Optimizing Operating Room Scheduling and Ensuring Fairness in Managing Waitlists for Hip and Knee Replacement

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INTRODUCTION: Inefficiencies in surgical services are a leading contributor to rising costs and increasing wait times in Canadian healthcare. Perioperative care comprises up to 48% of hospital budgets (operating room (OR) cost >$34/minute). Despite a steady increase in spending, wait times for surgery among most OECD countries, including Canada, have been increasing. Lack of timely surgical care can have a direct deleterious impact on patients; 19% of patients awaiting total hip arthroplasty report a quality of life “worse than death”. Delays are increasing with the rapidly growing demand for surgery, further exacerbated due to the COVID-19 pandemic. Currently, in many institutions, primary total hip and knee arthroplasties (THA and TKA) are scheduled from a surgeon’s waitlist on a first come first served basis, without consideration of patients’ severity (pain and function). The aim of this project was to determine if machine learning (ML) scheduling could increase OR throughput and ensure patient fairness with respect to access for THA and TKA surgery.

METHODS: A predict-then-optimize scheduling pipeline was first employed to improve prediction of duration of surgery for THA and TKA. Data was collected from all primary and revision THA and TKAs performed at a single institution from 2012 to 2022 (REB #4899). The features obtained from the data collected included age, gender, co-morbidities, and joint specific features such as arthritis severity, deformity and implant type. Using these features, various machine learning models were trained for each procedure type, and the best performing predictive model used in the optimization. To create the schedules, a multi-objective optimization was employed consisting of three objectives: utilization, wait time, and preoperative patient reported outcome measures (PROMs) (Figure 1). The utilization score was based on maximizing OR utilization during the regularly scheduled OR hours with a penalty for overtime. The wait time was based on the cumulative duration of a patient on the surgical waitlist and the preoperative PROM used the Western Ontario and McMaster Universities Arthritis Index (WOMAC) scores. The score for each objective was scaled between 0 and 1 to allow for comparability among objectives. The scaled objective values were then multiplied by importance weights, set by the scheduler to reflect their scheduling priorities, and summed to get the final score of the schedule. Using software written in Python, simulations of the scheduling process were performed.

RESULTS: A multi-layer perceptron (MLP) model was found to yield the best performance, with surgical duration predictions 10% better than a surgery-surgeon specific prediction currently used at our institution (based on the durations of the surgeon’s last twelve cases of each specific procedure). The optimized scheduler was able to perform 1740 hip and knee replacements that were performed from 2021-2022 in 66 fewer OR days, which represents a 13% decrease in resource utilization. Using a fixed pool of 500 patients, the utilization of OR time achieved was 97% of the maximum when only contributing 40% to this component objective (30% of the component objectives were assigned to preoperative PROMs and to time on waitlist) (Figure 2). The average WOMAC score and wait time of the patients scheduled increased 34% and 8% respectively, when contributing 30% each to the overall objective compared to 0%. Reducing these contributions to only 15%, led to only small decreases in the WOMAC and weeks on waitlist measures. Additionally, a simulated scheduling of 20,880 patients, resampling from the 1740 cases, was conducted to ensure no bias in wait time for various protected attributes such as gender, age, or BMI. There were no significant differences in patient wait times across these attributes.

DISCUSSION: By leveraging ML predictions and multi-objective optimization of elective scheduling of THA and TKA procedures, the efficiency of OR schedules can be increased. Moreover, this can be done in a fair way, ensuring no bias against patients based on their age, gender or BMI. The multi-objective scheduling optimization requires a trade-off between the relative weights of the different objectives, which may vary depending on the priorities of specific institutions.

SIGNIFICANCE: Optimized surgical scheduling of THA and TKA combats inefficiencies contributing to increasing costs and wait times in healthcare systems. The proposed fairness-focused multi-objective optimized scheduling system prioritizes individuals with more severe conditions while accounting for wait times and overall OR utilization.

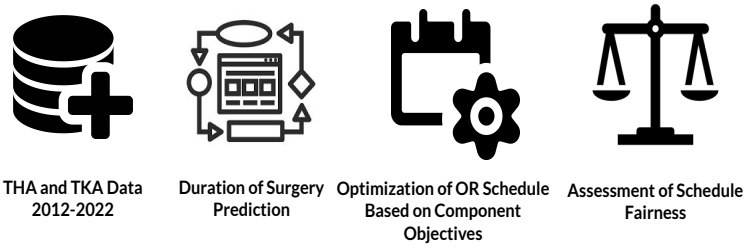

Figure 1. Predict-then-optimize scheduling pipeline for THA and TKA. Outcome measures include OR utilization, waitlist time and PROMs of scheduled patients.

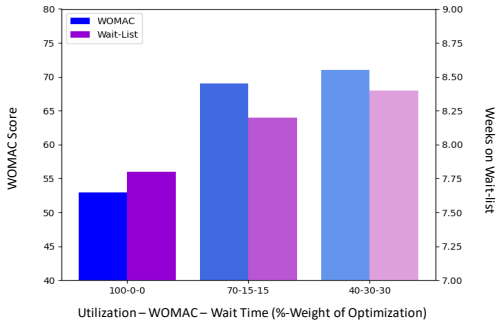

Figure 2. Selected patient’s preoperative patient reported outcome measures and time on waitlist with varying weighting of optimizer priorities.