Use of Artificial Intelligence (AI) in preoperative planning for Total Hip Arthroplasty (THA) surgeries

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INTRODUCTION:

The term AI (artificial intelligence) encompasses within itself the concepts of Machine Learning (ML) and Deep Learning (DL). For developing the input for pre-operative planning many of the ML/DL models make extensive use of radiographic information. AI has been used across different Total Hip Arthroplasty (THA) surgery applications to model outcomes with research spanning, from primary to revision THAs. Multiple factors across different demographic variables and surgery techniques have been studied. This review aims to highlight, consolidate, learn from, and utilize the information AI techniques provide to improve pre-operative planning and improve surgical outcomes.

METHODS:

A comprehensive review was conducted using PubMed, Cochran, EMBASE and CINAHL databases. Combinations of keywords "THA," "Total Hips arthroplasty," "Artificial Intelligence," "Machine Learning," and "Deep Learning." 288 articles were reviewed for information on the use of AI in THA. The inclusion criteria are reported studies where AI was used to develop ML/DL models retrospectively for THA surgeries or applied prospectively with an approved study. Exclusion criterion are where the applicability of the model to preoperative planning is limited. These were divided into different subgroups which were funneled down. Key publications in each of the subgroups were reviewed for methods, results, and conclusions.

RESULTS SECTION:

AI has been used in different areas within total hip and knee arthroplasties and the following are key results grouped together in different areas which will help guide applications in those grouped areas within THA. As exemplified below, AI has been used to predict outcomes in complex cases, predict dislocation risk, make in-vivo corrections/improvements during surgery as well as used to design patient-specific instrumentation to improve surgical outcomes.

Artificial Intelligence in THA: Within THA, the effectiveness of AI-assisted treatment of patients with Crowe type IV developmental dysplasia of the hip yielded high preoperative planning accuracy, early postoperative landing, and satisfactory short-term effectiveness. Another study performed a scoping review of studies utilizing AI-based image analysis to evaluate THA post-operative radiographs to evaluate implant positioning. These studies show AI can analyze radiographic images and urge the development of AI models that are translatable. In a large study, DL algorithms were developed for THA utilizing over a million CT images from over three thousand patients. These models were then validated on another study on radiographic and clinical outcomes and significantly reduced preoperative planning time. AI was also utilized to measure precise 3D analysis using CT or MRI via automatic segmentation of pelvic and thigh muscles in another study of forty-four patients where the outcomes were correlated to WOMAC index and JHEQ scores. The findings suggest targeting hamstrings, iliopsoas, and hip adductor muscles during preoperative and perioperative rehabilitation. A Machine Learning (ML) model for patient-specific transfusion rates following THA, identified factors associated with transfusion rates with predictive outcomes which lead to better pre-operative planning.

Artificial Intelligence as a dislocation risk predictor: ANN (artificial neural network) with nodes, hidden layers, and output layers were utilized in a unique study of over a million Hip implants and over twenty-five thousand dislocations in primary THAs. With inputs of demographics, implant position, head size, anteversion or spinopelvic alignment, type of surgery an output of post-operative dislocation within three months led to the development of a dislocation risk calculator which was implant-specific and included factors noted which influence the risk.

Artificial Intelligence to make in-vivo corrections: AI has also been successfully designed to study and autonomously correct pelvis orientation, identify cup retroversion, and determine cup orientation from pelvic radiographs in a THA. This is a unique example of AI aiding surgery, while it is being performed.

Artificial Intelligence in revision THA: While revision surgeries are undertaken for a variety of reasons, improving outcomes based on AI studies where ML models were developed based on demographic information from EHR (electronic health records) and surgical factors. These models yielded excellent performance to help with pre-operative planning to improve outcomes.

Artificial Intelligence in THA to help design patient-specific instrumentation: A key to a successful THA is patient-specific instrumentation used in THA. The use of AI, specifically, convolutional neural network (CNN) to process tomography images helped design patient-specific instrumentation (PSI). The demonstrable use of AI to design PSI-assist had better radiographic outcomes and yielded more accurate component positions, thus providing an option for more accurate surgical outcomes.

DISCUSSION:

The review exemplifies areas where AI has been utilized to study, understand, and develop predictive models for THA surgical outcomes. As the use of AI grows, more ML/DL models are developed to touch specific aspects of THA, that potentially optimize pre-operative planning leading to improved patient outcomes. This article highlights different areas where successful AI based ML/DL models have already been developed: for complex THA cases, predicting dislocation risk, making in-vivo corrections/improvements during surgery as well as used to design patient-specific instrumentation.

SIGNIFICANCE/CLINICAL RELEVANCE:

While risks remain with the premature adoption of AI and putting safeguards in place to remove biases, the promise of what AI can deliver for THA is real and substantial. More work is needed in other areas of THA and the field is expected to grow as more research is being pursued to improve patient outcomes after THAs. As more research continues to be undertaken, it is important to be mindful of where research has progressed, where risks/biases remain, areas where more research is needed, and utilize what is available to enhance patient outcomes.