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The effect of operative time on in-hospital length of stay in revision total knee arthroplasty

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Background: Revision total knee arthroplasty (TKA) is associated with increased rates of infections, readmissions, longer operative times, and lengths-of-stay (LOS) compared to primary TKA. Additionally, increasing operative times and prolonged postoperative LOS are independent risk factors for these postoperative complications in lower extremity total joint arthroplasty (TJA). This has led to an increased effort to reduce these risk factors in order to improve patient outcomes and reduce cost. However, the relationship between operative time and LOS has not been well assessed in revision arthroplasty. Therefore, the purpose of this study was to: (I) identify predictors of longer operative times; (II) identify predictors of longer LOS; and (III) evaluate the effects of operative time, treated as both a categorical variable and a continuous variable, on LOS after revision TKA.

Methods: The NSQIP database was queried for all revision TKA cases (CPT code 27487) between 2008 and 2016 which yielded 10,604 cases. Mean operative times were compared between patient demographics including age groups, sex, and body mass indexes (BMIs). To determine predictors of LOS, mean LOS were also compared between patient demographics in the same groups. To assess the correlation of operative time on LOS, the mean LOS for 30-minute operative time intervals were compared. Univariate analysis was performed with one-way analysis of variance (ANOVA) and *t*-tests. A multivariate analysis with a multiple linear regression model was performed to evaluate the association of LOS with operative times after adjusting for patient age, sex, and BMI.

Results: The mean LOS for revision TKA was 4 (±3) days. Further analysis showed that young age is associated with increased LOS ($P<0.01$). An analysis of operative times showed positive correlations with young age, BMI greater than 30 and male sex ($P<0.05$). The mean LOS of revision TKA patients was found to increase with increasing operative time in 30-minute intervals ($P<0.001$). Multivariate analysis showed that longer operative times had significant associations with longer LOS even after adjusting for patient factors ($\beta=0.102$, SE $=0.001$, $P<0.001$). These results also showed that out of all of the study covariates, operative times had the greatest effect on LOS after revision TKA.

Conclusions: Revision TKA is a complex procedure, often requiring increased operative times compared to primary TKA. This study provides unique insight by correlating operative times to LOS in over 10,000 revision TKAs from a nationwide database. Our results demonstrate that out of all the study covariates (age, sex, and BMI), operative times had the greatest effect on LOS. The results from this study indicate that less time spent in the operating room can lead to shorter LOS for revision TKA patients. This relationship further underscores the need for improved preoperative planning and intra-operative efficiency in an effort to decrease LOS and improve patient outcomes.

Keywords: Operative times; lengths-of-stay (LOS); revision total knee arthroplasty (revision TKA); predictors

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Introduction

Revision total knee arthroplasty (TKA) is associated with worse patient outcomes when compared to primaries, including increasing blood loss, bone loss, readmissions, prolonged lengths-of-stay (LOS), and increased operative time (1,2). Nichols *et al.* performed an analysis of 526,481 total joint arthroplasty (TJA) patients, including 25,354 revision TKAs, in order to determine differences in costs and complications in primary versus revision arthroplasty. Within this cohort, revision arthroplasty was associated with increased rates of readmissions, complications, longer LOS, discharges to nursing facility, and transfusions as well as higher 90-day costs (2). These results indicate that there is room for improvement in the treatment of revision arthroplasty patients. With the increasing need for revision surgeries, there is increasing importance in identifying modifiable variables for these patients.

Operative times have historically been identified as an important factor in postoperative outcomes for TKA. Increasing operative times are associated with worse outcomes, such as increased rates of infections, thromboemboli, neurologic deficits, revisions, and other complications (3-10). Young *et al.* analyzed 61,438 TKAs in the New Zealand Joint Registry over a 13-year period and found increasing revision rates with operative times longer than 120 minutes (P<0.01) (10). Duchman *et al.* studied 99,444 patients undergoing TJA and found older age, obesity, and ASA 3 or 4 predicted an operative time greater than 120 minutes. This cohort showed increasing complication rates (5.9%) with operative times greater than 120 minutes compared to those less than 120 minutes (4.6% to 4.8%, P<0.001) (3). In a study of 353 TKAs, including primary and revisions, Peersman *et al.* found that operative times for patients who developed infections after TKAs were 33 minutes longer than for those who did not develop SSIs (P<0.001) (9). Additionally, revisions, bilateral surgery, medical comorbidities, morbid obesity, and any prior open surgery were considered risk factors for longer operative time (9). Many of the studies identifying the association between operative time and complications investigate primary TKAs. However, revision surgeries have longer procedure times and higher innate infection rates, which potentially portend even greater risk.

Increasing LOS has also been associated with higher complication rates, readmissions, and decreased patient satisfaction (11-14). Williams *et al.* performed an analysis of Medicare TJA patients and found that patients readmitted within 90-day showed significantly longer initial postoperative LOS compared to those that were not readmitted (3.81 *vs.* 2.10 days, P<0.001) (14). Within this cohort, a LOS greater than 4 days was almost twice as likely to be readmitted (P=0.001) (14). LOS have also been found to be a major driver of cost in TJA, further emphasizing the need to identify factors associated with LOS (15). Several studies have attempted to identify predictors for prolonged LOS in an effort to uncover modifiable risk factors. These include patient age, day of surgery, illness severity scores, female sex, preoperative walking aids, blood transfusions, ASA scores, and in-hospital ambulation (11,16). The elucidation of these risk factors can be utilized to identify patients who may require further in-patient optimization and therapy in order to decrease LOS and improve outcomes.

Revision TKA is an increasingly common, complex problem for both the patient and the surgeon. Prolonged LOS is associated with is associated with higher complication and readmission rates, which can be devastating for these patients. While studies have found that increasing operative time is associated with adverse complications following TJA, the effect increasing operative time may have on LOS has not been fully elucidated. Identification of the association between operative time and LOS, as well as the factors that affect them, can allow for targeted interventions in an effort to improve outcomes. Therefore, the purpose of this study was to: (I) identify predictors of longer operative times; (II) identify predictors of longer LOS; and (III) evaluate the effect of operative time, treated as a continuous and an ordinal variable, on LOS after revision TKA.

Methods

Database

Revision TKA cases were extracted from the American College of Surgeons (ACS) National Surgical Quality

Table 1 Patient demographics and clinical characteristics (N=10,604)

Variable	n [%]	Mean ± SD	Range
Age (years)		65±11	18 to 89
Sex			
Male	4,386 [41]		
Female	6,213 [59]		
BMI (kg/m^2)		33±7	15 to 68
Operative time (minutes)		148±61	30 to 497
LOS (days)		3.6±3.4	0 to 94

BMI, body mass index; LOS, lengths-of-stay; n, number of patients; SD, standard deviation.

Improvement Program (NSQIP) database. The database contains a number of patient and operation specific variables from millions of patients who were reviewed by a trained Surgical Clinical Reviewer are publicly available in the NSIQP database (1). This study was deemed exempt by the Institutional Review Board because the data is de-identified and available publicly.

Study population

A total of 10,723 revision TKAs were identified from the NSQIP database using Current Procedural Terminology (CPT) code 27487 January 01, 2008 and December 31, 2016. Inclusion/exclusion criteria was set so that cases with operative times less than 30 and/or greater than 500 minutes (n=50), body mass indexes (BMIs) less than 15 or greater than 70 kg/m^2 (n=66), and those with no reported LOS (n=3) were excluded (0.05%). After removing these cases, a total of 10,604 cases were included in the final analysis.

Study variables

Age, sex, and BMI, as well as operative times and LOS were extracted from each case and compared.

Predictors of operative times

Independent sample *t*-tests and one-way analysis of variance (ANOVA) were used to compare differences in mean operative times between patient demographics (age, sex, and BMI).

Predictors of LOS

To identify predictors of LOS, mean LOS for were compared between different patient age, sex, and obesity classifications with one-way ANOVA.

Effect of operative times on LOS

Univariate analyses with one-way ANOVA were performed in order to determine the associations between operative times and LOS. Operative times were separated into 30-minute time interval groups and treated as categorical variables. Mean LOS were determined for each operative time interval and were graphically evaluated to determine the relationship between operative time intervals and LOS.

Multivariate analyses were also performed in order to better understand the relationship between operative times and LOS. Multicollinearity among predictors were assessed with variance inflation factors (VIF), with VIFs greater than 3 used to identify potential collinearities. Because no collinearities were identified, all study covariates were included in the multiple linear regression model. A multiple linear regression model was utilized to evaluate the association of LOS with operative times after adjusting for patient factors (i.e., age, sex, and BMI).

Data analysis

Statistical Package for the Social Sciences (SPSS) version 22 for Windows (International Business Machines Corporation, Armonk, NY, USA) was used for data analysis. The threshold for statistical significance was maintained at a P value of less than 0.05.

Results

Study population and study variables

A total of 10,604 cases were included in the final analysis. Within these cases, the patient sample consisted of 6,213 women (59%) and 4,386 men (41%) with a mean age of 65±11 years and a mean BMI of 33±7 kg/m^2 (*Table 1*). Overall, the mean operative time for the study group was 148±61 minutes. The distribution of operative times was positively skewed (*Figure 1*) with a median operative time of 139 minutes (interquartile range 105 to 181 minutes). The mean LOS was found to be 3.6±3.4 days overall (*Table 1*).

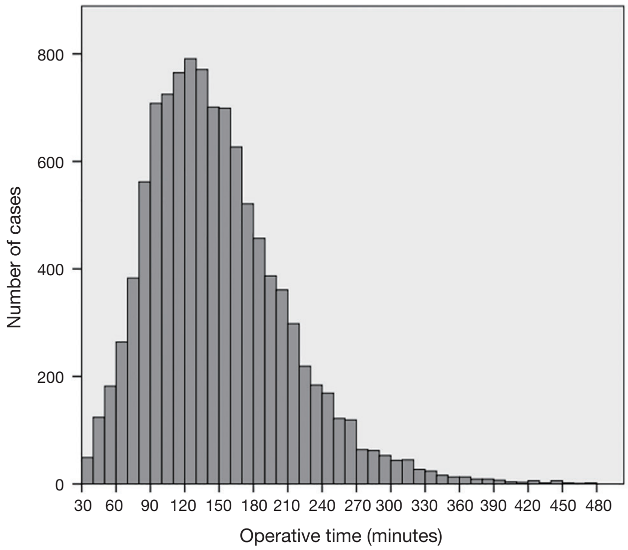

Figure 1 Distribution of operative times in the study population.

Table 2 Mean operative times of different demographic groups

Patient factor	Number of patients [%]	Mean operative time ± SD	P value
Age (years)			<0.001[a]
18–44	257 [2]	159±83	
45–64	4,597 [44]	150±61	
≥65	5,680 [54]	147±59	
Sex			<0.001[t]
Male	4,386 [41]	155±63	
Female	6,213 [59]	144±59	
Obesity			<0.001[t]
No	3,932 [37]	144±59	
Yes	6,672 [63]	151±62	

P values: [a], one-way ANOVA; [t], independent sample *t*-tests; SD, standard deviation.

Predictors of operative times

Mean operative times were longer for younger, obese men. This applied to patients between the ages of 18 to 44 years (159±83 minutes), compared with ages 45 to 64 years (150±61 minutes), and 65 years and older (147±59 minutes). Obese patients (BMI >30 kg/m^2) had longer mean operative times (151±62 minutes) compared to non-obese patients (BMI <30 kg/m^2; 144±59 minutes; P<0.001).

Table 3 Mean LOS of different demographic groups

Patient factor	Number of patients (%)	Mean LOS ± SD (days)	P value
Age (years)			<0.001[a]
18–44	257 [2]	3.6±3.0	
45–64	4,597 [43]	3.3±3.3	
≥65	5,680 [54]	3.8±3.5	
Sex			0.162[t]
Male	4,386 [41]	3.6±3.7	
Female	6,213 [59]	3.7±3.2	
Obesity			0.103[t]
No	3,932 [37]	3.7±4.0	
Yes	6,672 [63]	3.6±3.0	

P values: [a], one-way ANOVA, [t], independent sample *t*-tests; LOS, lengths-of-stay; SD, standard deviation.

Lastly, men had longer mean operative times (155±63 minutes) than women (144±59 minutes; P<0.001) (*Table 2*).

Predictors of LOS

Significant relationships between age and LOS (P<0.001) were identified with one-way ANOVA. Patients between the ages of 45 and 64 years had shorter LOS (3.3±3.3 days) compared to patients between 18 and 44 years (3.6±3.0 days), and patients 65 years and older (3.8±3.5 days; *Table 3*). No significant correlations were found between LOS and sex or BMI.

Effect of operative times on LOS

One way-ANOVA revealed relationships between operative time intervals and LOS. Progressively increasing operating time intervals showed progressively increasing differences in mean LOS (*Table 4*). The trend of increasing mean LOS with increasing operative time intervals was also observed in a line graph (*Figure 2*).

After accounting for potential confounding patient factors, a significant association was found between increased operative time and LOS (β=0.102, SE =0.001, P<0.001). Age was also shown to have a significant relationship with LOS (β=0.108, SE =0.003, P<0.001). Significant correlations were also found between LOS and sex (P=0.035) or BMI (P=0.022). These results show that

Table 4 Mean LOS of operative time thresholds

Operative time intervals (minutes)	Percentage of cases [%]	Mean LOS ± SD (days)	Difference in mean LOS	P value
<60	390 [4]	3.1±3.4		
61 to 90	1,240 [12]	3.3±2.7	0.2	0.305
91 to 120	2,220 [21]	3.4±2.8	0.1	0.062
121 to 150	2,247 [21]	3.6±3.8	0.2	0.122
151 to 180	1,826 [18]	3.6±3.4	0.0	0.745
181 to 210	1,189 [11]	3.9±3.8	0.3	0.079
211 to 240	689 [6]	3.8±2.3	0.1	0.761
241 to 270	393 [4]	4.4±4.6	0.4	0.017
>270	410 [4]	4.7±4.3	0.3	0.386

P values: independent samples *t*-test. LOS, lengths-of-stay; SD, standard deviation.

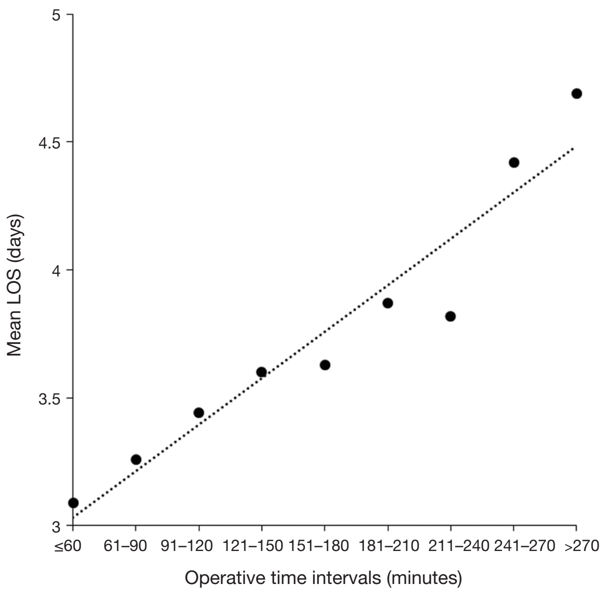

Figure 2 Line graph of mean LOS plotted against operative times. LOS, lengths-of-stay.

Table 5 Multiple linear regression model for LOS

Patient factor	Standardized coefficient (β)	Standard error	P value
Operative time	0.102	0.001	<0.001
Age	0.108	0.003	<0.001
Sex	0.020	0.067	0.035
BMI	0.022	0.005	0.022

LOS, lengths-of-stay; BMI, body mass index.

an increase in LOS by 1 day corresponds with a 10-minute increase in operative time (*Table 5*).

Discussion

This study aimed to identify the association between operative times and LOS in revision TKA. By analyzing operative times in 30-minute intervals and as a continuous variable, we found significant associations between these two variables. Specifically, as operative times increase, the postoperative LOS increases as well. Additionally, middle-aged patients were found to have longer operative times. When controlling for age, BMI and sex, operative time continued to have the most significant association with LOS.

Identifying the associations between operative times and LOS, as well as the factors that influence them, can be used to target interventions and alter orthopaedic practice. Both longer procedures and increased lengths of surgical stays have been correlated with greater healthcare costs making them a key priority for cost reduction (17,18). Attarian *et al.* identified several inefficiencies contributing to delays in the operating room including inconsistent staffing, delayed starting time, and poor surgical team coordination. By improving upon these inefficiencies, they were able to decrease LOS and improve upon early discharges (19). These factors may be particularly important in revision arthroplasty, as these procedures tend to be more complex. Therefore, appropriate staffing, communication, and coordination are vital in these cases. Improvements in both surgical processes and patient optimization, may allow for decreased operative time and thus improved patient outcomes.

The findings in this study are similar to the results from several other studies. Keswani *et al.* also utilized the NSQIP database to analyze revision TJA. This study looked at 4,977 revision TKA and 5,135 revision THA to find factors associated with readmission and LOS >75th percentile. Operative time (OR 1.006, P=0.0001), procedure etiology, age, functional status, higher ASA, higher wound class, and comorbidities were found to be associated with an extended LOS. However, operative times were not found to be associated with readmission rates (20). While this study also used the NSQIP database, it utilized LOS as a categorical variable. Our study aimed to use LOS as a continuous variable and thus decipher its relationship to operative time. Inneh *et al.* examined 2,638 TKA patients and found that longer operating time (P<0.001), advanced age (P=0.02), and certain preoperative comorbidities were independently associated with a longer LOS, defined as greater than 3 days. Additionally, socio-demographic factors were found to work synergistically in their association with longer LOS (21).

Belmont *et al.* analyzed 15,321 TKA patients from the NSQIP database between 2006 and 2010 to determine risk factors for 30-day morbidity and mortality. The group identified that, along with morbid obesity (BMI ≥40), age >80 and, ASA ≥3, also, operative time >135 minutes was found to be the most significant predictor of major complications (OR: 1.54). Further analysis showed that prolonged operative time, along with age, ASA, sex, and comorbidities, were associated with a LOS greater than 4 days (OR 1.90) (22). A study by Bohl *et al.* identified the associations between operative times, stratified into 15-minute intervals, and adverse effects following 165,474 TJA cases (6). This study found that increasing operative time is an independent risk factor for anemia requiring transfusion, sepsis, surgical site infection, urinary tract infection, wound dehiscence, renal insufficiency, readmission, and hospital stay greater than 4 days. In fact, complications proportionally increased for each 15-minute increase in operative time. Risk of surgical site infection, and prolonged LOS each increased by 9% with 15-minute increases in surgical time (6).

Conversely, Liodakis *et al.* looked at the NSQIP database for aseptic revision arthroplasties between 2011 and 2012 to determine risk factors for complications and LOS greater than 7 days. Age greater than 75 years and hematocrit <35 were predictors of complications in revision TKA. Operative time >180 minutes was found to be a predictor of prolonged hospital stay in revision total hip arthroplasty (P<0.001), but not in revision TKA in univariate (P=0.061) or multivariate (P=0.196) analyses. This study identified only ASA >2, hematocrit <35, and COPD as predictors of LOS >7 days in revision TKA (23). The present study differed in that it used LOS as a continuous variable instead of a cutoff at 7 days, which is significantly longer than the mean LOS seen in our data. Additionally, Liodakis *et al.* only included aseptic TKAs, which excludes the most common cause of revision. Therefore, this may not reflect the entire scope of revision TKA operative time and LOS.

This study does have some limitations. The retrospective nature of the study meant that the analyzed data was limited to previously collected information. Furthermore, covariates that were taken into consideration only included age, BMI, and sex. Comorbidity scores, such as the Charlson comorbidity index, may also be useful in assessing factors affecting LOS and the inclusion of such variables should be the basis of future work. Nevertheless, this study provides comprehensive predictive and correlative analyses between operative times and LOS on over 10,000 revision TKAs.

Conclusions

Revision TKA is a complex procedure that is associated with higher complication rates and worse patient outcomes compared to primary TKA. Therefore, every effort should be made to identify and improve upon factors that can influence patient outcomes. This study found that operative time had a significant association with LOS and, in fact, has a greater effect than age, sex, and BMI. These results show that interventions to improve operative times may be a valuable target in the effort to reduce LOS as well as hospital costs. The results of this study further underscore the need for improved operating room efficiency and patient optimization in an effort to improve patient outcome, satisfaction, and to reduce overall cost.

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None.

Footnote

Conflicts of Interest: MA Mont: AAOS, Cymedica, DJ Orthopaedics, Johnson & Johnson, *Journal of Arthroplasty*, *Journal of Knee Surgery*, Microport, National Institutes of Health (NIAMS & NICHD), Ongoing Care Solutions, Orthopedics, Orthosensor, Pacira, Peerwell, Performance

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