TITLE: Is it Feasible to Develop a Supervised Learning Algorithm Incorporating Spinopelvic Mobility To Predict Impingement In Patients Undergoing Total Hip Arthroplasty? A Proof-of-Concept Study.

AUTHORS AND CO-AUTHORS:
Andreas Fontalis[1,2], Baixiang Zhao[3], Pierre Putzeys[4], Fabio Mancino[1], Thomas Vanspauwen[4], Fabrice Glod[4], Ricci Plastow[1], Evangelos Mazomenos[3], Fares S Haddad[1,2]
INSTITUTION(S):
1.Department of Trauma and Orthopaedic Surgery, University College Hospital, London, 2. Division of Surgery and Interventional Science, University College London, Gower Street, 3. Wellcome / EPSRC Centre for Interventional and Surgical Sciences and Department of Medical Physics and Biomedical Engineering University College London, London, UK., 4. Hôpitaux Robert Schuman, Luxembourg-City, Luxembourg

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ABSTRACT INTRODUCTION: Precise implant positioning, tailored to individual spinopelvic biomechanics and phenotype, is paramount for stability in Total Hip Arthroplasty. While some studies have sought to predict instability and define a personalized safe zone for component placement, there is a notable gap in research utilizing Artificial Intelligence (AI) for predicting impingement. To this end, our study poses the following questions: 1) Is it feasible to devise an Artificial Intelligence algorithm tailored to the individual spinopelvic mechanics and patient phenotype to predict impingement? 2) how precise is the proposed algorithm in its predictions? and 3) can the algorithm's accuracy be augmented by integrating imaging data?

METHODS: In this international, multicenter study across two centres, we evaluated the feasibility and accuracy of an AI algorithm predicting THA impingement using patient phenotypes and spinopelvic mechanics. Our cohort consisted of adults undergoing primary robotic-arm assisted THA. Standard pre-operative imaging included a CT, weight-bearing AP pelvis radiographs, and lateral spine radiographs in the standing and relaxed-seated position. Impingement during specific flexion and extension stances were identified using the virtual Range of Motion (ROM) tool of the robotic software. Of our initial sample, 157 participants (aged 32-88 years) were included in our primary analysis. The primary AI model, the Light Gradient Boosting Machine (LGBM), used tabular data to predict impingement presence, direction (flexion or extension), and type. A secondary model integrating tabular data with plain AP pelvis X-rays was evaluated to assess for any potential enhancement in prediction accuracy.

RESULTS SECTION:
Focusing on the feasibility of a predictive algorithm, we identified nine predictors from an analysis of baseline spinopelvic characteristics and surgical planning parameters. Using 5-fold cross-validation and repeating experiments with 10 randomly selected seeds, the Light Gradient Boosting Machine (LGBM) emerged as the preferred model demonstrating both accurate prediction and robustness. LGBM achieved an accuracy of 70.2% with the 9-characteristic dataset. When provided with impingement data as additional input, LGBM and Linear Regression (LR) estimated impingement direction with approximately 85% accuracy. When provided also with the direction, a Support Vector Machine (SVM) model yielded 72.9% accuracy for type prediction. Given the critical nature of impingement prediction, LGBM was designated our chief model. Incorporating baseline demographics into the model did not amplify predictive capability of impingement, direction, and type. Addressing the efficacy of imaging data integration, we evaluated both MLP (for tabular data) and CNN (for X-ray image analysis). The preliminary attempt of combining both data types with the LGBM model yielded an impingement prediction of 68.1%. Both the combined and LGBM-only approaches paralleled in impingement direction prediction (84.39% vs. 84.54%).

DISCUSSION: This study is a pioneering effort in leveraging AI for impingement prediction in Total Hip Arthroplasty, utilizing a comprehensive, real-world clinical dataset. Our machine learning algorithm demonstrated promising accuracy in predicting impingement, its type, and direction. While the addition of imaging data to our Deep Learning algorithm did not boost accuracy, the potential for refined annotations, such as landmark markings, offers avenues for future enhancement. Prior to clinical integration, external validation and larger-scale testing of this algorithm are essential.

SIGNIFICANCE/CLINICAL RELEVANCE: For arthroplasty surgeons without access to CT-based navigation or robotic systems offering virtual Range of Motion, a refined AI algorithm predicting impingement based on individual patient phenotypes could be instrumental in guiding pre-operative planning and preparing surgeons for potential intraoperative challenges. In our proof-of-concept study, we successfully showcased the feasibility of an algorithm to predict impingement, exhibiting good accuracy in predicting impingement and type (bone-on-bone, implant-on-implant, implant-on-bone) and excellent accuracy in determining its direction.

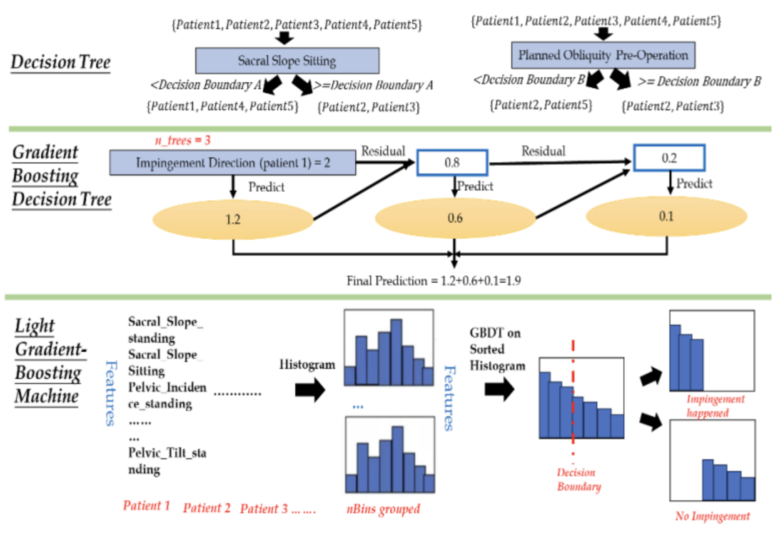

Figure 1. Schematical representation of our AI model.

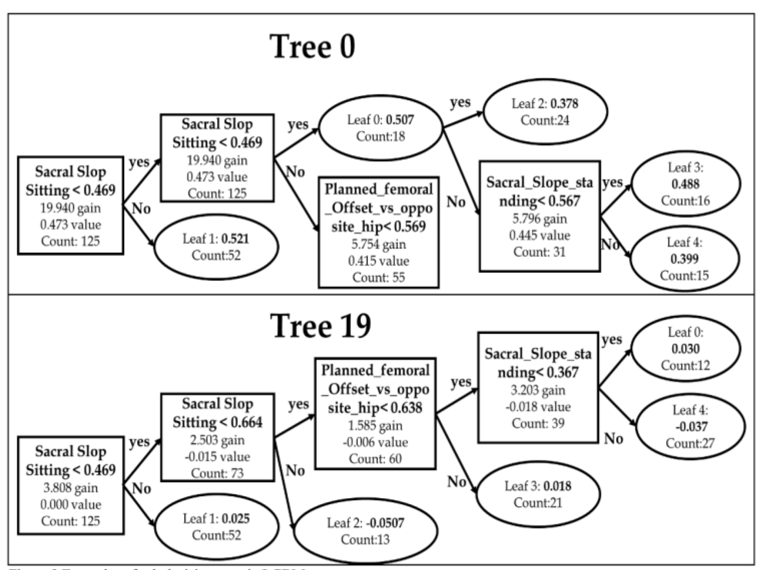

Figure 2 Examples of sub decision tress in LGBM