



Utilizing Machine Learning to Identify Pain Trajectories in Patients with Complex Pain Undergoing Total Knee Arthroplasty (Abstract# 2316111)

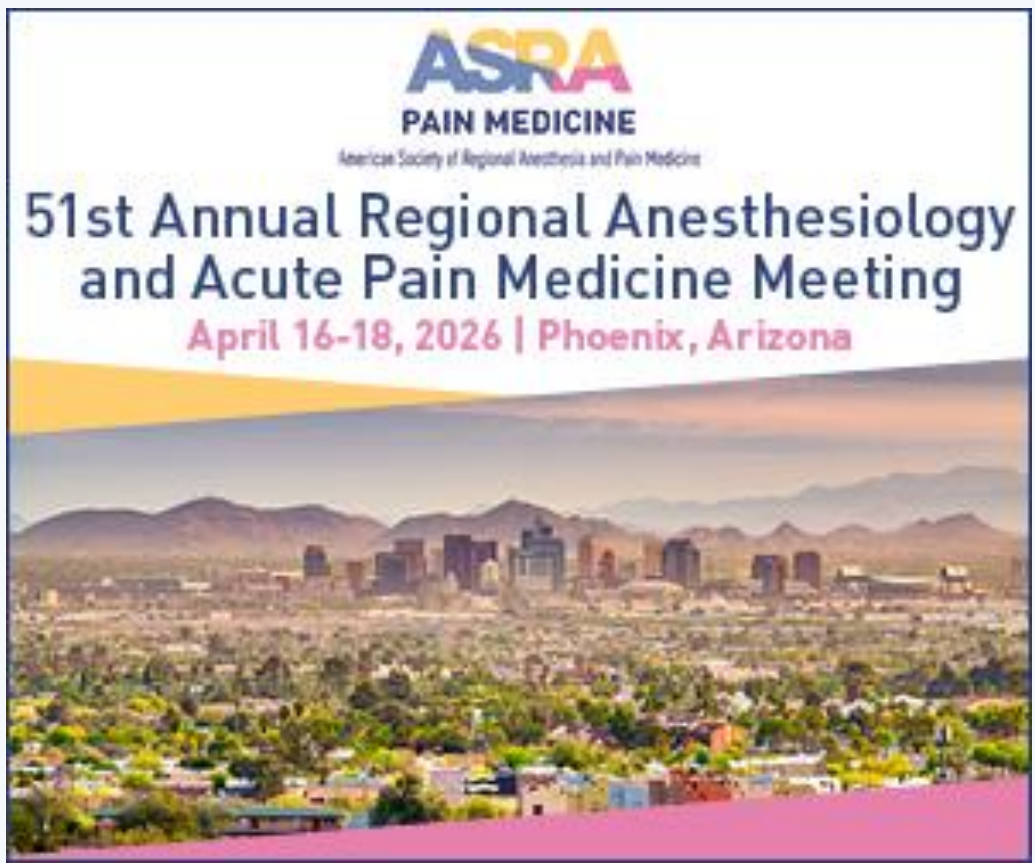
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INTRODUCTION

- Chronic pain affects nearly 25% of U.S. adults and complicates recovery after total knee arthroplasty (TKA), putting patients at increased risk for persistent post-surgical pain¹⁻³.
- At Hospital for Special Surgery, the Perioperative Pain Service (POPS) provides structured preoperative evaluations for complex/chronic pain, including screening for opioid tolerance, substance use, and psychosocial risk factors, guiding tailored perioperative care.
- Identifying distinct postoperative pain patterns and predictors in this high-risk group may enable earlier intervention and improved recovery.

METHODS

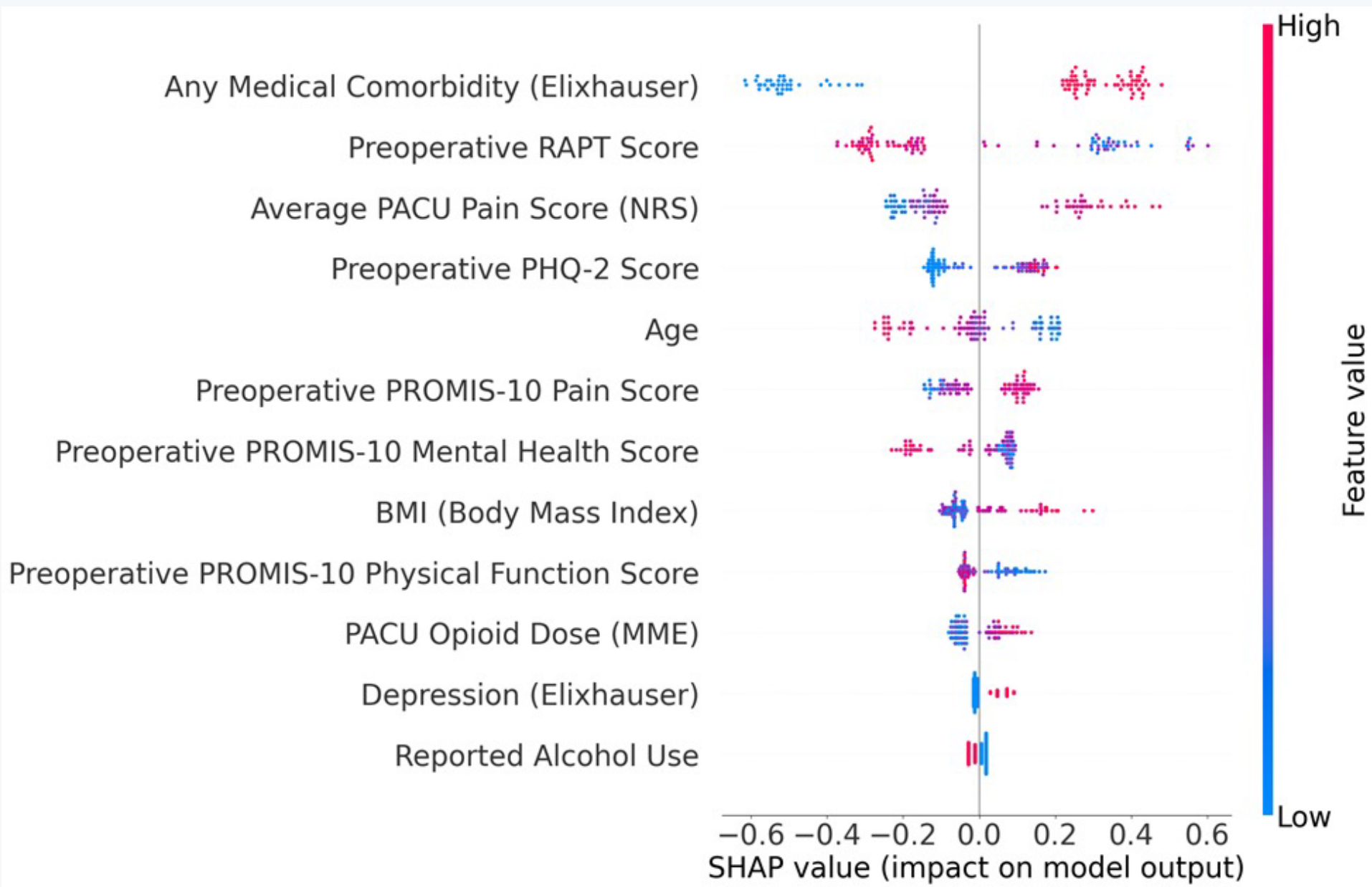
- This retrospective single-institutional study was IRB-approved (IRB#2021-1899 and IRB#2022-2392).
- Patients who underwent primary unilateral TKA managed by POPS's Complex Pain Service between January 14, 2022 and March 4, 2025 were identified.
- An unsupervised machine learning approach was employed to identify distinct postoperative pain trajectories. NRS pain scores and opioid use during the post-anesthesia recovery unit (PACU) and postoperative days (POD) 1–5 were clustered using K-means.
- Two postoperative pain trajectories were identified and compared across demographic, psychosocial, and clinical variables.
- Predictive modeling with XGBoost incorporated 37 preoperative, intraoperative, and PACU factors.
- Group differences were assessed using Wilcoxon rank-sum tests to compare unadjusted marginal differences for continuous variables between the two clusters and Chi-squared tests were used to examine the marginal association between categorical variables and the two clusters.
- Model performance was evaluated using accuracy, precision, recall, ROC-AUC, and PR-AUC, with feature importance assessed via SHAP values.

Among patients with complex pain, Elixhauser comorbidities, baseline pain/mental health scores, and PACU pain scores were identified as the strongest predictors of higher pain and opioid use.

Figure 1. Postoperative pain trajectories of two clusters of complex pain patients who underwent total knee arthroplasty identified using K-means



Figure 2. SHAP analysis of perioperative factors associated with Cluster 1 membership



References →



RESULTS

- Among 600 included TKA patients managed by the Complex Pain Service, two distinct pain trajectories emerged: Cluster 0 (n=482) showed lower pain scores and opioid consumption, while Cluster 1 (n=118) demonstrated higher pain and greater opioid use in the PACU and through POD1-5, longer hospital stays, and more breakthrough pain events (NRS ≥ 7) (**Figure 1**).
- Female sex, higher BMI, lower preoperative Risk Assessment and Prediction Tool (RAPT) scores, worse pre-operative PROMIS-10 Mental and Physical scores, higher pre-operative PROMIS-10 Pain and Patient Health Questionnaire-2 (PHQ-2) scores, and multiple comorbidities (depression, anxiety, diabetes, renal disease, obesity) were significantly associated with Cluster 1.
- Preoperative pain catastrophizing, concerns about pain, widespread pain indices, illicit drug use, and intraoperative factors including nerve block use, and computer assisted versus manual TKA, did not differ meaningfully between clusters.
- The XGBoost model achieved accuracy of 83% on the testing dataset. SHAP analysis identified the presence of any Elixhauser comorbidities, baseline pain/mental health scores, and PACU pain as the strongest predictors (**Figure 2**).

DISCUSSION

- Postoperative pain following TKA is heterogeneous; patients with pre-existing complex pain experience worse outcomes.
- Machine learning–derived trajectory analysis highlights heterogeneity even within patients already at high-risk for poor postoperative outcomes, underscoring the importance of early identification of modifiable factors and targeted optimization.
- Tailored interventions such as multimodal analgesia, mental health support, and individualized perioperative strategies may reduce severe acute pain and chronic pain risk to improve long-term outcomes in patients with pre-existing complex pain.