Predicting Risk of Secondary Meniscus Tears following Anterior Cruciate Ligament Reconstruction: A Machine Learning Analysis of 1,369 Patients with a Median Follow Up of 9 Years

Kevin Jurgensmeier, Sara E Till[1], Yining Lu[1], Alexandra Arguello, Michael J Stuart, Daniel B F Saris[1], Christopher L Camp[1], Aaron John Krych[1]
[1]Mayo Clinic

INTRODUCTION:
Surgical management of anterior cruciate ligament (ACL) injury seeks to improve stability and decrease the risk of further knee injury, including secondary meniscus tears. Prompt quantification of the risk for meniscus tear can inform clinical decision making and optimize prevention and intervention. Therefore, the purpose of this study was to develop and internally validate an interpretable machine learning model to quantify the risk of secondary meniscus injury in a longitudinal cohort following ACL reconstruction.
METHODS:
As a retrospective cohort study, a longitudinal geographical database was used to identify patients with a diagnosis of new anterior cruciate ligament injury between 1990 and 2016 with minimum 2-year follow-up. These patients were extensively reviewed to abstract relevant demographic, injury, and treatment information. Patients were followed for a new injury of the meniscus in the knee following ACL reconstruction. Four candidate machine learning algorithms were evaluated in the prediction of secondary meniscus tears. Performance of the algorithms was assessed through discrimination using area under the receiver operating characteristics curve (AUROC), calibration, and decision curve analysis. Model interpretability was enhanced utilizing global variable importance plots and partial dependence curves.
RESULTS: A total of 1,369 patients underwent ACLR with a median post-operative follow up of 9 years. Of these, 196 (14.3%) experienced a secondary meniscus tear at a mean time of 65 months following ACL reconstruction. The best performing model for predicting secondary meniscus tear was the random forest (AUROC = 0.763, 95% CI: 0.761-0.765; calibration intercept = 0.006, 95% CI: 0.005-0.007, calibration slope = 0.961 95% CI: 0.956-0.965, Brier's score = 0.119 95% CI: 0.106-0.131), and all four machine learning algorithms outperformed traditional logistic regression. Variable importance plots and partial dependence curves identified the following risk factors (in order of relative influence) for secondary tears: shorter time to return to sport (RTS), lower VAS at time of injury, increased time from injury to surgery, older age at injury, and proximal tear location.
DISCUSSION AND CONCLUSION: Machine learning models outperformed traditional prediction models and identified shorter time to RTS, lower VAS at time of injury, increased time from injury to surgery, proximal tear location, and age > 30 at time of injury as risk factors for secondary meniscus tears after ACLR. Following careful external validation, these models can be deployed in the clinical space to provide real-time quantifiable risk for counseling and timely intervention.