G98: Is there a role for employing Artificial intelligence and/or machine learning in management of orthopedic infections?

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Response/Recommendation:

AI may soon be used to manage orthopedic infections. Its main advantages are data mining and systematic information collection, which allows the creation of predictive, diagnostic, or treatment modules. Alas, it still struggles with external validation and generalizability issues.

Level of Evidence: Limited

Delegate Vote:

Rationale:

The integration of artificial intelligence (AI), machine learning (ML), or natural language processing (NLP) into healthcare has opened new avenues for managing complex conditions, including orthopedic infections. These technologies offer potential enhancements to several stages of bone and joint infection management by analyzing vast datasets to identify patterns not readily apparent through traditional methods. Patient usage of this technology is also expected to increase, with some studies examining the quality of the information provided by free-to-use chatbots with satisfactory results (3) (4).

Current research into AI in orthopedic infections can be broadly categorized into five main areas: prediction, prevention, diagnosis, treatment, and prognosis.

Prediction models using AI or ML are the most researched subject in the literature. AI-based prediction models have been applied to forecast infections, with promising results in several orthopedic and surgical contexts, such as predicting surgical site infections (SSIs) in lumbar spinal surgery and orthopedic trauma (5) (6) (7). These models often integrate clinical, laboratory, and operative variables, demonstrating robust predictive capabilities.

Studies like Chen et al. (2023) reported an exceptional performance of an ML model for SSI prediction in lumbar spinal surgery, using variables like hemoglobin, glucose levels, and Modic changes (8). Similarly, Ying et al. (2023) employed ensemble ML models to predict infections following tibial fracture fixation, with diabetes and procedural duration identified as key predictors (5). Despite these findings, retrospective, single-center studies and external validation limitations underscore the necessity for multicenter, prospective trials. All studies advocate using AI in infection prediction to complement clinical expertise.

As part of a preventive strategy, AI was also applied to ensure compliance with surgical antimicrobial prophylaxis (SAP) bundles, identify clinical risks, and optimize preoperative planning. For example, artificial neural network (ANN) models have demonstrated the ability to predict SSIs based on variables like preoperative white blood cell count and SAP compliance, with compliant patients showing a significantly lower SSI rate (9). AI's potential to enhance clinical risk management by identifying at-risk patients, optimizing perioperative conditions, and improving incident reporting processes has also been demonstrated (10) (11). Moreover, ML has shown promise in preventing periprosthetic joint infections (PJI) by aiding in preoperative optimization, surgical planning, diagnosis, and antibiotic selection (12) (13) (14).

Regarding diagnosis, Fu et al. (2021) used NLP to extract data from electronic medical records, demonstrating strong correlations with the Musculoskeletal Infection Society (MSIS) criteria, particularly regarding the growth of cultured organisms (15). Similarly, Kuo et al. (2022) compared an in-house ML system with the International Consensus Meeting criteria, concluding that ML is feasible and competitive for diagnosing PJIs (16).

Other studies have targeted specific diagnostic elements, such as laboratory data, pathology, and medical imaging. Paranjape et al. (2023) employed ML to analyze synovial fluid biomarkers, achieving an exceptional AUC of 0.99 compared to ICM criteria (17). Tao et al. (2022) applied deep learning to frozen pathological sections, achieving an AUC of 0.8 (18), while Nie et al. (2023) used AI with dynamic bone scintigraphy in 449 patients, reporting diagnostic accuracies of 86% for knee and hip infections (19).

Using AI to treat infections directly is the least researched area. It has been shown that AI engines are a good option for extracting structured information (e.g., occurrence of complications) from unstructured data sources like free text. This technology was applied in the automated surveillance of SSIs requiring reoperation within 90 days following lumbar discectomy, with a higher successful identification rate when compared with current procedural terminology and ICD codes (15). AI also has significant potential in wound management. AI-powered digital wound assessment tools, leveraging ML algorithms, can enhance the classification of wounds and provide detailed analyses of parameters such as size, depth, color, texture, granulation tissue, and signs of infection (16). Additionally, AI, combined with the analysis of electronic health records, can identify patients at higher risk of developing SSIs and facilitate monitoring and tracking, indirectly assisting in the patient's treatment (16).

Still, regarding ML co-adjuvants for patient treatment, Chen et al. (2024) have proposed an ML-based model for predicting vancomycin trough concentration in adult PJI patients. This random forest regression algorithm, with a relative accuracy of 82.8% and an absolute accuracy of 67.2%, might reduce the need for further blood testing and invasive procedures (17).

Concerning prognosis, studies focus on identifying high-risk patients and anticipating treatment failure. Shohat et al. (2020) developed a tool to predict failure after irrigation and debridement (DAIR) of infected hip and knee arthroplasties. This study identified prognostic markers such as elevated serum C-reactive protein and positive blood cultures, supporting its utility for decision-making (18). Wouthuyzen-Bakker et al. (2021) complemented this by integrating risk scores and ML to enhance predictions of treatment failure in acute PJIs managed with conventional DAIR (19). Further investigations by Klemt et al. (2022) for recurring infections following revision arthroplasties showed possible improvements in early detection of high-risk patients (20). The same author also investigated AI in PJI following aseptic revision, affirming that the excellent results advocate AI aiding surgeons in patient-specific risk stratification and assisting in preoperative counseling and clinical decision-making (21).

In conclusion, most studies show the importance of prognostic tools for improved risk stratification and individualized treatments in managing PJIs. Nonetheless, the main advantage of using AI for infection in orthopedics is for data mining and the systematic collection of information. Following this, decision-making may become easily tailored for each patient and their specific characteristics. Despite these advancements, the field remains in its early stages, characterized by promising developments and inherent challenges, such as the "black box" nature of ML models. This research area's novelty implies limited evidence, necessitating cautious optimism. As the field evolves, rigorous validation and integration into clinical practice will be essential to fully realize the benefits of AI and/or ML in managing orthopedic infections.

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