OVERLAPPING SURGERY IN PRIMARY TOTAL KNEE ARTHROPLASTY: ARE 6-WEEK COMPLICATIONS WORSE THAN SINGLE OPERATING ROOM SCHEDULING?

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ABSTRACT

Background: Overlapping surgery is common in high-volume total knee arthroplasty (TKA) practices and has come under recent scrutiny in the press. The aim of this study was to evaluate differences in 6-week clinical and radiographic outcomes for primary TKA patients between single and overlapping operating room (OR) days.

Methods: We retrospectively reviewed individual patient records of a consecutive series of primary TKAs with complete 6-week follow-up performed by a single academic surgeon between 2008-2016 (N= 452). Patients were stratified by single vs. overlapping OR days. 177 patients (39%) had an overlapping surgery. Age, body mass index (BMI), Charlson Comorbidity Index (CCI) and American Society of Anesthesiologists (ASA) class were recorded to assess for confounding variables. Outcomes included anesthesia time, 6-week readmission, unplanned return to OR, medical and surgical complication, and 6-week radiographic alignment.

Results: There were no significant differences in anesthesiology time (165.5 vs 164.5 min, p=0.85), medical or surgical complication rates (10.5% vs 6.2%, p=0.11), 6-week readmissions (4.4% vs 1.7%, p=0.12), or return to OR (1.8% vs 1.7%, p=1.00) before or after adjusting for age, BMI, gender, ASA and CCI. There was no difference between overlapping and single OR cohorts in rate of neutral coronal alignment (2°-8° valgus) (98.3% vs 98.9%, respectively, p=0.68) or presence of periprosthetic lucency (p=0.43).

Conclusions: This study demonstrates no differences in 6-week clinical or radiographic outcomes between patients undergoing primary TKA on single versus overlapping OR days. These results support the safe practice of overlapping surgical scheduling in high-volume primary TKA centers.

Level of Evidence: III

Keywords: concurrent surgery, overlapping surgery, patient safety, total knee arthroplasty, complications

INTRODUCTION

Overlapping surgery, or "running two rooms", has recently garnered public criticism following an October 2015 article published in the Boston Globe, titled "Clash in the Name of Care,"[1] that described a case in which a significant adverse event occurred while a surgical trainee operated without direct supervision, as the attending surgeon was concurrently operating in another operating room (OR).[1] This media attention triggered a senate inquiry into the efficacy and safety of the longstanding medical practice.[2,3] In response to widespread concern, Massachusetts General Hospital (MGH) and The American College of Surgeons (ACS) published definitions differentiating the practice of overlapping and concurrent operations and their proper use in academic medical centers.[4-7] The ACS defines concurrent operations as "Surgical procedures when the critical or key components of the procedures for which the primary attending surgeon is responsible are occurring all or in part at the same time".[4] In contrast, overlapping operations are defined as "the practice of the primary surgeon initiating and participating in another operation when he or she has completed the critical portions of the first procedure and is no longer an essential participant in the final phase of the first operation."[4] Critical or key components of each procedure are not universally defined, but rather depend on the expertise of the specific attending surgeon to make that decision. In addition to the formal guidelines published by the ACS, there are prominent opinion pieces in the surgical literature asserting that overlapping surgery is safe and efficient.[8-12] Concurrent operations are considered inappropriate, while overlapping operations are performed at the discretion of individual institutions. The American Academy of Orthopedic Surgeons has affirmed the ACS position on concurrent operations.

Overlapping surgery is appealing due to its increased

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Table 1: Six Week Patient Demographic Characteristics

Demographics	Overlapping Surgery (N = 177)	Non-Overlapping Surgery (N = 275)	P Value
Age (yr)*	59.7±11.2	60.4±10.0	0.469
Sex†			0.301
Female	104 (58.8)	176 (64.0)	
Male	73 (41.2)	99 (36.0)	
BMI†			0.179
<18.5 kg/m2	0 (0.0)	0 (0.0)	
18.5 to 24 kg/m2	11 (6.2)	10 (3.6)	
25 to 29 kg/m2	27 (15.2)	50 (18.2)	
30 to 34 kg/m2	52 (29.4)	62 (22.5)	
35 to 40 kg/m2	34 (19.2)	56 (20.4)	
>40 kg/m2	53 (30.0)	97 (35.3)	
ASA Rating†			0.369
1	3 (1.7)	8 (2.9)	
2	94 (53.1)	120 (43.6)	
3	42 (23.7)	75 (27.3)	
4	0 (0.0)	4 (1.5)	
Missing data	38 (21.5)	68 (24.7)	
Charlson Comorbidity Index sum score†			0.0025
0	96 (54.2)	118 (43.0)	
1	45 (25.4)	62 (22.5)	
2	12 (6.8)	25 (9.1)	
≥3	24 (13.6)	70 (25.4)	

*reported as mean ± standard deviation.
†reported as number of patients (percentage of cohort).

efficiency by maximizing surgeon's time operating and minimizing wait times for OR turnover, room set up, and anesthesia preparation. The primary surgeon delivers high quality care to a greater proportion of patients while training surgeons gain valuable experience and progressive independence. Participation of trainees in different surgical subspecialties has consistently been correlated with improved safety and patient care.[13-19] In addition, multiple surgical disciplines have demonstrated that overlapping surgery can be safely performed.[20-28] While the orthopedic literature is limited to short-term outcomes from hand, foot & ankle, and sports medicine procedures performed at an ambulatory surgery center, this study showed equivalent outcomes between overlapping and non-overlapping procedures.[20] In addition, a study of primary total hip and knee arthroplasty procedures with intraoperative complication rates, 90-day component revision rates, and 90-day postoperative complication rates showed no difference between overlapping and non-overlapping procedures.[28] We are aware of no studies to date reporting complication rates and individual radiographic analysis between overlapping and non-overlapping surgeries in primary total knee arthroplasty (TKA).

Primary TKA is commonly performed in overlapping operating theaters at high volume academic practices. We hypothesize there is no difference in clinical outcomes at six weeks. Therefore, the purpose of this study was to evaluate for any differences in 6-week clinical or radiographic outcomes for primary TKA patients between overlapping surgery and non-overlapping surgeries. We hypothesize that complication rates, patient reported outcomes, and radiographic outcomes will be similar, regardless of whether overlapping surgery was performed.

METHODS

Study Design

This project was reviewed by human subjects institutional review board and approved as exempt from informed consent. We performed a retrospective review of individual patient records in a consecutive series of eligible primary TKA performed by a single academic surgeon from April 2008 through April 2016. Patients with 6-week follow-up were included in the primary data analysis (n = 452). Cases were stratified by whether their surgery was performed on a day with non-overlapping ORs or overlapping ORs (n = 275 and 177, respectively). Although not randomized, cases were not systematically assigned to overlapping or non-overlapping days. On days with overlapping surgeries, cases were staggered to allow for the surgeon to complete the critical portions of a case and then transition directly to a second room for the critical portions of the next procedure. Critical portions were defined as initial incision through the completion of component cementing.

Patient Demographics and Clinical Indicators

Patient demographics as well as medical and operative data were obtained from electronic medical records. This information included age, body mass index (BMI), medical comorbidities, and American Society of Anesthesiologists classification (ASA). BMI was calculated from height and weight data and was stratified by the World Health Organization (WHO) classification. Charlson Comorbidity Index (CCI) was calculated as previously described using 16 comorbidities identified by the International Classification of Diseases codes, Tenth Revision (ICD-10).[29] Anesthesiology time was obtained from procedural documentation.

Table 2. Six Week Intraoperative and Postoperative Outcomes

Outcomes	Overlapping Surgery	Non-Overlapping Surgery	P Value
Intraoperative*			
Anesthesia time (min)	164.5±25.0	165.5±25.3	0.845
Postoperative†			
6-Week Readmissions	3 (1.7)	12 (4.4)	0.122
Return to OR	3 (1.7)	5 (1.8)	1.000
6-Week Complication	11 (6.2)	29 (10.5)	0.114

*reported as mean ± standard deviation.
†reported as number of patients (percentage of cohort).

Complications

Patient electronic medical records were accessed to review operative notes, progress notes, discharge summaries, clinic notes and postoperative admission notes to identify peri- and postoperative complications. Complications and revision surgery occurring within 6 weeks of the initial primary TKA were included. Complications included medical complications (deep venous thromboembolism/pulmonary embolism (DVT/PE), cardiac abnormality or arrhythmia, syncope, acute renal failure, stroke, pneumonia, or renal insufficiency), surgical complications (intraoperative fracture/ligament injury, wound dehiscence, wound drainage, cellulitis, hematoma, deep surgical site infection, or neuropathy), 6-week readmission, and return to OR. Indication for return to OR was documented in each case.

Patient Outcomes

Analysis of 6-week long leg radiographs included coronal alignment as previously described by The Knee Society.[30] Radiographic alignment was classified from long leg and lateral radiographs as neutral (2-8 degrees valgus alignment), varus (<2 degrees valgus alignment), or valgus (>8 degrees valgus alignment). One patient from the non-overlapping cohort and four patients from the overlapping cohort were excluded from radiographic analysis due to presence of post-traumatic deformity prior to surgery.

Statistical Analysis

Patient characteristics were described using means ± SD for continuous variables and proportions for categorical variables. The overlapping and non-overlapping cohorts were compared using t-tests for continuous and chi-square tests for categorical variables. Continuous variables that were not normally distributed were compared using the Wilcoxon Rank Sum test. This included age, BMI, ASA, CCI, anesthesiology time, WOMAC pain, and WOMAC functionality. Post-operative outcomes and complications were compared with logistic regression and generalized linear models with and without adjustment for age, BMI, comorbid conditions and ASA scores.

RESULTS

Overall, 177 of 452 primary total knee arthroplasty procedures with complete 6-week clinical and radiographic follow-up were performed with overlapping scheduling (39.2%). There was no significant difference in age (p = 0.469), sex (p = 0.301), BMI (p = 0.179), or ASA rating (p = 0.369) between patients who received an overlapping surgery versus those who received a non-overlapping surgery (Table 1). Patients who received an overlapping surgery had a lower Charlson Comorbidity Index sum score than patients receiving a non-overlapping surgery (1.0±1.7 vs 1.8±2.6; Table 1; p=0.0025).

There was no significant difference in anesthesiology time between overlapping and non-overlapping cases (164.5±25.0 vs 165.5±25.3; p = 0.845) (Table 2). Postoperative 6-week readmissions (1.7% vs 4.3%; p = 0.12), return to OR within 6 weeks (1.7% vs 2.2%; p = 1.00), and 6-week complications (6.2% vs 10.5%; p = 0.11) were not significantly different between overlapping and non-overlapping cases (Table 2). Surgical complications accounted for 70% of all reported complications (Table 3). Of the four patients with an intraoperative fracture or ligament injury, one patient suffered a peri-prosthetic intra-operative tibia fracture, one sustained a patellar tendon partial tear, another had a partial MCL avulsion that was reattached with two G2 suture anchors, and the fourth patient had a patellar tendon partial peel-off that was sutured to bone with #5 Ticron. In addition to specific intraoperative and postoperative complications, 3 patients (0.6%) received a manipulation under anesthesia for arthrofibrosis. All three of these patients made a full recovery within 6 weeks with no subsequent tendon tear or further complication at last follow-up.

Six-week radiographic outcomes showed similar rates of neutral coronal alignment (p = 0.681). Periprosthetic lucency was detected in 9 patients from the overlapping surgery group (9.3%), versus 11 patients in the non-overlapping group (6.5%, p = 0.434) (Table 4). In the

Table 3. Six Week Complications by Type

	Overlapping Surgery*	Non-Overlapping Surgery*
Medical Complication		
DVT/PE	1 (0.6)	7 (2.5)
Cardiac Abnormality or Arrhythmia	0 (0.0)	2 (0.7)
Syncope	0 (0.0)	0 (0.0)
Acute renal failure	1 (0.6)	1 (0.4)
Stroke	0 (0.0)	0 (0.0)
Pneumonia	0 (0.0)	0 (0.0)
Renal insufficiency	0 (0.0)	0 (0.0)
Surgical Complication		
Intraoperative Fracture/Ligament Injury	1 (0.6)	3 (1.1)
Wound dehiscence	4 (2.3)	8 (2.9)
Wound drainage	0 (0.0)	2 (0.7)
Deep surgical site infection[a]	1 (0.6)	1 (0.4)
Cellulitis	2 (1.1)	4 (1.4)
Neuropathy	0 (0.0)	0 (0.0)
Hematoma	1 (0.6)	1 (0.4)
All complications	11 (6.3)	29 (10.5)

DVT = Deep Venous Thromboembolism
PE = Pulmonary Embolism

* reported as number of patients (percentage of cohort).
[a] Deep surgical site infection defined as culture positive infection extending deep to fascial closure.

overlapping group there was one patient with varus alignment and in the non-overlapping group there were two patients with varus alignment (p=1.000). In the overlapping group, there were two patients with valgus alignment postoperatively, compared to one valgus in the non-overlapping group (p=0.562). Radiographic results of four patients in the overlapping group and one patient in the non-overlapping group were excluded from analysis due to preoperative deformity.

DISCUSSION

The current study is the first study evaluating the practice of overlapping surgery that we are aware of to include 6-week clinical and radiographic outcomes following primary total knee arthroplasty. Our analysis of 6-week outcomes of 452 consecutive primary TKA cases showed no significant differences in anesthesia time, 6-week readmissions, return to OR, 6-week complications, or radiographic long leg coronal alignment. Our outcomes in both overlapping and non-overlapping patient cohorts had favorable outcomes consistent with previous reports in the literature.[28,31] While we observed a significant difference in Charlson Comorbidity Index scores between overlapping and non-overlapping surgery groups, there was no difference in 6-week outcomes when controlling for this potential confounding variable. The observed difference in comorbidity, as measured by CCI, is potentially due to the random nature of case scheduling or thoughtful selection bias by scheduling personnel, although there is no protocol in place for scheduling higher-risk patients on non-overlapping OR days. Given the possible source of bias, we adjusted for patient demographics using logistic regression and generalized linear models, which did not detect a difference in clinical or radiographic outcomes between overlapping and non-overlapping scheduling.

Our overall conclusions are consistent with prior surgical analysis of overlapping outpatient orthopaedic,[20,28] neurosurgical,[21,22] spine,[23] thoracic,[24] otolaryngology[25] and pediatric procedures,[26] the results of each study showed no significant difference in clinical outcomes (complications,

Table 4. Six Week Radiographic Outcomes

	Overlapping Surgery	Non-Overlapping Surgery	P Value
Coronal Alignment†			
Neutral	170 (98.3)	271 (98.9)	0.681
Varus	1 (0.6)	2 (0.7)	1.000
Valgus	2 (1.1)	1 (0.4)	0.562

† reported as number of patients (percentage of cohort).

hospital readmission, and return to OR) among patients undergoing overlapping surgery versus non-overlapping surgery. This study adds to prior reports on the safety of overlapping surgery, which were thus far limited to 30-day or 90-day postoperative complications and/or were database-driven studies. Ours included analysis of radiographic outcomes and accuracy, in addition to 6-week complication metrics in an individualized review of over 450 consecutive patients at our institution. Furthermore, Hyder et al. published a large-scale retrospective review of 36,074 surgical cases from nationally standardized clinical data registries demonstrating that overlapping surgery does not place patients at greater risk of adverse outcomes.[27] Zhang also recently reported equivocal 30-day outcomes for 2,474 overlapping cases and 1,166 non-overlapping cases in sports medicine, hand and elbow, and foot and ankle procedures.[20] Hamilton reviewed 16,916 cases in overlapping and non-overlapping primary total hip and knee arthroplasty procedures, with no differences in intraoperative complication rates, 90-day component revision rates, or 90-day complication rates.[28] In contrast to certain procedures included in previous studies, large and elective inpatient procedures such as primary TKA may include a patient population with greater comorbidities and result in more substantial adverse events.

The safety and efficacy of overlapping surgery relies on the support of fellows, residents, and physician assistants. In academic medical centers, surgical trainee participation raises the question of whether additional risk is incurred by the patient. It has been repeatedly demonstrated that participation of trainees in different surgical subspecialties is correlated with improved safety and patient care.[13-19] Contrasting studies have demonstrated increased operative time, patients' length of stay, and non-home discharge associated with resident involvement.[34] Resident involvement is a highly imprecise term that is not captured identically across studies or specialties and is dependent on attending physician level of comfort and teaching abilities. At our institution, there is a surgical resident present in each operating room to assist the attending physician on an overlapping surgery day. The surgical team can additionally consist of a physician assistant and a medical student who play a complementary role to the attending physician and resident. Residents and fellows aid in the preoperative preparation as well as incision closure which may contribute to the safety, efficacy, and efficiency of overlapping surgery by allowing the attending surgeon to promptly begin the subsequent case.[8]

Surgeon variability in the definition of critical or key portions of surgical procedures presents a challenge for data interpretation. A recent study was conducted where 100 orthopaedic surgeons were surveyed with the goal of defining the critical portions of total hip arthroplasty and total knee arthroplasty procedures.[32] These two procedures were selected due to their prevalence and highly structured format. Despite these postulated advantages, overall critical portion agreement rates were 3.2% and 8.6% for hip and knee procedures, respectively. Poor intra-surgeon consensus demonstrates the necessity for the formal identification of critical portions in certain surgical procedures as suggested by the US Senate Finance Committee.[3] At our institution, standard protocol requires at a minimum that the attending surgeon be present from the initial incision through the completion of component cementing. Due to this institutional protocol, the uniformity in the degree of overlap for each case was not recorded. In addition to surgical trainee assistance on overlapping surgery days, proper patient disclosure about the possibility of overlapping surgery is a key component in delivering high quality patient care in an operational setting. Recent press reports highlighted the lack of disclosure in overlapping surgery cases and the public sentiments towards this issue.[1,33] To remedy this potential disconnect between the patient and the provider, MGH and other institutions, including our own, have implemented policies requiring the possibility of overlapping surgery to be disclosed on patient consent forms.[7,20-23] Proper disclosure and patient education in the practice of overlapping surgery aids in operational transparency while achieving comparable patient outcomes to non-overlapping surgery.

One limitation of our study is the retrospective nature involving a single academic medical center and a single provider. Although a prospective multicenter or multi-provider study has the potential to provide improved data, we elected to analyze a single attending surgeon's cases to maintain clinical and surgical consistency. In addition,

our medical center services a diverse patient population. Patient electronic health record data outside of our institution was not available in all instances. Certain adverse outcomes including range of motion, postoperative pain, stiffness, and strength deficits are subjective measures and were not included if they did not result in a 6-week readmission, return to OR, or documented complication. Despite this, an individualized, detailed chart review was performed to analyze the nature of each complication. Finally, the results of overlapping surgery by a single academic surgeon may not be generalizable to other practices that lack involvement of surgical trainees, appropriate support, and adequate resources.

Information regarding the practice of overlapping surgery in primary total knee arthroplasty is currently limited and this study aims to strengthen earlier claims pertaining to its practice. The topic is emergent among the medical community, and this data will hopefully aid future policy decisions about delivering surgical care without compromising patient safety. Future research examining the potential long-term effects of overlapping surgery on patient outcomes is suggested in order to expand the knowledge of the medical profession.

CONCLUSIONS

The results of this study demonstrate no differences in 6-week clinical and radiographic outcomes between patients undergoing overlapping versus non-overlapping primary total knee arthroplasty and support the safe practice of overlapping scheduling in high volume total knee arthroplasty centers.

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