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The measure of efficiency and effectiveness when using artificial intelligence (AI) in radiology

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THE MEASURE OF EFFICIENCY AND EFFECTIVENESS WHEN USING ARTIFICIAL INTELLIGENCE (AI) IN RADIOLOGY

ABSTRACT

Introduction: The use of artificial intelligence in radiology has helped radiologists identify patterns and abnormalities in medical images to diagnose and treat patients. Deep learning and machine learning algorithms have been used to assist physicians in detecting features that are not noticeable to the human eye. The FDA has approved almost 400 AI algorithms for radiology and estimated that the market for AI in medical imaging would grow from $21.48 billion in 2018 to $264.85 billion in 2028.

Purpose of the Study: The purpose of this research was to evaluate the use of artificial intelligence in radiology to determine its impact on diagnostic accuracy, interpretation time, and clinical workflow efficiency in imaging acquisition.

Methodology: The intended methodology for this qualitative study was a literature review with a semi-structured interview with an expert in AI used in radiology. Three databases were used to collect 8,349 total sources. The sources gathered from databases were reviewed and reduced to 29 sources that were limited to the English language and were published from the years 2015 through 2024. The last source was gathered from a semi-structured interview. Of the sources used, 20 were used in the results section.

Results: The research showed that the use of AI in radiology has improved diagnostic accuracy and interpretation time by providing physicians with additional information. Radiologists were able to improve their interpretation time by seconds using AI systems, which allowed for patients to be diagnosed and treated sooner. Clinical workflow efficiency showed improvement in getting better images and lowering patients contrast dosage, but it was shown that some AI systems created additional steps for technologists, resulting in a longer process.

Discussion/Conclusion: AI served as a second pair of eyes to detect abnormalities that could be missed by the human eye, which improved diagnostic accuracy and interpretation time. The literature review and semi-structured interview had mixed findings on whether AI improved imaging acquisition. Further study is needed to evaluate how artificial intelligence impacts radiology as it continues to grow.

Keywords: artificial intelligence, clinical workflow, diagnostic accuracy, imaging acquisition, interpretation times, medical imaging, radiology.

INTRODUCTION

Artificial intelligence (AI) has been used in many ways throughout the healthcare industry. The FDA has approved more than 520 AI medical algorithms, and almost 400 are for radiology (AHA, 2023). It has been used in areas like the supply chain to maintain clinical equipment stock and direct patient care to observe patient movement and vitals. It was first reportedly used in radiology in 1992 to detect microcalcifications in mammograms, when it was more commonly known as computer-aided detection (Cowen, 2023).

According to Cornell University, artificial intelligence (AI) could be defined as any artificial system that performed tasks under varying and unpredictable circumstances without significant human oversight or could learn from experience and improve performance when exposed to data sets (Cornell University, 2023). It has been used across many of the different medical imaging modalities, like X-ray, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), and Positron Emission Tomography (PET). Radiological technologists used imaging machines to collect images that were then interpreted by a radiologist to measure illness, manage, treat, and prevent serious health conditions (Hussain et al., 2022).

Leveraging the capabilities of AI, like deep learning models in medical imaging data, has been used to recognize complex patterns and features that were not noticeable to the human eye (Pinto-Coelho, 2023). AI models like deep learning and machine learning algorithms assisted radiologists in making more accurate and efficient diagnoses. In addition, machine and deep learning have relied on datasets to learn information before they have been implemented. Machine learning algorithms created analytical models based on data to improve prediction accuracy (Handelman et al., 2018). Deep learning algorithms used simple interconnected networks to extract patterns from data that solved complex problems (Mazurowski et al., 2019). AI algorithms were broken into two sections: supervised and unsupervised learning. In supervised learning, labeled information was given to the computer that related to the learning target and desired outcome measurements to be achieved (Handelman et al., 2018). In unsupervised learning, unlabeled information was provided to the computer, which meant the computer learned by finding patterns and similarities in the data (Kufel et al., 2023).

Deep learning is a subset of machine learning and the core of deep learning in medical imaging is convolutional neural networks (CNN), which are multilayered artificial neural networks with weighted connections between neurons that are iteratively adjusted through repeated exposure to training data (Cheng et al., 2021). In radiology, these networks are used in imaging classification, object detection, semantic segmentation, and instance segmentation (Cheng et al., 2021). This allows radiologists to map out medical images and determine a diagnosis. Deep learning algorithms used supervised learning to identify new information without further training.

For AI algorithms in medical imaging to be implemented, they must be approved by the U.S. Food and Drug Administration (FDA). Between the years 2008 and 2022, the FDA approved 201 AI algorithms for clinical practice (Mello-Thoms & Mello, 2023). It has been estimated that the market for AI in medical imaging would grow from $21.48 billion in 2018 to $264.85 billion in 2028 (Mello-Thoms & Mello, 2023).

The purpose of this research was to evaluate the use of artificial intelligence in radiology to determine its impact on diagnostic accuracy, interpretation time, and clinical workflow efficiency in imaging acquisition.

METHODOLOGY

The working hypothesis of this study was that the use of artificial intelligence in radiology has improved the quality of care by increasing diagnostic accuracy, reducing interpretation time, and increased clinical workflow efficiencies by reducing errors in imaging acquisition.

The intended methodology for this qualitative study was a literature review with a semi structured interview with an expert in AI used in radiology. Research articles and peer-reviewed literature were identified using Marshall University's PubMed, EBSCOhost and Google Scholar. The Google search engine was also used to research government and private associate websites. Key words used in the search included 'artificial intelligence' OR 'AI' AND 'radiology' OR 'medical imaging' AND 'increased diagnostic accuracy' OR 'reduced interpretation times' OR 'increased clinical workflow' OR 'imaging acquisition.' The twenty-nine articles reviewed were limited to the English language and were published from the years 2015 through 2024. The information obtained in these journals, websites, and articles were used as the source of primary and secondary material. Upon review of the literature review, the material was used to display information and form a conclusion. This search was completed by JW and validated by AC, who acted as a secondary reviewer and determined if the references met the inclusion criteria. Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Prisma) method, the search identified 8,349 relevant citations, and articles were excluded (N= 8,326) if they did not meet inclusion principles. Articles were included (N= 29) if they described the use of AI in radiology, diagnostic accuracy, interpretation time, clinical workflow efficiency, and imaging acquisition. Articles from other sources (N= 10) were also included in this search (Figure 2). These 30 references were subject to a full text review and used in both the introduction and result sections.

A semi structured interview was conducted with a healthcare professional who has experience using artificial intelligence programs in radiology. This included physicians, radiographers, or radiology department managers. The interview was conducted in person and tape recorded. A total of thirteen questions were asked that are based on the use of artificial intelligence in radiology (see appendix). The participant was recruited from the Charleston Area Medical Center. Marshall University IRB approval was obtained before interviewing the participant.

RESULTS

Diagnostic Accuracy

According to the Society to Improve Diagnosis in Medicine, diagnostic errors affected more than 12 million Americans each year (GOA, 2022). Many studies evaluating AI in medical imaging focus on measuring diagnostic accuracy by calculating sensitivity and specificity (Oren et al., 2020). The sensitivity represented clinical conditions and the specificity represented how often it correctly ruled out clinical conditions. This is known as the diagnostic accuracy test (DAT). The DAT indicated the proportion of individuals with the target condition correctly identified by positive test results and the percentage of individuals correctly identified by negative test results (Pacurari et al., 2023). A study was conducted that gathered data from nine other studies and analyzed the diagnostic accuracy of machine learning algorithms in medical imaging. The study used different medical imaging modalities like different CT scans and X-rays. The results of the study found that the use of machine learning in medical imaging had a sensitivity ranged from 0.81 to 0.99, a specificity ranged from 0.46 to 1.00, and an accuracy ranged from 77.8% to 100% (Pacurari et al., 2023). The U.S. Government Accountability Office conducted a technology assessment on the benefits of using machine learning algorithms in radiology and found that it led to earlier disease detection, more consistent medical analysis, and increased access to care (GOA, 2022).

Alowais et al., (2023), from the United Kingdom (UK) fed large datasets of mammogram images into an AI system to detect breast cancer, which reported an absolute reduction in false positives and false negatives by 5.7% and 5.9%, respectively. A study conducted in South Korea compared the diagnosis of breast cancer between AI systems and radiologists. The AI system exhibited higher sensitivity in diagnosing breast cancer with masses at 90% compared to radiologists at 78%, and the AI was better at detecting the cancer early at 91% compared to radiologists at 74% (Alowais et al., 2023).

Computer-Aided Detection (CAD) has been an AI model that was used to assist radiologists in the diagnosing process. It analyzed labeled data to find patterns and abnormalities in medical imaging, using supervised learning. This AI model was used to assist radiologists in interpreting medical images using the suggestion of response provided by image processing, computer vision, and machine learning techniques (Santos et al., 2019). The system was used to improve diagnostic accuracy by reducing the risk of human error and marking specific areas of images that seemed abnormal based on the dataset it learned to minimize the chance of a radiologist missing them (Deng, 2019). A study published in the Journal of Clinical and Laboratory Research had seven radiologists read 100 prostate MRI cases with and without the use of CAD. Winkel et al. (2021) found that with the use of CAD, radiologists were more accurate in detecting lesions, from 0.84 without CAD to 0.88 with CAD based on the standard Prostate Imaging Reporting and Data System (PI-RADS), with a 4.4% improvement (Figure 3).

According to Kathy Newsome, the manager of the Nuclear Medicine Department and Cardiac Imaging Center (CIC) at the Charleston Area Medical Center (CAMC), AI has helped improved diagnostic accuracy. An AI system used at the CIC was the Heartflow Fractional Flow Reserve (FFR), which is a system that measured the blood flow in the vessels and determined areas of blockages in the heart (Newsome, 2024). Heartflow FFR has helped with stent planning and with diagnosing and treating patients. Ms. Newsome stated that the use of Heartflow FFR improved diagnostic accuracy since it created an extra layer of information for physician and gave them more detail on the severity on the stenosis (Newsome, 2024). Using the system has shown to reduce death, reduce cardiac catheterization, and improve the results of coronary artery bypass graft surgery.

Interpretation Time of Medical Images

Radiology services have been continuously expanding, which has meant the increased workload for radiologists has hindered the time it took them to interpret an image. In some cases, an average radiologist had to interpret one image every 3 to 4 seconds in an 8-hour shift to meet workload demands (Hosny et al., 2018). AI was unlikely to completely take the place of radiologists when interpreting medical images, but it has assisted them by lowering the amount of time it has taken to interpret. As workload demands increased, so did the risk of human error.

CAD has been shown to reduce the time it takes a radiologist to interpret an image. Research conducted in 2021 that had seven radiologists interpret 100 prostate MRI cases found that with the use of CAD, the average time it took radiologists to interpret the scans was reduced from 103 to 81 seconds, which was a decrease of 21% (Figure 3) (Winkel et al., 2021). It has also been shown to enhance interpretation competency in mammograms and served as a second pair of eyes, which reduced the need for a second reading or observation from another radiologist (Guo et al., 2022). In mammography, the International Agency for Research on Cancer found that digital mammograms that are interpreted with the use of CAD showed a decreased of 23% in breast cancer related deaths (Guo et al., 2022).

Benedikt (2017) found that a study conducted by an imaging clinical research organization in 2016 compared the interpretation time and performance of 20 radiologists with and without the use of CAD. It required radiologists to interpret 240 cases of different types of mammograms. Digital Breast Tomosynthesis (DBT) images are 3-D mammograms that offer more detailed images compared to normal mammograms and typically took longer to interpret. The other type of mammogram used in the study was full-field digital mammography, which was a 2-D image. The study found that interpretation time with the use of CAD was improved by 29.2%, from 65.3 seconds to 46.3 seconds (Benedikt et al., 2017).

Hsu & Hoyt (2019) found that the use of AI when interpreting DBT scans allowed radiologists to reduce interpretation time. The study consisted of 24 radiologists interpreting 260 cases with and without the use of AI. According to Hsu & Hoyt (2019), with the use of AI, each physician significantly reduced interpretation time by an average of 34.7 seconds from 61.1 to 30.4 seconds (Figure 4). The study also found that using AI improved the ability to detect abnormalities and reduced the chance of needing to review the images again (Hsu & Hoyt, 2019).

The use of AI improved image acquisition, which in turn improved interpretation delivery time. Najjar (2023) found a study that examined radiologists analyzing chest x-rays found that the use of AI in image acquisition reduced interpretation delivery time from 11.2 days to 2.7 days. It allowed for more images to be read in a shorter amount of time, which was useful in emergency and trauma situations (Najjar, 2023).

Clinical Workflow Efficiency in Imaging Acquisition

Clinical workflow efficiency in imaging acquisition has been the process taken to ensure images were taken properly so that they were accurately interpreted by radiologists, which included taking the actual image. Radiologic technologists, also known as radiographers or technologists, were responsible for obtaining medical images. Their primary responsibilities were to create images of patients' bodies using medical equipment that has helped doctors diagnose and treat patients (AART, n.d.). Depending on the medical imaging modality they specialized in, they used machines like x-rays, MRIs, CTs, and PETs.

At CAMC's cardiac imaging center, Ms. Newsome has observed that AI has complicated the clinical workflow for technologists by creating additional steps. For example, with Heartflow FFR, technologists were required to log into the AI system and look up a patient's roadmap, which was a snapshot of medical issues AI identified in a patient's medical history. If a lesion was found above a certain size, the technologists became responsible for ordering the Heartflow FFR (Newsome, 2024). Before the roadmap system was added, physicians looked at the patient's scan and determined if they needed Heartflow FFR, but with the added lesion criteria technologists became responsible for ordering the test, which added more steps to their process (Newsome, 2024).

Other studies have found that AI has improved workflow efficiency in radiology departments by helping radiographers create clear images. Research has shown that AI improved low-quality scans by reducing noise and artifacts and enhancing contrast, which gave radiologists a clear image to interpret (Dargan, 2019a). Noise and artifacts were caused by the imaging machine or by the patient, for example, breathing or cardiac movement (Krupa & Bekiesińska-Figatowska, 2015). Patient movement or foreign objects in the patient's body also created noise and artifacts, which could cause the image to be difficult to interpret. It has been shown that AI algorithms within medical imaging machines automatically detected motion and determined whether a patient needed to be imaged again (Dargan, 2019b).

AI automation has also increased the workflow efficiency of imaging acquisition. Radiographers were responsible for choosing the best way to catch an image based on what the physician had ordered. If they were to choose the wrong imaging protocol, the image would not be useful to the radiologist, and the patient would have had to be scanned again. AI has assisted radiographers by suggesting which imaging protocol to select based on the physician's order and what they needed to see to accurately diagnose a patient (Hardy & Harvey, 2020). This helped speed the process of collecting the image and reduced the radiation a patient was exposed to. Some research showed that automation in postprocessing images helped radiographers with synthetic modality transfers, which created an image in one modality based on another modality image (Hardy & Harvey, 2020).

AI automation also helped radiographers adjust how a patient was positioned. In recent years, a 3-D infrared camera had been integrated into CT machine systems. Using an AI algorithm, a camera took a 3-D picture of a patient's body to look at the portion of the patient's body being scanned and automatically moved the table to position the patient in the best possible position for the scan (McCollough & Leng, 2020). This saved the radiographer's time trying to correctly position the patient and having to rescan them due to poor image quality. This meant AI improved radiology department workflow efficiencies by lowering imaging acquisition errors, so that images were processed and interpreted faster. It also improved the quality of care a patient received by lowering their radiation exposure and contrast media dose since they did not have to be rescanned. Research has shown that the use of automated positioning reduced contrast dosages for patients by 16% and saved radiographers 28% of the time it took to reposition the patient (Cellina et al., 2022).

DISCUSSION

The purpose of this research was to evaluate the use of artificial intelligence in radiology to determine its impact on diagnostic accuracy, interpretation time, and clinical workflow efficiency in imaging acquisition. The results of the literature review suggested, with the limited references available, that the use of artificial intelligences has improved many areas of radiology.

Diagnostic Accuracy

In reviewing the use of AI for diagnostic accuracy, a few studies found that using the diagnostic accuracy test (DAT) showed how AI has improved the rate of accuracy for radiologists who used AI to make a diagnosis. One study found that the use of machine learning in medical imaging had a sensitivity ranged from 0.81 to 0.99, a specificity ranged from 0.46 to 1.00, and an accuracy ranged from 77.8% to 100% (Pacurari et al., 2023). Computer-Aided Detection (CAD) and Heartflow Fractional Flow Reserve (FFR) are two AI systems used in radiology. CAD has been shown to assist radiologists in interpreting medical images using the suggestion of response provided by image processing, computer vision, and machine learning techniques (Santos et al., 2019). Winkel et al. (2021) found that with the use of CAD, radiologists were more accurate in detecting lesions based on the standard Prostate Imaging Reporting and Data System (PI-RADS), with a 4.4% improvement.

Interpretation Time of Medical Images

In reviewing the use of AI algorithms in interpretation time, the average radiologist had to interpret one image every 3 to 4 seconds in an 8-hour shift to meet workload demands (Hosny et al., 2018). CAD has been used to help radiologists reduce the time it takes to interpret an image and has served as a second pair of eyes to reduce the need for additional readings (Guo et al., 2022). This also helped reduce the need for observation from other radiologists or a second opinion. A 2021 study found that with the use of CAD, the average time it took radiologists to interpret the scans was reduced from 103 to 81 seconds, which was a decrease of 21% (Winkel et al., 2021).

Clinical Workflow Efficiency in Imaging Acquisition

In reviewing the use of AI in clinical workflow efficiencies in imaging acquisition, there were mixed findings. At CAMC's cardiac imaging center, Ms. Newsome has observed that AI has complicated the clinical workflow for technologists by creating additional steps. Other studies found that AI has improved imaging acquisition by reducing the noise and artifact in images, assisted technologists in selecting the best imaging protocol, and adjusted patients to get a better image. One study found that the use of automated positioning reduced contrast dosages for patients by 16% and saved radiographers 28% of the time it took to reposition the patient (Cellina et al., 2022). Another study showed that AI improved low-quality scans by reducing noise and artifacts and enhancing contrast, which gave radiologists a clear image to interpret (Dargan, 2019a).

Limitations

A potential limitation for this study is that only three research databases were used to gather sources, which means publication bias could be introduced. Another limitation is that there were limited statistical facts found to support that the use of AI has improved clinical workflow efficiencies.

Practical Implications

The implications of this study showed that, overall, the use of AI has had a positive impact on the radiology field. It has been shown that AI has improved diagnostic accuracy and interpretation time, which has improved patient outcomes. The study also showed that there were mixed reviews on whether AI improved clinical workflow efficiencies in imaging acquisition since additional steps were added to the technologist's process.

CONCLUSION

The literature review of the use of AI in radiology indicated that AI algorithms have improved diagnostic accuracy and interpretation time by serving as a second pair of eyes to detect abnormalities that could be missed by the human eye and improved imaging acquisition. However, the semi-structured interview indicated that AI programs have created an extra step for technologists, resulting in a longer imaging acquisition process. Further study is needed to evaluate how artificial intelligence impacts radiology as it continues to grow.