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Artifical intelligence use in orthopedics: an ethical point of view

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- Artificial intelligence (AI) is increasingly being utilized in orthopedics practice.
- Ethical concerns have arisen alongside marked improvements and widespread utilization of AI.
- Patient privacy, consent, data protection, cybersecurity, data safety and monitoring, bias, and accountability are some of the ethical concerns.

Keywords
- artificial intelligence
- machine learning
- deep learning
- orthopedics
- ethics

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Introduction

The age of artificial intelligence (AI) began during the second half of the 20th century. The term 'artificial intelligence' was coined in 1955 by John McCarthy, a computer and cognitive scientist, and his associates (1). They proposed that if certain aspects of human intelligence, such as learning, abstraction, language, and problem-solving could be described in an accurate and detailed way, it would be possible for a machine to simulate these human capabilities. Today, the evolution in machine learning (ML) has reached a level of sophistication that enables machines to gather data, learn, analyze a process, define a problem, and come up with a solution. These capabilities have resulted in various degrees of defining AI and its associated terms (see Table 1). In recent years, AI has infiltrated every aspect of life, including medicine. In the medical arena, AI typically occurs in the form of either algorithms or robotic technologies. The ability to gather, analyze, and store big data has resulted in the creation of algorithms for calculating specific risks, expected patient satisfaction, and even the expected success rate for procedures or medications. Additionally, in orthopedics and other disciplines, evolving robotic technology has reached a state that could allow a surgeon, at least hypothetically, to remotely operate on patients. With the ability to assist in decision-making processes, increase surgical precision, and minimize the time spent on certain aspects of surgery, such as the use of endoscopic knot-tying robots, for example, AI and robotic technology have earned a permanent seat in the operating theater.

Ethical concerns have arisen, however, alongside the marked improvements and widespread utilization of AI in orthopedics. In 2019, the European Federation of National Associations of Orthopaedics and Traumatology (EFORT) published a guideline on aspects of AI applications in the field of orthopedics and traumatology that warrant ethical consideration (2). Examples include the protection of patient privacy while gathering and utilizing patient data, algorithm biases created based on the data collected, and cybersecurity concerns or accountability for undesirable outcomes (2, 3). The aim of this paper is to discuss the pros and cons of AI applications in orthopedics and traumatology from an ethical perspective.

Orthopedic applications of artificial intelligence

AI has gained increasing popularity in orthopedic practice (9, 10), including clinical, preoperative, intraoperative, and postoperative settings. AI also has a role in the research setting. Federer *et al.* published a scoping review on AI in orthopedics in 2021, which emphasized the noticeable increase in the number of AI-related published articles during the previous 3 years (11). This body of research was primarily focused on image interpretation and clinical decision-making. The most frequently reported

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Table 1 A brief dictionary of common terms in artificial intelligence.

Terms	Definition
Artificial intelligence (AI)	Myers *et al.* (3) noted that AI was an 'umbrella term' that covered several concepts such as machine learning, deep learning, and artificial neural networks. AI can be largely defined as 'computers simulating human intelligence.' In other words, such computers can store and analyze big data, recognize hidden patterns in the data, establish algorithms based on the data, as well as define problems, create solutions, and, in some instances, execute them.
Machine learning (ML)	Broadly speaking, ML corresponds to the type of computer systems that analyze and sort data in two steps. In the first step, the computer studies the exemplary data set and develops a mathematical model based on that set. In the second step, the computer uses the established model to make predictions for any new questions that arise. ML can be either supervised or unsupervised. Unsupervised ML requires frequent checks for errors and discrepancies and should also be based on a much bigger data set (3, 4, 5, 6).
Deep learning (DL)	DL is a type of ML, albeit a very complicated one. DL simulates the neuronal networks of the human brain, in that it consists of multiple connections and several layers. Simulating the multiple connections that neurons make with each other and how they intercommunicate involves several parameters in DL that substitute for the brain's neurons, and that are also determined by the (unsupervised) machine. These parameters are connected to each other in multiple layers, yielding a network of connections that the machine uses to develop a model for predicting answers to the relevant questions. Finally, many inputs can be reduced to a simple 'yes or no' question. These parameter networks are known as artificial neuronal networks (ANN) (3, 4, 7).
Natural language processing (NLP)	Using NLP, machines process languages in various forms, such as patients' electronic medical files or conversations between the patient and the physician. The raw information in written texts is subsequently transformed into structured data which can aid in establishing models and algorithms (3, 8).
Black box phenomenon	The result of a computer's data analysis might include outputs or other criteria that human scientists are unable to understand or rationalize. This phenomenon is known as the 'black box phenomenon' (3).

AI-associated body region was the spine (43%), followed by the knee and hip, respectively (11).

Preoperative applications

Image interpretation is an important application of AI in orthopedics. AI applications were developed to allocate patients to certain classifications, rule out or diagnose fractures, identify normal anatomic structures, detect scoliosis, tumors, degeneration of spine or segmentation of vertebrae, and to grade osteoarthritis, among others (11, 12, 13). AI can also facilitate the clinical decision-making process. By using ML algorithms, predictions about mortality and morbidity risks of certain procedures, as well as success rates and patient satisfaction, can be made. Total knee arthroplasty (TKA) provides a good example for demonstrating the role of risk prediction and outcomes (14). AI requires training data and a more extensive data set results in a more reliable algorithm. In the case of arthroplasty procedures, patient registers containing data from more than 10,000 patients provide the foundation upon which algorithms rely. The suitability of performing TKA strongly affects patient satisfaction. With AI, it is possible to analyze multiple variables and their interrelationships and to predict, for example, if the operation is appropriate for a particular patient. In sports medicine, AI tools can potentially aid physicians in predicting the risk of injury to athletes, or the satisfaction of patients, by relying on specific imaging data (15).

Intraoperative applications

Intraoperative applications of AI in orthopedics are primarily confined to hip and knee arthroplasties. Robotic technology has also been introduced in arthroplasty procedures (14, 16), and more than two decades ago, navigation-assisted arthroplasties entered the surgical arena. The principal goal was to evaluate the suitability of specific bony cuts and soft tissue balancing through navigation, known as 'passive technology.' 'Robotic technology,' which can be either active or semi-active, was the next step. With passive technology, the surgeon has full control. With active technology, the robot performs tasks independently. In semi-active technology or 'haptic technology,' the robot provides feedback to the surgeon about its actions, a scenario that is also known as robotic-arm-assisted total knee surgery (16). Batailler *et al.* recently published a systematic review on the current use of AI in knee arthroplasty and concluded that the technology has a role in planning surgeries, improving the accuracy of alignment of the lower extremity, positioning of implants, and determining soft tissue balance (14). In addition, the reproducibility of specific procedures and patient-reported outcomes have been found to improve with robotic technology (14, 16). AI can also be utilized during the training of surgical residents. Instead of practicing on cadavers, residents can use AI as a training tool (14).

Augmented reality (AR) and virtual reality (VR) are future features of computer-assisted surgery. By using computer-related tools, such as goggles and tracking devices, among other techniques, artificial information can be fused with real-world images. If not yet today, in the near future, these applications will aid surgeons intraoperatively in cases that involve complex tumor surgeries, spinal interventions, arthroplasties, osteotomies, among others (17, 18).

Postoperative applications

Patients' compliance with postoperative rehabilitation programs, their degree of mobility, gains in range of motion, pain status, and analgesic use, along with outcome analyses based on self-reports, can be monitored via AI algorithms integrated in wearable smart devices that transmit relevant clinical information. For example, during the postoperative period, TKA patients can wear smart devices connected to their smartphones to monitor their condition. The devices would transmit patients' data to remote monitoring platforms (3, 19).

Ethical considerations

As an integral part of medical practice, AI could be revolutionary and groundbreaking. It is no longer in the realm of 'science fiction' that AI will become an indispensable component of surgical practice, with continuing developments in the field of data science, computer science, and robotic technologies. These advances will be beneficial for patients, as AI offers the potential to improve patient care, estimate the risk of morbidities or complications, aid diagnosis, make preoperative and intraoperative assessments, assist in surgical procedures, provide feedback to the surgeon, and monitor postoperative patient care (9, 20). However, rapid progress that challenges regulatory mechanisms may also involve dangers that lead to ethical dilemmas. As exciting and groundbreaking as the pros of AI applications are, the cons also need to be thoroughly assessed. To address these concerns, some countries have already developed specific regulatory standards for the use of AI in clinical practice (21).

From a medical ethical standpoint, an innovation should be in harmony with the Declaration of Geneva from the World Medical Association, with the intention that AI in medicine should not be used to evoke discrimination with respect to age, gender, race, religion, disability, or other social or cultural criteria (2). At first glance, one could assume that this principle would be followed in good faith. However, that is not always the case. A major problem is often posed by unconscious discrimination. AI relies on computing big data, finding patterns through the data, and constituting algorithms on that basis. Big data may contain big biases as it is not always clear whether the data represent an entire population or a specific subset. If certain minorities are not well represented and evaluated, for example, the training data will be flawed, and the algorithm based on that set will be faulty. To avoid misrepresentations and establish data safety, data sets must be carefully monitored (20). The quality of medical data should also be regulated and monitored. Otherwise, low-quality medical records will lead to faulty guidance and misrepresentations in data sets. In addition, changes in the population and medical practices should be recorded regularly to update AI processes. Such a barrier could be overcome by the continuous monitoring of data sets and state-of-the-art medical knowledge and practice, as well as rechecking and adjusting AI algorithms, accordingly (3).

Patient privacy, consent, and confidentiality should also be taken into account when data is collected for AI applications in orthopedics (9). The corporations developing AI technology often gain access to the stored data of a particular patient population. This type of access could violate both patient privacy and confidentiality, in addition to violating data protection regulations. Patients must have the right to control their personal data, including how their data will be used, for how long, and for which purposes. Once data has been accessed, it should be clear that patients do not lose their rights to withdraw their consent; yet, in practical terms this right cannot be guaranteed because the relevant data has already been processed. For purposes of data protection, patient data may be anonymized. However, such anonymity also means that patients lose control over their data once it has been accessed (14).

Informing patients about AI-associated procedures could potentially pose an ethical problem. A patient can give consent after he/she has been fully informed about the procedure to be performed, other possible alternatives, the rationale leading to the treatment choice, potential risks, and associated complications. If the AI procedures run into the 'black box phenomenon' such that neither the doctor nor the patients understand the underlying procedures, the concept of informed consent becomes worthless. Consent may have been provided, but if the information is not properly understood, such consent may not be informed (3). One can assume that informing the patient with a statement such as 'our algorithm has chosen this procedure for you, and we think it is the right choice for you, but, we cannot explain why' cannot be acceptable or sufficient for obtaining consent.

Furthermore, the automation of procedures, such as a robot planning the bony incisions, directing the incisions, and informing the surgeon about the accuracy of his or her instrumentation during a TKA, may lead to a phenomenon called 'deskilling' (22, 23). This phenomenon reflects the concern that surgeons could lose their high standards of knowledge, skills, and experience if technological aids are excessively used. Under normal circumstances, this may not be an important issue; however, in the event of a system collapse due to malware, a cyberattack, or any other possible technical issue, the surgeon who has lost the ability to manage the situation could cause serious damage to a patient.

At the present time, one might assume that surgeons can manage every type of issue that can also be managed automatically through AI. In the event of a malfunction, therefore, the physician in charge would realize this and act upon it. If a surgeon does not utilize conventional procedures on a daily basis, or if these are omitted from the medical education program altogether and handed over to AI, conventional surgical skills may be gradually lost. Until AI procedures include a better solution for preventing this scenario, medical professionals should continue to learn and practice conventional methods as well.

Continued practice of conventional techniques is also important if AI contradicts the physician with regard to an indication or a diagnosis. In this situation, a surgeon may question whether he/she should pursue his or her own decision or proceed with what AI has suggested. In this scenario, classical surgical knowledge and experience are important. The primary concern is that the physician who lacks background knowledge and experience may lose his or her self-confidence based on these factors and will have no choice but to be overly reliant on AI algorithms. In the event of faulty algorithms, for whatever reason, over-reliance on AI may ultimately cause harm to patients (9).

Cybersecurity is also an important factor. Data security and patient privacy could be easily violated if data are stolen. Moreover, software systems can be attacked at any time, leaving them vulnerable to the total collapse of the systems relying on them. Malware and threats may cause system collapse or incorrect guidance, both of which would have detrimental consequences. Threats will always exist that need to be neutralized. As noted by Finlayson, securing a system is more difficult than finding a back door for breaking the system (3, 24).

Finally, accountability is a serious concern in the use of AI technologies (20). Imagine the following scenario: A corporation develops a specific automated medical technology. The regulatory parties either approve or disapprove it. Upon approval, the product appears on the market. Hospitals acquire the technology, and specially trained medical practitioners adopt it in their regular practice. We should consider AI as a supplementary tool that makes some decisions and provides answers instead of, or to support, a physician, a situation that could lessen the burden, adjust workload, prevent burnout, and create extra time for surgeons to engage with patients, etc. In the case of surgical procedures, utilization of these technologies may yield greater surgical precision, increased accuracy of implant positioning, and fewer human errors. We could continue to enumerate the upsides; however, if we look at the downsides, such as an unwanted event occurring with this technology, the critical question becomes: who will be held accountable? The computer scientist, the corporation, the regulatory agencies, the hospital, or the doctor? Certainly not the computer. The issue of accountability remains a tough and challenging question, and legal systems may require regular updates, or more information, in order to answer it.

Conclusion

At some point in the future, computer technology may reach a level where a human presence is no longer necessary in medical practice. For the time being, such a scenario appears unrealistic. The degree of technical development in AI could be regarded as a utopia come to life; however, such a utopia also presents a dystopic challenge. As mentioned previously, machines require supervision. Data sets also need to be monitored and discrepancies checked. Human beings are still required for these tasks. Machines do not get tired and can work continuously. Such functions may eliminate human error, but what about computer error? It is well known that algorithms can get confused by simple changes to expressions or images, resulting in a different conclusion when confronted with the same situation, an error that humans are not likely to make. With these scenarios in mind, AI is currently supported by augmented intelligence, in which a medical practitioner is in charge of caring for the patient, while supported by assistance from AI systems.

In conclusion, existing applications of AI in orthopedics are gaining enormous ground. AI and robots play important roles in making clinical decisions, analyzing images, establishing diagnoses, and estimating risks, morbidities, and complications. In addition, AI assists in performing some of the steps in specific orthopedic procedures and during postoperative patient monitoring. New developments are accompanied by new ethical challenges and AI in orthopedics is not devoid of these concerns. Patient privacy, consent, data protection, cybersecurity, the safety and monitoring of data, bias, and accountability are some of the ethical issues associated with AI. Currently, differing points of view on these topics are being debated, but facing the current stage of development is only the beginning. As AI technology improves, new and unprecedented ethical dilemmas may become increasingly evident.

ICMJE conflict of interest statement

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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