradigms requires the implementation of innovative strategies to transform students into competent professionals.**

Objectives: **To assess knowledge and satisfaction of medical students before and after the use of a new humanized digital model of active learning, called virtual case-based learning (VCBL).**

Methods: **This was a descriptive, documentary analysis of the teaching-learning process of medical students. Data obtained from theoretical knowledge assessment and satisfaction evaluation questionnaires applied in 2018 and 2019 were analyzed, and the new VCBL was compared with the traditional active methodology PBL (problem-based learning). Descriptive and association analyses were made using the Statistical Package for the Social Sciences.**

Results: **A total of 167 evaluation forms administered to medical students were analyzed. In the evaluation of theoretical knowledge, the 2018 and the 2019 student groups had a mean of 41.7% and 73.3%, respectively ($p<0.001$). Among the students who responded to the satisfaction evaluation form, 76.0% gave the highest rating to question one, and 83.0% to question two. Nearly 70.0% of students positively evaluated knowledge acquisition with the Paciente 360 platform; 78.0% reported to feel prepared for working in outpatient care; and 94.0% positively evaluated the new method.**

Conclusion: **In this initial study, the results indicate that the new active method for humanized digital medical education, the VCBL, can help in the betterment of the teaching-learning process, promoting knowledge and satisfaction by the students.**

Keywords: **Computer Simulation; Education, Medical; Aprendizagem; Students, Medical; Humanization of Assistance.**

Introduction

Problem-based learning (PBL) is a pedagogical approach that has been used in medical education over the years. This teaching-learning method recommends activities guided by clinical cases as trigger problems, and is aimed at capacitating students to discuss diagnoses, therapeutic decisions, and other aspects of clinical reasoning faced by physicians in daily practice.[1,2]

In consonance with current challenges, medical education has experienced rapid changes in all the world.[3] The biggest challenge for physicians has been to create opportunities and stimulate student's interest for an essence that goes beyond clinical reasoning discussed in the classrooms or labs, that is, the bond with patients.[4]

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In the university facilities, students can inevitably develop cognitive and scientific excellence. However, affection and humanization of care can only be experienced during actual practice. For example, opportunities of face-to-face consultations and physical contact with patients are only offered during internships.[1,4]

Therefore, consolidation of new educational paradigms requires implementation of strategies that transform students into competent professionals.[3] This continuous search has contributed to the emergence of innovating, active methodologies of teaching, learning and assessment.[5]

The method and the stages of clinical simulation have a greater educational potential as compared with conventional teaching methods, regarding the development of knowledge and training of specific abilities, due to the opportunities of experiencing reality-like, simulated clinical scenarios.[6-8] However, as it consists of an in-person teaching-learning proposal, including the use of manikins or simulated patients, clinical simulation requires quantitative and qualitative programs to confirm the results obtained in different contexts before replicating and synthesizing them in educational science.[9]

Based on educational paradigms and unmet needs, an original model of simulation-based learning, named "virtual

case-based learning (VCBL)", was launched. VCBL offers a potential solution for limitations of conventional simulation-based methods, as it considers blended learning (in-person and online learning) for a better in-person experience with the patient, without compromising patient safety. For this purpose, an innovative learning platform was used, to humanize digital interaction of learning. Thus, the objective of this study was to assess knowledge and satisfaction of medical students before and after the implementation of the new humanized model of active learning method called VCBL.

Methods

Study design and population

This investigation was an exploratory, descriptive, and documentary analysis. The study consisted of collecting and registering of data obtained from a theoretical knowledge assessment, and from an instrument for self-confidence and satisfaction evaluation, administered to 167 students in the eighth semester of medical school in a public university in the south of Brazil.

The study population was divided into two periods, 2018 and 2019. In 2018, the students took the course of Cardiology through the PBL method, which has been used in the university for 20 years (the first university to use PBL in Brazil). In 2019, the VCBL was applied, which was proposed as a new active learning method. The steps of the study protocol and of the two learning models analyzed in the study are presented in Figure 1.

For the students in the eighth semester of the medical course in 2018, the course of Cardiology was offered following the traditional PBL method, as follows: 1) the teacher presents the clinical case; 2) the students search the content in the literature and present the problem solution. In this model, the teacher stimulates the decision-making process among the students by tutorial discussion and expository class.[10] The students were divided into groups of 10 to work and solve the problem; discussions were made based on support materials created using PowerPoint, and the clinical case described in a text.

In 2019, the group of students that took the discipline of Cardiology underwent this new proposal of active learning method, called VCBL. This VCBL model has an interactive virtual platform of humanized clinical cases, which were the same as those discussed in the PBL method (chronic coronary artery disease, atrial fibrillation, arterial hypertension, and dyslipidemia), but presented in a humanized interactive simulation, through the *Paciente 360* platform.

The VCBL method has the same stages as the PBL method, in addition to synchronous interactions with the *Paciente 360* platform (with the teacher support) or asynchronous (without the teacher support) for self-reflection of humanized clinical thinking.

To assess students' cognitive knowledge, a theoretical test with 25 multiple choice questions was administered to both groups (2018 and 2019). The questions addressed the topics covered in Cardiology over the semester, as follows: acute and chronic coronary disease, arrythmias, arterial hypertension and dyslipidemia. Thus, the subject, the time to conclude the test, the difficulty level, and the stage for clarification of doubts were similar between the study periods. In addition, the students of 2019 completed an instrument of satisfaction about the VCBL method and the use of the *Paciente 360* platform.

Instrument for the active approach to medical education

The VCBL was applied through an online platform of active medical education, with realistic simulation of clinical cases. The platform presents clinical cases with real people and enables the student to interact and make decisions in all stages of a medical consultation in different subjects and specialties. Therefore, the instrument promotes empathy and affection for medical learning, in a humanized, interactive and innovative way.

The *Paciente 360* platform was developed aiming at improving academic quality of medical education and academic connection with the incoming generations of students. The platform has been used in universities in Brazil and other countries since 2019.

In the asynchronous method, the students, from their homes or any other place, without the help from teachers or tutors, can assist patients with different simulated diseases, take medical history, perform physical examination, order and analyze laboratory and imaging tests, make the diagnosis and choose the best treatment for the case (Figure 2). The teacher gives feedback on correct and incorrect decisions to the students; also, through the synchronous mode, the teacher can present the clinical case and promotes discussions about all steps among the students of the group.

Data collection

The theoretical exam was composed of 25 multiple-choice questions and evaluated cognitive knowledge of students in 2018 and 2019.

The instrument that evaluated students' satisfaction and self-confidence with current learning, applied in 2019, was composed of five Likert-scale questions, constructed by teachers of Cardiology of the same university.

Satisfaction with current learning was assessed by two 10-point Likert scale: 1) In a 0-10 point scale, what is the likelihood of recommending *Paciente 360* to a friend?"; and 2) In a 0-10 point scale, how do you classify the VCBL method for humanized, interactive clinical cases, currently used in the course of Cardiology, as compared with the traditional PBL method used in previous courses (Nephrology and Pneumology) during the same period?

In addition, three questions evaluated the level of self-confidence (a little confident, slightly confident, somewhat confident, quite confident, extremely confident): 3) "How do you evaluate your learning progress with *Paciente 360*?"; 4) "Do you feel more prepared for working in outpatient care?"; and 5) "How do you evaluate the topics discussed?".

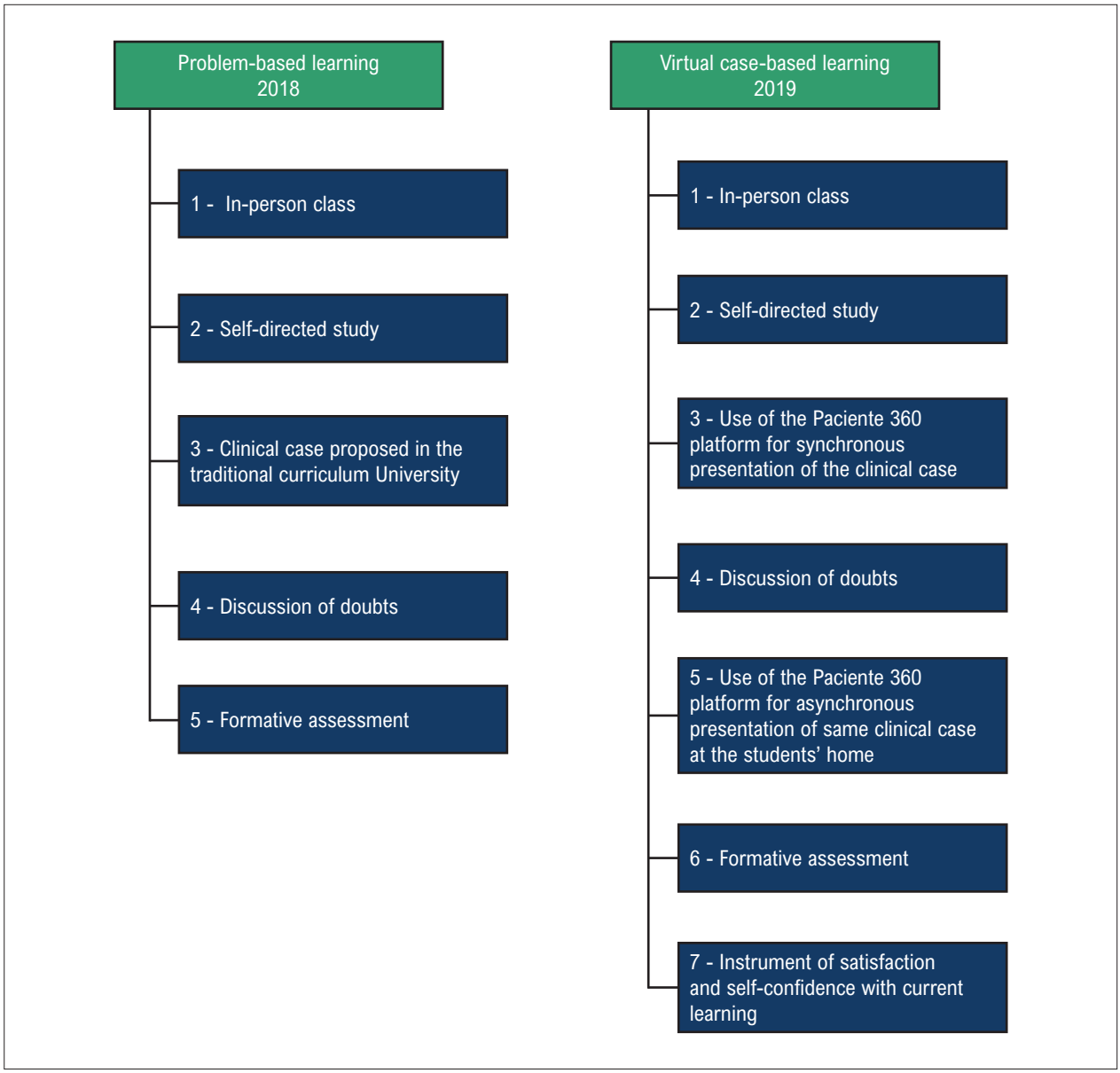

Figure 1 – *Flowchart of the learning models' steps and the document of analysis..*

For data collection, an instrument was constructed to identify, organize and register individual ratings obtained from the students in the theoretical test administered in 2018 and 2019, and in the questionnaire on satisfaction administered in 2019. The steps proposed in the literature were used,[11] including the analysis and organization of the materials available, data interpretation and critical analysis of the documents.

Statistical analysis

Descriptive analysis of data was made by absolute and relative frequencies of categorical variables, and mean and standard deviation of continuous variables.

Comparisons between mean and continuous variables were analyzed by the Student's t-test after the normal distribution of data was confirmed by the Kolmogorov-Smirnov test.

Analysis was made using the Statistical Package for the Social Sciences (IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.). A $p<0.05$ was considered statistically significant.

Ethical aspects

The human research ethics committee of the State University of Londrina was consulted for the development of the present study. The informed consent was waived, as all participants were informed about the objective of the study and had the guarantee of anonymity.

Figure 2 – *Use of the synchronous and asynchronous modes of the virtual case-based learning (VCBL) method.*

Results

A total of 87 theoretical, formative evaluations applied in 2018 were examined. For the 2019 group, 80 theoretical tests were analyzed, and 17.5% of the students missed the seven-day deadline to fill up the questionnaire about satisfaction with the use of the VCBL model as an active learning method (Chart 1). The comparison including the non-respondents is presented in supplementary material (Table S1).

Figure 3 shows the comparison of theoretical knowledge evaluated. The 2018 students had a mean of 41.7% (20-60% variation) of correct answers, and the 2019 students had a mean of 73.3% (44.0-92.0% variation) ($p<0.001$).

With respect to satisfaction with current learning, 76.0% of the students gave the highest rating (9-10) to question number one, and 83.0% to question number two (Figure 4).

Nearly 70.0% of the students felt "quite confident" about the learning acquired after using the *Paciente 360* platform; 78.0% felt "somewhat confident" or "quite confident" in working in the outpatient care; and 94.0% felt "quite confident" and "extremely confident" about the content approach through the new learning proposal (Figure 5).

Discussion

When entering the clinical field, medical students face several situations that require the integrated application of theoretical knowledge and practical abilities, associated with the development of humanization and empathy with patients to guarantee integral care.[12] Studies[12,13] have corroborated that traditional teaching-learning methods have not fulfilled the requirements of contemporary medical environment, with a gap between formal education and humanized, integrated practice.

Chart 1 - Study population by instrument of evaluation and learning method

Year	Number of students	Learning model	Evaluation instrument
2018	87	Problem Based Learning	Theoretical evaluation
2019	80	Virtual Case Based Learning	Theoretical evaluation Evaluation instrument for satisfaction, self-confidence and learning progression

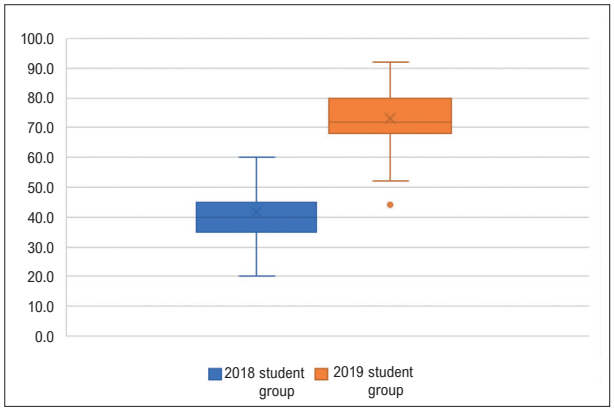

Figure 3 – *Comparison of mean percentage of correct answers in the evaluation of theoretical knowledge between the 2018 and the 2019 medical student groups.*

Today, realistic simulation has been used in many universities, in attempt to train professionals that meet the demand of current labor market.[6,8,14] Most methods are based on non-human simulation with manikins or avatars. A recent study[15] reported a limitation of these methods, as the stages of realistic simulation do not enable students to develop empathy and to socialize with the real patients. The authors suggest the need for new methods to address these objectives.

The present study demonstrated the feasibility and efficacy of the new simulation model of learning proposed so that other universities can use it. This method was shown to be effective in the formative evaluation of theoretical learning in the discipline of Cardiology. Mean ratings obtained from the 2019 student group were more than 30.0% higher than those from the 2018 group, indicating that the teaching-learning process was potentiated by the steps proposed by the VCBL method.

Integrated simulation technologies have been through rapid development. Digital medical education has played a more and more important role in the training of medical students in clinical knowledge and abilities.[13] Today, there is no simulation method that depicts, in a realistic manner, all physiological, mental and behavioral components of patient care.[16] Thus, recognizing satisfaction and self-confidence of students in participating of new education strategies contribute to their improvement.

All students who participated in this study would recommend the *Paciente 360* platform to a friend. Of all participants, 76.0% rated the highest scores (9-10) in the Likert scale for satisfaction. Approximately 90.0% of the individuals answered to feel "quite confident" or "extremely confident" about learning progression with the platform, resulting in higher level of self-confidence among students.

Steps three and five (Figure 1) of the VCBL method are considered the "core" of the new methodology. In VCBL, the platform is used as a tool in the active methodology, focusing on discussion of humanized, interactive, clinical cases, first guided by teachers (synchronous mode), then held and reinforced by the students in an inverted class fashion (asynchronous), ensuring a more profound and multistage realistic learning.

This interactive learning software allows virtual, face-to-face or remote contact with a simulated patient during medical history taking, physical examination, complementary tests and decision-making. Virtual physical examination allows simulation of inspection, palpation, percussion, and auscultation of all body systems. Besides, during simulated consultation, the student can suggest diagnostic hypotheses, order and obtain results of complementary tests and plan the most adequate treatment to the case. Likewise, the teacher can use this tool in the steps of tutorial discussion with their students in a synchronous mode.

Self-confidence is considered an indicator of proactivity in clinical situations for a successful outcome. For this reason, professionals must feel confident to act in an assertive way, and avoid unnecessary delays in health care, and increased anxiety and errors.[10,17]

More than 80.0% of the students rated the highest scores (9-10) the learning method used in the course of Cardiology as compared with the method used in previous courses. Nearly 80.0% of students answered to feel "somewhat confident" or "quite confident" in working in outpatient care, and 94.0% classified the content approach strategy in the VCBL as "very good" or "excellent.

Results of the present study corroborate previous scientific studies in which VCBL was used. This strategy promotes the immersion and proximity of the public into the themes and expands the access to health education through real and humanized interactions.[18,19] In addition, 70.0% of students gave positive feedback in the Net Promoter Score to a pilot practical activity of clinical care in which a virtual patient, referred for cardiological symptoms. Both studies confirm that the *Paciente 360* platform is an appropriate teaching model for continuing and humanized medical education in cardiology, as the instrument promoted high degree of satisfaction, perception of knowledge acquisition, and preference for the digital model of clinical case discussion.

Some methodological limitations should be addressed for correct interpretation of our results. Data from the year 2018 were collected retrospectively, and in this period, the only evaluation tool available was the theoretical assessment. In 2019, the same evaluation method was used, but with the addition of instruments on satisfaction and self-confidence. Therefore, we were able to perform comparative analyses and add differential items to this original, VCBL method. Also,

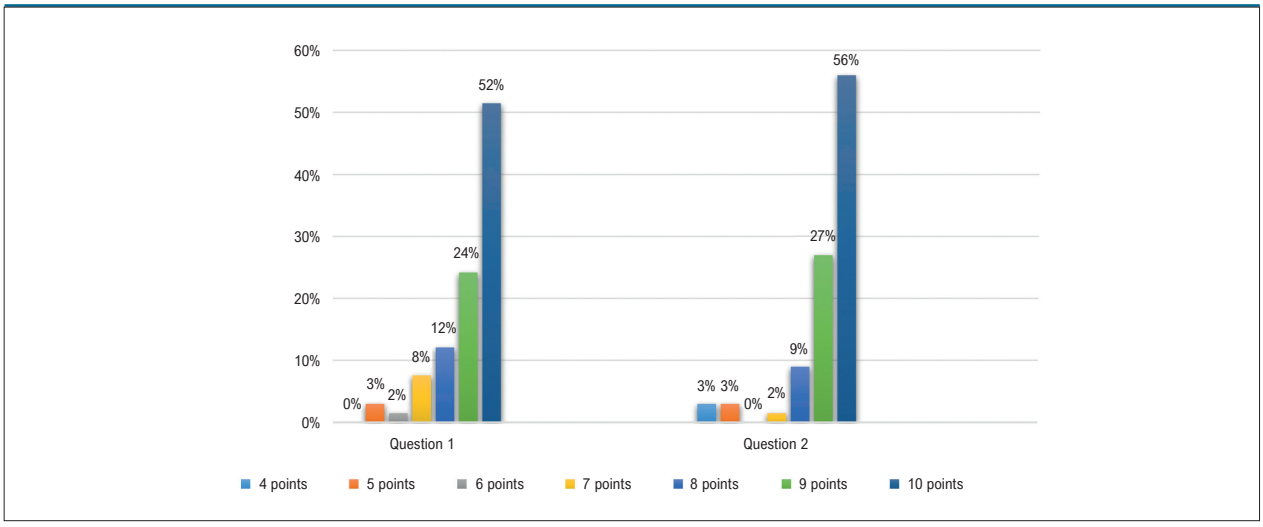

Figure 4 – *Satisfaction ratings to learning progression by medical students, 2019.*

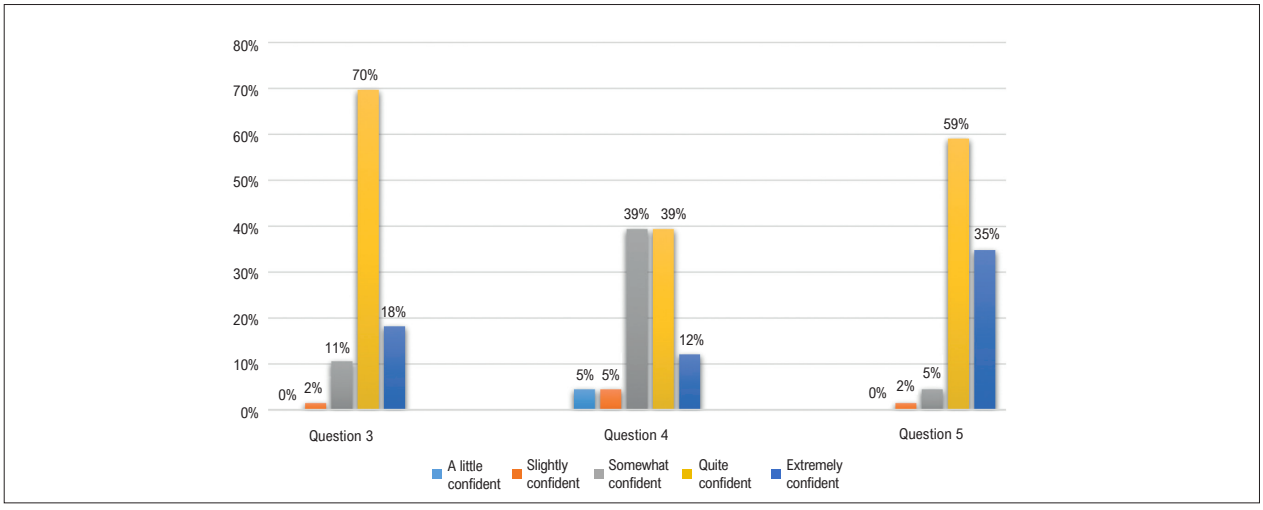

Figure 5 – *Self-confidence about learning progression through the use of the new learning method proposed to medical students in 2019.*

although there is not a direct measure of the contribution of this method to knowledge, since the highest scores may be resultant from other institutional processes, there was a high degree of satisfaction with the platform, and the opportunity of a simulated, realistic and humanized immersion into the cases, possibly responsible for increased engagement and interest by the students. It is also important to mention that the word "humanization" has been considered as a polysemic term in scientific literature, and this new pedagogical strategy may be used with the aim of promoting humanization in Brazilian medical education.

Conclusion

The present study indicated an improvement in the teaching-learning process of medical students after the use of the VCBL model as compared with the traditional PBL method, even with limitations of the study. There was a high degree of satisfaction towards this new platform of active methodology of medical education called *Paciente 360*. This software promoted a humanized, immersive and realistic learning.

Although further research is needed to confirm the efficacy of this learning strategy and tool, we expect that this model, based on active methodology of medical education to the X, Y and Z generations, may foster the implementation of the method and creation of similar ones in different universities. Thus, to help in the construction of better and updated medical curricula, the students should have expanded opportunities to experience a simulated, interactive, digital and humanized type of education.

Conflicts of interest

Manoel Fernandes Canesin, Fabrício Nogueira Furtado, Rodrigo Marques Gonçalves, Diogo Cesar Carraro and Thaísa Mariela Nascimento de Oliveira work at *Active Solutions*, which owns the authorship of the *Paciente 360* platform.

Author Contributions

Conception and design of the research and Acquisition of data: Canesin MF, Furtado FN, Gonçalves RM, Rodrigues R, Fuganti CJ, Mesas CE, Uemura L; Analysis and interpretation of the data: Canesin MF, Furtado FN; Statistical analysis: Furtado FN, Oliveira TMN; Writing of the manuscript: Canesin MF, Carraro DC, Oliveira TMN; Critical revision of the manuscript for important intellectual content: Canesin MF, Furtado FN, Carraro DC, Oliveira TMN.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

This study is not associated with any thesis or dissertation work.

Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

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*Supplemental Materials

For additional information, please click here.

Incor Residency Program in Adult Cardiology in 2022: 40 Years Preparing Cardiologists for the Demands in Brazil

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Abstract

Background: Considering demographic data related to the cardiologist's fields of work in Brazil, the administrative board of the InCor medical residency program decided for an update of its curriculum content, to adapt the educational process to the cardiologist's work reality.

Objective: This article aimed to describe the recent updates applied to the InCor medical residency program.

Methods: In the article, we described the recent updates on the InCor residency program, and compared the current curriculum track with the previous one. We also presented the rationale for these changes, based on the literature on the participation of cardiologists in the labor market.

Results: There was a reduction in the working hours of residents in training in the intensive care unit, and an increase in the outpatient activities of primary and secondary prevention. Also, the didactic content was reformulated and became organized by the corresponding division.

Conclusion: The update of the curriculum track of the InCor medical residency program was required in order to adapt it to the Brazilian labor market. The commission in charge of this update is aware that this is a dynamic process that may need changes over time.

Keywords: Cardiology; Medical residency; Medical Education.

Introduction

Cardiovascular diseases are a serious concern in Brazil and in the world, representing the main cause of death in Brazil, and responsible for a high proportion of health costs. However, a large part of the Brazilian population still does not receive adequate cardiovascular care, due to scarcity of resources and poor training of specialist physicians. A better education of health professionals can help to change this scenario, although understanding the necessary changes in the cardiology fellowship programs is not an easy task.

Drawing a parallel between cardiology residency programs in Brazil and in developed countries can help identify potential improvement targets. However, it is essential to identify the physician's placement and main field of work after graduation, to adapt the process of professional formation to the market reality.

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According to Scheffer et al.,[1] in 2020, there were nearly half million physicians in Brazil, corresponding to 2.4 doctors per thousand inhabitants. Of these, 4.1% (n=17,802) are cardiologists, placing Cardiology among the top ten specialties with the highest number of physicians (8.47 per 100,000 inhabitants). Despite the increasing number of professionals, resulting from the emerging of new undergraduate medical courses, the number of professionals is unequally distributed across geographical regions in Brazil (between urban, peripheral and rural areas) and across the health system (between the private and the public sectors, and between primary, outpatient and hospital care).[1] According to the same study,[1] only 8.16% of professionally active cardiologists have a title of intensive care specialist. Although working shifts in the emergency department and in intensive care units (ICUs) does not require a title of specialist, this may suggest that working shifts in these locations represent only a transitory stage of their professional lives in Brazil. On the other hand, the preference for and the longer duration of internship in emergency medicine, in detriment of other areas, in the cardiology residency program, may not reflect the current professional profile of cardiologists.

In 2017, the Brazilian Cardiology Society (SBC) conducted a survey among its members to identify the

professional profile of cardiologists in Brazil.[2] A total of 2101 physicians filled out the questionnaire; 70.5% had obtained the title of cardiology specialist from the SBC and 29.5% had applied for the title; 49.3% reported to work at three or more different places, and 46.5% reported that the public hospital was the most common place of work. This indicates that the cardiology training program is mostly carried out in public hospital schools, where the physician learns much of the practical aspects of the scenario in which he/she will be probably inserted after finishing the residency. Another cross-sectional observational study[3] involving physicians who graduated from the University of Sao Paulo Medical School showed that more than half of them worked both in the private and the public sectors, and 63.4% worked in private offices and clinics.

This article aims to describe the changes implemented in the medical residency program (MRP) of the Heart Institute (InCor) of the University of Sao Paulo Medical School.

Medical residency program

The Incor MRP was created in 1982, when it was accredited by the Residency Committee (COREME, *Comissão de Residência Médica*). Since then, 796 physicians, coming from all Brazilian federative units, completed the cardiology fellowship program. The curricular track of the Incor MRP comprised, in the first year, of two months of training in urgency and emergency, one month of training in diagnostic methods, and nine months of training in outpatient and inpatient care. The intern passed through the units of atherosclerosis, chronic heart disease, valve disease, heart failure, heart transplant, hypertension, lipids and pacemaker. The second year of the program was comprised of an internship in outpatient care of patients with conditions like arrythmia, cardiomyopathies, aortic disease and congenital heart disease. In addition, there was a great number of activities focused on intensive care – five months exclusively dedicated to the training at the coronary care unit, at the medical ICU and the postoperative ICU. Table 1 exemplifies the curriculum in force until 2021.

Although it is an extremely competent and comprehensive program, the new coordinators of the InCor MRP have decided for an update, considering that it is essential that the curricular content reflects the practice of the contemporary cardiologist in Brazil. This process involved a long period of discussion by the group composed of directors of the clinical units of the institution, including lecturers (listed at the end of this paper) of the University of Sao Paulo who have worked in residency programs for decades.

Then, some change points have been defined: first, it was decided that each stage of the residency would be developed at the respective unit/center to enable better organization and continuity of the topics. This dynamic process would also allow the unification of didactic programs across the centers and the concentration of the main competencies for the interns in each stage. Tables 2 and 3 and Figures 1-4 present an example of the program and competencies defined by the heart valve disease and chronic coronary disease/atherosclerosis centers.

Second, the total workload in intensive care units determined in the fellowship program was considered disproportionate given the actual working participation of cardiologists in this area, and the total of hours the residents spent in the ICU were then reduced. Third, in light of the active participation of cardiologists in outpatient care and considering that it involves strategies of primary and secondary prevention, the division of prevention was created. In this unit, the intern has the opportunity to gain work experience in areas that were not covered by the program so far, such as geriatric cardiology, cardiopulmonary rehabilitation and outpatient screening, in addition to pre-existing fellowship, including lipids, hypertension, smoking, outpatient care of heart disease patients at secondary care level at an external clinic. Figure 5 presents the new curricular program that entered into force in 2022.

Table 1 – Curriculum of the University of Sao Paulo Medical School Institute of Heart (InCor) medical residency program in force until 2021

First year	Second year
Urgency and emergency (two months)	Medical ICU (two months)
Heart valve disease (two months)	Coronary care unit (two months)
Atherosclerosis and chronic coronary disease (two months)	Postoperative ICU (one month)
Artificial cardiac pacing (one month)	Myocardiopathies (one month)
Heart transplant (one month)	Congenital heart disease (one month)
Heart failure (one month)	Clinical arrhythmia (one month)
Graphical methods (one month)	Referral (one month)
Hypertension (15 days)	Elective internship (one month)
Lipids (15 days)	Aortic diseases (15 days)
	Cardio-oncology (15 days)

ICU: intensive care unit.

Table 2 – Didactic training content of the heart valve disease unit

Class number	Class content
1	Diagnosis and management of valve heart disease
2	Pathophysiology of valve heart disease
3	Rheumatic fever
4	Aortic stenosis
5	Aortic insufficiency
6	Mitral stenosis
7	Mitral insufficiency
8	Treatment of tricuspid valve disease
9	Coronary disease and heart valve disease
10	Infective endocarditis
11	TAVI
12	Frailty in patients with heart valve disease
13	Amyloidosis and aortic stenosis
14	Anticoagulation
15	Complications of TAVI
16	Guidelines
17	Review of 120 questions
18	General review

TAVI: transcatheter aortic valve implantation.

Table 3 – Didactic training content defined by the unit of chronic coronary disease/atherosclerosis

Class number	Class content
1	Pathophysiology of the atherosclerotic plaque
2	Interpretation of coronary angiography
3	Fundamentals of pharmacological treatment
4	Reduction of residual risk in diabetics
5	Anticoagulation in CCS
6	Long term antiaggregation in CCS
7	DAPT – selection and duration
8	Uncommon causes of CCS
9	Indications for revascularization
10	Selection of the intervention strategy
11	Chronic coronary syndrome and ventricular dysfunction
12	Investigation and stratification of CCS
13	CCS in special populations
14	Use CCTA and CMR in CCS
15	Stress echocardiography in CCS
16	Nuclear medicine in CCS
17	Reduction of residual lipid risk
18	Rehabilitation in CCS
19	Technical aspects of revascularization surgery
20	Graft selection in revascularization surgery
21	Technical aspects of percutaneous coronary intervention
22	Treatment of refractory angina

CCS: chronic coronary syndrome; DAPT: Dual antiplatelet therapy; CCTA: Coronary computed tomography angiography; CMR: cardiac magnetic resonance

Entry pathways

In Brazil, to become a cardiologist, after graduating from medical school, the physician must complete two years of internal medicine residency, followed by two years of cardiology fellowship. Until 2021 there were two entry pathways in the InCor residency program. The first one was a selection process consisting of an exam that is the same for every clinical specialty of the institution, with a salary predicted for the entire residency period and 28 openings. The second one consisted of a selection process that was exclusive of the Incor. The interns had a lower workload, there were some differences in the rotations and no salary predicted. These physicians who have fully completed their training do not get a certificate in cardiology from the Brazilian National Medical Council, and still have to pass the Brazilian Cardiology Society exam.

Considering the need to homogenize medical residency training at InCor, in 2022, the number of openings increased to 52, as requested and conceded by the Brazilian Ministry of Health and Sao Paulo State's Secretariat of Health. All residents, once passed the exam, follow the same curricular program, and hence other entry pathways were excluded.

Conclusion

To adapt the residency program in cardiology offered at InCor to the labor market in Brazil, we believed that an update of the curricular program was required, focusing on outpatient activities of primary and secondary prevention, which accounts for a considerable volume of the cardiologist practice in the country.

The administrative board of the InCor MPR understands that this is a dynamic process that may need modification. The InCor MRP was already implemented and has been constantly monitored by a commission created in previous years to follow-up and meet the demands of resident physicians and teachers of the program.

COMPETENCIES	LEVEL 1 Observation	LEVEL 2 Supervision	LEVEL 3 Indirect supervision	LEVEL 4 Remote supervision	LEVEL 5 Able to teach
I BASIC ASSESSMENT					
Physical examination of patients with heart valve disease					
Ultrasound as an extension of physical examination in heart valve diseases					
Weekly case presentations and classes					
II CLINICAL ASSESSMENT					
Management of patients with aortic insufficiency					
Management of patients with aortic stenosis					
Management of patients with mitral insufficiency					
Management of patients with mitral stenosis					
Management of patients with tricuspid stenosis					
Management of patients with pulmonary insufficiency					
Management of patients with pulmonary stenosis					
Management of patients with multiple valve disease					
Management of patients with valvular prosthesis					
Management of patients with infectious endocarditis					
Indication and treatment with chronic oral anticoagulation					
III COMPLEMENTARY ASSESSMENT					
Interpretation of ECG in heart valve disease					
Interpretation of chest X-ray in heart valve disease					
Interpretation of stress test in heart valve disease					
Interpretation of cardiopulmonary test in heart valve disease					
Interpretation of transthoracic echocardiogram in heart valve disease					
Interpretation of transesophageal echocardiogram in heart valve disease					
Interpretation of chest tomography in heart valve disease					
Interpretation of cardiac magnetic resonance in heart valve disease					
Interpretation of cardiac scintigraphy in heart valve disease					
Interpretation of hemodynamic parameters on cardiac catheterization					
Interpretation of angiotomography (TAVI protocol)					
Integration of clinical and complementary data					
IV INTERVENTIONAL TREATMENT					
Pre-operative clinical assessment					
Transcatheter treatment of aortic valve disease					
Transcatheter treatment of mitral valve disease					
Surgical treatment of aortic valve diseas					
Surgical treatment of mitral valve disease					
Surgical treatment of other heart valve diseases					
Indication of pacemaker after surgery					
V POST-INTERVENTION CARE					
Pharmacological strategies after the surgical procedure					
Pharmacological strategies after transcatheter procedure					
Management of post procedure arrythmias					
Management of post procedure complications					

Figure 1 – *Competencies pre-established by the division of heart valve disease. TAVI: transcatheter aortic valve implantation.*

	COMPETENCIES	Supervision in the outpatient clinic	Supervision in the ward	Complementary test	Hemodynamics	Surgical center
		Number of patients	Number of patients	Number of patients	Number of patients	Number of patients
I	**BASIC ASSESSMENT**					
	Physical examination of patients with heart valve disease	180	30			
	Ultrasound as an extension of physical examination in heart valve diseases	10				
	Weekly case presentations and classes					
II	**CLINICAL ASSESSMENT**					
	Management of patients with aortic insufficiency	20	3			
	Management of patients with aortic stenosis	40	6			
	Management of patients with mitral insufficiency	30	6			
	Management of patients with mitral stenosis	30	5			
	Management of patients with tricuspid insufficiency	20	4			
	Management of patients with tricuspid stenosis	2	1			
	Management of patients with pulmonary insufficiency	2	1			
	Management of patients with pulmonary stenosis	2	1			
	Management of patients with multiple valve disease	30	6			
	Management of patients with valvular prosthesis	30	10			
	Management of patients with infectious endocarditis	5	5			
	Indication and treatment with chronic oral anticoagulation	40	5			
III	**COMPLEMENTARY ASSESSMENT**					
	Interpretation of ECG in heart valve disease	180	30			
	Interpretation of chest X-ray in heart valve disease	180	30			
	Interpretation of stress test in heart valve disease	5	1			
	Interpretation of cardiopulmonary test in heart valve disease	3	1			
	Interpretation of transthoracic echocardiogram in heart valve disease	180	30	10		
	Interpretation of transesophageal echocardiogram in heart valve disease	20	5	3		
	Interpretation of chest tomography in heart valve disease	50	10	3		
	Interpretation of cardiac magnetic resonance in heart valve disease	10	5	3		
	Interpretation of cardiac scintigraphy in heart valve disease	3	3	3		
	Interpretation of hemodynamic parameters on cardiac catheterization	5	5		2	
	Interpretation of angiotomography (TAVI protocol)	20	10		2	
	Integration of clinical and complementary data	180	30			
IV	**INTERVENTIONAL TREATMENT**					
	Pre-operative clinical assessment	120	30			
	Transcatheter treatment of aortic valve diseas				2	
	Transcatheter treatment of mitral valve disease				2	
	Surgical treatment of aortic valve diseas					2
	Surgical treatment of mitral valve disease					2
	Surgical treatment of other heart valve diseases					1
	Indication of pacemaker after surgery		2			
V	**POST-INTERVENTION CARE**					
	Pharmacological strategies after the surgical procedure	60	30			
	Pharmacological strategies after transcatheter procedure	10	30			
	Management of post procedure arrythmias	10	10			
	Management of post procedure complications	10	10			

Figure 2 – *Estimative of patients seen at the unit of heart valve diseases. TAVI: transcatheter aortic valve implantation.*

COMPETENCIES	LEVEL 1 Observation	LEVEL 2 Supervision	LEVEL 3 Indirect supervision	LEVEL 4 Remote supervision	LEVEL 5 Able to teach
I BASIC ASSESSMENT					
Clinical history and general/specific physical examination in the investigation of CCS					
To master knowledge about pathophysiology, diagnosis and management of CCS					
Weekly case presentations and classes					
II CLINICAL ASSESSMENT					
Investigation of CCS					
Stratification of patients with CCS					
Implementation of a treatment plan in CCS					
Long term follow-up in CCS					
Secondary prevention of CCS patients/reduction of residual risk					
Treatment of diabetes in secondary prevention					
Treatment of dyslipidemia in secondary prevention					
Antithrombotic therapy in CCS					
Management of patients with INOCA					
CCS with left ventricular dysfunction					
CCS in special situations: elderly, AF and CRD					
III COMPLEMENTARY ASSESSMENT					
Interpretation of ECG in CCS					
Interpretation of stress test in CCS					
Interpretation of cardiopulmonary test in CCS					
Interpretation of transthoracic echocardiogram in CCS					
Interpretation of coronary angiotomography					
Interpretation of cardiac magnetic resonance in CCS					
Interpretation of cardiac scintigraphy in CCS					
Interpretation of coronariography in CCS					
Integration of clinical and complementary data					
IV INTERVENTIONAL TREATMENT					
Indications for selection of interventional strategies					
Preoperative clinical assessment					
Management of medications in the perioperative period					
Surgical treatment in CCS					
Percutaneous treatment in CCS					
V POST-INTERVENTION CARE					
Pharmacological strategies after the surgical procedure					
Pharmacological strategies after transcatheter treatment					
Postpericardiotomy syndrome and postoperative AF					
Management of complications after the intervention					
Periprocedural AMI					
VI CLINICAL RESEARCH					
Scientific methodology in CCS					
Relevant clinical studies on CCS and critical analysis					

Figure 3 – *Competencies pre-established by the division of chronic coronary disease/atherosclerosis. INOCA: ischemia and no obstructive coronary artery disease (INOCA); CCS: chronic coronary syndrome; AF: atrial fibrillation; AMI: acute myocardial infarction; CRD: chronic renal disease.*

	COMPETENCIES	Supervision in the outpatient clinic	Supervision in the ward	Complementary test	Hemodynamics	Surgical center
		Number of patients	Number of patients	Number of patients	Number of patients	Number of patients
I	**BASIC ASSESSMENT**					
	Clinical history and general/specific physical examination in the investigation of CCS	180	30			
	To master knowledge about pathophysiology, diagnosis and management of CCS	10				
	Weekly case presentations and classes					
II	**CLINICAL ASSESSMENT**					
	Investigation of CCS	50	5			
	Stratification of patients with CCS	50	5			
	Implementation of a treatment plan in CCS	30	5			
	Long term follow-up in CCS	50				
	Secondary prevention of CCS patients/reduction of residual risk	40				
	Treatment of diabetes in secondary prevention	20				
	Treatment of dyslipidemia in secondary prevention	20				
	Antithrombotic therapy in CCS	20	5			
	Management of patients with INOCA	10				
	CCS with left ventricular dysfunction	20	10			
	CCS in special situations: elderly, AF and CRD	20	5			
III	**COMPLEMENTARY ASSESSMENT**					
	Interpretation of ECG in CCS	180	30			
	Interpretation of stress test in CCS	50	1			
	Interpretation of cardiopulmonary test in CCS	5	1			
	Interpretation of transthoracic echocardiogram in CCS	180	30	10		
	Interpretation of coronary angiotomography	50	20	3		
	Interpretation of cardiac magnetic resonance in CCS	20	5	3		
	Interpretation of cardiac scintigraphy in CCS	50	10	3		
	Interpretation of coronariography in CCS	100	30	3	5	
	Integration of clinical and complementary data	180	30			
IV	**INTERVENTIONAL TREATMENT**					
	Indications for selection of interventional strategies	30	30			
	Preoperative clinical assessment	20	30			
	Management of medications in the perioperative period	30	30			
	Surgical treatment in CCS	20	30			1
	Percutaneous treatment in CCS	20	20		5	
V	**POST-INTERVENTION CARE**					
	Pharmacological strategies after the surgical procedure	30	30			
	Pharmacological strategies after transcatheter treatment	20	20			
	Postpericardiotomy syndrome and postoperative AF	20	10			
	Management of complications after the intervention	20	10			
	Periprocedural AMI	10	20			
VI	**CLINICAL RESEARCH**					
	Scientific methodology in CCS	10	10			
	Relevant clinical studies on CCS and critical analysis					

Figure 4 – *Estimative of patients seen at the unit of chronic coronary disease/atherosclerosis. INOCA: ischemia and no obstructive coronary artery disease; CCS: chronic coronary syndrome; AF: atrial fibrillation; CRD: chronic renal disease.*

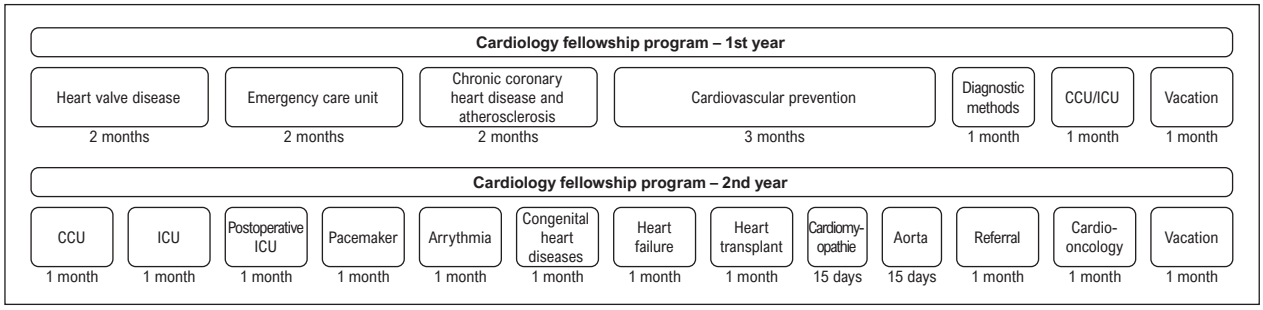

Figure 5 – *Curricular program of the Incor residency program implemented in 2022. ICU: intensive care unit; CCU: coronary care unit.*

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Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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This article does not contain any studies with human participants or animals performed by any of the authors.

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