COMMENTARY

Machine Learning: the Future of Total Knee Replacement

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Total knee replacement (TKR) is one of the most common surgeries worldwide, with > 1 million performed last year. Many patients have seen tremendous benefit from TKR; however, studies have shown that up to 20% of patients are not satisfied with the results of this procedure.[1,2] This equates to about 200,000 patients worldwide every year who are dissatisfied. This is a huge concern to patients, surgeons, implant manufacturers, hospitals, and health care payers.

Many attempts to improve satisfaction in TKR have been tried, including computer navigation, minimally invasive surgery, rotating platform prostheses, gender-specific implants, different materials, changes in pain management, and revised postoperative rehabilitation.[3-7] However, these efforts show no significant improvement in satisfaction.

The most common method of TKR today involves using a long rod placed through a drill hole in the femur. Standardized cuts on the femur and tibia are made through metal cutting blocks. Only metal mechanical instruments are used to perform the surgery, and all patients are aligned the same. However, anatomic studies have shown that patient anatomy in 3 dimensions (3D) varies widely from patient to patient.[8] Our current technique seems far removed from modern engineering, where we now see extensive use of artificial intelligence (AI) to improve outcomes.

Machine learning (ML) is considered a subset of AI that involves the use of various computer algorithms. ML allows the computer to learn and continually improve analysis of data. Large sets of inputs and outputs are used to train the machine to make autonomous recommendations or decisions.[9,10]

Seven years ago, our team at the Phoenix Veteran Affairs Medical Center in Arizona published a randomized controlled trial evaluating a new, individualized alignment technique for TKR.[11] This method used 3D-printed guides made from an MRI of an individual patient's knee. Instead of aligning all knee replacements the same, each patient was aligned according to their unique anatomy. Compared with the conventional alignment technique, the newer technique showed significant improvement in all outcome scores and range of motion at 2 years postsurgery. There has been a great deal of interest in individualizing TKR, and many articles and techniques have followed.[12]

Our surgical technique has evolved since publishing our trial. Currently, knee X-rays are digitally templated for each patient. Understanding the patient's preoperative alignment can then assist in planning a TKR in 3D. A plastic 3D-printed guide is manufactured in Belgium, shipped to the US, sterilized, and used in surgery. These guides fit accurately on the patient's anatomy and allow precise angles and depth of resection for each surgical bone cut. Our research has shown that these guides are accurate to within 0.5° and 0.5 mm for the bone cuts performed in surgery. After surgery, we track patient-reported outcomes (PROs), which can then be used in ML or logistic regression analysis to determine alignment factors that contribute to the best outcome.[13]

Soon, use of a robot will take the place of the templating and preplanning, allowing the 3D plan to be immediately produced in surgery by the software installed in the robot.[14-16] Each patient's preoperative alignment can then be immediately compared with the postoperative result, and smartphone technology can allow a patient to input their PRO after the surgery is healed.[17]

Collecting all this information in a large database can allow ML analyses of the outcomes and individual alignment.[14-17] As the factors contributing to the best clinical results are determined, the computer can be programmed to learn how to make the best

recommendations for alignment of each patient, which can be incorporated into the robotic platform for each surgery. Also pre- and postoperative factors can be added to the ML platform so we can identify the best preoperative patient parameters, anticoagulation program postoperative rehabilitation program, etc, to help drive higher PROs and satisfaction.

Multiple surgical robots for TKR are now on the market. Orthopedic literature includes ML algorithms to improve outcomes after total hip arthroplasty.[18] The EHR can be used to develop models to predict poor outcomes after TKR. Integrating these models into clinical decision support could improve patient selection, education, and satisfaction.[19] AI for adult spinal surgery using predictive analytics can help surgeons better inform patients about outcomes after corrective surgery.[20,21]

With worldwide TKRs expected to exceed 3 million over the next decade, ML using large databases, robotic surgery, and PROs could be key to improving our TKR outcomes.[22] This form of AI may reduce the large number of patients currently not satisfied with their knee replacement.

Author disclosures

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