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Brief Report

Transforming orthopedics: A glimpse into the future with artificial intelligence

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ABSTRACT

Artificial intelligence (AI) has found numerous applications within the health-care domain, particularly in orthopedics, spanning from accurate image recognition and pre-operative planning to post-operative care and rehabilitation. Several studies have demonstrated the successful integration of AI models into osteoarthritis diagnosis and knee and hip arthroplasty. Despite promising advancements, ethical considerations demand careful attention. The future entails interdisciplinary collaboration to unlock the full potential of AI in reshaping orthopedic care.

Keywords: Arthroplasty, Artificial intelligence, Deep learning, Machine learning, Orthopedics

INTRODUCTION

Amidst the rapid evolution of technology, artificial intelligence (AI) and machine learning (ML) have emerged as transformative forces across various medical domains, including orthopedic surgery. This commentary seeks to delineate the strides made in orthopedic AI applications, transcending specific procedures to encompass the broader landscape of orthopedic care.

METHODS

A comprehensive literature review was conducted using the PubMed/MEDLINE, Web of Science, and Google Scholar databases, covering publications from inception through July 2024. The search included the terms "Artificial Intelligence," "Machine Learning," "Deep Learning," "Orthopedics," and "Arthroplasty," among others. This search yielded 513 articles, which were then screened by title and abstract to identify original research and review articles written in English over the past 10 years. Articles were included if they were relevant to the application of AI in orthopedics, while those focusing on AI in other subspecialties or with inaccessible full texts were excluded. In addition, references known to the author or manually selected from the reference lists of screened articles were also included.

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DISCUSSION

Image analysis and diagnostics

AI has found extensive application in image analysis and diagnostic capabilities in orthopedics. AI algorithms provide invaluable support to orthopedic professionals and musculoskeletal radiologists. In a recent systematic review of 61 included studies, AI algorithms' pooled sensitivity and specificity for detecting osteoarthritis were 94% (95% confidence interval [CI]: 90, 97) and 91% (95% CI: 77, 97), respectively.[1] This not only expedites the diagnostic process but also ensures accurate and earlier interventions. Moreover, the current literature provides evidence of AI's proficiency in image recognition, classifying knee osteoarthritis with radiographic accuracy comparable to a fellowship-trained arthroplasty surgeon.[2] AI has also demonstrated excellent reliability in orthopedic fracture detection and classification.[3] This potential holds significant value, and future strategies should prioritize integrating AI applications into medical record systems, particularly within non-orthopedic settings like primary care physician practices.

AI in pre-operative planning

One of the significant contributions of AI in orthopedics lies in pre-operative planning. Advanced algorithms analyze patient data, including medical history, imaging results, and demographic features (including age, sex, height, weight, and body mass index), to assist surgeons in devising personalized and precise treatment plans.[4] This not only enhances the efficiency of surgical procedures but also minimizes the risk of complications. This is evident in the reliability of AI in predicting total knee arthroplasty (TKA) component sizes, which exhibited an accuracy ranging from 88.3 to 99.9% ± 1 size.[4]

Surgical assistance

Integrating AI-powered robotic systems has ushered in a new era of surgical precision. These systems assist surgeons during procedures, offering real-time feedback and enhancing the accuracy of interventions. The application of AI in intraoperative decision-making presents promising avenues, as evidenced by Verstraete *et al*.,[5] who successfully harnessed ML models to optimize balance and alignment during TKA surgery.

Post-operative rehabilitation

AI has also been employed in post-operative care following orthopedic procedures. Movement monitoring sensors were found to facilitate continuous tracking of patients' post-operative range of motion progress, enabling early detection of potential issues and timely interventions that optimize the recovery and rehabilitation process.[6] In addition, ML holds promise in reducing post-operative opioid requirements and associated complications in total hip arthroplasty by enhancing pre-operative screening and providing support for high-risk patients.[7]

Challenges and ethical considerations

While the integration of AI in orthopedics holds immense promise, it is not without challenges. Ethical considerations surrounding patient and data privacy, algorithm bias, and decision-making responsibility in AI-assisted surgeries require careful consideration.[8] For instance, Luo *et al*.[9] have undertaken efforts to standardize and formulate guidelines such as the "Guidelines for Developing and Reporting Machine Learning Models in Biomedical Research". The orthopedic community must actively engage in discussions to establish clear guidelines and frameworks that ensure responsible and ethical use of AI technologies.

AI algorithms may inadvertently reinforce biases in health care due to the quality and diversity of the datasets used for training, which could affect certain patient populations disproportionately. In addition, legal and regulatory issues present significant challenges. One pressing question is: Who bears the liability when AI-guided, robot-assisted surgeries result in poor outcomes, such as malfunctioning arthroplasty? Is the responsibility solely on the surgeon operating the system, or does the technology provider share accountability? The current legal frameworks often place the onus on health-care providers, but as AI systems take on more decision-making roles, the need for updated legal guidelines becomes evident. Future regulations must clarify liability in cases where AI and robotic systems contribute to errors, as suggested by Luo *et al*.[9] Clear protocols regarding oversight and responsibility will be critical as AI continues to shape surgical practice.

Impact on the training of future surgeons

The increasing reliance on AI and robotic technologies in surgery raises concerns about the potential deskilling of surgeons in traditional techniques. As AI systems take on more diagnostic and intraoperative roles, there is a risk that future surgeons may become overly dependent on these tools, potentially undermining their manual dexterity and decision-making abilities in non-AI-assisted environments.[10] In scenarios such as natural disasters, humanitarian crises, or information technology disruptions caused by hackers, where AI technologies may be unavailable, surgeons could struggle to perform complex procedures without technological aid.

To mitigate this risk, surgical training programs must emphasize a dual approach: while embracing AI for its

benefits, they should also ensure that surgeons maintain core competencies in traditional methods, fostering resilience in both high-tech and low-resource settings.[10,11] This balanced training approach is crucial for developing well-rounded surgeons capable of adapting to diverse and unpredictable environments.

FUTURE DIRECTIONS AND RECOMMENDATIONS

As we navigate the evolving landscape of AI in orthopedics, a collaboration between orthopedic surgeons, engineers, and data scientists becomes paramount. In the future, it will be important to focus on developing robust AI models and ensuring their widespread availability for external validation. In addition, efforts should be made to compare these models with existing standard-of-care tools. Continued research and development will pave the way for even more sophisticated AI applications, shaping the future of orthopedic care.

CONCLUSION

The symbiotic relationship between orthopedics and AI reshapes how musculoskeletal disorders are diagnosed and treated. Embracing these technological advancements not only enhances surgical precision and patient outcomes but also propels the orthopedic field into a new era of innovation. As we move forward, it is crucial to address challenges, uphold ethical standards, and foster interdisciplinary collaboration to unlock the full potential of AI in orthopedics.

ETHICAL APPROVAL

Institutional Review Board approval is not required.

DECLARATION OF PATIENT CONSENT

Patient's consent is not required as there are no patients in this study.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY FOR MANUSCRIPT PREPARATION

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

CONFLICTS OF INTEREST

There are no conflicting relationships or activities.

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