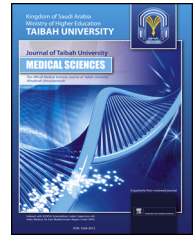




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Original Article

Impact of resident involvement on complication rates in revision total knee arthroplasty



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المخلص

أهداف البحث: نتيجة لزيادة عدد عمليات تقويم مفصل الركبة، فإن عدد عمليات مراجعة تقويم مفصل الركبة مستمر في الارتفاع. لكن عدد جراحي العظام المدربين على تقويم المفاصل لم يواكب هذه الزيادة، وسيقع العبء المتزايد في النهاية على عاتق جراحي العظام غير المتخصصين. أظهرت الأبحاث أن مشاركة الأطباء المقيمين في عمليات تقويم مفصل الركبة الأولية لا ترتبط بزيادة مضاعفات ما بعد الجراحة، ولكن عمليات مراجعة تقويم مفصل الركبة أكثر تعقيداً ولم يتم دراسة تأثير مشاركة المقيمين بشكل جيد.

طرق البحث: باستخدام قاعدة بيانات البرنامج الوطني لتحسين جودة الجراحة بالكلية الأمريكية للجراحين، شملت هذه الدراسة 1834 عملية مراجعة تقويم مفصل الركبة أجريت بين عامي 2008 و 2012. من هذه العمليات، شارك الأطباء المقيمون في 863 عملية. تم تصنيف وتحليل المعلومات الديموغرافية، والأمراض المصاحبة، وأوقات الجراحة، ومدد الإقامة، ومضاعفات ما بعد الجراحة لمدة 30 يوماً، حسب مشاركة الأطباء المقيمين.

النتائج: لم ترتبط مشاركة الأطباء المقيمين مع زيادة مهمة في المضاعفات على المدى القصير. كانت أوقات العمليات أطول بشكل ملحوظ مع مشاركة المقيمين (147.5 دقيقة مع مشاركة المقيمين مقابل 124.55 دقيقة بدون مقيم). كما كانت

مدة الإقامة بعد الإجراءات بمشاركة المقيمين أعلى بمقدار 0.34 يوماً، لكن هذا لم يصل إلى الأهمية الإحصائية.

الاستنتاجات: ارتبطت مشاركة المقيمين في مراجعة تقويم مفصل الركبة بزيادة كبيرة في وقت الجراحة. ومع ذلك، لم تكن هناك زيادة كبيرة في معدل المضاعفات بعد الجراحة في غضون 30 يوماً. تدعم هذه النتائج استمرار مشاركة المقيمين في مراجعة حالات تقويم مفصل الركبة وإدارة ما بعد الجراحة.

الكلمات المفتاحية: نتائج ما بعد الجراحة؛ مراجعة تقويم مفصل الركبة الكلي؛ تدريب المقيمين؛ تقويم مفصل الركبة الكلي

Abstract

Objectives: The number of revision total knee arthroplasty (TKA) procedures continues to rise, a direct consequence of the increase in primary TKA. The number of arthroplasty-trained orthopaedic surgeons has failed to increase at a corresponding rate, and the increased burden will ultimately fall on non-specialized orthopaedists. Resident involvement in primary TKA has not been found to increase postoperative complications, but revision TKA is more complex and the impact of resident involvement has not been well studied.

Methods: Using the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database, this study identified 1834 revision TKA procedures between the years 2008 and 2012. Of these procedures, 863 included resident involvement. Demographic information, comorbidities, operative

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times, length of stay (LOS), and 30-day postoperative complications were stratified by resident and non-resident involvement and analyzed.

Results: Resident involvement was not associated with a significant increase in short-term complications. Operative times were significantly longer with resident involvement (147.50 min with resident involvement vs. 124.55 min without a resident, $p < 0.001$). Length of stay after procedures with resident involvement was higher by 0.34 days, but this did not reach significance ($p = 0.061$).

Conclusion: Resident involvement in revision total knee arthroplasty was associated with a significant increase in operative time; however, there were no significant increases in postoperative complication rates within 30 days. These findings support continued resident involvement in revision total knee arthroplasty cases and post-operative management.

Keywords: NSQIP; Postoperative outcomes; Resident training; Revision total knee arthroplasty; Total knee arthroplasty

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Introduction

Total knee arthroplasty (TKA) is commonly performed to alleviate pain and improve function in patients with end-stage joint disease.^{1,2} The success rates of 93.8% at 10 years and high patient satisfaction scores have resulted in an expansion of the patient population in whom the procedure is indicated.^{3,4} These factors, in combination with an aging and increasingly comorbid population, are expected to increase the number of primary and revision TKAs performed. By 2030, the number of revision TKA surgeries is expected to reach 268,200 per year.⁵ While the rate of revision has remained constant at approximately 6.2–7.0%, the total number of revisions continues to climb from the increase in primary TKA.^{6–8}

The projections for the demand for revision TKA exceed the supply of fellowship-trained arthroplasty surgeons. Therefore, it is essential that non-arthroplasty trained surgeons become well-versed in revision TKA during residency training.⁹ Revision TKA offers unique challenges such as bone loss, ligamentous insufficiency, and deformity.^{10,11} Residents must have experience and be adept at overcoming any challenge that may arise. With heightened resident involvement, it is vital to evaluate their possible impact on the outcome of revision TKA procedures.

The assessment of factors that may contribute to post-surgical complications for revision TKA would allow insight to reduce costs and improve patient outcomes. Previous studies have shown that resident involvement in orthopaedic procedures does not result in increased complication rates.^{12–14}

However, the specific effects of resident involvement in revision TKA have yet to be determined.

The goal of this study is to determine the impact of resident involvement on revision TKA outcomes using patient comorbidities, preoperative variables, and 30-day postoperative complications recorded by the National Surgical Quality Improvement Program.

Materials and Methods

The National Surgical Quality Improvement Program (NSQIP) is a national database that compiles data on surgical outcomes and clinical information. Data was collected from 2008 to 2012 from over 400 hospitals including private, public, academic, and non-academic hospitals in both rural and urban locations. This database is maintained by the American College of Surgeons and follows patients for a total of 30 days post-operatively to determine any complications that may arise during this time. Complications, comorbidities, demographics, and other preoperative factors are recorded to assist in understanding variables that may contribute to patient outcomes.

Patient selection

Patients selected for the study underwent a revision total knee arthroplasty defined by the Current Procedural Terminology (CPT) Codes 27486 (revision of total knee arthroplasty, with or without allograft; 1 component) and 27487 (revision of total knee arthroplasty, with or without allograft; femoral and entire tibial component) between 2008 and 2012. A total of 1834 revision TKAs met this inclusion criteria, and 47.06% ($n = 863$) documented the involvement of a resident physician. The remaining 52.94% ($n = 971$) documented no resident physician involvement. Additionally, 31.46% ($n = 577$) of the included procedures were CPT Code 27486, and 68.54% ($n = 1257$) were CPT Code 27487. Procedures that failed to record resident involvement data ($n = 2250$) were excluded from the study.

Data collection

The NSQIP records the highest level of resident surgeon scrubbed in on the procedure. This variable is listed as “PGY” in the database, and the surgical reviewer records the resident level “1–6” in the field for this variable. Cases that did not include resident involvement recorded a “0” in this field. This study included procedures that recorded residents level PGY1–5, notably excluding fellows (PGY6). Excluded cases left this field for resident training level blank.

Demographics and outcomes

Patient demographics and comorbidities are recorded in [Table 1](#). Outcomes within 30 days post-surgery included graft/prosthesis/flap failure, surgical site infections, wound dehiscence, reoperation, pneumonia, unplanned intubation, deep vein thrombosis (DVT), pulmonary embolism (PE), ventilation greater than 48 h, renal insufficiency, acute renal failure, urinary tract infection, stroke, peripheral nerve injury, cardiac arrest, and myocardial infarction.

Statistical analysis

Preoperative demographics, medical comorbidities, and postoperative outcomes were compared between cases with and without resident involvement using two-sided chi-square and Fisher's exact tests. Variables related to operative time and length of stay (LOS) were adjusted using a multivariable linear regression in order to remove their potentially confounding influence on the association between operative time or LOS and resident involvement. All statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, North Carolina).

Results

Complications with resident involvement

Preoperative characteristics are shown in Table 1. Variables showing statistical significance using two-sided chi-square and Fisher's exact tests include gender (43.90 with resident involvement vs 38.76 without a resident, $p = 0.0286$), type of anesthesia ($p < 0.001$), hypertension requiring medication (64.08 with a resident vs. 70.75 without a resident, $p = 0.0027$), and diabetes status ($p = 0.0012$). Table 2 shows univariate comparisons of complication rates

Table 1: Medical comorbidities and preoperative demographics.

Medical comorbidities and preoperative demographics (expressed as percentages)	Resident present (863)	Resident not present (971)	P-value
Gender			
Male	43.90	38.76	0.0286
Female	56.10	61.24	
ASA classification			
ASA 1	1.51	1.03	0.118
ASA 2	43.92	40.10	
ASA 3	50.52	55.67	
ASA 4	3.94	2.99	
ASA 5	0.12	0.00	
Race			
American Indian or Alaska Native	0.54	1.12	0.120
Asian	0.27	0.56	
Black or African American	12.25	9.38	
Native Hawaiian or Pacific Islander	0.00	0.22	
White	86.94	88.73	
Anesthesia			
Epidural	2.78	2.78	<0.001
General	59.44	59.90	
MAC/IV sedation	0.46	0.21	
Monitored anesthesia care	0.12	0.21	
Regional	10.20	2.37	
Spinal	26.42	34.43	
None	0.35	0.00	
Other	0.23	0.10	
COPD	3.71	3.81	1
Congestive heart failure in 30 days before surgery	0.35	0.31	1
History of myocardial infarction 6 months prior to surgery	0.12	0.21	1
History of angina in 1 month before surgery	0.70	0.85	0.792
Acute renal failure (post-op)	0.23	0.31	1
Previous percutaneous coronary intervention (PCI)	9.40	9.59	0.936
EtOH >2 drinks/day in 2 weeks before admission	2.32	2.77	0.654
Previous cardiac surgery	5.22	5.33	1
History of revascularization/amputation for peripheral vascular disease	0.70	0.85	0.792
Currently on dialysis (pre-op)	0.35	0.62	0.514
History of transient ischemic attacks (TIA)	3.48	3.94	0.621
CVA/Stroke with neurological deficit	0.70	1.28	0.243
Paraplegia	0.46	0.43	1
Hemiplegia	0.00	0.11	1
Quadriplegia	0.12	0.00	0.479
Chemotherapy for malignancy in ≤30 days pre-op	0.35	0.21	0.675
Disseminated cancer	0.23	0.21	1
Steroid use for chronic condition	4.17	3.09	0.258
Weight loss (>10% loss body weight in last 6 months)	0.58	0.93	0.434
Bleeding disorders	5.10	4.94	0.915
Prior operation within 30 days	2.67	3.28	0.491
Hypertension requiring medication	64.08	70.75	0.0027

(continued on next page)

Table 1 (continued)

Medical comorbidities and preoperative demographics (expressed as percentages)	Resident present (863)	Resident not present (971)	P-value
Current smoker within one year	11.12	11.64	0.769
Diabetes status			
Diabetes mellitus managed with insulin	6.84	6.18	0.0012
Diabetes mellitus managed without oral agents or insulin	81.58	78.58	
Diabetes mellitus managed with non-oral and non-insulin agents	8.23	7.62	
Diabetes mellitus managed with oral agents	3.36	7.62	
Functional health status prior to surgery			
Independent	94.29	94.42	0.945
Partially dependent	5.71	5.58	
Inpatient	98.84	99.28	0.342

between revision TKA procedures performed with and without resident involvement. A statistically significant increase was observed in both total operative time and LOS with resident involvement (147.50 min with a resident vs. 124.55 min without a resident, $p < 0.001$ and 4.77 days with a resident vs. 4.01 days without a resident, $p < 0.001$, respectively). Although not reaching significance, many complication rates decreased with resident involvement.

Multivariable regression model/risk factors

Significant results from the regression model for operative times are shown in Table 3. Operative times increased by 25.92 min with resident involvement ($p < 0.001$). Patients with ASA Classification 1 had shorter operative times by 38.87 min ($p = 0.016$). Operative time also decreased in patients who had a prior operation within 30 days (-25.40 min, $p = 0.006$), and for those designated as outpatient (-51.91 min, $p = 0.002$).

Table 2: Total operative time, length of stay, and postoperative complications.

Operative time, length of stay, and postoperative complications	Resident present (863)	Resident not present (971)	P-value
Operative time (min)	147.50	124.55	<0.001
Length of stay (days)	4.77	4.01	<0.001
Graft/Prosthesis/Flap failure	0.00%	0.10%	1
Superficial infection	0.93%	0.41%	0.246
Deep infection	0.46%	0.93%	0.276
Wound dehiscence	0.81%	0.72%	1
Reoperation	3.01%	4.02%	0.258
Pneumonia	0.58%	0.62%	1
Unplanned intubation	0.35%	0.41%	1
Deep vein thrombosis	1.16%	0.62%	0.315
Pulmonary embolism	0.12%	0.62%	0.129
Ventilation >48 h	0.23%	0.41%	0.690
Renal insufficiency	0.35%	0.31%	1
Acute renal failure	0.12%	0.31%	0.627
Urinary tract infection	1.74%	1.75%	1
Stroke/CVA	0.00%	0.10%	1
Peripheral nerve injury	0.12%	0.31%	0.627
Cardiac arrest	0.00%	0.21%	0.502
Myocardial infarction	0.23%	0.51%	0.458

Significant results from the regression model for LOS are shown in Table 4. Patients who had a prior operation within 30 days of revision TKA had longer hospital stays ($+6.95$ days, $p < 0.001$). Patients identifying as Native Hawaiian or Pacific Islander had an increase in LOS by 5.31 days ($p = 0.032$). Those who experienced a cerebrovascular accident (CVA) had an increase in LOS ($+1.94$ days, $p = 0.034$). The involvement of a resident did not translate to a significant increase in LOS ($+0.34$ days, $p = 0.061$).

Table 3: Multivariable regression analysis with total operative time as the dependent variable.

Covariates	Change in operative time, min	P-value
Gender – Female	-12.95	<0.001
ASA Classification 1	-38.87	0.016
ASA Classification 2	-7.74	0.036
Race – Black or African American	13.77	0.010
Anesthesia – Regional	-10.61	<0.001
Anesthesia – Spinal	-12.02	0.001
Prior operation within 30 days – Yes	-25.40	0.006
Outpatient	-51.91	0.002
Resident present	25.92	<0.001

Table 4: Multivariable regression analysis with length of hospital stay as the dependent variable.

Covariates	Change in length of hospital stay, days	P-value
Age	0.029	<0.001
ASA classification 2	-0.81	<0.001
ASA classification 4	1.88	<0.001
Race – Black or African American	1.34	<0.001
Race – Native Hawaiian or Pacific Islander	5.31	0.032
Cerebrovascular accident	1.94	0.034
Steroid use for a chronic condition	1.11	0.024
Prior operation within 30 days – Yes	6.95	<0.001
Outpatient	-2.70	0.003
Resident present	0.34	0.061

Discussion

The results of this study using the ACS-NSQIP database suggest that resident involvement in revision total knee arthroplasty does not significantly increase postoperative complications within 30 days. This large national database study of 1834 cases found that operative time increased an average of 25.92 min. Despite this increase in operation time the number of 30-day postoperative complications was low in both patient cohorts. This highlights the general safety and efficacy of revision knee arthroplasty procedures. Importantly, the increase in operative time seen with resident participation did not lead to an increase in deep infections (0.46% versus 0.93%).

It is projected that the number of revision TKA surgeries performed yearly will increase to 268,200 by 2030.⁵ As the total number of revision TKAs continues to rise, it is crucial that non-arthroplasty fellowship-trained orthopaedic surgeons develop the skills necessary to execute these challenging and unique procedures. The Accreditation Council for Graduate Medical Education (ACGME) recognizes total knee arthroplasty as a core competency with an established minimum quota to be performed by orthopaedic surgery residents.¹⁵ However, revision procedures present opportunities for additional complications and proficiency is not directly measured. It is crucial that residents finish their training with a strong understanding and proficiency in revision knee arthroplasty to be able to face the increased burden on the field. This leaves attending surgeons with the challenge of balancing patient care and creating a safe environment for resident education.¹⁶

Patients can be wary of resident participation when undergoing surgery. Their comfort level with the resident can hinge on the training level of the resident, attending participation in the procedure, the complexity of the surgery, and the steps of the procedure that the resident will be performing.^{17,18} Resident involvement has been linked to increased patient morbidity in general and vascular surgeries.¹⁹ This increase in patient morbidity has not been seen in orthopaedic procedures.^{13,20–22} However, these studies focused on primary arthroplasty cases and the effect of resident participation in more complex revision cases is still largely unknown. A study reviewing resident involvement in revision total joint arthroplasty revealed an increase in patient morbidity, but it did not stratify patients according to the type of revision arthroplasty performed.²³ This increase in postoperative complications with resident involvement was not seen in this study. Similar to several other orthopedic procedures,²⁴ these results encourage resident involvement during revision TKAs.

Both septic and aseptic complications can lead to revision surgery after primary TKAs. These complications can include periprosthetic joint infection (PJI), periprosthetic fractures, aseptic loosening, polyethylene wear, and implant failure. As a result, patients are often left with significant bone loss and soft tissue damage that can be challenging to overcome and lead to poor operative outcomes compared to primary arthroplasty.^{25–27} After revision surgery, one of the most feared complications is infection, as it can lead to poor long-term outcomes, with septic complications

found to increase more rapidly following revision TKA.²⁸ A known risk factor for PJIs following arthroplasty procedures is increased operative times.²⁹ No association between resident involvement and postoperative infections was observed, despite longer operative times with resident participation.

The multivariable regression analysis separated out demographic and preoperative variables to determine individual factors impacting LOS and operative time. This revealed reduced operative times with female gender, ASA classifications 1 and 2, regional or spinal anesthesia, recent surgical procedure, and outpatient procedure. These findings have been supported by previous studies.^{30–33} Similar to other surgical specialties, operative time increased with resident involvement.^{34–39} Teaching on altered anatomy present during revision TKA is challenging and may be a factor contributing to this finding. This may also stem from residents lacking confidence in their surgical skills due to decreased autonomy and stricter requirements regarding faculty supervision.^{40–42} It is crucial that orthopaedic residents gain these skills and are able to perform at an attending level to help combat the growing demand for revision knee arthroplasty.⁴³

Patient's LOS showed a modest increase with resident presence (0.34 days), but this did not reach significance. This is similar to the findings of other studies that analyzed the impact of residents on patient LOS.^{23,44} Age, ASA classification, race, history of stroke, and medication effects were all associated with a statistically significant increase in LOS. These preoperative risk factors have been linked to increased patient morbidity and increased LOS in primary TKA procedures.²³ The results of this and previous studies suggest that patient comorbidities are the strongest predictor for increased length of stay, not the involvement of a resident.

Strengths and limitations

The NSQIP database helps to evaluate the impact of resident involvement during orthopaedic procedures on a large scale. The data was collected by a trained surgical reviewer: this is more accurate than what is produced by insurance claims, but the extent of resident involvement was not quantified. Furthermore, the data was collected across multiple institutions and may not be completely standardized. The database does not account for resident involvement in post-operative care or control for perioperative care provided by residents of other specialties (i.e. medicine or anesthesia). Additionally, the database only collects outcomes within 30 days of surgery so long-term outcomes are not recorded. Some adverse consequences of common surgical missteps will not be present until years after the procedure.⁴⁵ It should also be noted that data is from 2008 to 2012. This is because the datapoint for resident involvement was removed from the NSQIP after 2012, so we were not able to include more recent data.

Despite these limitations, this is the largest study to evaluate the impact of resident involvement on 30-day postoperative complications for revision TKA. These results indicate that resident participation during revision TKAs is not harmful and may be protective in some cases.

Conclusion

Resident involvement in revision TKA resulted in no significant increase in 30-day complication rates, morbidity, or mortality. Resident involvement significantly increased operative time but did not increase infection rate or total length of stay. These findings support continued resident involvement in revision total knee arthroplasty cases and postoperative management.

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Conflict of interest

The authors have no conflict of interest to declare.

Ethical approval

IRB approval was not necessary given that these data were obtained from a de-identified national database.

Authors contributions

BA: formal analysis, writing – original draft, writing – review and editing; JBW: formal analysis, writing – original draft, writing – review and editing; KC, BS: formal analysis, writing – original draft, writing – review and editing; MS: writing – original draft preparation, writing - review and editing; GM: formal analysis, writing – review and editing; NM: conceptualization, supervision, writing – review and editing; RJ: conceptualization, supervision, writing – review and editing; SN: conceptualization, supervision, project administration, writing – review and editing. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

ACS NSQIP disclaimer

The American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

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