Predicting Risk of Graft Retear and Contralateral ACL Tears following Anterior Cruciate Ligament Rupture and Reconstruction: An Analysis Using Interpretable Machine Learning

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INTRODUCTION: Anterior cruciate ligament reconstruction (ACLR) can be a successful procedure in restoring knee stability. However, secondary ACL injury, either through graft failure or contralateral tear, are known complications. Revision ACLR can significantly impact patients' ability to successfully return to previous activities. Thus, the purpose of this investigation was to develop and internally validate an interpretable machine learning model to quantify the risk of graft retear and contralateral ACL rupture in a longitudinal cohort treated with ACLR.

METHODS:

An established geographic database of more than 600,000 patients was used to identify patients with a diagnosis of anterior cruciate ligament rupture between 1990 and 2016 with minimum 2-year follow-up. Medical records were reviewed for relevant patient information and four candidate machine learning algorithms were evaluated for prediction of graft retear and contralateral ACL injury in patients following ACLR. Performance of the algorithms was assessed through discrimination, calibration, and decision curve analysis. Model interpretability was enhanced utilizing global variable importance plots and partial dependence curves.

RESULTS:

A total of 1,517 patients met inclusion criteria. Among them, 142 (9.36%) had graft rerupture and 132 (8.70%) had a contralateral ACL injury following index surgery. The best performing models achieved an area under the receiver operating characteristics (AUROC) curve of 0.70 for prediction of retear and 0.67 for prediction of contralateral ACL rupture. Notable predictors for increased risk of graft retear included younger age at injury, BMI>30, return to sport <250 days, initial time to surgery >75 days, utilization of allograft, femoral/tibial fixation with suspension/expansion devices, concomitant collateral ligament injury, and active or former smoking history. Predictors of contralateral ACLR injury included younger age at initial injury, BMI>25, active smoking history, initial time to surgery >75 days, history of contralateral knee arthroscopies, and involvement in contact sports.

DISCUSSION AND CONCLUSION:

Less than 10% of all patients who undergo ACL reconstruction should be expected to sustain either a graft rupture or contralateral ACL injury. Machine learning models outperformed traditional prediction models and identified BMI>30, active or previous smoking history, and time to surgical intervention >75 days as common risk factors for both graft retear as well as contralateral tear following ACL rupture. Following careful external validation, these models can be deployed in the clinical space to provide real-time quantifiable risk for counseling and timely intervention.