A ADVANCED JOURNAL IN ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING TRENDS IN BIOLOGICAL SCIENCES
Open Journal

Review

Artificial Intelligence in Orthopaedic Imaging: Present State, Obstacles and Prospects for the Future

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Article information
Received: December 22nd, 2023; **Revised:** February 1st, 2024; **Accepted:** February 10th, 2024; **Published:** March 22nd, 2024

Cite this article
Mekonnen Y, Namuduri S, Bhansali S. Artificial intelligence in orthopaedic imaging: Present state, obstacles, and prospects for the future. 2024; 3(1).
doi: https://doi.org/10.70705/ppp.bioai.2024.v03.i01.pp11-15

ABSTRACT

In particular, digital technology has improved healthcare for humans. The development of software to enhance the provision of high-quality care and patient management has been greatly advanced by computer processing of big data and data science. Here we will take a look at the latest developments in various imaging modalities as they relate to cutting-edge AI (Artificial Intelligence) technology. We will also provide a quick rundown of the problems that these advancements are causing. A total of twenty papers from a variety of journals were consulted in compiling this assessment. Some of the databases that are used include PubMed, Scopus, Springer, Research Gate, and a number of magazine blogs. When it comes to directing the proper treatment and management of a wide range of musculoskeletal problems, AI has shown to be an invaluable tool for physicians and orthopedic surgeons. X-rays, MRI, CT scans, and other imaging modalities may be used to detect osseous anomalies including cancers, fractures, and spine problems with the use of AI-assisted tools such as Bone View, BoneXpert, XRAIT, the fastMRI dataset, and Spin Analyzer. AI has the potential to develop a computerized information system that can identify changes in bone density or loss, fractures, cancers, and other medical conditions, allowing for more accurate diagnosis and treatment. Also, as we'll see with x-rays later on, AI tools can take over a lot of the repetitious labor that doctors do. This makes doctors' jobs easier, which means they can focus on providing better treatment and have more time to do other things.

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 computer programs and hardware designed to carry out a variety of jobs in a manner consistent with human intellect. Machine learning (ML) is a subfield of AI that teaches computers to learn and use that knowledge to generate better predictions based on the data they already have. "Data Training" is what machine learning algorithms do to help with prediction and decision making. To adapt the algorithms to specific requirements or boost their performance, however, human intervention is crucial1. A area of machine learning, deep learning (DL) describes a model that uses an artificial neural network architecture to simulate the way the human brain's neural connections operate. Deep learning techniques are built upon neural networks. Another name for it is "artificial neural networks," which use a collection of algorithms to simulate brain function. A deep neural network (DNN) is a kind of neural network that has more than three layers, including the inputs and outputs.2. Convolutional Neural Networks (CNNs) are the most popular deep learning algorithms for computer vision because of their superior performance. The three layers that make up this multilayer network are the convolutional, pooling, and fully connected ones. There has been a surge in the number of initiatives in the last couple decades that are using AI to solve orthopedic-related issues. Using AI in orthopaedics mostly means gaining understanding of potential outcomes, making solutions tailored to individual patients, and lowering security risks.Using AI increases the accuracy of diagnoses by over 90%. It is not uncommon for initial X-rays to overlook occult fractures and joint instability in as many as half of the patients. By using AI based solutions, the percentage of missed instances may be significantly reduced. Significantly reduced morbidity and mortality and cheaper costs for healthcare systems and individuals are the results of faster and more precise diagnosis. By analyzing massive amounts of medical data, these systems are able to identify abnormalities5. In order to help radiologists prioritize

viewing x-rays with positive fractures, AI systems can automatically recognize and classify studies that are positive for fractures. As a result, patients may have to wait less time for a positive fracture diagnosis at the clinic or hospital. Image analysis makes use of ML for a variety of purposes; the three most prevalent are detection, classification, and segmentation. A spatial or temporal localization of one or more objects (anatomical landmarks) is required for picture detection. If a medical exam is used as an example, the result may be either positive or negative for a certain ailment. This is because image classification in ML assigns a category to the photos. picture segmentation usually starts with an input picture or images that have already recognized the contour or interior of an item or objects of interest using either voxels (points defined in 3D space) or pixels (points defined in 2D space). If sufficiently robust, ML algorithms provide an automated way to analyze photos, which can accommodate differences in images produced by various machines or operators. With the ongoing refinement of ML approaches, the number of ML applications in orthopedic imaging is projected to grow significantly. Both the interpretative and noninterpretive parts of the image chain will undergo radical changes as a result of artificial intelligence. Artificial intelligence (AI) can help with non-interpretive tasks such as optimizing scheduling, reducing radiation dose and artifact in computed tomography (CT) images, new ways to generate and use radiology reports, and automatically protocoling exams. Bone age determination, body composition measurements, osteoporo-sis screening, 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 osteoarthritis8 are all examples of AI applications in image interpretation.

A total of twenty publications published in scholarly journals throughout the world were consulted for this assessment. Some of the databases that are used include PubMed, Scopus, Springer, Research Gate, and a number of magazine blogs.

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 im- ages 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 attention9. AI may be able to spot small fractures which are otherwise invisible to radiologists and other hu- man 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 bones10.

(I) BoneView

It is revolutionary artificial intelligence software which is developed by the French company Gleamer11. It assists radiolo- gists 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 soft- ware. It yields results within 30 secs at the point of care, providing physicians with additional support to help improve patient management12. 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, Bon- eView 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 ob- tained 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%, specifici- ty 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 healthcare13. 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 lan- guage processing software to understand human language14. 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 di-

agnostic productivity and effectiveness while also improving patient experience dur- ing hospital visits15.

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 imag- es from CT images. This is particularly useful for patients who are unable to undergo MRI8. 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 MRIs16,17. This dataset serves as a benchmark for training and evaluation of new devel- opments in image reconstruction and it serves as an example and a stimulus for the release of similar publicly available datasets in near future17.

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 dose19. New artificial intelligence-based deep learning reconstruction (DLR) and post-processing tech- niques 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 re- duce image noise across a broad range of doses. It also eliminates the compromise between dose and image quality and delivers clinical, operational and financial benefits20. The radiation dose is minimized through automation and optimiza- tion of data acquisition process, including positioning of the patient and acquisition parameter setting18.

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 tech- niques, 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 texture18. 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 prefer- ence of the user. It also plays an AI-extend role which helps calculate the bone health index. The introduction of BoneX- pert facilitates increased accuracy and precision of assessment of bone age, and the radiologist's time is saved to perform other complex imaging tasks22.

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 identi- fies 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 field23.

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 im- ages24. A number of Computer Aided Detection (CAD) systems have been developed to segment and diagnose osteosar- coma from medical images, especially MRI and CT scans. But these systems come with their own limitations and chal- lenges and thus to overcome these obstacles While Slide Images (WSIs) are being utilized by researchers today to im- prove the accuracy of osteosarcoma detection25. 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 ac- curate demonstration of details of tumor margins and also vascular emboli as compared to the conventional CT image models26.

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 doc- tor should be held responsible. Thus, it is important that ML is meticulously studied, managed, and appropriately validat- ed 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 ques- tion the usefulness of AI28.

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 condi- tion.

AI now guides orthopedic surgeons in real time to help avoid any mistakes. Using this allows surgeons to get their preci- sion 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 it29.

Conclusion

Every link in the imaging value chain stands to benefit substantially from AI implementation. AI has the potential to detect changes in bone and cartilage with a degree of accuracy that allows for the prediction of illness before it shows up clinically. Not only that, it evaluates imaging orders for their suitability in predicting which patients are most likely to suffer a fracture, which in turn improves image quality, patient centricity, imaging efficiency, and diagnostic accuracy, all of which are beneficial to both the patients and the referring clinicians. The management strategy as a whole will become more efficient, and patient satisfaction will rise as a consequence. This innovative technology will have an effect on people's lives regardless of the misinformation about its interpretability, job loss, and automation. Both academics and medical professionals have begun to embrace and incorporate these technologies into their respective fields of study and patient care. Several subspecialties of orthopedics rely heavily on AI, including trauma, spine surgery, cancer, arthroplasty, and many more.

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