Patient-Specific Hip Arthroplasty Dislocation Risk Calculator: An Explainable Multimodal Machine Learning Based Approach

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Introduction
Total hip arthroplasty (THA) is among the most common elective surgeries in the United States. While typically THA is quite successful, complications can occur. Implant dislocation is the most common complication of THA that might require revision surgery. However, there are also well-described intraoperative choices within a surgeon’s control that can be used to mitigate the risk of dislocation.

Hypothesis
We hypothesize that a multimodal machine learning-based pipeline can predict the patient-specific risk of dislocation following primary THA that can help surgeons with preoperative planning.

Methods
This study retrospectively evaluates 17,073 patients who underwent primary THA between 1998-2018. A test set of 1,733 patients was held out. A hybrid network of EfficientNet-B4 and Swin-B vision transformer was developed to classify patients based on 5-year dislocation outcomes from preoperative anteroposterior (AP) pelvis radiographs and clinical (demographics, comorbidities, and surgical) characteristics. The most informative imaging features, that the mentioned model extracted were selected and concatenated with clinical features. A collection of these features was then used to train a multimodal survival XGBoost model to predict the individualized risk of dislocation. A clinical-only survival XGBoost was trained as a benchmark to compare addition of imaging features. C-index was used to evaluate the multimodal survival model on the test set and compare it with the clinical-only model. Integrated gradient maps and Shapley additive explanation (SHAP) values were used for the classifier and survival model explanation, respectively.

Results
On the holdout test set, the clinical-only model achieved a C-index of 63.8% (95% CI: 59.5%-68.1%); adding imaging features boosted multimodal model performance to a C-index of 73.6% (95% CI: 69.2%-78.0%). Imaging features represented 4 of the top 5 and 10 of the top 13 most influential variables in the multimodal model. The imaging feature showed focus of the model on the area of maximum load in the hip joint articulation, the lesser trochanter, and the acetabular teardrop.

Conclusion
A multimodal calculator for predicting dislocation was introduced by combining preoperative characteristics and radiographic features of patients undergoing primary THA. This study highlights the superiority of imaging features compared to clinical variables and the synergy between these modes of patient evaluation.

Statement of Impact
The developed tool enables patient-specific dislocation risk prediction with an acceptable C-index, and more importantly, shows the degree to which this risk is modified by decisions within a surgeon’s control.

Keywords
Deep Learning; Total Hip Arthroplasty; Dislocation; Multimodal Learning; Survival Analysis