Acta Scientific Orthopaedics (ISSN: 2581-8635)

Volume 7 Issue 7 July 2024

Review Article

Artificial Intelligence in Orthopaedics: The Future is Here

Syed S Ahmed*

Department of Trauma and Orthopaedics, Maidstone and Tunbridge Wells NHS Trust, United Kingdom

***Corresponding Author:** Syed S Ahmed, Department of Trauma and Orthopaedics, Maidstone and Tunbridge Wells NHS Trust, United Kingdom.

Received: May 27, 2024

Published: June 19, 2024

Abstract

Artificial Intelligence (AI) is an umbrella term theorising the replication of human intellect via computers [1]. It is the ability of machines to perform tasks that typically require human intelligence, such as learning, reasoning, and problem-solving. The term was initially coined in 1955 by a group of scientists, who proposed that these aforementioned aspects of human intellect could be simulated by machines. Since then, it has emerged as a revolutionary force across various domains of medicine and orthopaedics is no exception. Improvement in computer hardware, speeds, memory capacity and software has seen a surge in interest in the field of AI.

Keywords: Artificial Intelligence; Orthopaedics; Future

Introduction

AI has become an integral part of modern society with its ability to detect fraud, target social media advertisements and the outwardly omniscient abilities of ChatGPT [2]. With its ability to process vast amounts of data, learn patterns, and make predictions, AI is transforming the landscape of orthopaedic care. From diagnosis to treatment planning and personalised patient care, AI is playing a pivotal role in the entire patient care pathway. This could lead to enhancing efficiency, accuracy, and patient reported outcomes in orthopaedics.

The volume of data that is collected from patients is expanding. There is no conceivable way that humans could comprehend and analyse this data without the use of technology. Algorithms based on this data could be used to predict patient outcomes. AI encompasses a field called ‘machine learning’ - this is the ability to ‘learn and adapt’ based on algorithms which surpass human comprehension. Machine Learning (ML) allows machines to improve their performance by developing experience with the help of statistical and mathematical tools For example, being shown thousands of images of normal radiographs and then images of a fracture. The AI algorithm can then recognise a fracture or fracture patterns accurately.

Deep learning (DL) is a more refined form of ML that studies computational models. It is the analysis of large sets of data (unsupervised) to predict an area of interest.

This paper will discuss the impact AI has on the image recognition, diagnostics and enhanced analytics, treatment planning, rehabilitation and training the future generation of surgeons. It will also analyse the future direction of AI and the challenges associated with it which are mainly the ethical concerns surrounding patient privacy, algorithm biases, ownership of data and accountability.

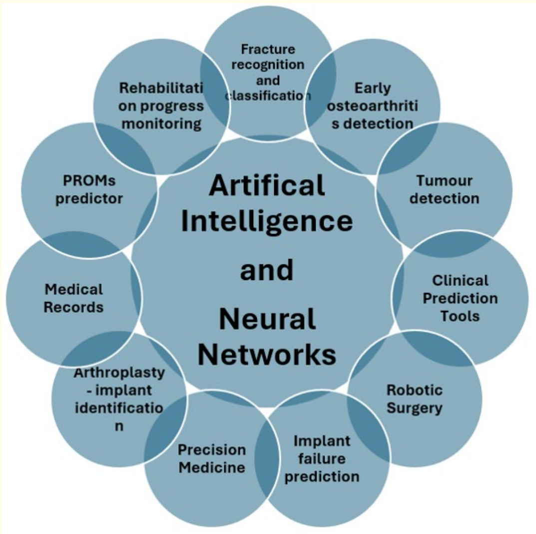

Figure 1: Artificial Intelligence - Applications in Orthopaedics.

Image recognition and diagnostics

One of the significant contributions of AI in orthopaedics is in the realm of medical imaging. AI algorithms can analyse complex imaging data such as X-rays, MRIs and CT scans, to identify subtle abnormalities that may go unnoticed by human eyes. This not only speeds up the diagnostic process but also improves accuracy, leading to early detection of musculoskeletal pathology. AI-powered image recognition systems excel in detecting fractures, tumours and other abnormalities. There have been encouraging studies to show that it can diagnose occult fractures of the scaphoid just as accurately as human specialists [3]. Therefore, there is potential to relieve some of the burden of routine image reporting which could reduce the workload of radiologists and possibly also reduce interpreter error.

A study compared the performance of orthopaedic surgeons with AI at detecting femoral intertrochanteric fractures. It was found that the diagnostic accuracy of AI was comparable to that of human performance. However, the main benefit was speed. AI was found to be 16 times faster at diagnosis than orthopaedic surgeons [4].

AI has shown potential to detect tumours. A convolutional neural network has shown, that it can detect a tumour in the proximal femur more accurately, when compared to clinicians [5]. Machine learning can therefore be used for the analysis of uncertain lesions and also predict prognosis and outcomes following these diagnoses.

Image recognition software can be a much sought-after tool. Studies have looked at using AI to analyse post-operative radiographs following total hip and knee arthroplasty [6]. Further research on this could have an implication on pre-operative planning and potentially facilitate more accurate implant positioning.

In revision arthroplasty, surgeons are unable to identify the implants 10% of the time preoperatively and 2% of the time intraoperatively. AI to detect and diagnose implant failure and loosening, could be an invaluable tool in revision arthroplasty. This would help order the necessary extraction equipment and facilitate surgery without much bone loss, reduce surgical time, blood loss and enhance recovery [7].

AI systems can highlight specific regions of interest, assist in quantifying disease progression, and even predict potential complications. As a result, orthopaedic surgeons can make more informed decisions based on comprehensive and precise diagnostic information. However, both internal and external validation is required before clinical implementation. This is challenging to achieve as small changes in protocols or different radiological doses/radiation in institutes can invalidate previous algorithms and make it difficult to translate.

Treatment planning and personalised medicine

Orthopaedic treatments often require personalised approaches due to the unique anatomical variations and patient-specific factors. AI algorithms aid in developing personalised treatment plans by considering a patient's medical history, genetics, lifestyle and other relevant data. This facilitates the tailoring of interventions to meet the specific needs of each patient, optimising outcomes and minimizing potential risks.

Additionally, AI plays a crucial role in predicting the success of orthopaedic procedures. Machine learning models can analyse historical data to forecast the likelihood of successful outcomes for various treatments. This information assists both surgeons and patients in making well-informed decisions regarding the most suitable course of action.

Postoperative rehabilitation is a critical phase in orthopaedic care and AI contributes significantly to this aspect as well. Wearable devices equipped with AI algorithms can monitor patients' movements and provide real-time feedback on their rehabilitation progress. This allows for the timely adjustment of rehabilitation protocols, ensuring optimal recovery and reducing the risk of complications.

Furthermore, AI driven remote monitoring systems can enable surgeons to keep a track of implant performance outside a clinical setting. This could potentially detect issues early on, preventing complications and the need for repeated outpatient visits.

Robotics and AI

Robotic surgery has developed rapidly in the field of orthopaedics in the last few years. This has allowed more accurate placement of implants and less soft tissue damage [8]. It relies on accurate imaging of the joint, limb alignment and soft tissue tension. The semi active robots allow for surgical planning followed by surgeon-controlled resection with haptic feedback limiting deviation from the surgical plan. This has enabled surgeons to make cuts to the accuracy of millimetres and position implants to the degree of where it is planned. However, in robotics, the knowledge and ultimate decision of correct implant positioning ultimately lies with the surgeon and his or her experience. AI technology can be used to determine accurate positioning of implants in order to not only minimise complications but also improve long term wear and outcomes [9].

'Deep learning' using post-operative radiographs has been used to predict risk of complications leading to revision arthroplasty. It was found that algorithms could predict implant dislocation within five years of having a hip arthroplasty. This could be used to identify high risk patients. Machine learning of risk factors for instability, such as spinal fusion, spino-pelvic alignment can be used to determine the functional 'safe zone' in order to position the acetabular cup accurately (using a robot) to prevent impingement and instability.

Orthopaedic oncology

AI is still in its infancy in its application in orthopaedic oncology. An area of special interest is automated image-based diagnosis. AI/ML can be used in the detection of bone lesions which are not obviously evident on plain film radiographs. In a multi-institutional study over 1300 radiographs have been used to for differentiating between benign, intermediate and malignant tumours. They achieved an accuracy of 73.4% compared to the accuracy of 71.3% of two trained radiologists [10]. This could lead to a reduction in the need for further scans and invasive diagnostic procedures.

Prediction of local recurrence in primary bone tumours is another area of focus for clinical outcome prediction using AI. Previously, clinical and imaging features have been demonstrated to be effective in predicting local recurrence of bone tumours. For example, factors such as involvement of proximal tibia, younger age, irregular margins or paint brush-border sign and adjacent soft tissue invasion have been correlated with increased rate of recurrence of giant cell tumours. These tumours, usually managed with intralesional curettage, have a recurrence rate of 12%-65%. A study used AI neural networks, on MRI images of patients with giant cell tumours that were followed for an average of 6 years. They combined imaging and patient data (age, and tumour location) and reported an accuracy of 78.6% in correctly predicting recurrence [10]. The clinical application of these findings is not clearly established; however, these calculations could potentially be used to determine length of postoperative surveillance to evaluate for recurrence.

A significant benefit of AI is image segmentation. In oncology, tumour analysis is done manually with slice-by-slice segmentation, this can now be performed in seconds. This would really aid clinical decision making such as radiation planning and assessment of post-operative therapeutic effects. AI based automatic segmentation has been used to calculate tumour burden of bone metastasis from prostate cancer. Segmentation of the skeleton on CT and using the areas of high uptake, a tumour burden index was calculated, which was associated with overall survival [11].

Sports medicine

The application of AI in sports medicine has been mostly confined to MRI detection of soft tissue injuries. The most common of these being soft tissue injuries of the knee i.e. anterior cruciate ligament (ACL) and meniscal tears. Development of automated methods in diagnosing ACL and meniscal tears is the most active area of research. The availability of complex neural networks that can detect soft tissue injuries in other areas is still limited.

Simulation and training in orthopaedics

The traditional apprentice approach to training is becoming increasingly difficult to sustain due to the constraints placed on both trainers and trainees in the currently overwhelmed health service. Orthopaedic trainees currently develop a complex skill set by effectively practicing on patients under supervision. The concept of virtual reality (VR) surgical training could improve on efficiency and also patient safety. Modern simulation allows surgeons to develop both procedural and sensory skills. The application of AI could enhance the training experience, providing the user with individualised feedback and also an immersive operative experience based on surgical anatomy. This would develop motor skills that are second nature, especially helpful during stressful emergency conditions.

VR headsets worn by the surgeon can be used to display interactive holograms. This allows the visualisation of the real world and the manipulation of digital content. Surgeons could plan and practice complex operations before stepping into the operating room. Retinal displays could allow surgeons to better understand patients' native anatomy whilst operating. One could plan surgical resections and osteotomies accurately intraoperatively using augmented reality. This could facilitate metal work placement without the need for intra operative radiation. The overarching advantage being patient safety and giving surgical trainees experience whilst mitigating adverse events.

Challenges and ethical considerations

While the integration of AI in orthopaedics holds immense promise, there are challenges and ethical considerations that must be addressed. Data privacy, the interpretability of AI algorithms and the potential for bias in data collected, are critical concerns that require careful attention. Additionally, ensuring that AI complements, rather than replaces, the expertise of orthopaedic professionals is essential to maintain 'the human touch' in patient care.

Rapid progress in the field is testing the regulatory mechanisms and may lead to ethical dilemmas. One has to be cautious that AI in 'medicine and surgery' does not discriminate on criteria that is based on data sets and algorithms. AI relies on 'big data' which may have large amount of bias associated with it. If certain minorities are not well represented, the algorithms that evaluate them will be flawed. Therefore, it is vital that the quality of medical data we gather is regulated and monitored.

AI is as good as its data and the development of robust data entry frameworks are integral to avoid errors. AI applications used outside the institutes they were designed for, without external validity, could be prone to systematic errors and have widespread implications for patients.

Patient privacy and confidentiality is another concern with data collection. The technological companies involved in development of AI applications, have access to a lot of private and confidential data. Individuals must have control over how their data is used and for how long. It is argued that in these instances, patient data is anonymised. However, this means that rights over this data are handed over to large corporations and all control is lost too.

There is also the issue of securing data and preventing a cyber-attack. Data can be easily stolen by malware. Therefore, cybersecurity is critical to ensure that all the private data is securely stored and managed.

Consenting patients for a management option given to them by an AI algorithm becomes complex. In this instance, neither the doctor nor the patient completely understands why a certain procedure has been chosen or over another. The concept of 'informed consent' becomes insignificant.

Earlier it was described how AI, along with robotics, can revolutionise implant positioning. However, one must be mindful that if future generations of surgeons perform procedures with automation, where the robot has planned the bone incisions and informed the surgeon exactly where to place the implants, it could potentially lead to surgeons becoming 'deskilled'. Surgeons could lose the knowledge, skills and experience required to perform these procedures. Under a circumstance, such as a system failure due to a malware or a software bug, it would be highly concerning if the surgeon has lost the ability to perform the procedure using conventional methods.

Currently, one can assume that if there is a failure of technology, the surgeon can always fall back on the conventional surgical skills that they have been obtained during their training. However, if these skills are completely omitted from surgical training due to tasks being handed over to AI, they may well be completely lost. Future surgical training should teach the surgeons conventional techniques so they can choose whether they wish to proceed with AI suggestions or use their own personal judgement and acumen.

The issue of accountability is a key factor to consider too [12]. We have already established the challenge involved in regulating this constantly evolving technology. A corporation manufactures technology that automates certain surgical procedures; this technology is then sold to a third-party implant manufacturing company which is then in turn bought by a hospital. It is then used by highly skilled surgeons trained to use the technology. However, if there is a serious or untoward incident that occurs due to the technology - who is accountable? This becomes extremely challenging to regulate and the medicolegal system will need to have protocols and procedures in place to address the same.

The future of ai in orthopaedics

AI has the potential to revolutionise orthopaedic care by improving diagnostics and treatment. Common uses of AI in joint reconstruction include analysing imaging for automated diagnosis, evaluating implants and predicting surgical outcomes. The principle value of AI is data driven optimisation of outcomes [13]. The technology has already shown that 'big data' can be used to support decision making and improve patient reported outcome measures (PROMs) [14].

Studies have demonstrated interventions in hip and knee arthroplasty that not only lead to statistical but also clinically significant difference in PROMs. AI algorithms can be used to risk profile and anticipate patients at risk of having adverse outcomes or major complications [15]. This would allow not only early intervention but also tailored consenting following having discussed individual material risks.

However, there are considerable capital costs involved and given the financial strain already on our health service, one needs to carefully examine cost benefit analysis before widespread adoption.

In addition to enhancing surgical outcomes, AI can also play a role in orthopaedic rehabilitation. By analysing patient data, AI algorithms can develop personalised treatment plans that consider individual needs, abilities, and goals. This approach can lead to more efficient and effective rehabilitation, helping patients to recover faster and more fully.

In 2016, Professor Stephen Hawking declared AI to be "either the best or the worst thing, ever to happen to humanity [16] and similar anxieties have been raised by Geoffrey Hinton (labelled the 'godfather of AI' due to his work in the field) and Sam Altman, CEO of OpenAI (the developer of ChatGPT). It is therefore an innovation for us to embrace, but with caution.

Conclusion

The transformative role of artificial intelligence in orthopaedics is undeniable. With the advancements in machine learning, robotics, and virtual reality, AI has the potential to revolutionise the field of orthopaedics and improve patient outcomes. The future of AI in orthopaedics is promising, with the potential for improved diagnostics and treatment, enhanced patient recovery times and reduced healthcare costs. However, there are also the aforementioned ethical considerations and challenges to implementation that must be addressed.

The 'digital twin' of oneself could well be the cornerstone of personalised medicine. This could prevent disease progression with planned interventions and tailor treatment outcomes to the genome level of the patient.

There is promise with implant identification, recognising malpositioning, detecting early features of loosening and failure. This could impact surgical outcomes and prognosis.

By embracing these technological advancements responsibly, the orthopaedic community can usher in a new era of improved patient reported outcomes and satisfaction. As AI continues to evolve, it will undoubtedly play an increasingly important role in the field of orthopaedics, hopefully benefiting both patients and healthcare providers alike.

Bibliography

1. Han XG and Tian W. "Artificial intelligence in orthopaedic surgery: Current state and future perspective". *Chinese Medical Journal (England)* 132.21 (2021).
2. Bernstein J. "Not the Last Word: ChatGPT Can't Perform Orthopaedic Surgery". *Clinical Orthopaedics and Related Research®* 481.4 (2023).

3. Langerhuizen DWG., *et al*. "Is Deep Learning on Par with Human Observers for Detection of Radiographically Visible and Occult Fractures of the Scaphoid?" *Clinical Orthopaedics and Related Research®* 478.11 (2020).

4. Liu P., *et al.* "Artificial intelligence to detect the femoral intertrochanteric fracture: The arrival of the intelligent-medicine era". *Frontiers in Bioengineering and Biotechnology* 10 (2022):927926.

5. Park CW., *et al.* "Artificial intelligence-based classification of bone tumors in the proximal femur on plain radiographs: System development and validation". *PLoS One* 17 (2022).

6. Jang SJ., *et al.* "Comparison of tibial alignment parameters based on clinically relevant anatomical landmarks a deep learning radiological analysis". *Bone and Joint Open* 3.10 (2022).

7. Borjali A., *et al.* "Detecting total hip replacement prosthesis design on plain radiographs using deep convolutional neural network". *Journal of Orthopaedic Research* 38.7 (2020).

8. Begum FA., *et al.* "Robotic technology: Current concepts, operative techniques and emerging uses in unicompartmental knee arthroplasty". *EFORT Open Reviews* 5.5 (2020).

9. Lisacek-Kiosoglous AB., *et al.* "Artificial intelligence in orthopaedic surgery EXPLORING ITS APPLICATIONS, LIMITATIONS, AND FUTURE DIRECTION Introduction: artificial intelligence, time for clear nomenclature". *Bone Joint Research* 12.7 (2023).

10. Eweje FR., *et al.* "Deep Learning for Classification of Bone Lesions on Routine MRI". *EBioMedicine* (2021): 68.

11. Lindgren Belal S., *et al.* "Deep learning for segmentation of 49 selected bones in CT scans: First step in automated PET/CT-based 3D quantification of skeletal metastases". *European Journal of Radiology* (2019): 113.

12. Loftus TJ., *et al.* "Artificial Intelligence and Surgical Decision-making". *JAMA Surgery* 155.2 (2020).

13. Karnuta JM., *et al.* "The value of artificial neural networks for predicting length of stay, discharge disposition, and inpatient costs after anatomic and reverse shoulder arthroplasty". *Journal of Shoulder and Elbow Surgery* 29.11 (2020): 2385-2394.

14. Borjali A., *et al.* "Detecting total hip replacement prosthesis design on plain radiographs using deep convolutional neural network". *Journal of Orthopaedic Research* 38.7 (2020):1465-1471.

15. Yi PH., *et al.* "Automated detection & classification of knee arthroplasty using deep learning". *Knee* 27.2 (2020).

16. Stephen Hawking. "AI will be "either best or worst thing" for humanity | Stephen Hawking | The Guardian (2024).