NARRATIVE REVIEW

Can artificial intelligence change the face of orthopaedic surgery? Current and future concepts

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Abstract

Orthopaedic surgery has evolved remarkably into a highly specialised and advanced medical field. The discipline has seen substantial improvements in surgical techniques and the development of subspecialties. Outcomes can vary widely, with some procedures not yielding the expected improvement in quality of life. This variability in outcomes leads to inconsistencies in the standard of care. Artificial intelligence emerges as a powerful tool to bridge gaps in knowledge and standardise care across the orthopaedic field. Artificial intelligence can assist in various aspects of orthopaedic surgery, such as image recognition, risk assessment and clinical decision-making. However, the implementation of artificial intelligence in orthopaedics is not without challenges. The reliance on large datasets raises concerns about data ownership, privacy and the potential for algorithmic bias. As artificial intelligence continues to evolve, its role in orthopaedics will likely expand, offering new opportunities to optimise patient care and improve the overall quality of healthcare.

Keywords: Artificial intelligence, Orthopaedic, Surgery, Healthcare system.

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Introduction

Orthopaedic surgery has certainly revolutionised from the time of its evolution as a specialty amidst battlefield and warfare almost 300 years ago to an extent beyond recognition. With improved surgical techniques, enhanced understanding of disease progression, development of subspecialties, provision of better services and training programmes, all point towards improved outcomes in all divisions of orthopaedic surgery, including trauma, tumour, spinal surgeries and infections etc.

Despite these advances, there are still outcomes that need improvement and a hundred per cent outcome cannot be guaranteed. For example, in total hip replacement (THR) surgeries, up to 4% of patients do not experience any improvement in the quality of life (QOL) following surgery.[1] Furthermore, uniform outcomes are not found across patients and hospitals.[2] To improve the likelihood of success is what institutions and physicians strive for. Partly, innovative ideology and methods can help in achieving this target by pushing the boundaries of the available knowledge.

However, another way is to ensure that all surgeons and institutions start producing the best outcomes via a number of approaches, like using databases,[3] such as the international Joint Registries of United Kingdom and Australia, or the Trauma Banks of the United States.[4] This shall help in improving knowledge and ensuring that information is freely shared among surgeons and their institutions. Guidelines have been established, like the Advanced Trauma Life Support (ATLS) and the National Institute for Health and Care Excellence (NICE),[4] to make sure that surgeons treat their patients with the best available evidence. Furthermore, different programmes have been initiated to help healthcare providers (HCPs) reassess their decisions regarding patient care, like making sure that patients suffering from complicated orthopaedic problems are reviewed by experts in the field.[4]

Yet, one can still find variability in practice despite all these measures and research. For example, consulting a surgeon in Germany for a shoulder problem increases the risk of a shoulder arthroplasty six times more than in the UK.[5] Similarly, visiting a spinal surgeon with lesser years of experience would increase the chances of a procedure for a fusion compared to when a patient would consult a surgeon with more experience.[6] The number of primary joint arthroplasty procedures carried out in an institute per annum is inversely proportional to the cost of the procedure and the risk of complications.[7] The aforementioned examples show how drastically medicine is progressing, so much so that it is not possible for professionals to keep pace with these changes, which, consequently, means that the standard of care is not uniform across healthcare systems. For example, in April 2013, NICE published guidelines regarding using cement augmentation for the treatment of compression fractures

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in the vertebra. However, only one month later, new data may have resulted in guideline modification.[8] Consequently, maintaining a uniform standard of care has become more complex.

Artificial intelligence (AI) provides two solutions. Firstly, having the ability to access knowledge beyond the current limitations. Secondly, streamlining the process of distribution of data.

Different specialties like radiology, oncology and basic sciences etc., have studied AI.[9-12] Despite this, AI has not been integrated into the curriculum at most medical schools as it is considered irrelevant, which means AI capability and its challenges remain unknown to a lot of physicians.

AI is a broad term involving other categories, like machine learning (ML), which is further sub categorised, and one of them is deep learning[13,14] The goal of AI is to allow a machine, for example a computer, to perform special tasks that can either match or even exceed human performance. Advances in computing power, storage of data, and accessibility of high-quality data have driven the expansion of AI into the healthcare field as well. Problems specific to orthopaedics, such as image recognition, preoperative risk assessment and clinical decision-making, and analysis of classification scores of trauma patients, are beginning to be addressed using AI-based methods (Table).[15-28]

AI can easily be incorporated in the field orthopaedic surgery owing to several reasons. In orthopaedic surgery the processes are straightforward and clear-cut with national classification of institutions as per the level of care they provide. Also, this field is on the path of continuous progression with rapidly changing techniques, and owing to the increased demand of care required from the elderly population, it is an expanding speciality. The procedures in this speciality always consider cost effectiveness as a critical element. Finally, AI algorithms can conveniently be generated as both national and international systems for collection of data are already in place.

The current narrative review was planned to use orthopaedic surgery as an example to elaborate the significance of AI in the field of medicine, and the importance of the role of physicians in incorporating AI into their practice.

What is AI?

AI is a term devised by John McCarthy as a theory that suggested the use of computers to carry out tasks by the process of identifying patterns with minimal or even no participation of humans.[29,30] A more recent and precise definition of AI is the application of algorithms that provide machines the ability to solve problems that traditionally required human intelligence.[31] In easier terms, the goal of AI is to replicate human intelligence by using machines. AI appears to be promising when it comes to solving several problems regarding healthcare. AI entails machinery and gadgets that are able to carry out tasks that are basically the characteristic of human intelligence, including drafting, comprehending language, identifying patterns, learning and solving problems. Most importantly, AI can even learn from mistakes, and make improvements, which is similar to experiential learning.

Table-: Examples of leveraging AI for orthopaedic applications.

Study	Application
Thong et al[15]	Optimisation of 3-D spine model vectors for the automatic detection of adolescent idiopathic scoliosis.
Olczak et al[16]	Identification of fractures from radiographic images
Chen et al[17]	ML-based predictions for physician order entry show that prioritising small amounts of recent data is more effective than using larger amounts of older data toward future clinical predictions.
Kruse et al[18]	Prediction of hip fractures from dual x-ray absorptiometry
Cilla et al[19]	Use of MLto optimize short-stem THA design to produce optimal mechanical performance.
Konda[20]	An AI system (PersonaCARE) helps manage NYU's middle age and geriatric fracture population based on all of the principles of value-based care.
Karnuta et al[21]	Determined that a bundled care model for hip fractures is an unsustainable value-based model.
Ramkumar et al[22]	Predicted length of stay, inpatient costs, and patient disposition for lower extremity joint replacement.
Shah et al[23]	Automatic measurement and segmentation of articular cartilage thickness in healthy knees on MRI
Harris et al[24]	Prediction of 30-day complications and mortality following TJA.
Greenstein et al[25]	ANN utilisation of in-house EMR data to predict skilled nursing facility utilisation following TJA.
Fontana et al[26]	ML to preoperatively predict with fair to good accuracy which patients may achieve minimally clinically important differences postoperatively in TJA Use of NLP to identify orthopaedic surgical site infections.
Thirukumaran et al[27]	Use of NLP to identify orthopaedic surgical site infections
Galbusera et al[28]	Use of NLP to identify orthopaedic surgical site infections

Valuable review of Artificial Intelligence and ML in spine research.

3-D= 3 dimensional, ML= machine learning, THA= total hip arthroplasty, NYU=New York University, MRI= magnetic resonance imaging, TJA=total joint arthroplasty, NLP= natural language processing, ANN= artificial neural networks, and EMR= electronic medical records.

With the rapid increase in affordable computational power and rapid growth in data sets, AI has revolutionised from being just theory to an unparalleled tangible application.[29] AI has become fundamentally integrated into many facets of society, from autonomous driving cars and video streaming recommendations to online purchase recommendations and advertisements, by retrieving exponential amounts of data in close to real-time.

AI can be divided further into artificial general intelligence (broad AI) and narrow AI. At this moment in time, all AI is narrow AI. An example of narrow AI is when only one task is the main focus, such as recognising an image or translating speech. In narrow AI, the goal is to identify associations of predictive power in data by using software. ML does not require recognition of associations in data in advance, rather it can establish patterns on its own without having prior knowledge of the domain in question.

ML and AI

ML consists of a process that entails describing various links or connections among chunks of data in order to foresee incidents, like the artificial neural network or neural net, which mathematically portray the processing ability of neurons in humans. McCulloch and Pitts described that artificial neural networks represent the processing capabilities of human neurons mathematically.[32] Artificial neural networks are now able to carry out functions such as image recognition and automated driving. This is owing to increased access to data and availability of more powerful computers. Deep neural networks and deep learning have led to most of these advancements.

Back propagation is a method by which data is assessed in layers in order to determine associations among different aspects of it without any prior speculation. This is the basis of the algorithm used in deep learning.[33] Hence, with the help of deep learning, millions of layers of data become available for scrutiny, making it a more efficient method to analyse data when it comes to research in clinical practice.

Despite the kind of method used to analyse data, a supervised learning system remains essential. This system involves two input sources in order to produce the final result; a human who determines the framework or variables, and a machine. For example, in order to establish the final diagnoses of a fracture, the input from a human (X-ray films labelled as fractures or non-fractures) is combined with that of a machine (pixels per area in the image).

Applications of AI in healthcare

AI can open doors for better patient care in the several domains, like in establishing a diagnosis based on information collected from signs and symptoms of the disease along with any investigations carried out. In other words, coming to a conclusion after assessment of data available. It can determine a management plan according to the diagnosis in addition to monitoring therapeutic effects. AI results in advances in clinical research as a result of in-depth evaluation of disease processes and modification of management patterns. Besides, it results in increased efficiency within healthcare systems by assessing resource allocation and making adjustments according to demand.

A good example of AI implication in terms of establishing a diagnosis is vertebral body compression fractures. The sensitivity of an ML system in diagnosing a vertebral level compression fracture is 95.7% in comparison to that of a senior radiologist. Similarly, the sensitivity of diagnosis of the grade of vertebral body height-loss and analysis of fracture are 68% and 95%, respectively, which is higher compared to a radiologist.[33,34]

Considering the role of ML in terms of disease management, evaluation of postoperative complications in the following example demonstrates the level of attainable efficiency by incorporating AI. Kim et al. focussed on the training of an artificial neural network utilising data of 22,629 patients.[35] Postoperative complications were predicted by their neural networks and patient's American Society of Anaesthesiologists (ASA) classification. When compared, it was concluded that the neural network was more successful in determining postsurgical events, such as venous thromboembolism (VTE) and wound complications. All things considered, it can be assumed that healthcare facilities with less patient turnover and physicians with less experience can highly benefit by utilising AI in clinical practice.

To elaborate further, recognition of different kinds of tumours,[36] research in drugs,[37,38] genetics[39] and immunology[40] are being carried out using AI. Unfortunately, not much data is available regarding the implementation of AI in the fourth sector, meaning the modification of the system after assessment.

It is essential to recognise the significance of progression in healthcare after the implementation of AI in clinical practice. Although statistics might be impressive, some limitations in certain aspects still remain. Hence, the same results cannot be inferred in all environments. Nevertheless, the potential of progression should not be underestimated, and it must also be kept in mind that AI can neither be entirely developed nor implemented overnight. However, the concept and possibility of creating a team of AI and physicians in order to optimise efficiency is foreseeable.

AI and Healthcare: Suggestive Role in Orthopaedic Surgery

Orthopaedic services consist of a network of physicians and patient activity. Patient activity involves tasks carried out by the patient before and after being reviewed at healthcare facilities along with post-intervention events. Although processes in orthopaedics are precisely stated, collection of data as a part of process management remains a challenge.[41] This concern has been addressed with the help of patient involvement in designated clinical pathways, data-sharing with primary care and digital health tools.[41,42]

AI provides a "digital closed-loop feedback" system to process and modify data collected from clinical processes, allowing the possibility for long-term follow-up. For example, establishing an early diagnosis in a primary care setup owing to better access to diagnostic testing, followed by being paired with a suitable surgeon in order to receive appropriate care (management plan and indicated intervention). All this is carried out by AI after the analysis of previous data, and, in turn, also contributes to algorithms for future references.

Challenges of AI

Orthopaedic imaging and histological sections are examples of data that is already present for diagnosis with the help of AI. In terms of management and research, the data available is still scarce, but under continuing development. For example, data collected from the National Joint Registry in the UK in 2010 has allowed physicians to assess why metal-on-metal hip implants have a high tendency of undergoing a revision procedure. These registries have also allowed elaboration on failure rate of metal-on-metal hip implants along with possible implications, like the risk of cancer.[43] The early involvement of orthopaedic surgeons with AI is essential in order to establish algorithms and datasets that can be used by them in the near future. For example, AI can assist an orthopaedic surgeon in selecting the kind of implant suitable for their patient based on pre-determined variables, such as age and gender.

AI requires vast amount of data in order to provide solutions for healthcare systems. Considering this, there arises the issue of ownership of this data. It may be proposed that all health-related data should be deemed open to public so that it can be used to develop algorithms for the greater good. An important aspect that needs consideration is the fact that algorithms have the potential of mirroring any bias. An example of this is legal algorithms that were deemed controversial owing to racial bias.[44] When building algorithms for healthcare, it is essential that they are free from any bias, such as race, gender, obesity or socioeconomic factors.[44]

Nevertheless, the aforementioned requires a significant amount of investment from governments and physicians. Besides, the amount of research required for development would also need experts in the field of technology. Most of this is not quite affordable for majority organisations which gives rise to a competitive environment among them. In this scenario, organisations benefitting the most from AI development in orthopaedics would have a greater purpose of making investments.

AI in orthopaedics should be considered similar to any other newly introduced imaging technique or implant. In order to have a solid framework, it is essential that orthopaedic surgeons are involved earlier in the development of algorithms. In addition, it is important that the entire process is overseen by physicians in order to eliminate the chance of development of pathways that would lead to a specific investor gaining more profit by suggesting a particular implant or referral pathway. Considering this, particular controls, such as a firewall, could be put in place.

At present, AI is in the initial stages of development and is mostly experimental, but with the passage of time its relation with humans will evolve. It is foreseeable that it will assist physicians in establishing diagnosis and in coming up with more precisely suitable management plans for patients entirely with the help of algorithms built on the results of previous experiences summarised in the form of datasets. Clinicians' input and participation in building of algorithms would be essential in order to ensure ethical practice, honour the patient's wishes, and maintain patient confidentiality.[44,45] However, the implementation of this system will face the challenge of accountability. Ethics, legalities and the relationship involving patients, clinicians and algorithms must be considered while building the framework so that a clear-cut and defined boundary is in place. This will determine clear limits for AI to work within defined parameters.

Conclusion

The incorporation of AI in the healthcare system is something undeniable. As robotics have enhanced the performance of surgeons in challenging surgeries, AI is suggestive of assisting clinicians in their clinical practice. In order for patients to gain maximum benefit from this, it is essential that clinicians are involved in its development sooner rather than later so that the forthcoming challenges can be overcome by putting together experts from multiple disciplines. Nevertheless, significant issues, such as the ability of AI to process each patient as an individual entity, or the ethical aspects, might be too complex for mathematical representation and eventually being incorporated into an algorithm. However, AI combined with clinician input will uphold clinical values, and has great potential for patient welfare.

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