“The Role of Artificial Intelligence in Medical Imaging”

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Abstract

The rapid development in the fields of Artificial Intelligence (AI) and Machine Learning (ML) has brought improvements and innovations towards the automation of various mundane day to day tasks. The application of AI and ML has shown tremendous potential in improving every aspect of diagnostic medical imaging be it patient care, image acquisition and analysis, or reduction in patient dose. The aim of this study was to discuss the benefits of AI use in different areas and modalities of diagnostic medical imaging, their current application, and some of the concerns against wider use. Studies show that the use of AI has reduced the time for obtaining diagnostic image across all modalities and has allowed for faster treatment initiation. The efficiency in image analysis was comparable to humans. Lack of common operational standards, interoperability, and communication among various types of AI models and algorithms based on small sample size causing differential diagnosis, transparency, and security issues are main concerns against wider adoption.

Introduction

Artificial Intelligence (AI) is the presence of human intelligence in machines providing them with the ability to think like humans and mimic human actions. AI is continuously evolving and has made rapid strides in mimicking human activities. They are classified as weak or strong based on whether they focus on a particular job or complex job. The AI used in the medical imaging is strong AI with algorithms designed to excel to recognize complex patterns in diagnostic images. It can provide automated quantitative assessment of the images. Healthcare and medicine are increasingly becoming data intensive. Integration of AI into clinical workflow as a tool to assist the physician will help in faster and more accurate reproducible image assessment. Desire for improved efficiency in clinical care has been the primary driver behind the rapid advancement of AI. The purpose of this paper is to increase awareness on the rising use of AI in medical imaging, their effect and to discuss the pros and cons AI in imaging. The detail explanation of the process by which the AI works is beyond the scope of this essay.

AI and algorithm

Algorithm is a set of well-defined instructions that function as a pathway to achieve the end result from an established initial situation. Algorithms are analogous to human brain and nerve signals. Having a proper algorithm is essential for AI to be efficient. With a proper algorithm AI is able to perform complex tasks of quickly analyzing huge amount of data and recognizing patterns, efficiently assessing the radiographic images, and detecting pathology without subjective bias. Machine learning (ML) is the process by which an AI performs the complex tasks by learning from experience. Deep learning (DL) is a subfield of ML where the AI is trained to learn the supervised or unsupervised tasks. Convolutional neural network (CNN)

is a class of DL which provides the AI the ability to detect and classify distinct features, pattern recognition and detection of anomalies. The larger the sample datasets, the better trained CNN is leading to more capable AI.

Type of AI

AI is classified into seven categories based on the degree to which they can emulate human-like functions.

1. Reactive machines: the oldest form and have no memory- based functionality, only respond to different inputs.
2. Limited memory: ability to learn from previous data to make decisions and perform tasks.
3. Theory of mind: conceptual, possess ability understand the entities it is interacting with by understanding their needs, emotions, and thought processes.
4. Self-aware: final stage of AI, hypothetical as of now, able to understand emotions of entities it interacts with, but also form its own emotion and beliefs.
5. Artificial Narrow Intelligence (ANI): can only perform a specific type of task they are programmed for, have a narrow range of competencies, and used in medical imaging.
6. Artificial General Intelligence (AGI): have multi-functional capabilities to function like a human being in all aspect.
7. Artificial super intelligence (ASI): pinnacle of AI, self- aware and outperforms humans.

Application in identifying cardiovascular anomalies

Cardiovascular diseases are the most common cause of deaths globally. AI in cardiac imaging modality is used in numerous solutions ranging from image acquisition, reconstruction,

and diagnosis. AI use has decreased the reconstruction time for cardiac MRI and has helped the cardiologists with automated pathology classification in electrocardiography. AI models were developed from twelve studies for automated image analysis in Invasive Coronary Angioplasty (ICA) for frame selection, segmentation, lesion assessment, and functional assessment of coronary flow (Molenaar et al., 2022). Even though only three AI models were externally verified, the AI showed moderate to good performance.

The ability of AI to identify relevant structures is crucial for detecting, localizing, and classifying coronary lesions. The coronary arteries are three-dimensional (3-D) structures captured in two-dimensional (2-D) image results in overlap, foreshortening, and difficulty in assessing true 3-D stenosis grade (Molenaar et al., 2022). The use of low-dose radiation along with heart motions and overlapping tissues causes blur and low signal-to-noise ratio. This issue makes it prone to subjective interpretation and causes delay in diagnosis and treatment. Most studies on automated ICA image analysis have trained algorithms to automatically segment coronary arteries in coronary angiography with 98% recognition accuracy and 85% sensitivity (Molenaar et al., 2022). AI could also be trained in real-time coronary stenoses detection which would help in identification of lesions that may otherwise have gone unnoticed. This would allow accurate and faster diagnosis and treatment planning. Owing to smaller sample sizes of images there is the risk of algorithmic bias. This issue could be resolved by subgroup analysis on larger image sample.

Application in neurology

One of the applications of AI in neurology is the detection of neurodegeneration through image analysis. AI can automatically measure biomarkers of Alzheimer's disease and rate of

brain atrophy.AI-based CT scan assessments allow the automated lesion segmentation of hemorrhagic infarcts, or automated detection and quantification of hemorrhagic expansion (Nagamine et al., 2020). AI is also able to detect early warning signs of ischemia on CT images. AI is used in traumatic brain injury (TBI) to lessen the impact of secondary brain injury by controlling intracranial pressure. In 2019 researchers from Finland developed an algorithm that could predict 30-day mortality for TBI patients with 80% accuracy based on variables such as intracranial pressure, arterial pressure, and motor and eye movement components of Glasgow Coma Scale (Raj et al., 2019).

Application in musculoskeletal injuries (MSK injuries)

Use of AI on musculoskeletal injuries ranges from assessing the appropriateness of imaging orders to helping predict the patient's risk at fracture. Use of AI has improved the image quality, noise reduction, and diagnostic accuracy (Gyftopoulos et al., 2019). AI has been proposed to reduce the image acquisition time in MRI by developing the algorithm to separate targeted image content from the aliasing artifacts. Early studies have shown promising results in terms of image quality and diagnostic accuracy when AI accelerated knee MRI is compared to conventional MRI up to four times (Wang et al., 2016). Similar principle was used to acquire the quality image on CT scans efficiently while decreasing the patient dose. In a study performed, more than 90% of radiologists found that the quality of low-radiation-dose CT images produced in part with the use of an AI was equal to or greater than that of CT images obtained using standard radiation doses (Cross et al., 2017). The most common use of AI in MSK injuries is the pattern detection and image interpretation. The AI algorithms have been used to diagnose fractures, bone age and

strength, and various pathologies (Gyftopoulos et al., 2019). Thoracic and lumbar spine fractures were detected and localized with 95.7% accuracy with the use of AI (Burns et al., 2017).

Application on oncology

Cancer is the second common cause of death globally with early detection being the key to saving the life of the affected individual. AI algorithms were found to be able to annotate skin lesions (including melanoma) as precisely as dermatologists (Shimizu & Nakayama, 2020). The accuracy with which the AI is able interpret mammograms for breast cancer screening is increasing too. In a study conducted on AI use for pathological slides analysis, it was observed that AI detected thirteen different types of cancers including breast, lung, and colorectal cancer (Shimizu & Nakayama, 2020). AI could also map out potential cancer cells and determine likelihood if the cells were cancerous.

Another important use of AI in oncology is in the field of genomic sequencing to detect any mutation leading to suppression of Tumor Necrosis Factor (TNF) or formation of oncogene. AI can be used to sequence the genome in the tumor sample and classify each mutation with clinical phenotypes quickly (Shimizu & Nakayama, 2020). This leads to efficient phenotyping as the possibility of human error is removed and allows us to develop personalized treatment.

Pros and cons of AI in imaging

Use of AI has dramatically increased the efficiency in the medical care and medical imaging. Shorter image acquisition times, efficient detection of anomalies, reduction on patient dose while acquiring better quality images, and ability to develop personalized treatment are the benefits of AI. AI lacks subjective bias, as opposed to humans, which ensures comparable results

each time. It has enabled us to obtain comparable diagnostic images with lesser patient doses and reduced the chances of repeats. This is in accordance with the principles of ALARA. Less time acquiring the image means more time available to provide best quality patient care.

The efficiency of AI is dependent on its algorithm. A well written algorithm requires a huge collection of sample images to train the AI in detection of patterns and anomalies. Since the use AI in medical imaging is recent, the algorithms developed are based in smaller sample sizes. This creates the possibility of skewed results and may not be efficient in use in different subtypes of population. AI and algorithms are not currently being regulated by a central agency and different hospitals around the world are using different types. This leads to the issue of lack of common operational standards, interoperability, and communication among various types of AI. This also causes differential diagnosis and transparency and security issues surrounding the algorithms.

Discussion

The use of AI and machine learning has shown a great promise in transforming every medical imaging. It allows for a more streamlined process of obtaining biographic information and archiving images after it is acquired. In different studies usage of AI has constantly instituted reduced imaging acquisition and diagnosis times across multiple imaging modalities like x-ray, MRI, and CT. The ability to detect and localize anomalies, categorize the pathologies, reduction of noise in the image while reducing the patient dose has improved the diagnosis time. This has allowed for more time for quality patient care, rapid personalized treatment plans while ensuring no extra harm to patient from increased radiation dosed. AI has reduced repeats, false positives, and misdiagnosis that usually occurred due to subjective bias on the radiologist. Even with the

rapid development of algorithms with a small sample size AI has shown the efficiency comparable to humans. The efficiency will only improve once more sample images are used to develop better algorithm and better regulations are in place standardize it.

Summary/Conclusion

AI has the potential to dramatically improve every aspect in medical imaging from image assessment to image interpretation and diagnosis. It allows for faster, efficient, and comparable image acquisition while reducing the patient dose. It allows for better imaging and tissue mapping when there is risk of tissue overlaps or blur from motion. It also reduces the image interpretation and diagnosis time allowing for faster and more personalized treatment. A well written algorithm eliminates the possibility of subjective bias or misdiagnosis. We are still at the early stages of AI use in medical imaging and the algorithms are written with smaller sample sizes. Large sample sizes and standardization of algorithms are needed to develop AI to achieve comparable results all over. The privacy and security issues will be resolved once AI is regulated across the board allowing for interoperability and communication across different locations. AI will eventually take over laborious and time-consuming tasks in medical imaging allowing time for human technologists for proper patient care and treatment.

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Multiple choice questions:

1. What does AI stand for?
    a. Analog International
    b. Automated Infiltration
    c. Automated Ischemia.
    d. Artificial Intelligence
2. What does ML stand for?
    a. Muscular lesions
    b. Macular lithotripsy
    c. Machine learning
    d. Mathematical linguistics
3. Algorithm is:
    a. is a set of well-defined instructions.
    b. a pathway to achieve the end result from given situation.
    c. is based on sample images datasets.
    d. All of the above.
4. Use of AI in Invasive Coronary Angioplasty (ICA) has
    a. 98% recognition accuracy and 85% sensitivity
    b. 85% recognition accuracy and 98% sensitivity
    c. 99% recognition accuracy and 95% sensitivity
    d. None of the above.
5. The advantages of use of AI in cardiovascular imaging includes:
    a. Decreased reconstruction time for cardiac MRI.

b. Automated pathology detection.

c. Functional assessment of coronary flow.

d. All of the above.

6. What is the most common use of AI in musculoskeletal (MSK) injuries?

    a. Pattern detection & image interpretation to detect fractures.

    b. Detection of level of biomarkers.

    c. Annotation of skin lesions.

    d. Detection of early signs of ischemia.

7. How accurate is AI in detecting Thoracic and Lumbar spine fractures?

    a. 95.7%

    b. 98%

    c. 85%

    d. 60%

8. What is the second common cause of death globally?

    a. Diabetes

    b. Cancer

    c. Fractures

    d. Tuberculosis

9. Oncology is the study of:

    a. Heart diseases

    b. Brain pathology

    c. Cancer and treatment

    d. Fractures of long bones

10. The main concerns of AI use is:

    a. Risk of skewed result due to algorithm based on small sample size.

    b. Lack of interoperability.

    c. Lack of standards for operations.

    d. A and B only

    e. A and C only

    f. A, B and C

Answer key:

1. D
2. C
3. D
4. A
5. D
6. A
7. A
8. B
9. C
10. F