The adoption of AI in clinical practice – Exploring neuroradiologists' perceptions and perspectives

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Abstract

Title: The adoption of AI in clinical practice – Exploring neuroradiologists' perceptions and perspectives

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As the world population ages, the prevalence of chronic health conditions increases, and healthcare faces an ever-growing demand for services with progressively higher costs. This is particularly concerning for non-communicable diseases such as neurological disorders, which are a known burden of mortality, morbidity and disability.

In neuroradiology, as in other medical fields, Artificial Intelligence (AI) has the potential to unlock cost reduction while simultaneously improving the efficacy of health services. However, despite the existence of numerous AI applications in healthcare, its adoption by healthcare institutions is still in its infancy and heavily dependent on health professionals' acceptance and expectations towards AI.

In this dissertation, the perceptions and perspectives of neuroradiologists towards the adoption of AI in clinical practice are explored. An online survey conducted collected responses from 184 neuroradiologists and showed that the use of AI is still low and that AI-specific knowledge is limited. Despite showing an overall positive attitude towards the use of AI, neuroradiologists are primarily concerned about technological malfunctions and lack of regulation. Results show a positive association between AI knowledge and a positive attitude towards its use. On the other hand, a negative association was found between AI knowledge and fear towards it. No significant relationship was found between age and AI use.

Reassurance through providing explanation and validation of new technologies, suitable working conditions, and the creation of a robust legal framework are possibilities in the making to raise trust, provide encouragement, and establish AI readiness.

Keywords: Artificial Intelligence; Healthcare; Neuroradiology; Applications; Technology Acceptance Models; Clinical practice.

Resumo

Título: A adoção de IA na prática clínica – Exploração das perceções e perspetivas dos neurorradiologistas

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Com o envelhecimento populacional, as doenças crónicas aumentam e a saúde enfrenta uma procura cada vez maior pelos seus serviços, com custos progressivamente mais elevados. Isto é particularmente preocupante nas doenças não infeciosas, como as doenças neurológicas, que contribuem decisivamente para a mortalidade, morbilidade e incapacidade.

Na neurorradiologia, como em outras áreas médicas, a Inteligência Artificial (IA) tem o potencial de reduzir custos e melhorar a eficácia dos serviços de saúde. Contudo, apesar das inúmeras aplicações de IA, a sua adoção pelas instituições de saúde é baixa e depende fortemente da aceitação e expectativas dos profissionais de saúde.

Nesta dissertação, exploramos as perceções e perspetivas dos neurorradiologistas em relação à adoção de IA na prática clínica. Um questionário online realizado a 184 neurorradiologistas mostrou que o uso de IA é baixo e que o conhecimento de IA é limitado. Apesar de haver uma atitude geral positiva em relação ao uso de IA, os neurorradiologistas estão preocupados com problemas tecnológicos e a falta de regulamentação, entre outros. Os resultados indicam uma associação positiva entre o conhecimento de IA e uma atitude positiva em relação ao seu uso. Por outro lado, foi encontrada uma associação negativa entre o conhecimento de IA e o medo de IA. Nenhuma relação significativa foi encontrada entre a idade e o uso de IA.

Assegurar a explicação e validação de novas tecnologias, criar condições de trabalho adequadas e desenvolver uma estrutura legal robusta são requisitos em desenvolvimento para assegurar a diligência no uso de IA.

Palavras-chave: Inteligência Artificial; Cuidados de Saúde; Neurorradiologia; Aplicações; Modelos de Aceitação Tecnológica; Prática clínica.

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List of Abbreviations

AI – Artificial Intelligence

AIM – Artificial Intelligence in Medicine

DL – Deep Learning

EE – Effort Expectancy

EMR – Electronic Medical Record

FC – Facilitating Conditions

ML – Machine Learning

NCD – Non Communicable Disease

NLP – Natural Language Processing

PE – Performance Expectancy

PEU – Perceived Ease of Use

PU – Perceived Usefulness

SI – Social Influence

TAM – Technology Acceptance Model

TOE – Technology-Organizations-Environment

UTAUT – Unified Theory of Acceptance and Use of Technology

0. Introduction

The world population is aging. In public health, there are several challenges resulting from this demographic change. One major issue concerns the expected increase in the prevalence of many chronic health conditions, which reduce the quality of life (World Health Organization, 2006). This is particularly concerning for non-communicable diseases (NCDs), which are currently "responsible for 80% of the disease burden in the EU countries and the leading causes of avoidable premature deaths" (European Commission, n.d.)

Neurological disorders are NCDs that affect the central and peripheral nervous system, namely the brain, spinal cord, nerves, and muscles (World Health Organization, 2006). Some examples include dementias such as Alzheimer's disease, epilepsy, stroke, and other cerebrovascular diseases, migraine, multiple sclerosis, Parkinson's disease, brain tumors, and traumatic disorders, among others (World Health Organization, 2016).

Neurological disorders are responsible for 12% of deaths globally (World Health Organization, 2006). These diseases are equally known for their high impact on disability and dependency. For this reason, it can be considered that the measures of prevalence fail to accurately represent the burden caused by these diseases (OECD, 2017). Furthermore, it is expected that in future years with global growth and aging, this burden will only increase, aggravating human and financial costs (Feigin et al., 2019; World Health Organization, 2006).

The diagnosis of neurological disorders can be challenging, especially when clinical manifestation is common to different diseases (Arani et al., 2018; Tolosa et al., 2021). Neuroimaging techniques allow doctors to study the brain's structure and function, being an important tool for diagnosis, prognosis, and monitoring of neurological conditions (Middei, 2022). However, such techniques are expensive (Neiman Institute, 2012; Sailer et al., 2015) and time-consuming, as they produce large amounts of data that must be manually analyzed by neuroradiologists, among other medical specialists (Lima et al., 2022; Siuly & Zhang, 2016).

Artificial Intelligence (AI) is an expanding field with numerous applications in neuroradiology. The large amount of data generated in health, as well as the increasing computational power available, open a window into the possibility of an AI revolution in healthcare (Zaharchuk et al., 2018). Expectations for AI in healthcare are tremendous, as it is expected to unlock improved efficiency in care delivery while saving costs (Accenture, 2017; Mckinsey, 2020; PWC, 2017).

Despite the continuous emergence of new AI solutions for healthcare, it seems that their adoption is not keeping up the pace and that implementation issues require addressing (Huisman et al., 2021; Shaw et al., 2019). End-users of AI-based digital solutions, such as neuroradiologists, are expected to adopt new technologies and integrate them into their workflow. Thus, the successful implementation of an AI strategy is heavily dependent on the attitudes influencing the acceptance of AI solutions (Lichtenthaler, 2020).

Previous research has started to look into this matter by studying radiologists' thoughts and expectations regarding the use and future of AI. However, some studies failed to measure previous knowledge on AI, thus leading to results that might fall short (Coppola et al., 2021; European Society of Radiology, 2019). On the other hand, most studies employed general questions about AI without resorting to practical examples, which might have biased the results, as well as excluded some radiologists less familiar with the topic from participating (Huisman et al., 2021; Waymel et al., 2019). Lastly, none of the studies explored findings through the lens of technology acceptance models, which might be a relevant feature for analyzing the perceptions and expectations that may condition the adoption behavior.

The aim of this research is to explore the perceptions and perspectives of neuroradiologists towards the adoption of AI in clinical practice. In the scope of analysis, we try to answer three research questions, with hypotheses regarding the influence of age on AI use and the impact of AI knowledge on the predisposition towards its use. This research is mainly descriptive and uses a quantitative method via survey employment to characterize and understand trends in neuroradiologists' viewpoints towards AI adoption. This broad picture of the phenomena can be relevant for institutions trying to implement AI in their services by providing insights on potential challenges and contributing to well-informed decision-making.

The chosen methodology will contribute to addressing some of the shortcomings described in existing literature through the employment of a survey that is based on technology acceptance models, assesses previous knowledge of AI, and includes practical example illustrations to encourage participation, even from the participants that are less familiar with AI.

1. Literature Review

1.1.Artificial Intelligence

Artificial Intelligence (AI) is an umbrella term covering different techniques in which machines are able to mimic human cognition, such as learning or problem solving (Chartrand et al., 2017; Kaplan & Haenlein, 2019; Krittanawong et al., 2017; Pesapane et al., 2018; Vaishya et al., 2020).

Despite many authors' attempts to describe AI, there is still no consensual definition. For the purpose of this work, the definition chosen is the one given by the European Commission, in which AI refers to "systems that display intelligent behavior by analyzing their environment and taking actions – with some degree of autonomy – to achieve specific goals" (European Commission, 2018). Moreover, "AI-based systems can be purely software-based, acting in the virtual world (e.g. voice assistants, image analysis software, search engines, speech and face recognition systems) or AI can be embedded in hardware devices (e.g. advanced robots, autonomous cars, drones or Internet of Things applications)" (European Commission, 2018).

AI can be thought of as a prediction technology. According to Agrawal et al. (2018) prediction is the process of filling in missing information using the existing data to generate new information. Shaw et al. (2019) take this framing a step further, mentioning the potential involved in predicting estimations of the true information that is missing, which translates into taking actions based on more accurate information.

There is usually no single right answer for which is the best AI tool or strategy to apply, as there is always some sort of trade-off involved (Agrawal et al., 2018). In fact, the perceived value of using AI tools is based on the trade-off between the potential benefits and risks involved. Thus, when benefits are higher than the expected risks, the perceived value of using such tools is greater (Esmaeilzadeh, 2020). Popular AI techniques in healthcare applications include, among others: Machine Learning (ML), Deep Learning (DL), and Natural Language Processing (NLP).

NLP is an AI subfield that focuses on extracting useful information from narrative text to machine-understandable data, so that AI algorithms can be directly performed (He et al., 2019; Jiang et al., 2017).

ML is a subfield of AI in which algorithms are trained to learn from data without explicit programming, in an attempt to optimize a prediction algorithm between inputs and outputs (Chartrand et al., 2017; He et al., 2019; Pesapane et al., 2018). Inputs in healthcare may include patient data, such as age, gender, or relevant clinical information, whereas outputs may be the desired medical outcomes (Jiang et al., 2017). DL is a technique inside the ML field where "multiple processing layers are used to learn representations of data with multiple layers of abstraction" (He et al., 2019b, p.31).

From manufacturing robots to smart assistants, AI has become an essential component of how firms operate in several industries and its transformative potential is gradually reshaping how business is done. As tasks that were once exclusively performed by humans can now be accomplished by machines, sometimes in a faster, better, and more efficient way (Gursoy et al., 2019; Kaplan & Haenlein, 2019), companies are faced with the decision of integrating AI into their business strategy.

1.2.AI in Healthcare

Artificial Intelligence in Medicine (AIM) can be traced back to the early 1970s (Szolovits, 2019), with some researchers already predicting a major disruption in the healthcare system following the introduction of computers in the field (Schwartz, 1970). In fact, by that time, Schwartz (1970) forecasted the possibility that computers could radically change the role of doctors, as well as their education and the nature of medical recruitment.

The emergence of AIM was linked to a response to the progressively pressuring needs in healthcare, namely, the demand for improved efficiency and better-quality services. On the other hand, the intensifying shortage of medical manpower, aligned with the unbalanced geographic distribution of the available physicians, contributed to this growing problem (Schwartz, 1970; Szolovits, 2019).

As modern medicine evolves, life expectancy around the world has improved substantially, and the pressure on healthcare systems is higher than ever as they struggle to respond to an ever-growing demand for their services (Mckinsey, 2020). Bearing this in mind, it becomes evident that despite the huge increase in medical complexity and the standards set for it, the cognitive capabilities of physicians remain relatively fixed, creating a big challenge in terms of delivering the best care (Szolovits, 2019).

From a managerial point of view, there are also concerns regarding the progressively higher costs associated with providing increasingly better services to a growing population. According to several renowned consulting companies, AI has the power to unlock major costs reduction while simultaneously improving quality and access to health services (Accenture, 2017; Mckinsey, 2020; PWC, 2017). Furthermore, the increasing availability of large digital datasets and the developments made in computing power make it possible for this paradigm shift to take place in healthcare (Allen et al., 2019; Jiang et al., 2017; Kulkarni et al., 2020).

The advantages of AI are a widely discussed topic in medical literature. Through AI algorithms, machines can be trained and learn from health data to obtain relevant insights, even in situations where the human observer would not be able to obtain them (He et al., 2019; Jiang et al., 2017).

When applied to the medical field, AI tools can perform a wide range of functions, assisting doctors in clinical decisions such as diagnosis, prioritizing tasks, treatment protocols, or risk prediction (Ramesh et al., 2004; Rong et al., 2020). In some cases, AI may perform tasks in a faster, more consistent, and more accurate way than physicians. This means that automating specific tasks might be the key to reducing medical error and improving productivity as well as allocation of human capital, especially when tasks are low in complexity but very time-consuming (He et al., 2019; Rong et al., 2020).

As machines may potentially outperform humans in routine tasks, speculation grows on whether doctors will be replaced by AI (Bluemke, 2018; Yu et al., 2018). However, despite the overall excitement around the potential of these emerging technologies and their current applications, it is most likely that AI will augment physicians' capacities instead of fully replacing them (He et al., 2019; Jiang et al., 2017; Shaw et al., 2019). This happens because most AI tools are designed to undertake a specific task rather than an entire job position. Indeed, the full replacement of a healthcare professional would imply that every single task of that specific position would be automated or allocated to another human (Shaw et al., 2019).

Healthcare providers and professionals may need to prepare for a future in which the workforce will see a synergy between man and machine, and new "hybrid" roles will most likely emerge (Jha & Topol, 2016; Mckinsey, 2020).

Although this synergy is still far from reality, current intelligent technologies in healthcare are living proof that the sector is experiencing the impact of AI. From wearable devices that monitor patients' sleep patterns and heart rate to algorithms that can successfully identify abnormalities in medical imaging and robotic arms used in surgeries, AI applications can be integrated into every stage of health prevention, regardless of whether they are more patient or clinician centered.

Healthcare needs to be safe, effective, equitable, patient-centric, timely, and efficient (Institute of Medicine, 2001) and in most of these directions, it is expected that AI may contribute as a powerful leverage tool.

1.3.AI applications in Neuroradiology

Neuroradiology is a medical specialty in Portugal or subspecialty in other countries, and it focuses on diagnosing abnormalities of the head, brain, spine, and neck through medical imaging. This is one of the leading medical fields in terms of the diversity and number of AI applications (Olthof et al., 2020; Pesapane et al., 2018). According to the U.S Food and Drug Administration, medical imaging refers to several different technologies used to view the human body in order to diagnose, monitor, or treat medical conditions. These include Ultrasound Imaging, Magnetic Resonance Imaging, Radiography, and Computed Tomography, among others (Food and Drug Administration, 2018).

As researchers continue searching for new or improved ways to innovate healthcare more and more studies are being published encouraging the emergence of clinical AI tools, already commercially available in the neuroradiological field (Kaka et al., 2021).

In the AIM field, specialties that heavily rely on medical imaging, including radiology, have been particularly studied by researchers in the discipline of computer vision, which tries to communicate visual understanding to a computer system (Chartrand et al., 2017; Kulkarni et al., 2020). Visual task approaches allow radiologists to extract relevant insights from medical images, such as details or patterns unrecognizable to the human eye, so new information can be added to imaging reports (Noguerol et al., 2019).

DL has shown potential in this field, as it can be applied to simpler tasks, like image segmentation, and more complex tasks, including image detection, classification, generation, or reconstruction, among others (Yao et al., 2020). When applied to clinical practice, these tools aim not only at improving timelier diagnosis by shortening time-consuming image analysis but also at reducing medical errors. At the same time, they provide doctors with the ability to deal with impractical datasets (Noguerol et al., 2019; Yao et al., 2020). Another major potential involved in this sort of technology concerns the improvement of patients' access to imaging, particularly in remote areas (Liew, 2018).

In recent years, multiple studies have been published on the potential of DL on neuroimaging, within a wide range of neurological problems, like intracranial hemorrhage, vascular lesions, or head and neck tumors (Kaka et al., 2021; Yao et al., 2020). Improvements made in such techniques are contributing to developments in the detection and treatment of neurological disorders such as stroke (Herweh et al., 2016; Tang et al., 2011), multiple sclerosis (Beadnall et al., 2019), or Alzheimer's disease (Liu et al., 2018).

However, AI applications in radiology and its subspecialties go far beyond medical imaging as they show potential to impact a broader range of processes involved in the clinical workflow (Choy et al., 2018). These include more general tasks such as order scheduling, patient screening, consulting with other clinicians, or report elaboration. This is important, as radiologists spend considerable time on tasks unrelated to image interpretation, that could potentially be assisted by AI technologies (Kulkarni et al., 2020; Noguerol et al., 2019).

In time, it is expected that a range of AI tools will be adopted by neuroradiologists in their workflow, with a positive overall impact on productivity while also improving the quality of services and patient satisfaction (Choy et al., 2018). However, there are still numerous challenges that need to be addressed for the large-scale adoption of these technologies to take place. Research shows that, among others, regulatory obstacles and ethical issues concerning patients' safety and privacy are still a work in progress. On the other hand, the lack of incentives for data sharing, the need for data standardization frameworks, and the difficulties experienced in the explainability of "black-box" models are also major challenges to tackle in the future (He et al., 2019; Jiang et al., 2017; Noguerol et al., 2019; Yu et al., 2018).

1.4.AI from the medical community perspective

When thinking of the adoption of AI in clinical practice, it becomes evident that the healthcare workforce will play a major role in the integration, use, and improvement of such tools. "The greatest challenge to AI in these healthcare domains is not whether the technologies will be capable enough to be useful, but rather ensuring their adoption in daily clinical practice" (Davenport & Kalakota, 2019, p.97).

Research studies regarding the implementation of information technologies such as electronic medical records (EMR) have shown that the success or failure heavily depends on the extent of physicians' resistance to its application (Lapointe & Rivard, 2006). In a study conducted with family physicians on their attitudes and perceptions towards EMR, low perceived usefulness, as well as lack of belief in the abilities of the tool were pointed out as possible factors affecting the usage of EMR (Loomis et al., 2002).

In the light of such studies, doctors' perceptions and beliefs on AI tools are most likely a relevant insight for researchers and health leaders trying to integrate AI into daily clinical practice. Indeed, some authors mention that in the medical community there is still some reluctance to use AI technologies (Noguerol et al., 2019; Pesapane et al., 2018). Therefore, it is important to understand and explore factors building up to negative perceptions, as investing in AI technologies without acknowledging potential issues in acceptance and intention to use might turn out to be a waste of resources (Esmaeilzadeh, 2020).

Despite results showing overall general positive attitudes towards the use of AI, recent studies within the radiological community have identified a latent uncertainty among doctors (Coppola et al., 2021) highlighting concerns regarding the lack of AI knowledge and training (Huisman et al., 2021; Waymel et al., 2019).

1.5.Technology Acceptance Models

The Technology Acceptance Model (TAM) was proposed in 1989 by Davis, and it aims to explain technology acceptance behavior. TAM posits a simple framework where the adoption of technology is determined by behavior intention, which in turn is affected by two main variables: perceived usefulness (PU) and perceived ease of use (PEU) (Davis, 1989; King & He, 2006). PU is defined as the extent to which a person finds that using the technology will improve his or her performance, whereas PEU is related to the extent to which a person finds that using the technology will be easy and effort-free. Additionally, TAM theorizes that PU is also influenced by PEU, in the sense that, as technology becomes easier to work with, it will also prove to be more useful (Venkatesh & Davis, 2000).

Despite TAM being broadly used, partially due to its simplicity and explainability, research in the area of technology acceptance models grew, to the point where researchers had to choose between numerous adaptations of models or the original ones, ignoring contributions from the alternative constructs (Venkatesh et al., 2003). This was the motivation behind the proposal of the Unified Theory of Acceptance and Use of Technology (UTAUT), a synthesized revision of the existing models.

UTAUT proposes four main predicting factors on behavioral intention and user acceptance: performance expectancy (PE), effort expectancy (EE), social influence (SI), and facilitating conditions (FC). PE, in resemblance to PU, is defined as the extent to which a user believes that using the technology will improve his job performance. EE is much similar to PEU, as it concerns the easiness of using the technology. SI is the extent to which someone perceives that important others believe he should use the technology. Finally, FC relates to organizational and technical infrastructures and their perceived supporting role in technology usage by the individual. Additionally, FC is the only variable that influences directly the usage, rather than the behavioral intention behind it (Venkatesh et al., 2003).

Despite being widely used for assessing the acceptance of general technologies, studies that make an intersection between technology acceptance models and AI acceptance by healthcare professionals are rare.

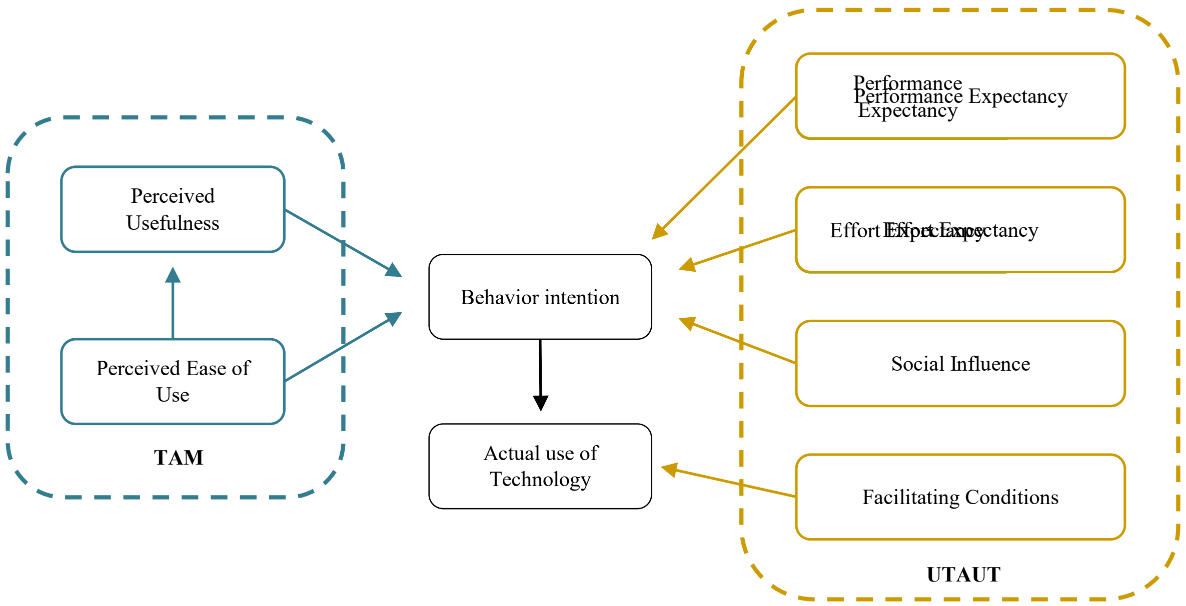


Figure 1- Simplified scheme of technology acceptance models (adapted from Davis et al., 1989 and Venkatesh et al., 2003)

1.6. Previous studies

While research on new innovative AI health products and their potential advances, it seems as though less attention has been paid to the user on the other side, especially when it comes to healthcare professionals. This is perceptible by the reduced number of studies on doctors' perceptions and attitudes towards the use of AI. Interestingly, there are a few studies published on this topic that focus on radiologists, possibly because this is a data-driven specialty that relies on medical imaging, one of the most promising areas for AI (Pesapane et al., 2018).

Coppola et al. (2021) surveyed 1032 members of the Italian Society of Medical and Interventional Radiology on their expectations and opinions about AI. The results highlighted that a considerable amount of 18.0% of the respondents was uncertain about the adoption of AI, whereas 5.0% were unfavorable. Identified potential issues included concerns regarding poorer professional reputation, when compared to other medical specialties, and workload increase as a consequence of AI system maintenance and data analysis. In general, the results showed an overall favorable opinion towards AI adoption. However, the lack of additional questions related to AI-specific knowledge or familiarity was a limitation, as it prevented the authors from finding any correlation between previous knowledge and overall attitude towards AI.

In a study conducted on 270 French radiologists regarding their expectations, perceptions, and knowledge of AI, 73.3% of the respondents agreed they had insufficient knowledge of AI, and a vast majority of 94.4% considered the possibility of attending generic education on the field (Waymel et al., 2019). As to the overall opinion, results showed an optimistic forecast, with expected improvements in the daily workflow of radiologists. Nonetheless, the authors pointed out the likelihood of a biased overall opinion on AI, as most respondents had to answer questions on a topic to which they claimed to have insufficient knowledge.

At an international level, the European Society of Radiology (2019) analyzed 675 answers from their members on a survey about expectations for AI in 5-10 years. Results showed that almost half of the participants (47.6%) did not currently use AI, in contrast to 20.4% who did, and 30.4% responded that they were planning to use it. Relevant insights from the study included perceptions of the expected reduction in job opportunities (41.9%) and expectations that AI will make radiologist-patient interaction more impersonal (33.7%). As the scope of this study was more future-oriented, one important limitation concerned the time barrier, as most questions were aimed at forecasted opinions and not at the current viewpoint on the topic.

More recently, Huisman et al. (2021) investigated the knowledge and attitudes of radiologists and residents in 54 mostly European countries. Among the main conclusions, results showed that low AI-specific knowledge appears to be associated with fear, whereas a higher knowledge in the AI field seems to be associated with a positive attitude about AI. It is important to point out that in this study one major limitation concerned the measurement of AI-specific knowledge. AI knowledge was measured based on a single question, regarding self-perceived knowledge. This imprecision in measurement is particularly relevant in topics where there is still a lack of a consensual definition, such as AI, as it increases the subjectivity around the concept.

Based on the above studies, it becomes apparent that AI knowledge and training was a common topic, perceived as limited among several radiologists. In addition to this, some authors reported the lack of or the subjectivity involved in assessing AI-specific knowledge, as most questions were based on self-perception. Despite overall positive perceptions of radiologists towards AI, there are still concerns worth further exploring. It is also worth mentioning that none of the above studies were based on Technology Acceptance Models, which could be an important feature to a better understanding of the perceptions building up to a more willing mindset for AI adoption.

The following table summarizes the main similar studies found and its results.

Author (Year)	N	Type of doctor	Main findings
Coppola et al. (2021)	1032	Radiologists	• Radiologists had an overall positive attitude to AI implementation. • Main perceived concerns included poorer reputation (60.3%) and increased costs and workload (39.0%). • Radiologists agreed that AI needs specific regulation for integration into clinical practice.
Doraiswamy et al. (2020)	791	Psychiatrists	• About half of the sample believed that AI would substantially impact their job but only 3.8% felt that their jobs would become obsolete. • Psychiatrists were skeptical that AI could perform their tasks with the same performance, especially in empathic care. • Results showed uncertainty about the risk-benefit of AI in mental health.
European Society of Radiology (2019)	675	Radiologists	• Participants expected AI to impact reporting workload (74.7%), job opportunities (55.6%), and that it would change the profile of radiologists into a more clinical one (53.9%). • Only 20.4% of the sample reported using AI. • Radiologists agreed they should be involved in the AI solutions development and validation.

Huisman et al. (2021)	1041	Radiologists	• Limited knowledge about AI appeared to be associated with fear, whereas intermediate to advanced knowledge about AI seemed to be associated with a positive attitude towards AI. • Age appeared to be negatively associated with having a positive attitude towards AI.
Oh et al. (2019)	669	Physicians[1]	• Familiarity with AI was low, despite many respondents seeing AI as useful in healthcare (73.4%) • The main expected applications for AI included helping diagnose (83.4%) and making treatment plans (53.8%). • In general, participants didn't think AI could replace a doctor, and most (78.9%) would favor human opinion over AI in medical decisions.
Sarwar et al. (2019)	487	Pathologists	• Respondents were generally optimistic about AI, with 73.3% reporting interest or excitement in this topic. • Participants emphasized that, before an AI implementation, issues such as insufficient AI training and lack of regulation need to be addressed.
Tasdogan (2020)	68	Anesthesiologists	• Only 36.8% of the participants considered having sufficient AI-specific knowledge • Respondents agreed that AI would drastically impact all fields of medicine (64.7%), but only 2.9% foresaw a complete replacement of physicians by AI.
Waymel et al. (2019)	270	Radiologists	• Insufficient knowledge about AI was reported by 73.3% of the sample • AI was expected to have a positive impact on the future practice of radiology (79.3%) • Expectations focused on decreasing medical errors (81%), time-saving in exams interpretation (74.4%), and increasing doctor-patient time (52.2%)

Table 1- Similar studies and its main findings

[1] The medical specialty of the participants is not specified by the authors.

2. Methodology

The nature of this research is mainly descriptive and uses a quantitative method to understand the perceptions and perspectives of neuroradiologists regarding the use of AI in clinical practice. In descriptive studies, the focus of the research is to specify the manifesting characteristics of a certain phenomenon (Sampieri et al., 2012), which is in line with the aim of this thesis, and by doing so, expand the in-depth understanding of the phenomena.

Three research questions were conceptualized and the following hypotheses were formulated:

Research Questions	Hypotheses
RQ1: What are the perceptions and perspectives of neuroradiologists towards the use of AI in their clinical practice?	---
RQ2: Does the age of neuroradiologists influence their use of AI in clinical practice?	H1: A neuroradiologist's use of AI is influenced by his/her age.
RQ3: What is the impact of specific-AI knowledge of neuroradiologists on their predisposition towards its use?	H2: A positive attitude towards the use of AI is influenced by previous knowledge about AI.
	H3: The fear of AI is influenced by previous knowledge about AI.

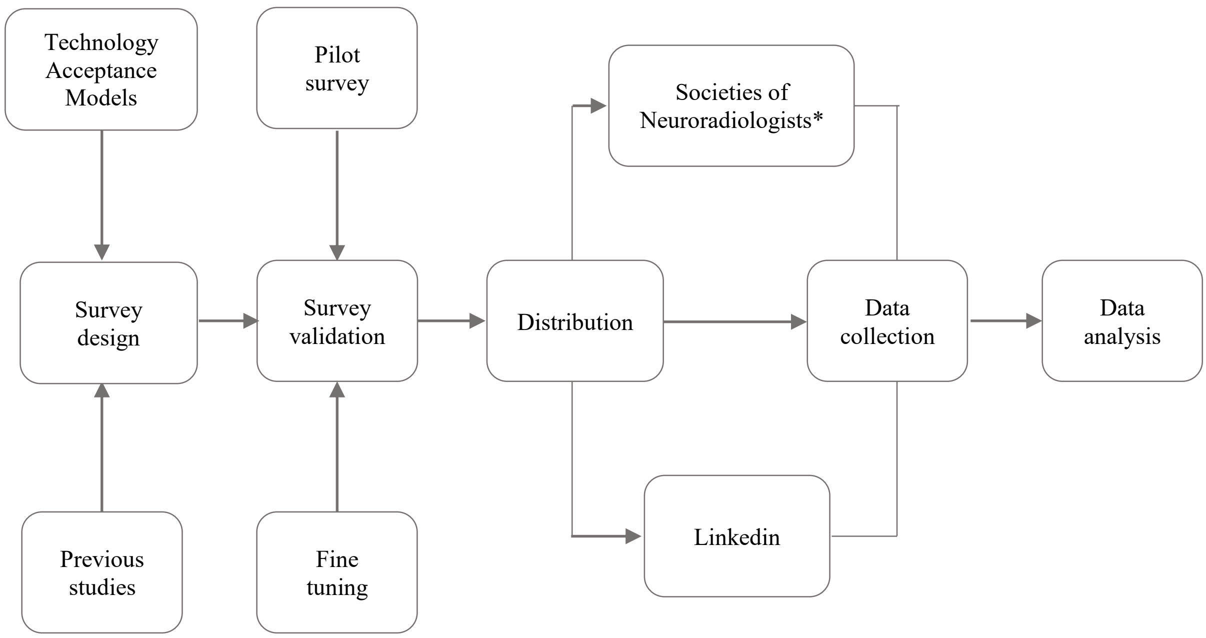
Table 2 - Research questions and hypotheses

To help address the questions, an online survey was designed for data collection. "Surveys are a convenient method for collecting quantitative data about perceptions and opinions of participants" (Mellinger & Hanson, 2017, p.30). Moreover, a survey-based approach allows quantifying answers, thus being a useful insight to understand trends in neuroradiologists' viewpoint towards AI adoption.

2.1.Survey development and distribution

The survey was developed based on previous relevant literature, such as previous similar studies, as well as existing models on technology acceptance. The script was validated by two experts who fulfilled the pilot survey and after fine-tuning some questions, it was published. It was designed in the *Qualtrics* web application and it was available for seven weeks, from December 20th to February 6th. The distribution of the survey was done through two main channels: societies of neuroradiologists and LinkedIn.

A total of 17 societies of neuroradiologists were contacted, from which 7 responded and 5 agreed to share the survey through their members. In the LinkedIn platform, a private message was sent to the estimated amount of 300 neuroradiologists. The criteria used for sending a message included both being a neuroradiologist, as well as having the current job position located in a European country. The standard email sent to the organizations' presidents as well as the message sent to neuroradiologists through LinkedIn can be found in Appendixes I and II. Figure 2 summarizes the methodology process.



* European Society of Neuroradiology, Portuguese Society of Neuroradiology, Spanish Society of Neuroradiology, French Society of Neuroradiology, and Danish Society of Neuroradiology

Figure 2. Methodology process

2.2.Survey structure

The survey's structure includes four main blocks aiming to assess: demographics (1), knowledge (2), perceptions (3), and perspectives (4).

The first block collects demographic information, such as age, gender, workplace characteristics and specific background.

The second block aims to assess neuroradiologists' knowledge about AI through a set of 3 questions where we assess: self-perceived knowledge on a Likert scale ranging from 1 (very insufficient) to 5 (very good); the definition of ML (in which only one of the answers is accurate) and current experience with AI tools.

The third block contains several questions regarding perceptions about the use of AI in clinical practice. The first seven questions are affirmations to which the respondents must specify their agreement on a Likert scale from 1 (strongly disagree) to 5 (strongly agree), while the last question is a multiple choice. Questions 11 to 16 are an adaptation based on TAM and UTAUT, as shown in Table 2.

Questions	Assess
Q11: I think that AI tools improve diagnosis accuracy (i.e. decrease medical error)	Performance Expectancy
Q12: I think that AI tools accelerate some tasks, thus improving time response to patients	
Q13: Working with AI tools requires more effort (e.g. time invested) than working without AI tools	Effort Expectancy
Q14: My institution promotes the use of AI in clinical practice	Facilitating conditions
Q15: My institution has the right conditions (e.g. good quality dataset, capable IT services, advanced digital solutions) to support AI adoption in clinical practice	
Q16: I feel pressured by my colleagues or institution to use AI in daily clinical practice	Social Influence

Table 3 – Questions based on TAM and UTAUT

We also included some questions regarding the learning needs of AI, such as the number of hours that should be dedicated to this matter, or the most relevant topics to be taught.

The fourth and last block of the survey explores the perspectives and concerns of neuroradiologists. It starts with a 50 seconds video in which an expert on AI is talking about its potential and applications, mentioning that “many conditions could be AI-diagnosed.”. This block mainly focuses on hypothetical situations in which participants are asked about their expectations, recommendations, emotions, and reactions before different scenarios through multiple-choice questions.

2.3. Survey analysis

After data collection, descriptive statistics were used to characterize the sample in the four main blocks of assessment. Moreover, for both RQ2 and RQ3, three different Chi-Square tests were performed under a confidence interval of 95%. The Chi-Square test is a commonly used statistical tool for analysing the existence of an association between categorical variables (Franke et al., 2012). In order to conduct robust statistical tests, the following variables were contemplated:

- **Age**

  The sample was divided into 2 groups: people with less than 44 years old and people above 45 years old.

- **Knowledge about AI**

  We considered that a neuroradiologist had knowledge about AI when at least 2 out of 3 of the following criteria were met:

  - Having assessed one’s knowledge as sufficient or higher (Q8 – self-evaluation);
  - Having chosen the correct definition of ML in Q9[2] (hetero-evaluation);
  - Using AI tools in clinical practice (Q10a)

- **AI use**

  We considered that respondents use AI if they replied with “Yes” to Q10a: Do you use AI-based tools in your clinical practice? (e.g. a software that detects, quantifies or classifies a certain lesion based on medical imaging)

[2] “AI branch in which algorithms are trained to learn from data without explicit programming”

- **Fear of AI**

Fear of AI was considered in participants that selected the option “Afraid” in Q20: How does this scenario make you feel? Choose up to 3 options

- **Positive attitude towards AI**

We considered that a participant had a positive attitude if he selected a positive reaction to Q23a: What are your initial thoughts?[3] and agreed to at least 2 out of 3 of Q11-Q13.

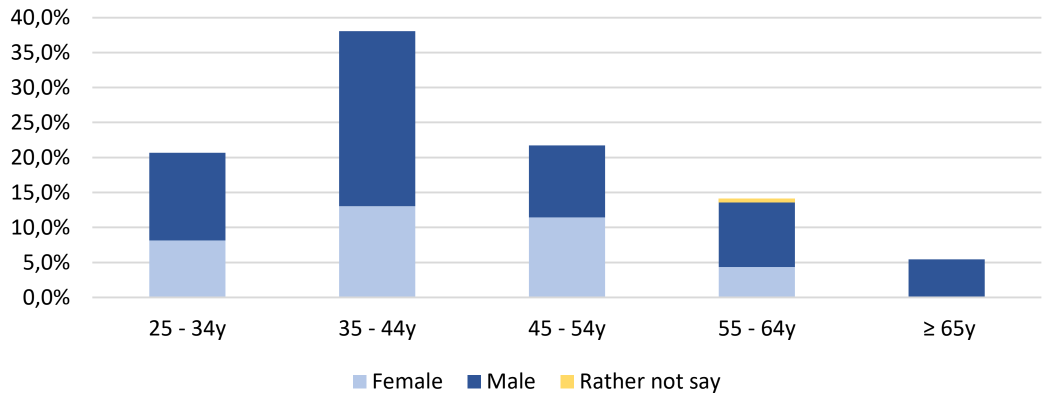
In the Q13 answer scale, the lowest agreements correspond with a higher acceptance. Thus, we inverted its answer scale to match positively with Q11 and Q12.

[3] “I want to be involved”, “I want to help push this process forward”, or “Wow! I want to be ahead of the game, I am in!”

3. Results

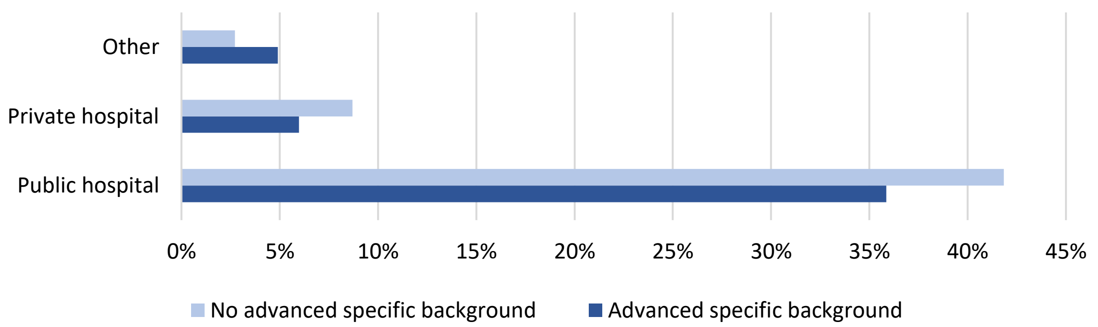
3.1. Demographics

A total of 184 complete survey responses were collected. Gender distribution was slightly unbalanced, with 62.5% of male respondents. Age distribution revealed that 58.7% of neuroradiologists were below 44 years old and that the median age category was 35-44 years old. A minority of respondents (5.4%) were above 65 years old.



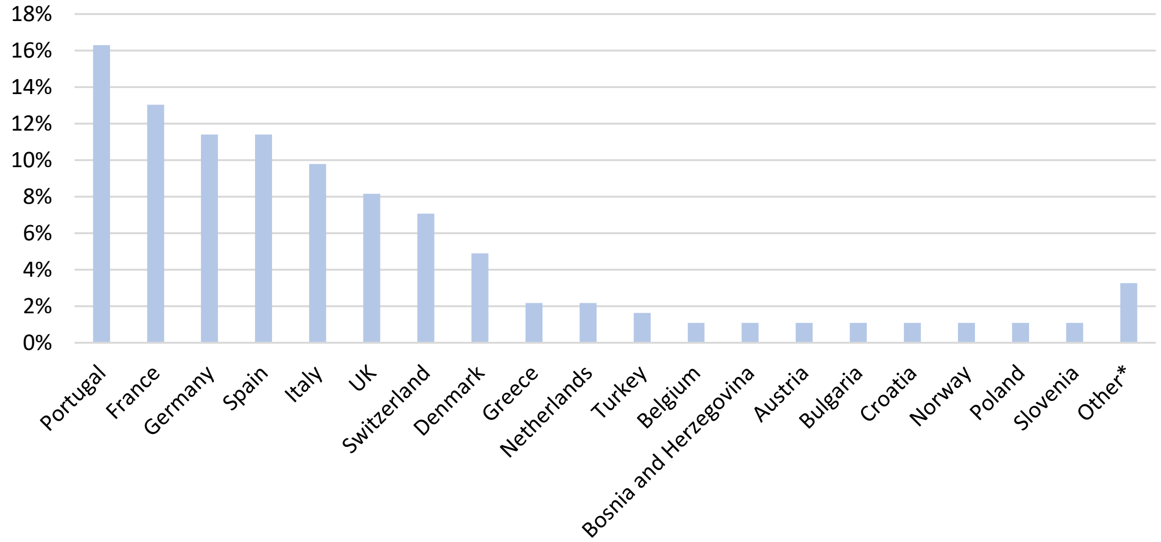
Graph 1 - Age and gender distribution in the sample

Specialists represented 89.7% of the sample and 10.3% were interns. In terms of further academic learning, almost half of the respondents (46.7%) claimed to have an advanced specific background (such as a research fellowship or a PhD). As for the main site of professional activity, public hospitals accounted for 77.7% of responses and private hospitals for 14.7%.



Graph 2 - Distribution of main working site and advanced specific background in the sample

The geographical distribution of the respondents' working countries included a total of 25 European countries, with its distribution represented on Graph 3.

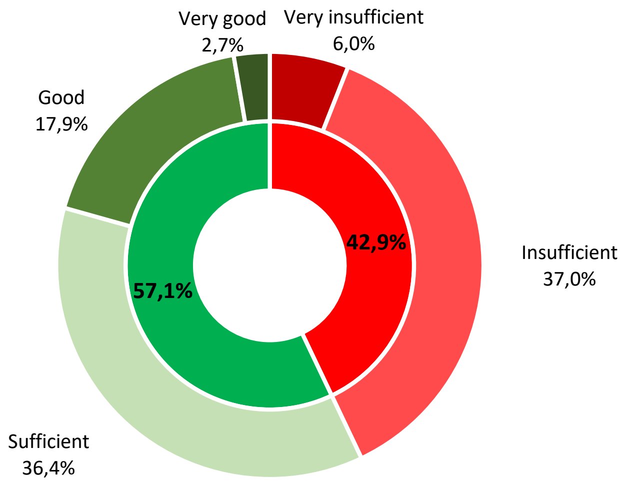


*Finland, Hungary, Ireland, Romania, Slovakia, and Sweden

Graph 3 - Distribution of the working countries in the sample

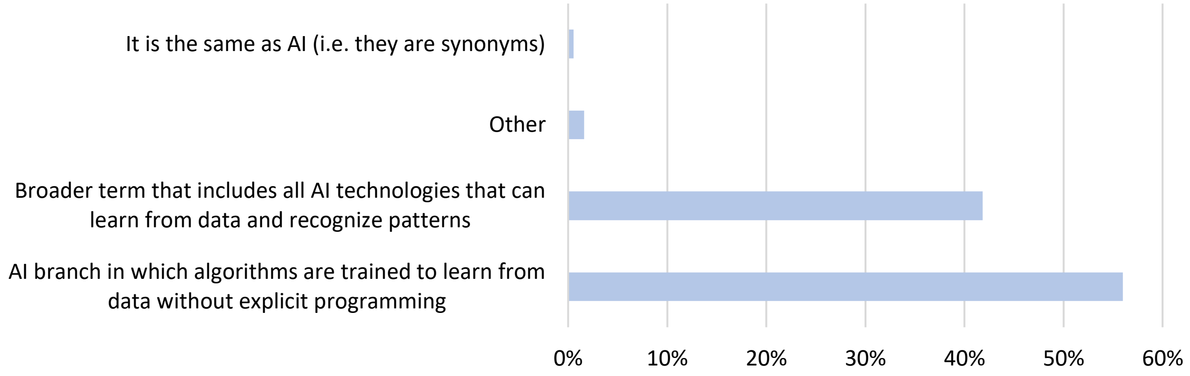
3.2.Knowledge about AI

The following graph reports the self-perceived knowledge about AI in the sample.



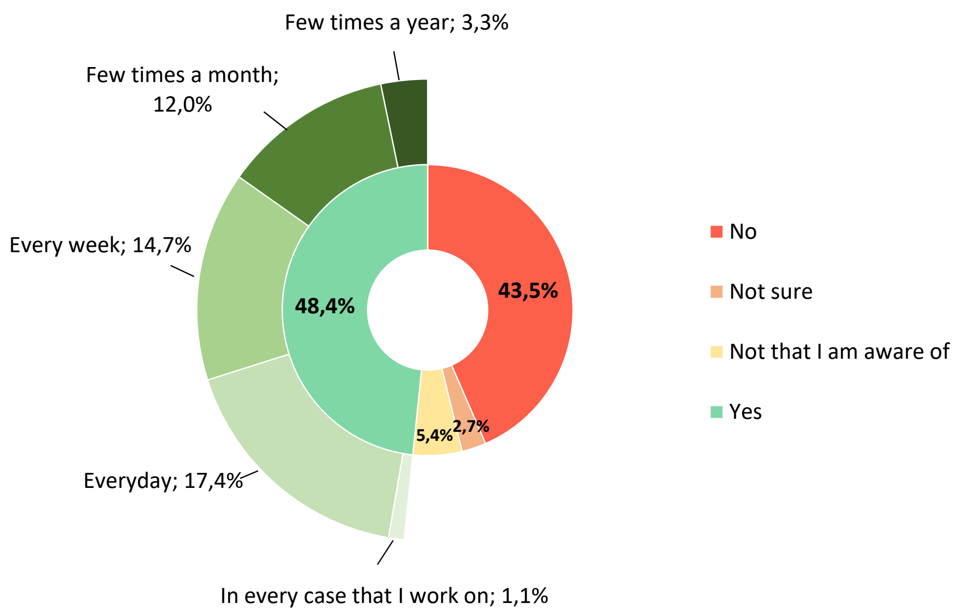
Graph 4 - Answer distribution to Q8: How would you classify your knowledge about AI?

As for the definition of ML, results show that 56.0% of the sample chose the most accurate response, while 41.8% believed ML to be a broader term than AI (Graph 5).



Graph 5 - Answer distribution to Q9: How would you define "Machine Learning"?

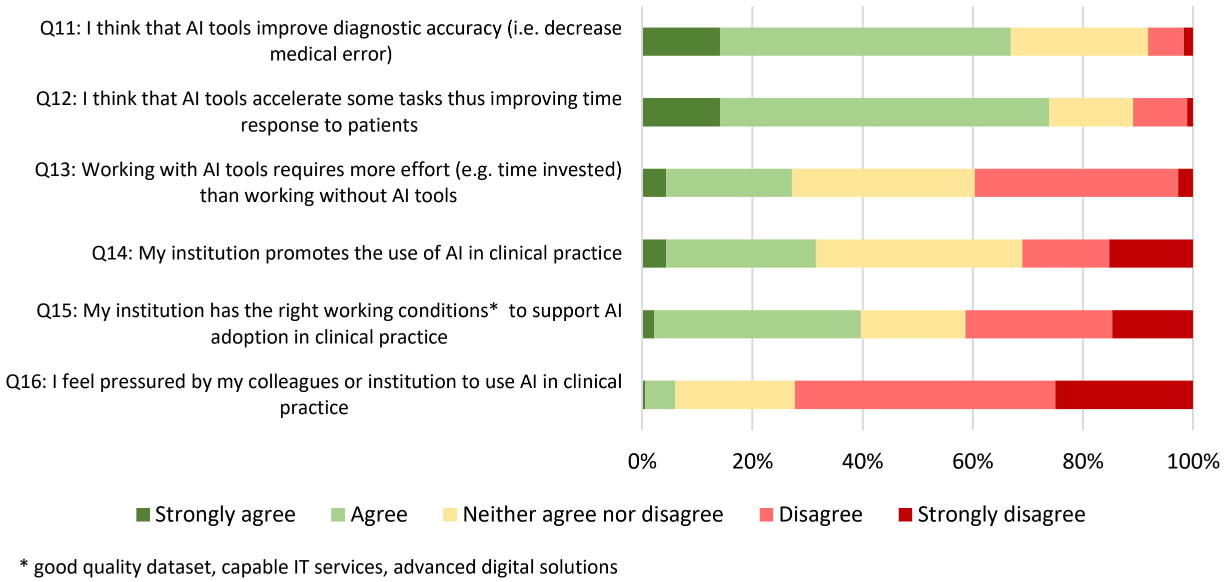
The results for AI use were almost balanced, with a positive answer (Yes) from 48.4% of neuroradiologists. From the participants that claimed to be using AI, results showed that a majority of 68.5% are actually using AI with a high frequency (at least every week). For more information, see Graph 6.



Graph 6 – AI use and frequency of use in the sample

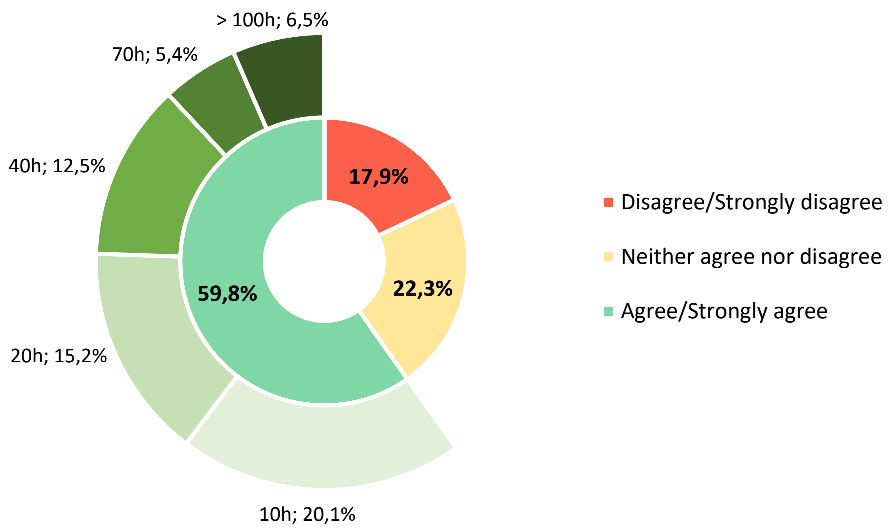
3.3. Perceptions about AI

The following graph summarizes the responses to Q11-Q16 related to perceptions about AI.



Graph 7 - Distribution of the perceptions about AI in the sample (Q11-Q16)

Concerning AI education, 59.8% of the neuroradiologists acknowledged that AI training should be included in the medical curriculum. When asked about the number of hours that AI training should replace in traditional medical training, responses showed that the options with the lowest time periods were usually the most voted.

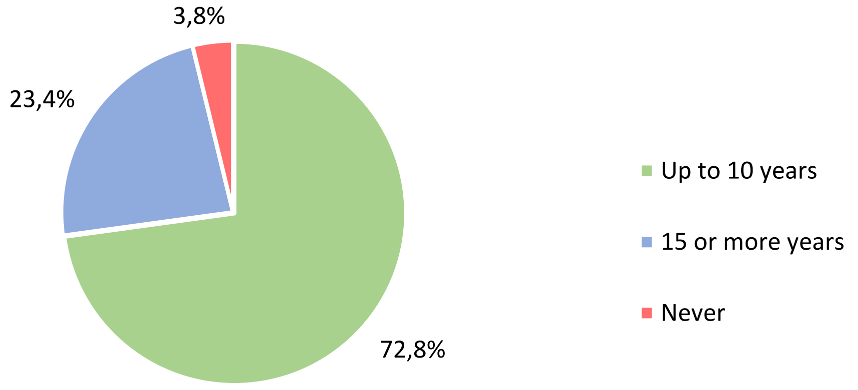


Graph 8 - Answer distribution to Q17a: There should be AI training in the medical curriculum and Q17b: How many hours of traditional medical training should be replaced by AI training?

Concerning the AI topics that should be taught, almost half of the sample chose “Limitations and challenges” (47.3%), followed by “Understanding the construction of algorithms” (21.7%) and “Taking the lead in AI solutions development” (19%).

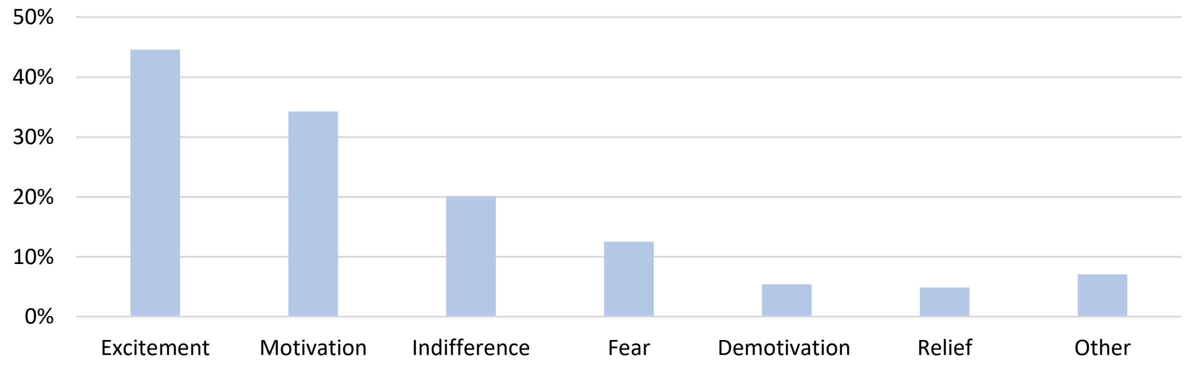
3.4. Perspectives about AI

The following graph illustrates the answer distribution to Q19: In this video we hear Dr. Eric Topol, an expert in digital medicine, saying that “many conditions could be AI-diagnosed”. When do you think this will become a reality?



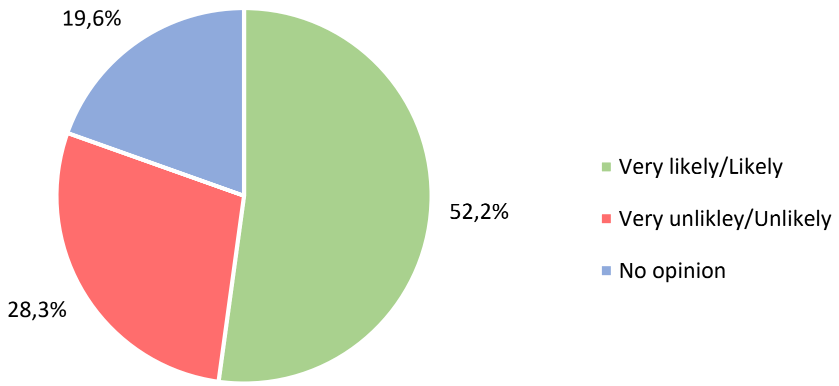
Graph 9 - Forecast on the time until many conditions can be AI-diagnosed (Q19)

When confronted with this possible scenario, the most frequently stated emotions were excitement (44.6%), motivation (34.2%), and indifference (20.1%). Fear was the fourth most stated emotion, voted by 12.5% of the respondents.



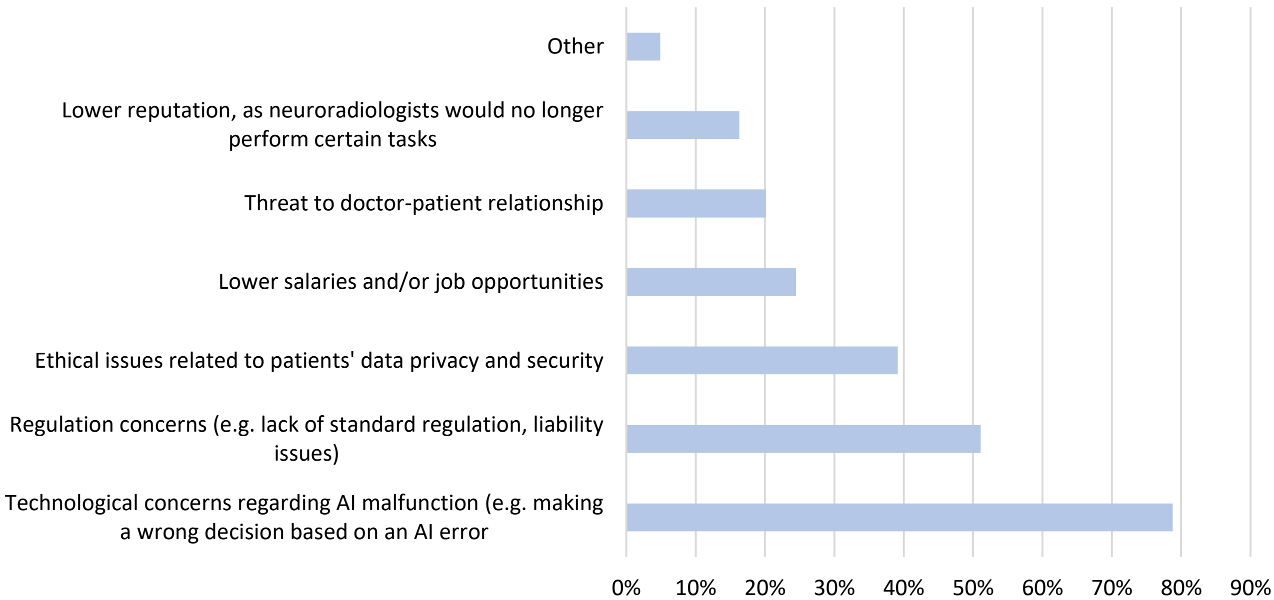
Graph 10 - Distribution of reported emotions in an AI scenario

When faced with the statement that neuroradiologists who use AI will replace neuroradiologists who don't", more than half the sample (52.2%) agreed this scenario to be likely (n=74) or very likely (n=22). Graph 11 shows the overall answer distribution to this question.



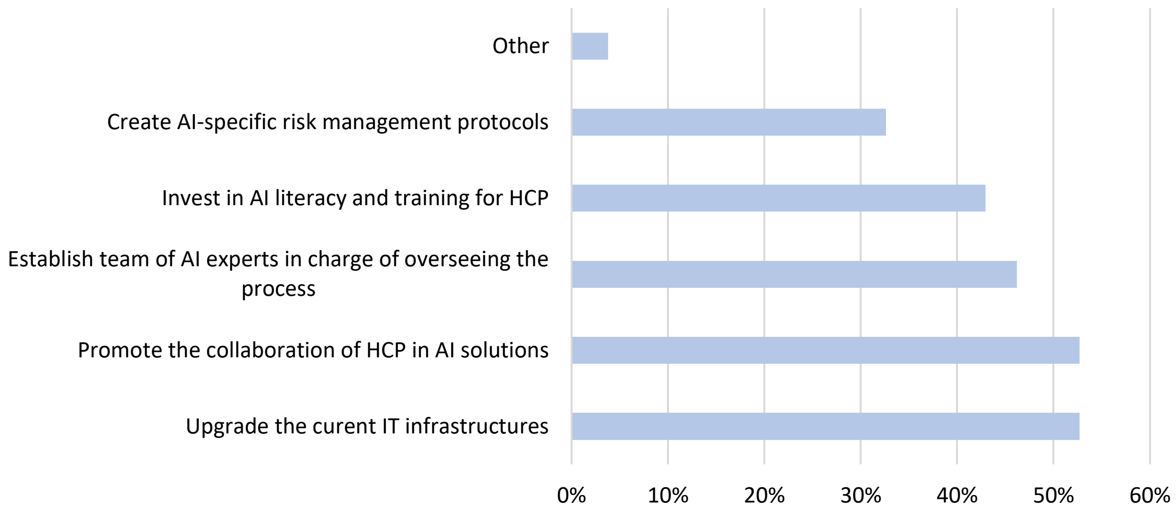
Graph 11 - Answer distribution to Q21: How likely is it that neuroradiologists who use AI will replace neuroradiologists who don't?

Regarding concerns with AI, the most highlighted ones were related to technological malfunctions (78.8%) lack of regulation (51.1%), and ethical issues with data privacy and security (39.1%). For more information about expressed concerns with AI see Graph 12.



Graph 12 - Answer distribution to Q22: In this scenario of AI automation what would be your major concerns? Choose up to 3 options

The following graph illustrates the recommended steps for accelerating an AI strategy.



Label: HCP – Healthcare professionals

Graph 13- Distribution of the recommended steps to accelerate AI strategy in the medical field (Q23b)

4. Results analysis

The following table summarizes all the variables that were tested for possible associations using the Chi-Square test.

Independent variable	Dependent variable	X^2 (df[a])	Significance
Age	AI use	0.052 (1)	ns[b]
	Fear	2.511 (1)	ns
	Positive attitude	0.906 (1)	ns
Knowledge about AI	AI use	50.631 (1)	p<0.001
	Fear	5.236 (1)	p = 0.022
	Positive attitude	4.407 (1)	p = 0.036
Working country[c]	AI use	4.843 (1)	p = 0.028
	Fear	1.843 (1)	ns
	Positive attitude	9.285 (1)	p = 0.002
Main working sector[d]	AI use	0.930 (1)	ns
	Fear	0.095 (1)	ns
	Positive attitude	0.020 (1)	ns

[a] df, degrees of freedom
[b] ns, non-significant
[c] The variable working country was dichotomized into "working in Portugal" or "working outside Portugal"
[d] The main working sector was dichotomized into "public hospital" or "private hospital"

Table 4 - Summary of the results of associations between variables

4.1.Hypothesis testing

Three different Chi-Square tests were performed to test our hypotheses. When a statistically significant result was achieved (p-value<0.05) the Phi-coefficient (Φ) was applied to measure the direction of the association between variables. Its value ranges from −1 to +1, "with negative numbers representing negative relationships, zero representing no relationship, and positive numbers representing positive relationships" (Allen, 2017). The results show that while H1 should be rejected, H2 and H3 should not be rejected, as both of their p-values fall under 0.05. Table 5 summarizes our findings from the statistical tests.

Research Questions	Hypotheses	Results
RQ2	H1: A neuroradiologist's use of AI is influenced by his/her age.	$X^2 = 0.052$ (p = 0.820) Therefore, **H1 is rejected** (p-value > 0.05). According to this sample, there is no association between a neuroradiologist's age and his/her use of AI.
	H0: A neuroradiologist's use of AI is independent of his/her age	
RQ3	H2: A positive attitude towards the use of AI is influenced by previous knowledge about AI.	$X^2 = 4.407$ (p = 0.036) $\Phi = 0.155$ Therefore, **H2 is not rejected** (p-value <0.05). According to our sample, there appears to be a positive association (Phi>0) between knowledge about AI and having a positive attitude towards its use.
	H0: A positive attitude towards the use of AI is independent of previous knowledge about AI.	
	H3: The fear of AI is influenced by previous knowledge about AI	$X^2 = 5.236$ (p = 0.022) $\Phi = -0.169$ Therefore, **H3 is not rejected** (p-value <0.05). According to this sample, there appears to be a negative relationship (Phi<0) between knowledge about AI and fear towards its use, with those knowing more about AI having less fear of its application in healthcare.
	H0: The fear of AI is independent of previous knowledge about AI	

Table 5 - Hypotheses and results from the statistical tests

5. Discussion

RQ1: What are the perceptions and perspectives of neuroradiologists towards the use of AI in their clinical practice?

From the perceptions block, we can see that the questions related to PE were the ones with the highest agreement rates. This is in line with previous studies (Coppola et al., 2021; Waymel et al., 2019) and it indicates that most neuroradiologists acknowledge the augmenting abilities of AI tools. Moreover, only a small percentage of 27.0% agreed that working with AI requires more effort than working without AI. This is important information, as it indicates that EE is probably low among neuroradiologists, even for those who aren't accustomed to using AI tools.

Regarding facilitating conditions, results show mixed feelings about organizational readiness from neuroradiologists' perspectives. Previous studies investigated the factors building up to AI-readiness at firm-level and many authors apply the Technology-Organizations-Environment (TOE) framework, which divides the determinants into 3 categories: technological, organizational and environmental (AlSheibani et al., 2018; Jöhnk et al., 2021; Vasiljeva et al., 2021).

For the scope of our research, we will only comment on the organizational factors. In this category, Vasiljeva et al. (2021) focused on department readiness in terms of infrastructure, resources, and skills, as well as upper management support, which are the most relatable factors with Q14-Q15 on FC. The low agreement rates on both questions might indicate low implementation of AI technologies and or inadequate organizational readiness, not only in IT readiness but also from the lack of support by top management. Unfortunately, the lack of additional or open-ended questions on this topic prevented us from further exploring.

Only a minority of 5.9% in the sample admitted feeling pressured into using AI. Even though feeling pressured may not be the most accurate representation of SI, the fact that 25.0% of the sample strongly disagreed (the highest response rate from all the questions) and that 47.3% disagreed may indicate a lack of social incentives, such as being surrounded by colleagues working with AI, or having an institution which actively encourages its use.

This explanation is consistent with the results obtained with FC, as well as the low AI use rate found among the sample (51.6% of the respondents are not using AI tools). It is also worth mentioning that similar low AI use rates were found in the study by the European Society of

Radiology (2019), where 321 out of 675 radiologists (47.6%) mentioned that they were not using AI applications in clinical practice. However, our results were slightly higher than the ones obtained from Waymel et al. (2019), where 68.5% of the participant radiologists reported not using AI in their clinical practice, nor foreseeing any changes in the following year.

There are two things worth mentioning in our results for AI use. First, the hetero-evaluation question might not have been the best way to test knowledge on a basic definition. Indeed, ML is a basic concept in AI. However, as there is still missing a universal definition for AI, neuroradiologists with some knowledge on the topic might have failed to recognize the correct answer. Also, it is possible that more neuroradiologists are already using AI tools but did not recognize so (Shinners et al., 2020).

For perspectives, the results obtained were generally optimistic, with excitement and motivation being the two most voted emotions towards an AI-augmented scenario. A large share of neuroradiologists predicted an AI-based diagnosis reality in up to 10 years, which is similar to the forecast results obtained by Coppola et al. (2021) when asking radiologists about the expected time for AI to impact their profession (half the sample voted for 5-10 years and 20.3% voted for 10-20 years).

Interestingly, about half the sample (52.2%) agreed that neuroradiologists who use AI are likely to replace neuroradiologists that don't. Comparing this result with the ones got from fear of replacement by AI, which were significantly lower (Coppola et al., 2021; Huisman et al., 2021) one can say that the need for keeping up with innovation and its integration into clinical practice is already a trend in neuroradiology.

Moving on to concerns, the main anticipated issues related to technological malfunctions (78.8%), lack of regulation (51.1%), and ethical issues (39.1%), while lower reputation was one of the least voted concerns, in contrast to the study by Coppola et al. (2021). These insights are indicative of the uncertainty and mistrust that still exist in the medical field. Additionally, they emphasize the fact that transparency, as well as a robust legal framework, are key priorities in need of addressing that could substantially encourage AI adoption by physicians.

Upgrading the current IT infrastructures was one of the top suggestions by participants. Indeed, digital transformation remains a big challenge in healthcare (Gopal et al., 2019) with words such as "slow, complex, and bureaucracy" often being used to describe the current state of digitalization (Deloitte, 2020). As more and more medical data is being produced, interoperability becomes urgent to bridge the gap between potential meaningful information and the deployment of technologies that can actually use that data (Deloitte, 2020; Lehne et al., 2019).

Addressing gaps in digital literacy was also a highlighted recommendation, which is in line with previous studies (Huisman et al., 2021; Waymel et al., 2019), as with the rate of insufficient AI knowledge reported by our sample. Our results underline that AI training should be incorporated into the traditional medical curricula. Investing in AI training would certainly help build trust in AI, thus ensuring more confidence in deploying its technologies. Also, it would increase opportunities for doctors' inclusion in AI solutions development.

Ultimately, it was encouraging to see that neuroradiologists recommend the involvement of healthcare professionals in AI solutions. In truth, the future of AI health solutions will likely depend on the ability of multidisciplinary efforts between innovators and end-users such as doctors to develop efficient tools that can fit smoothly into the workflow of clinical practice.

RQ2: Does the age of neuroradiologists influence their use of AI in clinical practice?

The results for H1 indicate that the use of AI is independent of the age of neuroradiologists. According to existent literature, as age increases, consumers tend to have more difficulty in processing new information, which hinders the adaptation to new technologies (Morris & Venkatesh, 2000). In line with this information, a study on 356 German firms found that older workforces (smaller share of young employees) were negatively related to the probability of adopting new or improved technologies (Meyer, 2011). Similarly, Huisman et al. (2021) found increasing age as a negative predictor for an open and proactive attitude towards AI.

However, despite showing lower rates of technology adoption, older populations have never been more digital than today and, in some cases, even present similar technology use rates to adults under 65 years old (Pew Research Center, 2017). Moreover, recent statistics in the EU show that, from 2015 to 2020, the percentage of adults (16-74 years old) that used internet daily increased from 65% to 80% (Eurostat, 2021).

On the other hand, our sample was mainly represented by participants under 44 years old and people above 45 years old were included in the older group category. Also, from the senior group, only a minority of 5.4% was above 65 years old, which is the traditionally recognized indicator for defining an old person (United Nations, Department of Economic and Social Affairs, 2019).

It is also known that 65-year-olds nowadays have a significantly higher life expectancy, health status, and socioeconomic conditions than before (United Nations, Department of Economic and Social Affairs, 2019). Moreover, 65-year-olds today were already exposed, to some extent, to different technologies. A report on how baby boomers (people born between 1946-1964) view and use technology emphasized their unique historical perspective. This generation "grew up with technology: they were in their teens to early 30s when the first IBM PCs and Apples appeared, and were the innovators and early adopters of that era" (Rogers, 2009, p.3).

Therefore, we found two main reasons for the results obtained in H1. Firstly, our sample lacked a representative amount of older neuroradiologists, as it was unproportioned to younger participants. Such differences in age distribution might have resulted from less inclusive channels for survey sharing, such as email or LinkedIn. Also, in most EU countries, the retirement age is around 65 years old. Hence, there might not be as many neuroradiologists still in practice.

The second reason is that the effect of age on technology adoption might not have the same impact in this age group as in older seniors, such as people in their 70s or 80s. This is supported by Friemel (2016), who studied the digital divide among people above 65 years old. In his study, the author reported on data about internet use in Switzerland (1997–2013) to which he concluded that the major gap was not between the "pre-seniors" (50-59 years) and younger categories, but between the "old seniors" (70+) and the rest of the population. (Friemel, 2016).

Age remains a relevant factor for technology acceptance and adoption. Previous studies on predictors of technology acceptance in older adults have shown the importance of computer knowledge, as well as tutorial support on the acceptance outcomes (Holzinger & Miesenberger, 2009; Lee et al., 2011). As such, when making managerial decisions such as embarking on an AI strategy, managers should take into account the age of their target group, as the difficulty in adapting to new environments might differ according to age range.

RQ3: What is the impact of specific-AI knowledge of neuroradiologists on their predisposition towards its use?

In our sample, 42.9% of participants rated their knowledge about AI as either insufficient or very insufficient. Similar results were achieved in previous studies (Castagno & Khalifa, 2020; Waymel et al., 2019), and they pose an issue related to an AI literacy gap. Indeed, despite the consensual opinion concerning the importance of integrating AI training in the medical curricula, there seems to be a translation gap as medical schools struggle to plan and implement these changes (Grunhut et al., 2021).

This is particularly concerning if we take into account our findings in H2 and H3, which were both statistically significant. AI-related knowledge appears to influence the predisposition towards its use. On one hand, the knowledge about AI seems to be positively related to having an optimistic attitude towards its use, which is relevant, as people with a positive attitude are more likely to engage in AI adoption (Lichtenthaler, 2020; Wang et al., 2021). Also, according to the Diffusion of Innovations Theory, early adopters are crucial for driving a change in their working environment, as they will serve as pioneers for speeding the diffusion process among their peers (Rogers, 1983).

On the other hand, there appears to be a negative relationship between knowledge about AI and fear of AI, with those knowing more about AI having less fear towards its application in healthcare. Huisman et al. (2021) also found that limited AI-specific knowledge among radiologists appeared to be associated with fear, while an intermediate to advanced knowledge about AI was associated with a positive attitude towards AI.

In previous literature, the concept of “AI anxiety” has been used to discuss the fear and apprehension shown about “out of control AI” (Johnson & Verdicchio, 2017). A deeper look into the underlying sources of AI anxiety revealed contributing factors such as privacy violation anxiety, job replacement anxiety, learning anxiety, ethics violation anxiety, and lack of transparency anxiety, among others (Li & Huang, 2020). Indeed, in our research, the most stated concerns regarding AI indicate that neuroradiologists fear for patients’ safety, not only in medical terms (making a wrong decision based on an AI error) but also from an ethical perspective of data privacy.

6. Implications and Recommendations

- Artificial Intelligence is shaping the future of healthcare. Doctors and other health professionals are part of this (r)evolution, not only as end-users but also as disseminators of trust in these new technologies and empowering patients in using them.

- As the population ages, neurological disorders will spread, increasing pressure on the demand for efficient and cost-effective care. In neuroradiology, AI can play an important role in augmenting medical care and assisting health professionals in monitoring, diagnosing, and treating patients in an increasing health burden population.

- **Doctors and innovators** such as start-ups must work together in producing efficient AI tools that fit seamlessly into the workflows. An example of collaboration could be applied to pilot tests to measure the outcomes of AI tools and foster the improvement of solutions from medical feedback.

- **Health institutions** should integrate AI into their strategy and foster a working culture more prone to AI awareness, as it would encourage the involvement of all stakeholders in adoption behavior. Additionally, organizations should invest in adequate IT infrastructures and provide health professionals with opportunities to increase their AI literacy and skills (training sessions, seminars, etc.).

- **Medical schools** will have to adapt their curricula to prepare future doctors in AI by developing knowledge, attitudes, and skills associated with clinical AI and critical judgment of its applicability, thus shaping AI competent doctors. Dedicated courses, practical activities, and contact with experts in the field are some of the ways in which awareness and overall attitudes could be improved.

- **Governments and policymakers** should continue to work on a robust legal framework for AI regulation as it will increase trust and boost readiness for both organizations and health professionals.

7. Limitations and Future Research

Despite the efforts made in the survey distribution via different platforms, only 255 responses were obtained. However, over 184 complete responses were used for the analysis, which represents a good proportion and created a consistent sample. This was unexpected considering the very specific professional background and the COVID-19 pandemic work overload in the sector.

To assess the overall perceptions and perspectives on a topic that is not very familiar to some respondents could have led to some biased responses. To mitigate this risk simple questions were used, some of which included concrete examples to allow doctors less familiarized with AI to engage with the survey.

The quantitative nature of the study design prevented further exploration of the nuances and reasons behind some answers. This can be continued in future research now that this baseline has been created. Findings from this study can be relevant for future research using a qualitative methodology (with interviews, focus groups, or participant observation), contributing to an enhanced understanding of current and future trends in neuroradiology as they intersect with AI.

For future research, it would be interesting to explore the organizational context of participants, such as replicating this study in settings where AI tools are available in clinical practice. This would allow a better understanding of the rate of neuroradiologists rejecting AI by choice versus due to lack of opportunity. Additionally, it would be relevant to compare the perceptions and acceptance of doctors that have AI technologies available for use and the ones that don't. Such research could provide insights to help diffuse innovation, as the good examples of AI adoption could serve as pioneers for institutions willing to innovate in AI.

8. Conclusions

While there is excitement around the use of AI in Neuroradiology, its integration into clinical practice is still at an early stage, with some implementation challenges on the horizon.

Health professionals are at the core of this transformation and, as such, will need to adapt to new roles. According to our findings, improving knowledge of AI will probably reduce the fear associated with it and encourage a positive attitude towards its use. Investing in AI literacy of health professionals will add knowledge and contribute to enhancing skills required and consequently encourage their early involvement in the development and/or usage of intelligent solutions.

Neuroradiologists acknowledge the abilities of AI tools to improve their work and are willing to participate in an AI strategy. However, reassurance through providing the explanation and validation of new technologies, suitable working conditions, and the creation of a robust legal framework is still needed to raise trust, encouragement, and readiness.

This research contributes to a better representation and understanding of neuroradiologists' perceptions and perspectives regarding the adoption of AI in clinical practice. Moreover, its findings can support organizational decision-making and present new viewpoints on the best practices for a successful transition into AI implementation. The employment of questions based on technology acceptance models sheds light on neuroradiologists' perspectives on their institutional context. Also, they provided a starting point for further investigation, in this specialist domain but also in that of other medical and even non-medical healthcare professionals.

AI is seen to hold significant potential in Neuroradiology. This may be true of other fields in medicine. Increasing diagnostic accuracy, improving workflow efficiency, and cutting back on time-consuming tasks, are just a few ways AI will likely augment neuroradiologists' work productivity. For this transformation to happen, however, all stakeholders need to be involved under a clear AI strategy that focuses on improving the overall efficiency of their services, in a way that adds value not only to healthcare staff but also to patients.

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Appendix I – Email sent to contact societies of neuroradiology

Dear Dr. X,

My name is Leonor Monteiro. I am a portuguese student writing my master thesis in Business at Católica Lisbon School of Business and Economics (https://www.clsbe.lisboa.ucp.pt). My research focuses on the perceptions and projections of neuroradiologists regarding Artificial Intelligence (AI) in clinical practice. My work is under the supervision of Prof. Henrique Martins, an active researcher in Digital Health (https://www.henriquemartins.eu).

I have developed an online survey with the help of experts in the field, and I am sending you the script in attachment. My goal is to reach out to as many neuroradiologists in Europe as possible. Therefore, I would like to ask for your help as President of Y*: would you be so kind to share the link to this survey among the members of your association? I will gladly share the results with* Y*, as they can be in your interest. I am also including a small text, which I have shared with several contacts, as it may be helpful for sharing purposes.*

I look forward to hearing from you soon and will be available for any questions you might have via email or teams/zoom. Thank you for your attention.

Best regards,

Leonor Monteiro

www.linkedin.com/in/leonor-líbano-monteiro

Note:
X – Last name of the president of the society
Y – Name of the society of neuroradiology

Appendix II – LinkedIn message to contact neuroradiologists

Hello,

I kindly invite you to participate in my MSc thesis study about the perceptions and projections of neuroradiologists regarding Artificial Intelligence in clinical practice: https://ucplbusiness.co1.qualtrics.com/jfe/form/SV_3Dd4s31iE1f2ahg

Thank you in advance!

Leonor

Appendix III – Survey script

Dear participant,

This study is part of my MSc thesis in Business at the Católica Lisbon School of Business and Economics. My research focuses on the perceptions and projections of neuroradiologists regarding Artificial Intelligence adoption in clinical practice.

This is a multiple-choice survey and it should take no longer than 8 minutes to complete. Please choose the preferred language (portuguese or english) in the top right corner.

I kindly ask you to carefully read through the questions and answer them honestly. All answers will be anonymous and used for research purposes only.

Thank you for your participation!

Leonor Líbano Monteiro

Demographics

Q1: Gender
Female
Male
Rather not say

Q2: Age
25 – 34
35 – 44
45 – 54
55 – 64
≥ 65

Q3: Where are you currently working?
-

Q4: What is your highest educational degree earned?
Bachelor's degree
Master's degree
PhD

Q5: What is your current professional situation?
Specialist
Intern attending the first 2 years of training
Intern attending the last years of training

Q6: What is your main site of professional activity?
Public hospital
Private hospital
Other

Q7: Do you have any advanced specific background? (PhD, Research fellowship, etc.)
Yes
No

AI knowledge

Q8: According to the European Commission: "Artificial intelligence (AI) refers to systems that display intelligent behaviour by analysing their environment and taking actions – with some degree of autonomy – to achieve specific goals". Based on this definition, how would you classify your knowledge about AI?
1 (Very insufficient) 2 (Insufficient) 3 (Sufficient) 4 (Good) 5 (Very good)

Q9: How would you define "Machine Learning"?
Choose only one option
- It is the same as AI (i.e. they are synonyms)
- Broader term that includes all AI technologies that can learn from data and recognize patterns
- AI branch in which algorithms are trained to learn from data without explicit programming
- Other

Q10a: Do you use AI-based tools in your clinical practice? (e.g. a software that detects, quantifies or classifies a certain lesion based on medical imaging)
Choose only one option
- Yes
- No
- Not sure
- Not that I am aware of

If you answered "Yes" to the previous question:
Q10b. How often do you use AI tools?
- In all the cases that I work on
- Everyday
- Every week
- Few times a month
- Few times a year

Perceptions and attitudes towards AI

Please rate your agreement with the following sentences:
Q11: I think that AI tools improve diagnosis accuracy (i.e. decrease medical error)
1 (Strongly disagree) 2 (Disagree) 3 (Neither agree nor disagree) 4 (Agree) 5 (Strongly agree)

Q12: I think that AI tools accelerate some tasks thus improving time response to patients
1 (Strongly disagree) 2 (Disagree) 3 (Neither agree nor disagree) 4 (Agree) 5 (Strongly agree)

Q13: Working with AI tools requires more effort (e.g. time invested) than working without AI tools
1 (Strongly disagree) 2 (Disagree) 3 (Neither agree nor disagree) 4 (Agree) 5 (Strongly agree)

Q14: My institution promotes the use of AI in clinical practice
1 (Strongly disagree) 2 (Disagree) 3 (Neither agree nor disagree) 4 (Agree) 5 (Strongly agree)

Q15: My institution has the right conditions (good quality dataset, capable IT services, advanced digital solutions) to support AI adoption in clinical practice
1 (Strongly disagree) 2 (Disagree) 3 (Neither agree nor disagree) 4 (Agree) 5 (Strongly agree)

Q16: I feel pressured by my colleagues or institution to use AI in daily clinical practice
1 (Strongly disagree) 2 (Disagree) 3 (Neither agree nor disagree) 4 (Agree) 5 (Strongly agree)

Q17a: Please rate your agreement on the following sentence:
There should be AI training in the medical curriculum (with an eventual reduction in education time dedicated to traditional medical training, if needed)
1 (Strongly disagree) 2 (Disagree) 3 (Neither agree nor disagree) 4 (Agree) 5 (Strongly agree)

If you answered "Agree" or "Strongly agree":
Q17b. How many hours of traditional medical training should be replaced by Ai training?
- 10h
- 20h
- 40h
- 70h
- >100h

Q18: Which AI-related topic do you think is the most important to be taught in medical school? Choose only one option
- Limitations and challenges
- Understanding the construction of algorithms
- Taking the lead in AI solutions development
- Surviving the AI revolution
- None
- Other

Perspectives regarding AI

Please watch this short video (50 sec) before answering the next questions

https://www.youtube.com/embed/jZg5QhL3Ckc?rel=0&autoplay=1&start=130&end=178

In this video we hear Dr. Eric Topol, an expert in digital medicine, saying that "many conditions could be AI-diagnosed".

Q19: When do you think this will become a reality?

- In 2 years
- In 4 years
- In 6 years
- In 10 years
- In 15 or more years
- Never

Q20: How does this scenario make you feel? Choose up to 3 options

- Afraid
- Relieved
- Indifferent
- Excited
- Motivated
- Demotivated
- Other

Q21: How likely is it that neuroradiologists who use AI will replace neuroradiologists who don't?

1 (Very unlikely) 2 (Unlikely) 3 (No opinion) 4 (Likely) 5 (Very likely)

Q22: In this scenario of AI automation what would be your major concerns? (Choose up to 3 options)

- Lower salaries and/or job opportunities
- Lower reputation, as neuroradiologists would no longer perform certain tasks
- Ethical issues related to patients' data privacy and security
- Threat to doctor-patient relationship
- Regulatory concerns (e.g. lack of standard regulation, liability issues)
- Technological concerns regarding AI malfunction (e.g. making a wrong decision based on a AI error)
- Other

Q23a. Imagine the following situation: "You work in a hospital/institution and the Administration calls you to discuss about AI in the medical field"

What are your initial thoughts?
- I don't want to hear about this
- I am too busy for IT stuff
- I don't want to be replaced by AI, don't count with me
- I want to be involved
- I want to help push this process forward
- Wow! I want to be ahead of the game, I am in!

If you choose one of the last three options
Q23b. Which of the following steps would you recommend to accelerate the process? Choose up to 3 options
- Invest in AI literacy and training for healthcare professionals
- Upgrade the current IT infrastructures for a better support to AI tools
- Promote the collaboration of healthcare professionals in developing/improving AI solutions
- Establish a multidisciplinary team of AI experts in charge of overseeing the process
- Create specific protocols for risk management of AI-related problems
- Other

Thank you! This is not an AI-powered survey, but I am happy to provide more information about my research through s-mlpsmonteiro@ucp.pt (Leonor Monteiro)

Q24: I may come to conduct interviews on this topic. If you are ok with being contacted for a zoom interview let me know your email

Appendix IV – Descriptive statistics

Q1: Gender			
		Frequency	Percentage
Valid	Female	68	37,0
	Male	115	62,5
	Rather not say	1	0,5
	Total	184	100,0

Q2: Age			
		Frequency	Percentage
Valid	25 - 34	38	20,7
	35 - 44	70	38,0
	45 - 54	40	21,7
	55 - 64	26	14,1
	> 65	10	5,4
	Total	184	100,0

Q3: Where are you currently working?		
	Frequency	Percentage
Austria	2	1,1
Belgium	2	1,1
Bosnia and Herzegovina	2	1,1
Bulgaria	2	1,1
Croatia	2	1,1
Denmark	9	4,9
Finland	1	0,5
France	24	13,0
Germany	21	11,4
Greece	4	2,2
Hungary	1	0,5
Ireland	1	0,5
Italy	18	9,8
Netherlands	4	2,2
Norway	2	1,1
Poland	2	1,1
Portugal	30	16,3

Romania	1	0,5
Slovakia	1	0,5
Slovenia	2	1,1
Spain	21	11,4
Sweden	1	0,5
Switzerland	13	7,1
Turkey	3	1,6
UK	15	8,2
Total	184	100,0

Q4: What is your highest educational degree earned?

	Frequency	Percentage
Bachelor's degree	29	15,8
Master's degree	83	45,1
PhD	72	39,1
Total	184	100,0

Q5: What is your current professional situation?

	Frequency	Percentage
Specialist	165	89,7
Intern attending the first 2 years of training	10	5,4
Intern attending the last years of training	9	4,9
Total	184	100,0

Q6: What is your main site of professional activity?

	Frequency	Percentage
Public hospital	143	77,7
Private hospital	27	14,7
Other	14	7,6
Total	184	100,0

Q7: Do you have any advanced specific background? (PhD, Research fellowship, etc.)		
	Frequency	Percentage
Yes	86	46,7
No	98	53,3
Total	184	100,0

Q8: According to the European Commission: "Artificial intelligence (AI) refers to systems that display intelligent behaviour by analysing their environment and taking actions – with some degree of autonomy – to achieve specific goals". Based on this definition, how would you classify your knowledge about AI?		
	Frequency	Percentage
Very insufficient	11	6,0
Insufficient	68	37,0
Sufficient	67	36,4
Good	33	17,9
Very good	5	2,7
Total	184	100,0

Q9: How would you define "Machine Learning"? **Choose only one option**		
	Frequency	Percentage
It is the same as AI (i.e. they are synonyms)	1	0,5
Broader term that includes all AI technologies that can learn from data and recognize patterns	77	41,8
AI branch in which algorithms are trained to learn from data without explicit programming	103	56,0
Other	3	1,6
Total	184	100,0

Q10a: Do you use AI-based tools in your clinical practice? (e.g. a software that detects, quantifies or classifies a certain lesion based on medical imaging) Choose only one option		
	Frequency	Percentage
Yes	89	48,4
No	80	43,5
Not sure	5	2,7
Not that I am aware of	10	5,4
Total	184	100,0

Q10b. How often do you use AI tools?			
		Frequency	Percentage
Valid	In every case that I work on	2	1,1
	Everyday	32	17,4
	Every week	27	14,7
	Few times a month	22	12,0
	Few times a year	6	3,3
	Total	89	48,4
Missing	System	95	51,6
Total		184	100,0

Q11: I think that AI tools improve diagnosis accuracy (i.e. decrease medical error)		
	Frequency	Percentage
Strongly disagree	3	1,6
Disagree	12	6,5
Neither agree nor disagree	46	25,0
Agree	97	52,7
Strongly agree	26	14,1
Total	184	100,0

Q12: I think that AI tools accelerate some tasks thus improving time response to patients		
	Frequency	Percentage
Strongly disagree	2	1,1
Disagree	18	9,8
Neither agree nor disagree	28	15,2
Agree	110	59,8
Strongly agree	26	14,1
Total	184	100,0

Q13: Working with AI tools requires more effort (e.g. time invested) than working without AI tools		
	Frequency	Percentage
Strongly disagree	5	2,7
Disagree	68	37,0
Neither agree nor disagree	61	33,2
Agree	42	22,8
Strongly agree	8	4,3
Total	184	100,0

Q14: My institution promotes the use of AI in clinical practice		
	Frequency	Percentage
Strongly disagree	28	15,2
Disagree	29	15,8
Neither agree nor disagree	69	37,5
Agree	50	27,2
Strongly agree	8	4,3
Total	184	100,0

Q15: My institution has the right conditions (good quality dataset, capable IT services, advanced digital solutions) to support AI adoption in clinical practice		
	Frequency	Percentage
Strongly disagree	27	14,7
Disagree	49	26,6
Neither agree nor disagree	35	19,0
Agree	69	37,5
Strongly agree	4	2,2
Total	184	100,0

Q16: I feel pressured by my colleagues or institution to use AI in daily clinical practice		
	Frequency	Percentage
Strongly disagree	46	25,0
Disagree	87	47,3
Neither agree nor disagree	40	21,7
Agree	10	5,4
Strongly agree	1	0,5
Total	184	100,0

Q17a: Please rate your agreement on the following sentence: There should be AI training in the medical curriculum (with an eventual reduction in education time dedicated to traditional medical training, if needed)		
	Frequency	Percentage
Strongly disagree	3	1,6
Disagree	30	16,3
Neither agree nor disagree	41	22,3
Agree	76	41,3
Strongly agree	34	18,5
Total	184	100,0

Q17b. How many hours of traditional medical training should be replaced by Ai training?			
		Frequency	Percentage
Valid	10h	37	20,1
	20h	28	15,2
	40h	23	12,5
	70h	10	5,4
	> 100h	12	6,5
	Total	110	59,8
Missing	System	74	40,2
Total		184	100,0

Q18: Which AI-related topic do you think is the most important to be taught in medical school? Choose only one option		
	Frequency	Percentage
Limitations and challenges	87	47,3
Understanding the construction of algorithms	40	21,7
Taking the lead in AI solutions development	35	19,0
Surviving the AI revolution	14	7,6
None	6	3,3
Other	2	1,1
Total	184	100,0

In this video we hear Dr. Eric Topol, an expert in digital medicine, saying that "many conditions could be AI-diagnosed". Q19: When do you think this will become a reality?		
	Frequency	Percentage
In 2 years	19	10,3
In 4 years	15	8,2
In 6 years	25	13,6
In 10 years	75	40,8
In 15 or more years	43	23,4
Never	7	3,8
Total	184	100,0

Q20: How does this scenario make you feel? Choose up to 3 options		
	Frequency	Percentage
Fear	23	12,5
Relief	9	4,9
Indifference	37	20,1
Excitement	82	44,6
Motivation	63	34,2
Demotivation	10	5,4
Other	13	7,1

Q21: How likely is it that neuroradiologists who use AI will replace neuroradiologists who don't?		
	Frequency	Percentage
Very unlikely	13	7,1
Unlikely	39	21,2
No opinion	36	19,6
Likely	74	40,2
Very likely	22	12,0
Total	184	100,0

Q22: In this scenario of AI automation what would be your major concerns? (Choose up to 3 options)		
	Frequency	Percentage
Lower salaries and/or job opportunities	45	24,5
Lower reputation, as neuroradiologists would no longer perform certain tasks	30	16,3
Ethical issues related to patients' data privacy and security	72	39,1
Threat to doctor-patient relationship	37	20,1
Regulatory concerns (e.g. lack of standard regulation, liability issues)	94	51,1
Technological concerns regarding AI malfunction (e.g. making a wrong decision based on a AI error)	145	78,8
Other	9	4,9

Q23a. Imagine the following situation: "You work in a hospital/institution and the Administration calls you to discuss about AI in the medical field" **What are your initial thoughts?**		
	Frequency	Percentage
I don't want to hear about this	1	0,5
I am too busy for IT stuff	8	4,3
I don't want to be replaced by AI, don't count with me	4	2,2
I want to be involved	109	59,2
I want to help push this process forward	32	17,4
Wow! I want to be ahead of the game, I am in!	30	16,3
Total	184	100,0

Q23b. Which of the following steps would you recommend to accelerate the process? Choose up to 3 options		
	Frequency	Percentage
Invest in AI literacy and training for healthcare professionals	79	42,9
Upgrade the current IT infrastructures for a better support to AI tools	97	52,7
Promote the collaboration of healthcare professionals in developing/improving AI solutions	97	52,7
Establish a multidisciplinary team of AI experts in charge of overseeing the process	85	46,2
Create specific protocols for risk management of AI-related problems	60	32,6
Other	7	3,8