Unveiling the potential of artificial intelligence in orthopaedic surgery

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Abstract

Artificial intelligence is paving the way in contemporary medical advances, with the potential to revolutionise orthopaedic surgical care. By harnessing the power of complex algorithms, artificial intelligence yields outputs that have diverse applications including, but not limited to, identifying implants, diagnostic imaging for fracture and tumour recognition, prognostic tools through the use of electronic medical records, assessing arthroplasty outcomes, length of hospital stay and economic costs, monitoring the progress of functional rehabilitation, and innovative surgical training via simulation. However, amid the promising potential and enthusiasm surrounding artificial intelligence, clinicians should understand its limitations, and caution is needed before artificial intelligence-driven tools are introduced to clinical practice.

Key words: Artificial intelligence; Machine learning; Neural networks; Orthopaedic surgery; Predictive algorithms

Submitted: 7 August 2023; accepted following double-blind peer review: 14 August 2023

Artificial intelligence is evolving rapidly, with applications in medicine and surgery promising significant advances for patient care (Al-Hourani et al, 2021). Artificial intelligence may enhance the clinical armamentarium, with algorithms relating to diagnostic imaging, clinical prediction tools and precision medicine all being explored as solutions to orthopaedic challenges (Myers et al, 2020; Jang et al, 2022; Kunze et al, 2022) (Figure 1). The discussion around artificial intelligence is timely, as evidenced by the widespread coverage of ChatGPT, a chatbot that had amassed over 100 million active users within

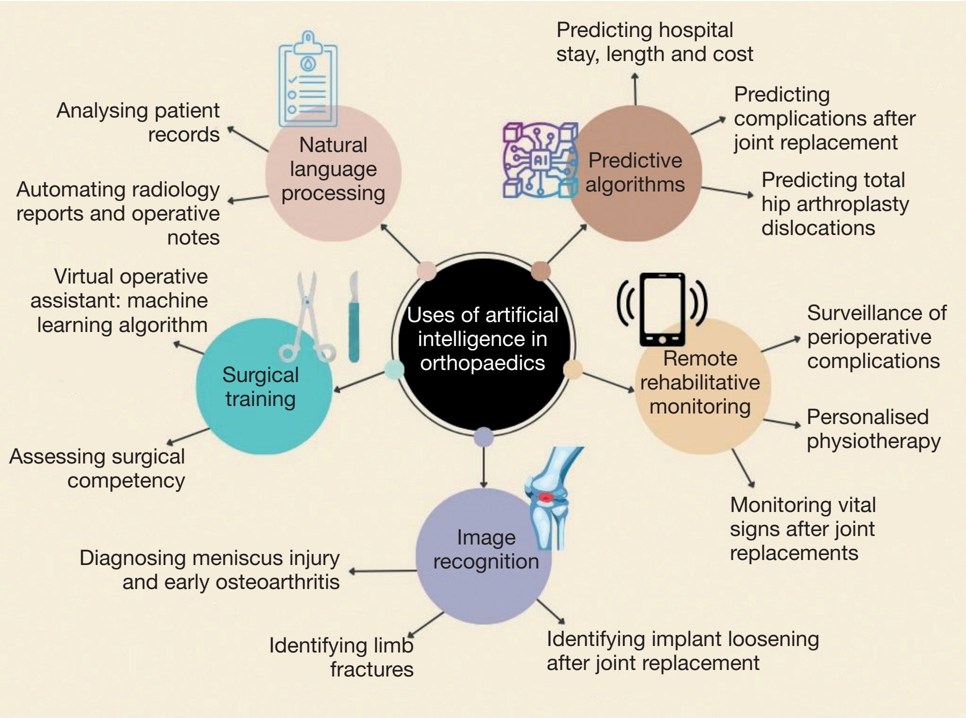

Figure 1. Current and promising uses of artificial intelligence within orthopaedic surgery.

How to cite this article:
Powling AS, Lisacek-Kiosoglous AB, Fontalis A, Mazomenos E, Haddad FS. Unveiling the potential of artificial intelligence in orthopaedic surgery. Br J Hosp Med. 2023. https://doi.org/10.12968/hmed.2023.0258

a month of its launch, a testament to the potential direction of artificial intelligence technology and public engagement (Kunze et al, 2023, 2022; Cheng et al, 2023). The surge in research validating artificial intelligence models for clinical applications is steadily gaining momentum and this work is critical before their adoption. In a nutshell, artificial intelligence uses complex algorithms capable of generating pragmatic output data (Myers et al, 2020). Subfields of artificial intelligence include machine learning with its respective branches of supervised, unsupervised and reinforcement machine learning, and deep learning, a more progressive subcategory of machine learning (Kurmis and Ianunzio, 2022). The new frontier of deep learning is artificial neural networks and convolutional neural networks which could be used in the analysis of imaging and visual tasks (Kurmis and Ianunzio, 2022; Prijs et al, 2022).

Neural networks

With image recognition arguably at the forefront of artificial intelligence orthopaedic technology, greater than 90% accuracy has been reported with use of convolutional neural networks to identify implant positioning and loosening in patients that have undergone total hip or knee arthroplasty (Farrow et al, 2021; Gurung et al, 2022). Similarly, artificial intelligence-based detection of fractures has reported sensitivity of up to 98%, along with successful application in diagnosing congenital hip dysplasia, meniscal tears and early osteoarthritis (Carmo et al, 2021; Archer et al, 2022; Kunze et al, 2022).

However, uptake of use of convolutional neural networks needs rigorous constructs and external validation, primarily because of challenges in translating algorithms across different institutions. Natural language processing is a complement to the imaging-based function of artificial intelligence which aims to interpret a large volume of written data. In orthopaedics, natural language processing offers potential benefits in analysing and automating electronic medical records, discharge summaries, operative notes and radiology reports (Myers et al, 2020).

Predictive tools

Predictive algorithms hold promise for optimising patient care pathways in the future. For instance, studies have demonstrated that artificial neural networks may have up to 91.8% accuracy in predicting hospital stay, cost and same-day discharge based on patient demographics and perioperative variables (eg neuraxial anaesthesia) for various medical conditions (Karnuta et al, 2020; Yeramosu et al, 2023). Predictive tools have been developed to assess mortality, transfusion and complication risk following elective arthroplasty (McDonnell et al, 2021; Wei et al, 2021; Innocenti et al, 2022). Kumar et al (2020) developed a machine learning algorithm that could predict patient-reported outcomes following shoulder arthroplasty up to 7 years postoperatively. Other predictive systems have focused on assessing the suitability of nerve blocks following anterior cruciate ligament reconstruction and predicting dislocation after total hip arthroplasty (Corban et al, 2021).

Gathering and using patient data

Smartphones and devices can now gather continuous, remote data on a patient's vital signs and progress (eg following total knee arthroplasty), allowing healthcare professionals to track milestones. The potential of artificial intelligence extends throughout the entire perioperative period, enabling surveillance of complications for early detection and effective management (Kim et al, 2022; Cheng et al, 2023). A thought-provoking article by Cheng et al (2023) questioned the status quo with the introduction of GPT-4, a newer model of ChatGPT. They suggested that this could be used as a tailored physiotherapy or exercise coach for individuals who may not otherwise have access to such guidance (Cheng et al, 2023). However, caution should be exercised by clinicians when using new technologies like GPT-4, as there is evidence it can generate incorrect responses which could be dangerous in the clinical setting, so vigilance is required (Leopold et al, 2023).

Virtual and augmented reality

Integrating artificial intelligence into virtual reality and augmented reality could allow standardisation of assessing surgical competency. Trainee progress can be monitored against an objective machine learning algorithm, facilitating personalised feedback. While still in its infancy, this technique could improve patient safety and reduce healthcare costs associated with trainees' procedural errors (Guerrero et al, 2023). The virtual operative assistant is a prime example of artificial intelligence-integrated training, where users could access immediate, real-time feedback, with the machine learning algorithm classifying their skills as either 'novice' or 'skilled'. Fazlollahi et al (2022) conducted a randomised trial that demonstrated the feasibility and effectiveness of this technology in improving surgical technique. Another noteworthy tool is the HoloLens 2 – a multifunctional augmented reality tool. When combined with machine learning algorithms, it has the potential to analyse medical images and assist in developing personalised treatment plans (Mah, 2023).

Limitations of artificial intelligence

Artificial intelligence can serve as a valuable adjunct to medical practice, aiding clinical acumen. However, limitations of artificial intelligence must be considered from the design phase, otherwise patient harm may ensue. Clinicians must clearly understand the disadvantages of artificial intelligence and proceed cautiously, until external validity is proven within acceptable margins of error (Jones et al, 2018).

Machine learning research must be published responsibly to avoid misleading conclusions and to better understand the 'black box' phenomenon, where algorithms detect unconventional data patterns that are incomprehensible by humans (Polisetty et al, 2022). There is a lack of retrospective analytics from artificial intelligence models, leading to a lack of reliable and valid reasoning (Myers et al, 2020; Kunze et al, 2022). While it has been estimated that artificial intelligence could slash healthcare costs in the United States of America by $150 billion by 2026, a multitude of factors could hinder its widespread adoption, including expenditure (Bohr and Memarzadeh, 2020). The cost–benefit may be attributed to the ease with which artificial intelligence is able to review large volumes of patient information known as 'big data' (Jones et al, 2018; Magan et al, 2020), but as with many artificial intelligence models that are not widely validated, monetary loss is a big gamble and training large datasets can be very costly.

Other pitfalls to be mindful of with the increased use of artificial intelligence include the cybersecurity risk of patient information, and 'over-fitting' of data. This corresponds to the algorithmic model focusing on minor data properties and thus either being limited or failing completely to generalise to novel datasets (ie the external validity of the artificial intelligence model) (Vigdorchik et al, 2022). Many articles emphasise the importance of accurately reporting training datasets since the algorithms are only as good as the data they are trained on. Thus, trustworthy and valid outputs can only be achieved through accurately captured data.

Conclusions

Ultimately, the use of artificial intelligence in orthopaedics could improve patient outcomes and reduce the workload of healthcare professionals. Artificial intelligence may be the cornerstone of future precision care, tailored to the individual patient phenotype. It could serve as a valuable tool for identifying fractures, streamlining surgical indications, detecting implant malpositioning and loosening, predicting hospital stay duration and associated costs, assessing functional outcomes, determining prognostic scores, and monitoring the rehabilitative phase with early prediction of complications. The current state of artificial intelligence technology requires a coordinated, collaborated effort to progress from proof-of-concept into clinical practice with externally validated, corroborated evidence, favouring its efficacy. Provided that meaningful questions, transparent methodology and high-quality data are used alongside externally validated tools, the future of artificial intelligence has immense promise in orthopaedic surgery. Systematic validation and reporting frameworks must be developed that prioritise safety and enable the responsible implementation of artificial intelligence in orthopaedics. Only by establishing a solid foundation of high-quality evidence can the safe uptake of this technology be facilitated.

Key points

- Artificial intelligence shows potential for improved patient care using predictive algorithms, pertaining to hospital length of stay, dislocation risk and postoperative complications following joint arthroplasty.
- Neural networks may be used to augment the diagnosis of fractures, detecting early osteoarthritis, hip dysplasia, implant malposition, and assisting implant identification in arthroplasty.
- The use of augmented and virtual reality mixed with artificial intelligence may give surgical trainees superior teaching opportunities and feedback to lower surgical error.
- Surgeons must remain cognisant of the limitations of artificial intelligence (such as overfitting) and proceed cautiously until external validity is proven within acceptable margins of error, before widespread adoption into clinical practice.

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Conflicts of interest

FS Haddad reports board membership of the *Bone and Joint Journal*, the *Annals of the Royal College of Surgeons* and the *British Journal of Hospital Medicine*; consultancy for Smith and Nephew, Corin, MatOrtho and Stryker; payment for lectures, including service on speakers' bureaus, for Smith and Nephew and Stryker; and royalties paid by Smith and Nephew, MatOrtho, Corin and Stryker (all are unrelated to this work). A Fontalis reports financial support from the Onassis Foundation for PhD studies – Scholarship ID: F ZR 065-1/2021-2022, and receiving the Freemasons' Royal Arch Fellowship with support from the Arthritis Research Trust (all unrelated to this work). E Mazomenos reports institutional grants from Wellcome/EPSRC Centre for Interventional and Surgical Sciences (WEISS) (Awards WT:203145Z/16/Z, EPSRC: NS/A000050/1), related to this work.

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