Development and Validation of Explainable Machine Learning Models to Predict Response to Platelet-Rich Plasma Injection in Patients with Knee Osteoarthritis

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INTRODUCTION

Advancements in artificial intelligence (AI), has had an important impact on various fields. These advancements have also permeated into the field of orthopedic surgery and joint preservation, any may optimize patient care. Orthobiologics treatment approaches, such as platelet rich plasma (PRP) have tremendous potential, but the primary limitation at this time is the variability and unpredictability in outcomes due to the heterogeneity in these preparations. This situation presents a unique opportunity for the utilization of machine learning (ML) assisted treatment algorithms, in order to improve patient outcomes. The purpose of this study is to develop and evaluate machine learning models predicting clinically meaningful improvement after PRP injection for knee osteoarthritis and determine the most influential pre-treatment factors.

METHODS

This retrospective study utilized data from 191 patient knees in our institutional Center for Regenerative Medicine registry, who received intra-articular PRP injections for knee osteoarthritis. Following feature engineering, 9 pre-injection predictor variables were utilized, including gender, age, PROMIS physical and mental scores, KOOS JR, VAS pain, SANE, Tegner activity scale, and Kellgren-Lawrence radiographic grade. The cohort was randomly divided into training (80%) and testing (20%) sets. Multiple machine learning algorithms were developed to predict clinically meaningful improvement at 6 months, including random forest (RF), XGBoost, support vector machine (SVM), and explainable boosted machine (EBM) models. Model performance was evaluated based on sensitivity, accuracy, precision, AUC-ROC, and F1-score. Feature importance weighting and partial dependency plots are utilized to elucidate associations between key predictors and outcome.

RESULTS SECTION

The EBM was determined to be the best model (F1 0.76 (CI 95% 0.57-0.89) accuracy 0.77 (0.64-0.9); sensitivity 0.67 (0.46-0.85); precision 0.82 (0.68-1) AUC-ROC 0.84 (0.7-0.97) due to superior explainability. PROMIS scores were found to be indispensable predictors; excluding them from the EBM deteriorated model performance to no better than chance (AUC-ROC 0.51 (0.32-0.7)).

DISCUSSION

The EBM model effectively predicted MCID attainment at 6 months post-PRP injection based on pre-treatment factors, simultaneously displaying feature importance and remaining explainable. Our approach provides a framework for leveraging predictive modeling and feature analysis to gain actionable knowledge from patient data.

SIGNIFICANCE/CLINICAL RELEVANCE

This study deploys machine learning models to predict minimal clinically important difference at 6 months after PRP injection for knee osteoarthritis, based on 9 pre-injection parameters. The interpretable models like explainable boosting machine effectively prognosticate outcomes with high accuracy while retaining model transparency, demonstrating machine learning's potential for personalized medicine.

IMAGES AND TABLES