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Review Article

Artificial Intelligence in Radiology, Emergency, and Remote Healthcare: A Snapshot of Present and Future Applications

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Abstract: This paper critically examines artificial intelligence in the healthcare sector and aims to identify concrete points of challenges and business value propositions first in radiology and then across healthcare more broadly. It discusses current applications in radiology and future uses of AI in healthcare, focusing on three main areas: (i) emergency incidents handling, (ii) intensive care unit treatment and (iii) augmented telemedicine, to which emergency radiology is a critical success factor. Despite some risks and compliance issues that need to be taken care of, this paper clearly shows that AI has the potential (a) to reengineer the business processes of the healthcare sector, using AI-assisted radiology as a driver and (b) to improve the effectiveness of the healthcare system as well as (c) to increase the quality provision of healthcare services. Despite its slow adoption, AI-assisted healthcare can indeed offer business/operational solutions that benefit all healthcare stakeholders.

Keywords: AI in Emergency Incidents Handling; AI in Healthcare Administrative Tasks; AI in Healthcare Services; AI in Radiology; AI in Remote Healthcare; Future AI Applications in Healthcare.

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1. Introduction

Among the several sectors where Artificial Intelligence (AI) is gaining ground as an integral component of digital solutions that transform business processes, the medical sector has appeared as an area where medical devices and tools experience the transformative power of AI. Today, medicine has the potential to harness "big data," utilizing the large quantities of information generated daily. The use of AI allows gaining insights into a vast amount of data produced by examinations worldwide instead of relying on the experience accumulated by single persons, no matter how well they are educated and trained, to read the results and make a decision[1]. AI application enables medical staff to tap into a worldwide knowledge base, which can be shaped when examination data are automatically extracted, categorized, classified, associated with protocols, etc. The scope and depth of applications is vast. Machine learning algorithms have proven helpful in predicting certain diseases' risks, and computer visualization has improved the detection rates of various health problems[2].

The rise of artificial intelligence in healthcare applications has been presented in [3], referencing the uses of AI in healthcare and the relevant value chain. However, most of these applications are still in an exploratory phase. Very few AI-assisted products exist in the biomedical engineering market, showing that the potential exists, but there is a long way towards adoption. A 2021 survey [4] revealed that 18% of the organizations were evaluating AI cases in healthcare, 26% did not engage in AI-based solutions, and only 19% had introduced some sort of AI model in real life.

AI in healthcare is seen as relevant in three main areas [5]: (a) diagnosis and treatment recommendations, (b) patient engagement and adherence, and (c) administrative activities. A variety of technologies have the potential to be helpful: neural networks and deep learning to assist doctors in diagnosis, physical robots in treatment, expert systems and predictive models in nursing, robotic process automation, and natural language processing for administrative work.

Scanning and imaging biomedical engineering technologies have precedence over other healthcare areas. The examination produces pure data that can be easily combined, compared, categorized, and enriched with previous patterns of similar examination results. Hence, it is not a surprise that radiology has been a pioneer field of AI application in healthcare, with some of the few products of the medical technology industry launched in this area. It is, therefore useful to look into radiology as the main current area of production AI applications to identify current challenges and value propositions that can drive further improvements and adoption of AI-assisted healthcare. Sometimes, the urgency of research to use new technologies obscures the clear identification of their business value; the same holds true for AI. This paper attempts to shed some light on this perspective. Furthermore, it proposes three areas for immediate future use of AI with imminent benefits for the healthcare sector, namely: emergency incident handling, intensive care unit processes, and augmented telemedicine. To all three of them, emergency radiology plays a role in their advancement and streamlining. Therefore, the challenges and business value propositions identified in the next chapter can be generalized to the three future AI-assisted healthcare areas discussed later in chapter three.

2. Current Applications of AI in Radiology

Our study focuses on radiology, as it currently pioneers the use of AI in healthcare; radiology has greatly benefitted from the advances in information technology processing capabilities in various fields (sensing, image processing, etc.). Imaging has been a powerful tool that offers immediate insight information in a visual format, which is immediately recognizable by the medical staff, but, on the other hand, it has incurred issues such as low-value utilization, higher-cost imaging services, and high volumes of images. As the imaging volume increases, radiologists must be more efficient and effective in interpreting. All these factors may facilitate medical personnel's acceptance of AI technologies. AI-assisted radiology was initially used in mammography back in 1992. These results paved the way for more AI in medical imaging applications[6].

The history of artificial intelligence in radiology, which can be found in [6], can be traced to the area of computerized radiology, where radiography meets computer science and vice versa. Signal and image processing have been rapidly developed as scientific domains in computer science, enabling advanced imaging techniques that allow smooth adoption and lower costs. AI represents a pivotal development that will continue to drive the evolution. The field of radiology has played a leading role in the digital transformation of medical examinations; augmented with AI, radiology has the potential to transform entire business processes in various areas of the healthcare sector. In the era of big data analytics, radiology reports and images generate “big data” acceleratedly, providing the required substrate for AI research [7]. Big data is usually defined using the five “Vs”, namely: Volume, Velocity, Variety, Veracity, and Value [8]; it is easily understandable that radiology image quality is big data since all five “Vs” testify positively to this end.

Regarding volume, only chest X-ray examinations create 2 billion images annually worldwide [9]. This huge number results from three factors: economic feasibility, technical availability, and diagnosis, which are the starting point for many biological situations with unhealthy symptoms. Interestingly, the availability of labeled images, which comprises the currency of AI research, is greatest with chest radiographs. For all these reasons, chest radiography has received a lot of attention from AI research [10].

Radiology imaging data qualify as big data in all five “Vs” – apart from the volume: velocity is the speed of producing data, variety is ensured due to different people being examined each time, veracity has to do with the truthfulness of the data which is ensured by the medical devices and value is obviously associated with the importance of a correct diagnosis.

A well-known medical AI dataset is ChestX-ray14. Collected between 1992 and 2015 by Wang et al.[11], it consists of radiographs from 30,805 unique patients. “The images were labeled with 14 medical conditions, such as emphysema, pulmonary nodules, and pneumonia, by four radiologists (three generalists and one thoracic subspecialist). The ground truth was later established by a majority vote of the four radiologists” [12].

Despite its weaknesses and deficiencies [12], [13], ChestX-ray14 is still a very good starting point for big data analytics and an appropriate testbed for AI algorithms to be applied. The availability of this dataset free of charge has boosted research activities in this area.

The applications of AI in radiology go quite far beyond the intuitive use for automating image interpretation, with functions in image acquisition, management, and population screening that will probably be more abundant in the coming years due to the value that would be provided in optimizing daily practice workflows [14], [15]. The disruptive power of AI has started transforming the radiology diagnosis business process, given that the basic steps comprise planning (tools set-up), radiology scanning, image production, prioritization, image assessment, diagnosis, delivery of results to the patient, and second-level analysis. It is critical that AI augments and enriches the prioritization, image assessment, and diagnosis tasks of the business process to improve the quality of service to the patients and enable radiologists to cope with the constantly increasing volume of required results. Therefore, it can be argued that AI has blurred the lines between interpretive and non-interpretive radiology.

While AI has many potential benefits in radiology, several challenges must be addressed. Some of the key challenges include:

- Greater Complexity: There has been an increase of five times (x5) in the number of images produced per scan. The number of images that require interpretation per examination has also increased. Diagnostic Computerized Tomography and Magnetic Resonance Imaging (MRI) represent a major improvement over X-rays because their data refer to three-dimensional results compared to two-dimensional images generated by X-rays. The increased complexity favors a more detailed examination but makes diagnosis more difficult, compromising diagnostic accuracy and, ultimately, health care delivery quality[16]. Due to this complexity, more and more radiologists are further trained in certain types of radiology images, reducing the scope of their involvement in radiology diagnoses. Complexity brings more specialization, reducing the available number of radiologists qualified to read certain images.
- Radiology Departments are pushed to their limits: Six percent (6%) of Radiologists worldwide report signs of burnout. The quotient of image volume divided by the available radiology medical doctors is steadily increasing due to viruses, population aging, etc. The COVID-19 pandemic may also have resulted in hiring freezes at the time, contributing to the shortage of radiologists[17].
- Diagnostic Errors: It is estimated that average diagnostic error rates range from 3% to 5%, which means there will be approximately 40 million imaging diagnostic errors annually worldwide. Although the percentage is low, it represents a large number of errors worldwide, which is considered to be reducible [18]. AI has a role in steepening the learning curve for those who assess radiology images.

The integration of AI in radiology presents significant challenges that must be addressed to ensure that it is effective, safe, and ethical – beyond this paper's scope.

Addressing these multi-disciplinary challenges will require collaboration between radiologists, data scientists, computer scientists, imaging experts, regulatory bodies, and other stakeholders to develop and implement effective solutions. Some key value propositions of AI in radiology include:

- Improved accuracy and speed: AI algorithms can quickly analyze large amounts of imaging data and detect subtle changes that human radiologists may miss. This can lead to faster and more accurate diagnoses, especially in complex cases.
- Enhanced workflow efficiency: AI can automate routine tasks such as image recognition and measurement, allowing radiologists to focus on more complex cases and ultimately increasing their productivity.
- Enhanced decision-making: AI algorithms can assist radiologists in making more informed decisions by providing them with additional information and identifying patterns that may not be immediately visible to the human eye. This can help radiologists to make more accurate and confident diagnoses.
- Better patient outcomes: By improving accuracy and speed, AI can help to identify medical conditions earlier and more accurately, potentially leading to better patient outcomes [19] and faster treatment.
- Reduced healthcare costs: AI can help reduce healthcare costs by improving efficiency, reducing unnecessary imaging tests, and decreasing the likelihood of misdiagnosis and subsequent treatment.

- Remote access: AI can improve radiology services in telemedicine, particularly useful in underserved areas with an obvious positive impact on patient care access and healthcare disparities.
- Customization: AI can be tailored to individual patient needs, allowing personalized and targeted treatment plans. This can lead to optimized patient journeys [20] and reduced healthcare costs.
- Access to care: AI can improve access to care in underserved areas by providing remote access to radiology services and enabling more efficient use of existing resources.
- Data analytics: imaging data qualify as big data in terms of volume, velocity, variety, veracity, and value. Therefore they can be handled by modern capabilities for processing large amounts of data (e.g., data warehouses/data marts, predictive algorithms, etc.) to reveal unseen patterns is absolutely useful in research and development. This can lead to new insights and discoveries in the field of radiology and ultimately increase speed and accuracy in diagnoses.

3. Future Applications of AI in Healthcare

3.1. Emergency Incidents Handling

Radiology is one of the first areas that enabled AI to be introduced to emergency incident handling. "There have been numerous reported studies examining the application of AI-based algorithms in identifying common emergency department conditions to ensure more rapid reporting and in turn, quicker patient care." [21] To this end, a multiclass NLP-based classification algorithm has been developed to enable automated assignment of protocols in nearly 70% of the cases, with very few errors combined with top-three protocol suggestions for clinical review[22].

Apart from that, there is a future application that has the potential to increase efficiency and effectiveness in emergency incident handling. The scenario is as follows:

When emergency medical incidents occur, people call the ambulance to take them to the hospital. When ambulances arrive at the hospital, patients are usually served on a first-come-first-served basis. Then, after a quick interview with the receiving medical doctor, they are given an emergency indicator. This indicator is a life-risk-based assessment for which patients are prioritized for treatment. However, it would be better if some more time could be saved. During commuting time inside the ambulance, the nursing crew could input some data according to the emergency incidents' medical protocols so that an AI system could suggest an emergency indicator to the receiving hospital as well as a list of the medical specializations that are necessary to handle this incident so that all the medical personal is timely called upon and adequately informed and prepared to start the treatment immediately. It may seem that the time saved from such an AI-assisted decision support system is insignificant, but a typical hospital in duty in the Athens area receives, on average, an emergency incident every five minutes. Overall, the total time that could be saved would really be substantial; moreover, the treatment of really serious incidents would be faster and more effective due to the early engagement of the appropriate medical staff.

A comprehensive survey of state-of-the-art computational intelligence technologies widely applied in emergency management is provided in [23].

3.2. Intensive Care Unit Treatment

In intensive care units (ICU), patients are usually wired with many equipment that record their physiological performance. Nursing and medical staff need always to keep an eye on the displays and the recordings to identify patterns of amelioration or deterioration of the patient's health situation. Moreover, it is often the case that the readings of the devices need to be interpreted in combination to provide a meaningful overall picture of the patient's health situation. Here is the value addition that AI can provide. Collecting the data in real-time from the various devices and comparing them with other such similar data, AI-assisted ICU's digital assistants may provide early warnings for possible deterioration of the patient's health and provide suggestions for possible interventions. For such a system to work, the world medical and IT community must move to the "creation of a standardization of a core group of data between different electronic health record systems, using a common dictionary for data labeling, which could greatly simplify sharing and merging of data from different centers", as explained in [24]. A review that covers "the current applications of AI medicine in the ICU, potential pitfalls, and other AI medicine-related topics relevant for the ICU", is provided in [25].

3.3. Augmented Telemedicine

In some countries with islands or populations dispersed in areas away from cities and villages, providing good quality first-level healthcare services is inherently difficult. Sometimes it is also hard to find a medical doctor of any kind of specialty. These problems result in social marginalization and increased inequalities in accessing medical services. Improved access to medical services for isolated areas is a major objective of the social and territorial cohesion political targets and strategies of the European Union[26].

To alleviate the problem of equal access to health services, telemedicine has been employed in some places; however, this requires an online session with a general practitioner who will help the patient use the equipment, read the displays of the devices, collect the results and then suggest a diagnosis and possibly some drugs for initial treatment. Embedding AI into a telemedicine infrastructure would benefit the patient with immediate diagnosis and an emergency indicator that would prioritize online sessions with specialized medical doctors. The benefits and limitations of AI-based telemedicine in various medical domains are discussed in [27].

3.4. Administrative Tasks

It has been reported [28] that AI-assisted administrative tasks reduce physicians' involvement by around 20%, which can be considered a significant improvement, allowing more time for diagnoses and treatments. The use of AI in administrative tasks, which, my nature, process personalized (not anonymized) data has to be compliant with the new EU regulation [29], called AI Act. This legislation introduces different rules for different risk levels, with medical devices and records being in the high-risk category [30]. Providers and users of healthcare AI software are obliged to register to an EU database of high-risk AI applications, implement high standards' quality and risk management systems, and monitor and audit their usage regularly to avoid non-compliance. Healthcare stakeholders should not consider these restrictions as impediments to the adoption of AI healthcare applications but rather as an accelerator of ethical and lawful implementations of these new technologies in healthcare. The scope of the AI Act covers all aspects of AI usage, not only administrative tasks; however, examination results are first anonymized and then inserted into databases as deep learning input.

4. Conclusions

Although AI presence is mostly transparent in healthcare operations, it has the potential to transform the doctor-patient interaction, by "improving the patient experience, helping to increase productivity, diagnostic accuracy and overall quality of care." [31]. However, AI applications are often linked to legal, ethical, and sociological issues [32]. It is beyond the scope of this paper to analyze these concerns.

Some of the standard tasks performed by medical practitioners and nursing staff include recognition, classification, categorization, and identification of resemblance to known problematic patterns of visualized or measured data received from the patient through examinations. However, AI can carry out these kinds of tasks faster and more effectively than humans. It is, therefore obvious that AI has a role to play in assisting the healthcare staff in the areas of radiology, emergency handling, intensive care, telemedicine, and administration. The benefits of using AI in the healthcare sector may indeed improve the quality of the healthcare services provision and, ultimately, people's quality of life; it is, therefore, necessary to remove the barriers, not by ignoring them, but by addressing them properly to achieve the best possible result for patients and the healthcare staff.

Some risks need to be taken care of, such as inappropriate data comparison and incompatible data sets' pattern matching. For example, the use of AI in radiology has been primarily developed for adult patients, whereas "it has not been shown to work consistently across the pediatric population"[33]. Further analysis of risks in AI-assisted healthcare services is outside this paper's scope.

Limitations of this paper include lack of analysis of most pertinent AI algorithms and technologies for quality healthcare services, organizational and technological prerequisites for reaping the benefits identified as value propositions in chapter two, detailed description of how the selected for future uses of AI in healthcare can result in successful case studies and lack of real-world environments of AI applied in healthcare for observations and suggestions for improvement.

Further research is already ongoing concerning the adoption parameters of AI in healthcare, focusing on radiology at the beginning. Our further research uses technology adoption models to identify the organization, marketing, and other implications for the faster adoption of AI-assisted healthcare technologies. Surveys and questionnaires have been completed; this further research is currently at the stage of the statistical processing of the collected results and will soon be published.

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