

Outcome Differences in Robotic vs Traditional Total Knee Arthroplasty

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Abstract

INTRODUCTION Robotic equipment has been increasingly employed in surgical procedures in recent decades, and orthopaedic total knee arthroplasties are included in this trend. Current literature, however, does not conclusively determine whether robotic-assisted TKA differs in surgical outcomes relative to the traditional procedure. This study aimed to compare complication rates, reoperation rates, readmission rates, length of stay, and OR time between the two procedure types. **METHODS** The National Surgical Quality Improvement Program database was used to analyze data points from TKAs performed at participating hospitals from 2022 to 2024. A retrospective analysis was performed, using propensity score inverse weighting with generalized linear models to compare procedures.

RESULTS Statistical analyses demonstrated patients that underwent the robotic procedure had lower rates of complications and readmissions, shorter hospital length of stay, and longer operation time compared to patients who underwent the traditional procedure.

CONCLUSIONS This indicates that robotic procedures, while costlier to perform, result in better outcomes which will lead to lower hospital costs..

Introduction

Total knee arthroplasty (TKA) is one of the most highly performed orthopaedic procedures due to its success and reliability in relieving pain associated with severe osteoarthritis [1]. In 2019, 480,958 primary TKAs were performed, a number that is increasing approximately 4.44% annually [2]. Despite this, 1 in 5 patients state dissatisfaction with their clinical result and approximately 22% had clinical complications, with postoperative anemia being the most frequent [3, 4]. Other common TKA complications consist of periprosthetic fracture, infection, aseptic loosening, and wound complications [1]. While these procedures have traditionally been performed with manual implant placements, robotic technology has gained increasing traction in these orthopaedic surgeries since the Mako was introduced in 2006 [5]. Major medical technology corporations have released various robotic arms to assist with the TKA procedure, including Stryker's Mako robot, Smith and Nephew's CORI robot, and Zimmer Biomet's ROSA robot. Many of these devices use Computed Tomography (CT) scans of the knee preoperatively to map the planned incisions and resections, thereby increasing precision of alignment and personalizing the procedure for each individual knee [6].

The implementation of robotic assistance into surgical procedures has altered many aspects of medicine, including physician workload, overall costs, and patient outcomes. Although the use of robotic technology has shown a decrease in physician stress, postural strain, and overall workload during surgical intervention, the procedure has been found to be significantly more expensive to perform by roughly \$3,000 per procedure [7, 8]. While robotic surgery has been thought to increase precision of alignment, there remains debate over whether the increased cost and surgical time associated with the robotic procedures provide an overall benefit to patients compared to the traditional procedures [9, 10, 11, 12]. The current literature does not clearly determine the difference in clinical complications,

reoperation, and readmission rates that result between the two procedures, and therefore does not conclusively address superiority of one over the other [13]. Current studies have conflicting findings on complication rates, where some find no differences between procedures and others have found decreased complications in robotic procedures [14, 15, 16, 17].

It is important to understand the differences in clinical outcomes between the two procedures so that surgeons can make evidence-based decisions on the extent to which robotic-assisted procedures should be employed. The purpose of this study was to determine how the utilization of robotic-assisted technology in knee arthroplasty impacts short-term readmission rates, reoperation rates, length of stay, and operation time, compared to traditional techniques.

Methods

Data Source

Data was retrieved from the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP). This database contains more than 240 clinical variables including preoperative patient characteristics, intraoperative variables, and 30-day postoperative outcomes. The NSQIP database is prospectively maintained and allows for high-powered, analyses. In comparison to other widely maintained surgical outcomes databases, the NSQIP database has been deemed more accurate [18, 19, 20]. IRB exemption was obtained due to lack of human subject research.

Data Collection

A retrospective review of the NSQIP database was conducted using Current Procedural Terminology (CPT) code 27447, which designates total knee arthroplasty (TKA). The NSQIP began collecting information on robotic-assisted surgeries in 2022. TKA patients were divided into two groups based on whether a robot was used during surgery; these two groups were designated as “Traditional” and “Robot-Assisted.” Patient demographic data collected included age, gender, race, ethnicity, BMI, and smoking status. Clinical comorbidities and risk factors data including diabetes, COPD, congestive heart failure, hypertension cancer, steroid use, bleeding disorder, functional status, ASA classification, and morbidity probability. Primary outcome variables included complication rate, readmission rate, reoperation rate, and length of hospital stay. A complication was defined as experiencing any type of surgical site infection, pneumonia, unplanned intubation, pulmonary embolism, ventilator occurrence, renal insufficiency or failure, urinary tract infection, stroke/cardiovascular occurrence, myocardial infarction, bleeding transfusion, DVT/thrombophlebitis, sepsis, septic shock, clostridium difficile colitis, or delirium. A secondary outcome of interest was operation time.

Data Analyses

To control for baseline preoperative differences between the two groups, we used propensity score inverse treatment weighting. For the 2022–2024 NSQIP cohorts there were 188,911 TKA operations of which 38,177 (20%) were robotic-assisted. Balance between groups on demographic and clinical covariates after weighting was assessed by the standardized difference. To compare groups on dichotomous outcomes (complication, readmission, reoperation) a generalized linear model with binomial distribution with logit link and robust standard errors was used. To compare groups on length of stay and operation time, generalized estimating equations with a negative binomial with log link and robust standard errors was used. Statistical Package for Social Sciences (SPSS) v30 was used for all statistical analyses and statistical significance was set at an alpha level of 0.05.

Results

Among all TKA patients 9686 (20.2%) patients who underwent robot-assisted surgery and 150,734 (79.2%) underwent traditional surgery. When comparing demographics and clinical comorbidities between the groups, inverse treatment weighting resulted in excellent balance across all patient characteristics (Table 1).

There was a significant difference between patients who underwent robotic-assisted TKA versus patients who underwent traditional TKA for complications (OR = 0.82, 95%CI = 0.77–0.86, $p < .001$), readmissions (OR = 0.92, 95%CI = 0.86–0.99, $p = .019$), but not reoperations (Table 2). Compared to traditional TKA, the complication rate was lower for robotic-assisted (3.7% vs 4.6%) and for readmission rate (2.6% vs 2.8%).

When comparing hospital length of stay, robotic-assisted TKA was significantly shorter than traditional TKA (Means: 1.03 days vs 1.28 days, $p = < .001$) (Table 2). Among the traditional TKA operation, 23.6% of the hospital stays were 2 or more days, while among the robot-assisted, it was 18.3% of the stays. Robot-assisted TKA operations took significantly longer to perform compared to traditional TAK operations (100.4 min vs 96.0 min, $p < .001$). As summarized in Fig. 1, most outcomes were favorable for the robotic procedure, except operation time.

Discussion

In this sample of 188,911 patients, we observed significant differences in complications and readmission rates, and length of hospital stay with better outcomes for robotic-assisted TKA compared to the traditional TKA. However, on average, robotic-assisted procedures were longer than traditional TKAs. This result was anticipated as more operation room (OR) time is allocated to the setup and configuration of robotic devices. The extent to which OR time is increased is dependent on the surgical team's experience with the robots and is often longer during the learning phase for knee mapping. Additionally, shortened hospital stays were observed in patients who underwent robotic-assisted TKA as compared to those who underwent traditional TKA, with patients often being discharged the same day. This is consistent with existing literature due to increased precision of the operation [8, 9, 11].

One article following a single surgeon's long term patient outcomes found the robotic TKA to significantly improve physical function and pain according to the reduced Western Ontario and McMaster Universities Osteoarthritis Index compared to the traditional TKA [21]. Another study indicated decreased pain levels, better range of motion, and higher 10-year survival rates for RA-TKAs compared to conventional TKAs [11]. Our study found additional support for RA-TKA in important clinical and surgical outcomes.

Given our findings, future directions may include analyzing the cost of OR time and turnover. Moreover, it could be insightful to investigate how decreased length of stay and increased OR time affect patients and the hospital system financially. Longer operating times have been independently associated with worse outcomes and increased complication rates in TKA procedures, but the robotic assistance also increases precision to improve outcomes [22]. In terms of burden on the hospital system, one study found the mean cost of OR time to be \$36 to \$37 per minute in addition to the increased \$3,000 expense for performing the procedure with the robot [23]. Exploring this interaction would be an interesting future direction.

Limitations

The main limitation of this study is that the NSQIP database only follows patients postoperatively for 30 days [24]. This means that any patient complications beyond those 30 days was not accounted for by the database. Another limitation of this study is that the robotic TKA was only introduced to the NSQIP database in 2022, so the data is limited to three years. Further, it is possible that there were confounders that the NSQIP did not collect, resulting in residual confounding not captured by the propensity score.

Conclusion

There was statistically significant and meaningful differences between robotic-assisted and traditional TKAs for complication and readmission rates. Robotic TKAs had longer procedure lengths, but shorter hospital stays for patients in comparison with the traditional TKA. There is room for further analysis from the perspective of long-term outcomes and financial impact on the patient and hospital to better understand whether the robotic-assisted TKAs can be considered superior to the traditional TKA.

Declarations

Author Contribution

S.H, A.M , and R.F. wrote the main manuscript. R. F prepared the figures. All authors reviewed manuscript.

Data Availability

The data is available in the tables and is from the NSQIP database

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Tables

Table 1: Demographic & Clinical Characteristics

Characteristic	Traditional (n=150,734)	Robot-Assisted (n=38,177)	Std Diff*
Age			
Mean ± SD	68.1 ± 9.0	68.1 ± 9.0	.002
Gender			
Female	61.1%	61.5%	.006
Race			
Asian	2.4%	2.5%	.009
Black	9.0	9.1	
Native Amer/Alaskan	0.7	0.7	
White	60.5	61.2	
Unknown	27.4	26.5	
Hispanic			
Yes	7.3%	7.0%	.008
BMI			
Mean ± SD	32.8 ± 6.4	32.8 ± 6.4	.000
Smoker			
Current	6.2%	6.1%	.000
Functional Status			
Independent	98.9%	98.8%	.001
Partially Dependent	1.1	1.2	
ASA Classification			
No Disturbance	1.0%	0.9%	.025
Mild Disturbance	43.5	42.6	
Severe Disturbance	53.5	53.6	
Life Threatening	2.0	2.8	
Diabetes	19.9%	20.4%	.004
History of Severe COPD	3.2%	3.1%	.001
Congestive Heart Failure	3.1%	3.1%	.001

<i>Hypertension</i>	64.2%	64.5%	.003
<i>Disseminated Cancer</i>	0.2%	0.2%	.002
<i>Steroid Use</i>	4.4%	4.4%	.000
<i>Bleeding Disorder</i>	1.8%	1.8%	.002
<i>Systemic Sepsis</i>	0.4%	0.4%	.001
<i>Morbidity Probability</i>			
Mean ± SD	2.7 ± 1.1	2.7 ± 1.1	.013

* Standardized Difference <.10 considered negligible and groups well balanced

Table 2: Conditional Logistic Regression Analysis for Binary Outcomes

Outcome	Coeff (B)	Std Err	Exp (B)*	95% CI	P-Value
Any Complication	-.205	.028	0.82	0.77 – 0.86	<.001
Readmission	-.081	.034	0.92	0.86 – 0.99	.019
Reoperation	.009	.060	1.01	0.90 – 1.13	.887
Length of Stay	-.215	.009	0.81	0.79 – 0.82	<.001
Operation Time	.049	.003	1.05	1.04 – 1.06	<.001
Incidence		95% CI			
Any Complication					
Traditional	4.6%	4.5 – 4.7			
Robot-Assisted	3.7%	3.6 – 3.9			
Readmission					
Traditional	2.8%	2.7 – 2.9			
Robot-Assisted	2.6%	2.4 – 2.7			
Reoperation					
Traditional	0.84%	0.8 – 0.9			
Robot-Assisted	0.85%	0.8 – 0.9			
Mean		95% CI			
Length of Stay					
Traditional	1.28	1.27 – 1.29			
Robot-Assisted	1.03	1.02 – 1.05			
Operation Time					
Traditional	96.0	95.4 – 95.8			
Robot-Assisted	100.4	100.0 – 100.8			

* Odds Ratio for any complication, readmission, reoperation, and Incidence Rate Ratio for length of stay and operation time

Figures

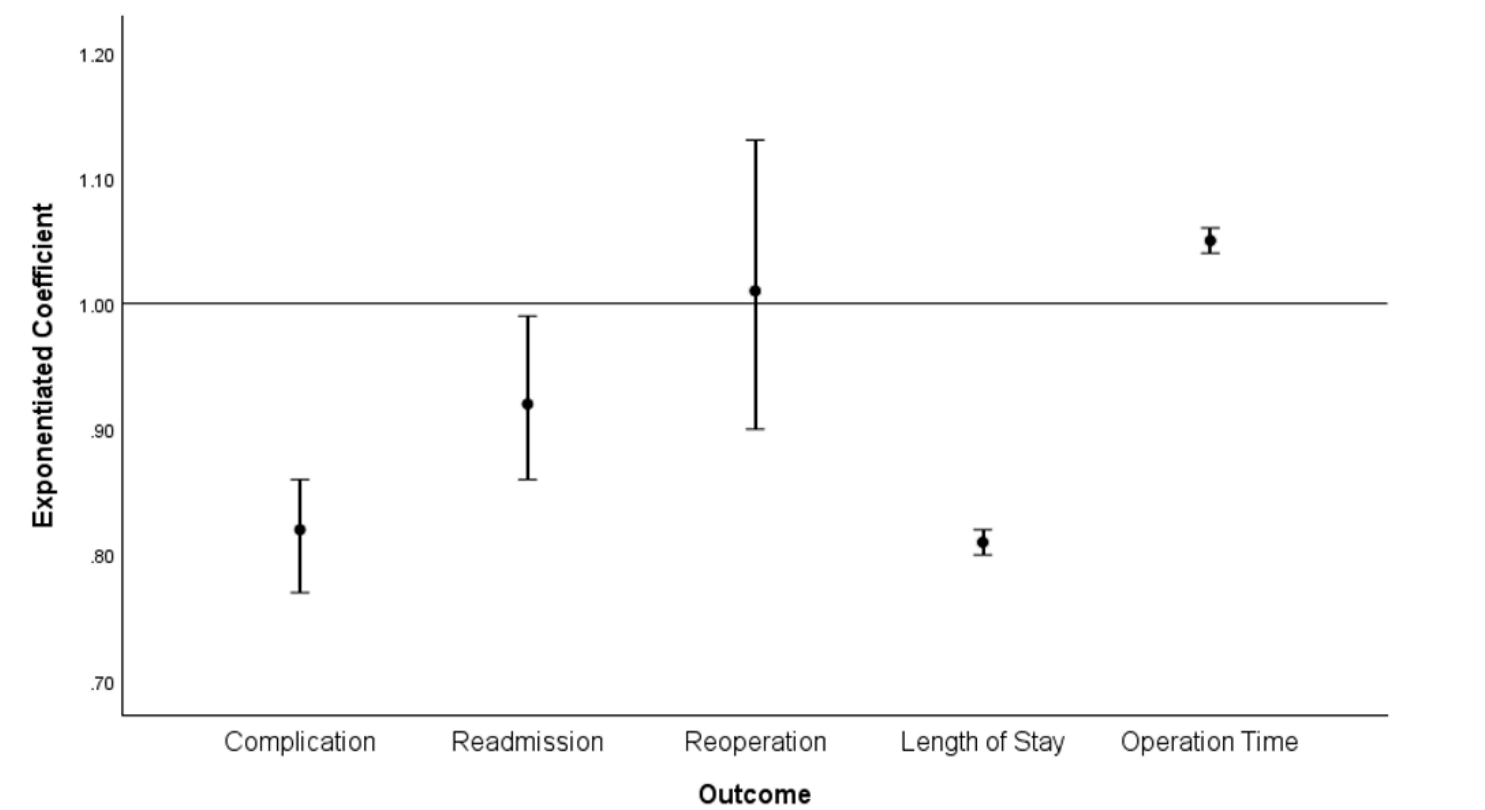


Figure 1

Effect Size Comparing Robotic to Traditional (reference) with 95% CI by Outcome