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Review

Application of Artificial Intelligence in Orthopaedic Imaging: Current trends, Challenges and Future Perspective

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Abstract

Digital technology has significantly advanced human life especially in Healthcare. Computer processing of big data and data science have come a long way in creating softwares that improve providing quality of care and patient management. The purpose of this review is to provide a structured understanding about the current trends in different imaging modalities based on the advanced AI (Artificial Intelligence) led technologies; also, briefly focus on the challenges being posed. The current review has been prepared after researching a total of 20 articles that were published in various journals. PubMed, Scopus, Springer, Research Gate and various magazine blogs are some of the databases used. AI has proven to accurately help Physicians and orthopedic surgeons helps in guiding the appropriate treatment and management of various musculoskeletal disorders. AI finds its applications in various osseous abnormalities such as fractures, skeletal tumors and spine disorders through imaging modalities such as X-rays, MRI and CT scans using AI-assisted tools like Bone View, BoneXpert, XRAIT, fastMRI dataset, Spin Analyzer to name a few. AI has the ability to create a digital information system for better diagnosis and treatment of patients such as detection of bone density or loss, fractures and tumors. In addition to that, AI tools can take over a bigger chunk of the repetitive work from physicians, as will be discussed later with x-rays, thereby reducing the workload on the physicians to allow them to provide better quality of care and free them up for performing more tasks.

***Keywords:** Artificial intelligence, machine learning, neural networks, imaging, Magnetic resonance imaging (MRI), Computed Tomography (CT) scan, bone scintigraphy, X-Rays*

Introduction

Artificial intelligence (AI) is a subfield of computer science which was first described by John MCCarthy and is defined as the use of computers and machines to mimic human intelligence to perform various tasks. Machine learning (ML) is the term nested under artificial intelligence which imparts the learning capacity for computers to make more critical predictions from data collected. Machine learning algorithms perform what is known as "Data Training" to aid in developing predictions and decision making. However, human input is essential to either modify the algorithms based on need or to improve the performance[1]. Deep learning (DL) is a subfield of machine learning and refers to a model with an artificial neural network structure and mimics the human brain's neural connections. Neural networks form the backbone of deep learning algorithms. It is also known as artificial neural networks (ANNs) mimic the human brain through a set of algorithms. A neural network which consists of more than three layers- including the inputs and outputs; can be considered as deep neural network (DNN)[2]. Computer vision assisted deep learning; especially Convolutional Neural Network (CNN) is the most widely used due to improved performance. It is a multilayer network consisting of convolutional layer, pooling layer and fully connected layer[3]. Over the last few decades there has been a significant increase in the number of initiatives leveraging the power of AI to address orthopedic-specific problems. The primary goal is to take advantage of AI in Orthopaedics to develop insights regarding the possible outputs, create patient specific solutions and reduce security issues[4]. Application of AI improves diagnostic accuracy by more than 90%. Using AI based systems efficiently decreases the number of missed cases by clinicians and healthcare professionals who sometimes miss occult fractures and joint instabilities in primary X-rays in up to 50% of patients. Faster and more accurate diagnosis leads to significant morbidity and mortality reduction and lower costs for the healthcare systems as well as the patients.

These systems use algorithms that receive a huge amount of patients' data, classify them and use them to determine abnormalities[5]. AI algorithms can quickly and automatically detect x-rays that are positive for fractures and categorize those studies in the system so that radiologists can prioritize reading x-rays with positive fractures. It potentially contributes to less waiting time for hospital or clinic visits before patients can get a positive diagnosis of fracture[6]. ML performs multiple tasks that aid in image analysis, with the most commonly used tasks being detection, classification and segmentation. In image detection one or more objects (anatomical landmarks) are localized spatially or temporarily. Image classification (in ML) allocates a category to images, for example, if the input is a medical exam, the output may be positive or negative for a particular disease. In image segmentation, there is typically an input of one or more images where a set of voxels (points defined in 3D space) or pixels (points defined in 2D space) that makeup either the contour or the interior of one or more objects of interest are identified. If adequately robust, ML algorithm offers an automated method for image analysis that can allow discrepancies in images resulting from different operators or machines. ML applications in orthopedic imaging are expected to increase rapidly as ML methods continue to be refined[7]. Artificial intelligence will transform every step in the imaging chain; interpretive and noninterpretive components. Non-interpretive tasks assisted by AI include ordering of appropriate imaging tests, automatic exam protocoling, optimized scheduling, shorter magnetic resonance imaging (MRI) acquisition time, and computed tomography (CT) imaging with reduced artifact and radiation dose, new methods of generation and utilization of radiology reports. Application of AI for image interpretation includes determination of bone age, body composition measurements, and screening for osteoporosis, fracture detection, evaluation of segmental spine pathologies, detection and temporal monitoring of osseous metastasis, diagnosis of primary bone and soft tissue tumors and grading of osteoarthritis[8].

The current review has been written after researching a total of 20 articles that are published in various journals globally. PubMed, Scopus, Springer, Research Gate and various magazine blogs are some of the databases used.

AI helps assess X-Rays and identify positive fractures: An insight into BoneView and XRAIT

X-Ray is the most commonly and widely used form of medical imaging. Each year it is estimated that 3.6 billion x-ray images are taken. 45% of radiologists report burnout due to reasons such as time pressure and the rising volume of scans. Artificial intelligence increases the speed of anomaly detection significantly as it can analyze images much faster than a human. AI decreases the workload of radiologists, lower burnout rates and allows radiologists to focus on patients that need more attention[9]. AI may be able to spot small fractures which are otherwise invisible to radiologists and other human observers. Scaphoid fractures are the most common fracture in the wrist but the upper 20% cannot be seen in the initial radiograph. Missing out such details can lead to wrist arthritis and debilitating pain affecting productivity and quality of life. To address this concern scientist at the University of Michigan and the Taiwan based Center for Artificial Intelligence in Medicine designed a deep convolutional neural network to spot small fractures. It exhibited increased sensitivity and specificity suggesting that deep CNN can be reliably trained to detect fractures in small bones[10].

(I) BoneView

It is revolutionary artificial intelligence software which is developed by the French company Gleamer[11]. It assists radiologists and emergency physicians in skeletal fracture diagnosis. It uses advanced algorithms to detect and localize lesions on X-rays, graphically highlighting areas of interest, before submitting the images to radiologists for validation. Fujifilm x-ray systems are equipped with a new image processing box called Ex-mobile enabling it to connect with BoneView software. It yields results within 30 secs at the point of care, providing physicians with additional support to help improve patient management[12]. Radiographic interpretation suffers from an increasing workload in emergency and radiology departments, while missed fractures represent up to 80% of diagnostic errors in the emergency department. Thus, BoneView was developed in order to overcome the many challenges the radiologists faced due to the conventional imaging techniques. This software significantly reduced the rate of undetected fractures by 30% and reduced the radiograph reading time by 15% [11]. Loic Duron and colleagues conducted a study between 2016 and 2018 to assess the performance of BoneView in an effort to improve radiographic interpretation. Prior to the study, the BoneView AI system was trained on 60,170 radiographs obtained from trauma patients. For the study, 600 adult patients in whom radiographs were obtained after a recent trauma, with/without, one/more fractures of the shoulder, leg, arm, hand, and pelvis at 17 French imaging centers were included. Six radiologists and six emergency physicians were asked to detect and localize fractures with and without the help of BoneView software. The AI aid improved the sensitivity of the physicians by 8.7%, specificity by 4.1% and reduced the average number of false-positive fractures by 41.9% in patients without fractures and mean reading time by 15.0% [12].

(II) X- Ray Artificial Intelligence TOOL (XRAIT)

The Australian researchers and software developers teamed up to create a tool that uses artificial intelligence to read x-rays. The new tool XRAIT significantly improved the fracture detection and thus changed the future of osteoporosis treatment. It uses the natural language processing software to understand human language and makes communication smoother and more uniform. It aids in the detection of broken bones which is one of the prominent areas within healthcare[13]. XRAIT can help optimize the patient management who are at high risk for development of osteoporosis. This enables prompt treatment or prevention and in turn reduces risk of secondary fractures and overall burden of ill-ness and death from osteoporosis. Many hospitals have implemented fracture liaison services to identify patients who can have fractures due to osteoporosis. Manual reading of the radiology reports of referred patients misses out some patients at risk of osteoporosis or detects them slowly. Here XRAIT aids in accelerating the process using natural language processing software to understand human language[14]. Jacqueline Center and team conducted an investigative study which included 5089 radiological reports obtained from patients aged more than 50 years who got a bone imaging test in recent months. The specialists looked at the XRAIT presentation against conventional analysis for identifying cracks in 224 patients. XRAIT identified 349 people from the results compared to 98 people identified by the physicians. This AI tool performed admirably accurately detecting fractures 70% of the time and non-fractures 90% of the time. Scarce healthcare resources can be maximized efficiently to manage patients identified with high risk factors with the help of this tool. It enhances the diagnostic productivity and effectiveness while also improving patient experience during hospital visits[15].

AI aids in Magnetic Resonance Imaging Image Acquisition- fast MRI Dataset

AI tools can aid in accelerating MRI examination such as with under sampling and super-resolution. These techniques favor the acquisition of excellent quality images without compromising the diagnostic accuracy. To foster development in image reconstruction for enhanced MRI, Facebook AI Research and NYU Langone Health collaborated to release the fastMRI dataset. This imaging dataset comprises MRI k-space data as well as Digital Imaging and Communications in Medicine images from knee MRI examinations. Another innovation in MRI imaging is the creation of synthetic MRI images from CT images. This is particularly useful for patients who are unable to undergo MRI[8]. The fastMRI data set is a large scale collection of both raw MR measurements and clinical MR images. This reduces the medical costs, minimizes the patient stress level and provides MRI accessibility in places where it is currently slow or expensive. The fastMRI dataset includes raw data from 1,500 fully sampled knee MRIs, DICOM images from 10,000 clinical knee MRIs and raw data from nearly 7,000 fully sampled brain MRIs[16,17]. This dataset serves as a benchmark for training and evaluation of new developments in image reconstruction and it serves as an example and a stimulus for the release of similar publicly available datasets in near future[17].

Impact of AI in Computed Tomography (CT) Scan Imaging

The current application of AI in CT makes use of the convolutional neural network (CNN) - based deep learning approach which minimizes the image noise (also known as de-noising) [18]. Missert et al. invented a CT image de-noising technique which is trained to identify noise and not specific anatomical structures, which ultimately improves image quality and reduces radiation dose[19]. New artificial intelligence-based deep learning reconstruction (DLR) and post-processing techniques have been recently introduced which consistently improve diagnostic image quality at the lowest possible dose across all patients and procedures. These techniques are capable of producing CT images in a matter of seconds to reduce image noise across a broad range of doses. It also eliminates the compromise between dose and image quality and delivers clinical, operational and financial benefits[20]. The radiation dose is minimized through automation and optimization of data acquisition process, including positioning of the patient and acquisition parameter setting[18].

Automated Bone Age Evaluation - BoneXpert

Bone age is a marker of bone maturity. BoneXpert is a commercially available machine learning tool for automated bone age evaluation. It was launched by the company Visiana in the year 2009. It uses conventional machine learning techniques, automatically segmenting 15 bones and then evaluating the bone age based on 13 bones (radius, ulna and 11 short bones) using features of shape, intensity and texture[18]. It finally transforms the intrinsic bone ages into Greulich Pyle (GP) or Tanner Whitehouse (TW) bone age, which are the most common bone age methods [21]. The method locates almost all the bones in the hand and wrist (sesamoid bones are excluded). A bone is rejected if its visual appearance falls outside the range covered in the machine learning process or if the bone age value deviates from the predefined average bone age. Even though it is classified as an AI-replace tool it can also be used as an AI-assist tool depending on the preference of the user. It also plays an AI-extend role which helps calculate the bone health index. The introduction of BoneXpert facilitates increased accuracy and precision of assessment of bone age, and the radiologist's time is saved to perform other complex imaging tasks[22].

Application of Artificial Intelligence in Spine Imaging- Spin Analyzer

Spine related diseases are a social and public health problem; wherein more than 27% of the population is estimated to suffer from spine disorders which increases with age. Early detection can be a task in such cases due to the high demand of neuroradiologists and specialists. The diagnosis can take up to weeks to complete which includes referral and waiting time for a specialist physician.

Spine AI is software for the analysis of spinal images obtained with MRI, X-Ray and CT scan. It aids in reading medical images of the spine, providing information about detected pathologies and measuring spine parameters. It clearly identifies and alerts the user of the presence of spine anomalies. Spine AI incorporates a workflow-driven, task-based user design, as well as real time analytical reports. This software uses the ML algorithms based on fully convolutional neural networks combined with insights from the medical field[23].

AI applications in Skeletal Tumor Imaging

The first attempts to introduce digital power into diagnostic procedures of primary bone tumors dates back to 1960. A Siamese CNN was proposed to research the capability of automated spinal metastasis detection in MRI. This approach accurately detected all metastatic lesions with false -positive rate of 0.4 per case. Another research proposed a ML-based whole-body automatic disease classification tool to distinguish benign and malignant bone lesions in F-NaF PET/CT images[24]. A number of Computer Aided Detection (CAD) systems have been developed to segment and diagnose osteosarcoma from medical images, especially MRI and CT scans. But these systems come with their own limitations and challenges and thus to overcome these obstacles While Slide Images (WSIs) are being utilized by researchers today to improve the accuracy of osteosarcoma detection[25]. An artificial intelligence (AI)- assisted CT/MRI image fusion technique is being developed which is a 3D model for preoperative tumor margin assessment. This AI technique depicted a more accurate demonstration of details of tumor margins and also vascular emboli as compared to the conventional CT image models[26].

Challenges and Limitations of Artificial Intelligence

AI has revolutionized the face of modern orthopedic imaging and surgery, but at present, its use is neither universal nor perfect. The limitations of AI are existing.

First, the use of AI is limited by the high capital cost, the time needed for its use (both in preparation and intra-operatively), the variable reliability of AI technologies, and the absence of long-term follow-up studies. Second, there are ethical considerations regarding the use of ML in orthopedic imaging. Working with bulk datasets increases the risks of breaching patient confidentiality and consent unless safeguards are in place, especially where conflicts exist between patient and commercial interests. Furthermore, in cases of misdiagnosis or maloperation, it is unclear whether the doctor should be held responsible. Thus, it is important that ML is meticulously studied, managed, and appropriately validated [27]. Third, to date, surgical robots and the AI technique can only be used to perform relatively simple procedures, and possess little autonomy and decision-making authority in treatment; these limitations have caused some people to question the usefulness of AI[28].

Future of Artificial Intelligence in Orthopedics

Artificial intelligence (AI) is quickly gaining momentum and being adopted in our daily lives. The use of AI continues to prove its efficiency and the great impact it has in healthcare especially in the field of orthopedics, which proves to be beneficial to patients and clinicians.AI has tremendously gained momentum in various orthopedic conditions be it bone fractures, cancer of the bone or skeletal surgeries. Patients often show a lot of enthusiasm when it comes to technology based diagnosis and treatment planning. Application of AI makes the work of the physician's easy and at the same time does not compromise with the efficiency of their work. Patients enjoy faster services with a more personalized approach to their specific issue.AI goes a step further to include more complex 3D images that give the whole picture and context to the problem at hand.AI technology features different recovery tools that can benefit patients in managing their condition.

AI now guides orthopedic surgeons in real time to help avoid any mistakes. Using this allows surgeons to get their precision right and offer patients the best quality treatment. This also greatly improves the patient’s overall experience. AI has proven to improve surgical procedures being undertaken by increasing successes and results of numerous surgeries.AI has proven to be one of the fastest-changing technologies with new inventions coming out to improve its use. The future of AI in Orthopedics is quite bright as more people continue to use it[29].

Conclusion

The use of AI has the potential to greatly enhance every component of the imaging value chain. AI can highlight changes in bone and cartilage accurate enough to predict disease before its clinical manifestations. In addition to this, assesses the appropriateness of imaging orders to help predict patients at risk for fracture, it can increase the accuracy of the diagnosis provided to the patients and to the referring clinicians by improving image quality, patient centricity, imaging efficiency, and diagnostic accuracy. This will result in improving the efficiency and the overall management plan and patient satisfaction. Irrespective of the misguiding's about the interpretability, loss of jobs and mechanization; this novel technology is here to stay and impact the lives of humans. Researchers and practitioners have started to accept and adapt these technologies in their research work and clinical practices respectively. AI plays a significant role in the various orthopedic subspecialties such as trauma, spine surgery, oncology, arthroplasty and various other areas.

Conflict of Interest

The authors declare no conflict of interest.

References

1. Joseph E Burns, Jianhua Y et al. Artificial Intelligence in Musculoskeletal Imaging: A Paradigm Shift. Journal of Bone and Mineral Research,2019. Vol 35, Issue 1 (28-35)
2. Eda Kavlakoglu. AI vs Machine Learning vs Deep Learning vs Neural Networks: What is the difference? (2020) IBM Cloud Blog
3. Ko, S., Pareek, A., et al. Artificial Intelligence in Orthopaedics: Three strategies for deep learning with orthopaedic specific imaging. *Knee Surg Sports Traumatol Arthrosc 30,* 758-761 (2022)
4. Myers TG, Ramkumar PN, et al. Artificial Intelligence and Orthopaedics: An Introduction for Clinicians. J Bone Joint Surg Am. 2020;102(9):830-840. doi:10.2106/JBJS.19.01128
5. Artificial intelligence Improves Orthopaedic Diagnosis. *Massachusetts General Hospital. Advances in motion. 2021*
6. Chadi Tannoury, Andrew Kompel. Artificial Intelligence accurately detects fractures on X-Rays, Alerts human readers. *Journal Radiology* (2021).
7. Wang VM, Cheung CA, Kozar AJ, Huang B. Machine Learning Applications in Orthopaedic Imaging. J Am Acad Orthop Surg. 2020;28(10):e415-e417. doi:10.5435/JAAOS-D-19-00688
8. Natalia Gorelik, Soterios Gyftopoulos. Application of Artificial Intelligence in Musculoskeletal Imaging :From the Request to the Report. *Canadian Association of Radiologists Journal 2021.* Vol 72(1) 45-59.
9. Cem Dilmaghani. AI in X-ray analysis: Benefits and Challenges. *AI Multiple (2022).*
10. Martin Stempniak. Artificial intelligence shows promise spotting small bone fractures invisible to humans on X-rays. *Radiology Business 2021.*
11. Loic Duron, Artificial Intelligence software BoneView helps radiologists and emergency physicians detect and localise fractures. *Interventional News* (2021)
12. Loic Duron, Alexis Ducarouge et al. Assessment of an AI Aid in Detection of Adult Appendicular Skeletal Fractures by Emergency Physicians and Radiologists: A Multicenter Cross-sectional Diagnostic study. *Radiology(2021)*
13. XRAIT reference -Derek Bagley. More than meets the eye: Artificial Intelligence and X-ray. *Bone and Mineral. Endocrine News (2020)*
14. Artificial Intelligence improves X-Ray Identification of Patients with Broken Bones. *Endocrine News (2020)*
15. AI in Fracture Detection- How AI is improving X-Ray Identification of Broken Bones. *DataFlair Team (2019)*
16. Jure Zbontar, Knoll F, et al, fast MRI: An Open Dataset and Benchmarks for Accelerated MRI (2018). arXiv:1811.08839v2 [cs CV]
17. Knoll F, Zbontar J, Sriram A, et al. fastMRI: A Publicly Available Raw k-Space and DICOM Dataset of Knee Images for Accelerated MR Image Reconstruction Using Machine Learning. Radiol Artif Intell. 2020;2(1):e190007. Published 2020 Jan 29. doi:10.1148/ryai.2020190007
18. C.H. McCollough, S.Leng et al. Use of Artificial Intelligence in Computed Tomography dose optimisation. *Sage Journals.* Volume 49, Issue 1 (2020).

19. Missert ,A.D., Yu, L., Leng , S., et al. 2020. Synthesizing images from multiple kernels using deep convolutional neural networks. Med. Phys 47, 422-430.

20. Mikael Strindlund. The Impact of Artificial Intelligence on CT Imaging. *Imaging Technology News* (2021).

21. Thodberg HH, Kreiborg S, Juul A, Pedersen KD. The BoneXpert method for automated determination of skeletal maturity. IEEE Trans Med Imaging. 2009 Jan;28(1):52-66. doi: 10.1109/TMI.2008.926067. PMID: 19116188.

22. Thodberg , H.H., Thodberg, B., et al. Autonomous Artificial Intelligence in Pediatric Radiology : The use and perception of BoneXpert for bone age assessment. *Pediatr Radiol* **52,** 1338-1346 (2022).

23. AI tools for Spine Analysis: New venture of Torus Medical and US Tech entrepreneurs. *Torus AI, Intelligence for Life (2021)*

24. Vogrin M, Trojner T, Kelc R. Artificial intelligence in musculoskeletal oncological radiology. Radiol Oncol. 2020;55 (1):1-6. Published 2020 Nov 10.

25. Bansal, P., Gehlot, K., Et al. Automatic detection of Osteosarcoma based on integrated features and feature selection using binary arithmetic optimisation algorithm. *Multimed Tools Appl* **81,** 8807-8834 (2022).

26. Du X, Wei H et al (2020). Artificial Intelligence (AI)- assisted CT/MRI Image Fusion Technique in Pre-operative Evaluation of a Pelvic Bone Osteosarcoma. *Front. Oncol* 10:1209.

27. Han XG, Tian W. Artificial intelligence in orthopedic surgery: current state and future perspective. Chin Med J (Engl). 2019 Nov 5;132(21):2521-2523.

28. Myers TG, Ramkumar PN, Ricciardi BF, Urish KL, Kipper J, Ketonis C. Artificial Intelligence and Orthopedics: An Introduction for Clinicians. J Bone Joint Surg Am. 2020 May 6;102(9):830-840.

29. AI is the Next Great Advancement in Orthopedic Technology: Bone Zone ,Oct 20,2020 https://bonezonepub.com/2020/10/20/ai-is-the-next-great-advancement-in-orthopedic-technology/

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