Transforming Rotator Cuff Tear Management: An In-Depth Review of Artificial Intelligence's Impact on Imaging and Patient Outcomes

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Introduction

Artificial intelligence (AI) is rapidly reshaping orthopaedic care and clinical practice, with growing applications in imaging, predictive modeling, and surgical decision-making. Rotator cuff tears represent a prevalent and formidable challenge in the field of shoulder surgery. Achieving an accurate diagnosis is paramount, as it lays the foundation for tailored treatment planning and significantly influences the prognosis. Moreover, implementing effective strategies for re-tear prevention is crucial in ensuring optimal surgical outcomes. Addressing these elements with rigor not only enhances patient recovery but also reduces the long-term burden of shoulder dysfunction.AI-based imaging models have demonstrated improved accuracy in detecting and characterizing rotator cuff pathology, while deep learning algorithms have been developed to predict re-tear risk following repair. Despite the progress made in the field, the existing literature remains disjointed, with the majority of studies focusing on specific, isolated aspects of care. This systematic review seeks to integrate the prevailing evidence regarding the application of artificial intelligence in the management of rotator cuff tears throughout the perioperative continuum, encompassing preoperative imaging, surgical planning, prognostic modeling, and postoperative rehabilitation.

Methods

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A comprehensive literature search was performed across PubMed, Scopus, and Embase from database inception to May 2025. The search strategy combined terms related to artificial intelligence, machine learning, and deep learning with terms for rotator cuff tears and rotator cuff repair. Eligible studies included those addressing AI-based imaging diagnosis, prognostic modeling, surgical planning, or postoperative outcome prediction.

The following data were extracted and recorded: image modality/plane, input features, age, gender, diagnosis (rotator cuff tears), ground truth references, AI algorithm, pretrained CNN, size of training set, size of testing set, size of validation set or validation method, and model performance (accuracy, sensitivity, specificity, AUC). The data extracted from the included studies were narratively reviewed.

Results

A total of 59 relevant studies were incorporated into the analysis. The results demonstrate that artificial intelligence (AI) exhibits strong diagnostic accuracy for rotator cuff tears across various imaging modalities. Convolutional neural network (CNN)-based models utilizing magnetic resonance imaging (MRI) achieved diagnostic accuracies exceeding 90% in multiple studies, with ultrasound-based models exhibiting comparable performance. Several studies applied AI to surgical planning, using preoperative imaging and clinical features to guide decision-making and optimize repair strategies. Prognostic applications focused on re-tear risk and functional outcomes: deep learning models achieved AUCs of 0.87–0.92 for re-tear prediction. In contrast, machine learning approaches predicted postoperative improvement with accuracies up to 96.9% internally and 79.6% externally validated. Across studies, ensemble methods (XGBoost, LightGBM) consistently outperformed logistic regression, underscoring the potential of AI to extend beyond diagnosis into prognosis and recovery trajectories.

Discussion

This systematic review illustrates the expanding role of artificial intelligence throughout the continuum of rotator cuff management, encompassing preoperative imaging interpretation to postoperative outcome prediction. An analysis of over 230,000 patients and imaging datasets reveals that AI consistently demonstrates robust diagnostic accuracy, particularly in the detection of conditions via MRI and ultrasound. These findings underscore the potential of AI as a dependable complement to the work of radiologists. Prognostic models, including deep learning algorithms predicting retear risk after repair, showed AUC values exceeding 0.80 in several studies, highlighting their promise in stratifying high-risk patients. Applications in surgical planning and rehabilitation remain underexplored, though preliminary work suggests feasibility in quantifying tendon healing and guiding individualized recovery. These findings suggest AI can augment each step of rotator cuff management by enhancing diagnostic precision, informing surgical decision-making, and predicting outcomes. Nonetheless, heterogeneity in datasets and lack of external validation remain significant barriers to clinical adoption. Future multicenter prospective studies are needed to validate these tools and integrate AI into clinical workflows.

Clinical Significance

AI demonstrates strong potential to enhance rotator cuff care by improving diagnostic accuracy and enabling risk stratification, but widespread adoption will require robust external validation and prospective clinical integration.