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REVIEW ARTICLE

Training in imaging. Challenges

Formación en imagenología. Desafíos

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Abstract

This is a review of concepts about the training required to perform with dignity in a very varied and dynamic specialty such as imaging. The text is prepared with the understanding that the term "training" is broader than specific training for the use of imaging techniques. Training includes, in addition to technical training, a set of skills and attitudes that will allow the imaging physician to prioritize his contributions to health care and prioritize the specialty as a whole. Thus, the review concludes that there are five fundamental aspects that must be included in the training of the imaging physician: technical training (appropriate use of imaging techniques), integration on equal terms into multidisciplinary teams in the various areas of medicine, the hierarchization of the doctor-patient relationship, learning from mistakes and adaptation to working together with artificial intelligence. Each of these concepts is developed in the text.

Keywords: *Imaging. Training. Capacity building.*

Resumen

Se trata de una revisión de conceptos acerca de la formación requerida a los efectos de desempeñarse dignamente en una especialidad muy variada y dinámica como lo es la imagenología. El texto está elaborado en el entendido de que el término «formación» es más amplio que la capacitación específica para el uso de las técnicas de imagen. La formación incluye, además de la capacitación técnica, un conjunto de aptitudes y actitudes que permitirán al médico imagenólogo jerarquizar sus aportes a la atención sanitaria y a la especialidad en su conjunto. En la revisión se llega a la conclusión de que hay cinco aspectos fundamentales que deben incluirse en la formación del médico imagenólogo: la capacitación técnica (uso adecuado de las técnicas de imagen), la integración en igualdad de condiciones a los equipos multidisciplinarios en las diversas áreas de la medicina, la jerarquización de la relación médico-paciente, el aprendizaje a partir de los errores y la adaptación a trabajar en conjunto con la inteligencia artificial. En el texto se desarrollan cada uno de esos conceptos.

Palabras clave: *Imagenología. Formación. Capacitación.*

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Introduction

Imaging is a medical specialty which is based on the analysis of morphological and functional data provided by images of the human body, obtained through ionizing radiation or other energy sources. The specialty also includes image-guided interventional procedures for diagnostic or therapeutic purposes[1].

It is a clinical-imaging specialty, as it involves the evaluation of the patient's clinical problem and its association with the data provided by the images. Furthermore, it is a multifaceted specialty due to the variety of imaging technologies used, each with specific indications, objectives and limitations, constantly evolving with technological advances.

In this article, we will analyze education in imaging, identifying the main challenges for the specialty, taking into account that education and training, although related concepts, have different approaches and objectives.

Education is a process that seeks the integral development of the individual, encompassing theoretical knowledge and general skills that will serve them throughout their lifetime or career. Training has a more specific and practical focus, and is aimed at improving the skills necessary to perform a specific task or function.

Due to all the characteristics mentioned in relation to imaging, it is difficult to analyze education in this specialty. The analysis must be considered from several perspectives: in what is strictly related to technical training (appropriate use of imaging techniques), in its integration with the rest of clinical medicine, in the context of the doctor-patient relationship, in the learning that is possible from mistakes made, and in its capacity to adapt to artificial intelligence (AI), with its potential to profoundly change the specialty.

In this article, we will develop concepts related to each of the aforementioned areas.

Technical training in imaging

The European Training Curriculum for Radiology defines a 5-year educational period, consisting of Level I education during the first 3 years, followed by a more flexible Level II program with potentially special interest rotations (electives) during the last 2 years[1]. According to this program, it is established that Level I should provide a knowledge of normal imaging anatomy and physiology; physical bases of image formation in all techniques; Picture Archiving and Communication Systems (PACS); radiological and hospital information systems, quality control and management; radiation physics, radiation biology and medical radiation protection, and techniques related to radiological procedures. Knowledge should also be acquired in pharmacology, contrast media applications and management of adverse reactions to these; basic aspects of computer science; fundamentals of clinical research, statistics and evidence applied to radiology; and radiological research.

The aforementioned concepts should be incorporated into the following radiology fields, which should be taught during the Level I education: breast imaging, cardiac and vascular radiology, chest radiology, emergency radiology, gastrointestinal and abdominal radiology, gynecological and obstetric radiology, head and neck radiology, interventional radiology, musculoskeletal radiology, neuroradiology, pediatric radiology, urogenital radiology, basic education in nuclear medicine, education and training in medical radiation protection, principles of image technology and acquisition, and molecular imaging, communication and administration, research and evidence-based medicine.

For Level II (years 4 and 5), the European Training Curriculum for Radiology promotes increased education in specific areas of interest while recognizing that the general competencies should also be maintained for subspecialist radiologists. Education during this period can be applied to two areas of interest among the aforementioned fields of radiology.

The European Training Curriculum for Radiology also establishes a Level III education/training, which is a full immersion in a radiological subspecialty after the completion of Levels I and II.

In Uruguay, training in the imaging specialty lasts four years[2]. The objectives of the first year are to understand the physical fundamentals of each of the diagnostic imaging methods, their indications, scope, limitations, and contraindications, radiological anatomy, the use of contrast media and their indications, adverse effects and contraindications. It also includes diagnostic imaging in emergency situations. The postgraduate program must support the preparation of imaging reports by the other physicians on the team. The second-year objectives are diagnostic imaging in oncology and in the most common cardiovascular, inflammatory, infectious, immune system, and congenital diseases. In the postgraduate program students are required to learn how to prepare an imaging report, always supervised by the rest of the department's teaching staff. The objectives of the third and fourth years are to complete the study of diagnostic imaging in less prevalent conditions and in more complex studies and treatments, as well as to train in the performance of interventional diagnostic and image-guided treatment procedures. The postgraduate student must be able to correctly prepare a report, receiving assistance from the rest of the team only upon request. Students will rotate for two months in each of the specialty's sections: digestive system, cardiothoracic, musculoskeletal, genitourinary, breast, ultrasound and Doppler ultrasound, computed tomography and magnetic resonance imaging of the body, neuroimaging, vascular, and pediatric imaging. The following complementary activities are planned: computer science, online bibliography, healthcare informatics, clinical epidemiology, statistics, and research methodology. In addition, a minimum of one on-call shift per week is included throughout the course.

Integration of imaging into clinical medicine

Imaging is currently an essential part of clinical medicine, and as its capabilities increase, the diagnosis and treatment of diseases have increasingly come to depend on imaging findings.

Medical images are also an important input in the prevention (screening programs), in the follow-up of treated patients, and in assessing the prognosis of many diseases. Furthermore, image-guided interventions can resolve pathologies, reducing morbidity and healthcare costs.

As an adverse effect, imaging requests without appropriate criteria often replace a correct clinical evaluation of the patient. Images are requested before patients are fully clinically evaluated, and the reports often replace clinical judgments, generating a demand for studies and reports that is sometimes unsustainable[3].

As a result, many "clinical" physicians develop the perception that imaging specialists work for them as providers of imaging reports, somewhat removed from direct patient care and interaction, and they do not consider them members, on an equal footing, of the multidisciplinary team. This underestimation is partly due to the attitude of many imaging specialists, who tend to remain isolated in the reporting rooms without adequate interaction with colleagues from other specialties or with patients. Imaging specialists need to prioritize their contributions to the patient care process, becoming an active member of the multidisciplinary teams.

The problem is that, given the broad and diverse nature of imaging, it is impossible for imaging specialists to integrate on equal terms into multidisciplinary teams in any area. This is when the need arises for the imaging specialist to further his/her training in a specific area of imaging (e.g., breast, neuro, musculoskeletal, thorax, body, etc.). In each area, they must master all imaging techniques and, in addition, must incorporate knowledge from other related disciplines. Only with this training will they be able to interact on equal terms with the clinical physician and be an important factor in resolving the patient's problem.

It is necessary to emphasize the importance of this subspecialization so that the doctor can integrate into multidisciplinary teams and his/her work can be prioritized. If the imaging specialist, in each area, does not have full knowledge of the diseases to be treated, the relevant clinical issues, and the impact of imaging findings on treatment selection, their contribution will be insignificant. As an example, it often occurs that an orthopedic surgeon can obtain more relevant information for diagnosis and treatment planning from a knee MRI than is found in the imaging report. This situation diminishes the prestige of imaging as a specialty and creates an environment conducive to the mastering of images becoming the responsibility of another specialty.

Imaging specialists must also enhance their communication skills with colleagues and serve as the reference point for consultation regarding the selection of the most appropriate imaging method to address a given clinical problem. By combining the ability to interpret images with an understanding of the clinical management of diseases, imaging specialists can add significant value to the patient's care[4-6].

It is also important that, within each imaging subspecialty, imaging specialists increase their training and experience in performing interventional procedures for diagnostic or therapeutic purposes, acting as the reference point and consultant for the undertaking of these procedures.

Postgraduate and residency programs should modify their curricula to adapt to these changes, accepting that it is essential that knowledge related to medical imaging be accompanied by a solid foundation in related disciplines (e.g., clinical practice, pathology, surgery, or oncology).

In addition, there are other actions that can be taken to facilitate the integration of imaging specialists into a multidisciplinary environment:

- Regular multidisciplinary meetings in which the imaging specialists actively participate in the discussion of complex cases together with attending physicians, surgeons, oncologists, etc.
- Rotations and cross-internships that allow imaging specialists to observe clinical and surgical procedures to understand the context of their work, and for clinicians to participate in image interpretation sessions.

– Encourage the participation of imaging specialists in multidisciplinary publications and research projects.

Imaging and the doctor-patient relationship

During the 21st century, there has been great progress in technology applied to medicine, primarily in the field of imaging, and such precision in diagnosis and treatment has never been achieved before. However, this process is accompanied by risks, such as the depersonalization of medical care, overdependence on technology, and the loss of clinical skills.

To counteract these risks, the concept of "humanizing medicine" is gaining ground, which involves minimizing the tendency to treat the patient as if they were an object, a simple illness, or specific symptoms, and remembering that behind every illness there is a person.

Imaging centers are places where patients undergo more or less aggressive diagnostic tests, which generate stress, uncertainty, and a need for information, and it is in these conditions that the opportunity arises for the imaging specialist to emerge from their isolation and become involved in the process of humanizing medicine.

In the current care model, clinical physicians can see their patients' images even before the report has been completed, and they are the ones who communicate the results. They often don't even believe the imaging specialists or don't fully understand or see the reported findings, and they rarely have time to review the images with patients.

Because imaging specialists have limited contact with patients, they are physically invisible to them, and their role as doctors also remains hidden from the majority of patients[7]. Furthermore, imaging specialists typically lack consultation rooms where they can speak with patients before or after examinations, nor are there any scheduled appointments in their daily schedules for such activities.

It is clear that the imaging culture, which until now has lacked a patient-centered approach, needs to be restructured, rejecting the perception that imaging specialists are simply physician-to-physician consultants and seeking greater interaction with patients[8,9].

Without a doubt these changes are not easy to implement due to the high demand for imaging studies and the usual overload of schedules, but it is advisable for those responsible for managing the work in imaging centers to consider including times and spaces for the imaging specialist to interact with patients in a private environment. In these instances, the specialist could provide the necessary information so that the patient can understand the objectives of the study, be aware of any eventual adverse effects of this, and ask questions about any concerns they may have about the procedure. Furthermore, after the corresponding study is performed, these instances can be used to communicate and explain the results if relevant findings are detected, considering that the imaging specialist is the most qualified for this task, ensuring that the patient understands the situation and raises any questions they may have.

The aforementioned are concrete initiatives to humanize medicine available to imaging specialists, which contribute to reducing patient stress and uncertainty.

Learning from errors

Many errors in the healthcare process can be attributed to flaws in image analysis[10], so it is important to learn about the types of errors that can occur, understand the mechanisms that lead to the error, and know what can be done to prevent or reduce the likelihood of their occurrence.

To understand the nature of imaging errors, it is necessary to review the image analysis process. The specialist interpreting an image extracts characteristics that they consider important (perceptual process), then analyzes these characteristics against reference standards learned during training or work experience (cognitive process), which leads them to develop a diagnostic hypothesis, and finally writes a study report (motor process)[11,12]. Errors in imaging can occur at any of these stages: perceptual errors, cognitive errors, and motor errors (Table 1)[10,11,13,14].

There are multiple factors that can contribute to the occurrence of errors in imaging, including work overload (causing fatigue, stress, and distractions), an inadequate environment for image analysis (excessive brightness, noise, inadequate temperature, excessive foot traffic), a lack of previous studies for comparison, insufficient clinical information, training deficiencies, and the inherent limitations of human perception.

It is also necessary to mention cognitive biases as error generators, these being psychological effects that produce a deviation in mental processing that leads to a distortion, an inaccurate judgment, or an illogical interpretation. There are several of these in imaging, and the most relevant ones are presented in table 2.

There are several actions that can be taken to learn from errors and simultaneously try to reduce their frequency:
- Select clinical cases in which errors were observed to discuss them as a group, not with a punitive spirit, but to identify what factors contributed to the error and design improvement strategies. It would be important for these meetings to be multidisciplinary to analyze how a lack of information or communication could have contributed to the error.
- Organize periodic meetings in which radiologists review their colleagues' interpretations to discuss findings, develop analysis and reporting protocols, and create a record of common errors and strategies to avoid them.
- Provide ongoing training, preferably multidisciplinary.
- Human factors attention: occupational health or mental health interventions, rest periods, avoiding schedule overload, etc.
- Conducting internal and external audits.
- Adaptation of the environment where the reports are made, a quality assurance program for studies, correct visualization systems, and AI support.

Adaptation to artificial intelligence in imaging

AI is a discipline that focuses on the creation of computer systems or combinations of algorithms that can perform tasks common to human intelligence, such as the ability to learn, solve problems, make decisions, and communicate in a manner similar to that of humans[15].

Within AI applied to medicine, there is a significant development of this technology in the field of diagnostic imaging, due to the characteristics of the medical imaging analysis process, which involves a series of steps that can be efficiently imitated by algorithms.

The development of AI is changing the way imaging is done, and imaging specialists need to be trained in this to remain current and maintain control over the imaging process, rather than becoming a mere accessory to the technology.

In 2021, a systematic review of AI applications in the imaging domain was published, including information from major global congresses (Radiologic Society of North America, European Congress of Radiology, Society of Imaging Informatics in Medicine) and market survey reports (technical blog posts, news, and articles)[16].

When the applications were classified according to their functionalities, it was observed that the majority of these (87%) focused on tasks grouped as "perception" and "reasoning," that is, related to assisting the specialist in interpreting images (interpretive functions). The development of these algorithms for cancer diagnosis is highlighted in several areas, and several publications report improved diagnostic performance with human review combined with AI algorithms[17,18].

Table 1. Types of imaging errors and their consequences

Type of error	Main characteristics	Relevant consequences
Perceptual error	There is a visible abnormality in the image that is not detected by the imaging specialist	Failure to dectect a tumor Disease progression without treatment
Cognitive error	This occurs when abnormal imaging findings are identified, but the physician draws incorrect conclusions	Over- or under-evaluation of a pathology Inadequate treatments
Motor error	This is a failure in one of the document management phases of the report	Incorrect identification Incomplete report Lateralization error, etc.

There are also other applications, called "non-interpretive," that perform a series of tasks relevant to the diagnostic imaging process, although not strictly linked to lesion detection[19], such as image processing and quality, radiation dose, improved radiology reports, improved workflow, and radiomics. We highlight the contribution of radiomics, which aims to find associations between qualitative and quantitative information extracted from medical images and clinical, laboratory, genomic, or other data, to support evidence-based clinical decision-making[20].

In the process of adapting to changes driven by AI, it is necessary to define where to direct the greatest efforts, since in the areas of detection, segmentation, classification, and quantification, imaging specialists have no chance of competing. However, in the area of inference, a process that involves integrating image data with concepts from different scientific fields and clinical specialties, we are still superior to machines and could still prevail if we work in that direction.

Some relevant AI items that imaging specialists should be trained in are:
- Basic concepts: understand what AI, machine learning, and deep learning are, and become familiar with convolutional neural networks (CNNs), which are essential for medical imaging analysis.
- Image segmentation and analysis: use of algorithms to identify specific regions, such as tumors or lesions.

Table 2. Cognitive biases and their characteristics and consequences

Cognitive bias	Main characteristics	Consequences
Tunnel vision	The imaging specialist identifies an obvious finding, focuses on it, and ignores other additional lesions.	Perception error
Search satisfaction	The imaging specialist finds an abnormal finding, consistent with their initial hypothesis, feels "satisfied" with the finding, and stops looking for other possible abnormalities.	Perception error
Alliterative error	Uncritically relies on the previous report.	Perception error Cognitive error
Anchoring bias	The imaging specialist remains fixed on their initial diagnostic impression, even when there is information that points to the contrary.	Cognitive error
Confirmation	Searching for data to confirm a specific hypothesis instead of searching for data that support an alternative hypothesis.	Cognitive error
Availability	Tendency to consider a known diagnosis first, either because it was recently studied or because a previous error was made in that specific pathology.	Cognitive error
Statistical	Tendency to affirm the most common diagnosis and omit a rare diagnosis, even when there is data that points in that direction.	Cognitive error
Conditioning	When the way a clinical problem is framed influences the imaging specialist.	Cognitive error
Attribution	All imaging findings are attributed to an underlying pathology	Cognitive error

Understand how algorithms can detect pathologies and correlate images with clinical outcomes.

– Interpretation of results: knowing how to read metrics such as sensitivity, specificity, receiver operating characteristic (ROC) curves, area under the curve, and others.
– Limitations and biases: identifying potential biases in training data and the risks of implementation in clinical practice.
– Ethical and regulatory aspects: data privacy (understanding regulations regarding secure data handling), familiarizing yourself with the approval requirements for AI tools, and understanding how to assume responsibility when an AI tool makes an error.

It is also worth mentioning that new roles may emerge for imaging specialists during AI implementation, and they must be prepared to work collaboratively with engineers.

Algorithms must be trained before being incorporated into clinical practice, for which training data sets (images) must be created, specific to each technique in which the algorithm will operate. Images must be anonymized and labeled (indicating a correct diagnosis, for example), and as data is added to the training set, the system increases the accuracy of its predictions (it learns)[21].

There must also be a validation data set used to monitor model performance during the training process. This stage will provide insight into the potential value of the algorithms in a clinically realistic setting.

After validation, the model must be exposed to a test dataset, this time unlabeled, which should provide information on the algorithm's expected accuracy. Finally, the system must be tested in a real clinical setting, different from the one in which it was trained, to evaluate its robustness to technical, geographic, and population variations. Generalization refers to the ability of an algorithm to be applied in different clinical settings.

Imaging specialists, together with engineers, can play a relevant role in the training, validation, and testing processes.

Conclusions

Imaging is an extremely diverse and dynamic specialty that constantly evolves, hand in hand with technological advances. Imaging specialists must be able to adapt to changes, maintain control of imaging processes, and remain current by making valuable contributions to healthcare of the patient.

Education is understood as a broad process that seeks the integral development of the individual. It encompasses theoretical knowledge (training) for specific tasks, but also the general skills and attitudes that will be useful throughout the entire professional career.

Based on what we have analyzed in this text, it can be concluded that there are five fundamental aspects that should be included in the education of imaging specialists: technical training (appropriate use of imaging techniques), integration on equal terms into multidisciplinary teams in the various areas of medicine, hierarchization of the doctor-patient relationship, learning from errors, and adapting to working together with AI.

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Ethical considerations

Protection of humans and animals. The authors declare that no experiments involving humans or animals were conducted for this research.

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