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Post-operative outcomes, including opioid utilization and length of stay, following total knee arthroplasty: A retrospective case matched series comparing conventional and robotic-assisted total knee arthroplasty

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Abstact

Background: With the rise of robotic arm-assisted total knee arthroplasty (TKA) cases, there is a need to determine if there are clinical benefits associated with this technology. The purpose of this study was to further evaluate if robotic-assisted TKAs result in improved inpatient postoperative outcomes compared to conventional TKAs.

Materials and Methods: After IRB approval, a retrospective chart review of 100 robotic-assisted primary TKAs and 100 matched controls undergoing conventional TKA was performed. Patients underwent primary TKA from 2016 to 2018 with minimum 6-month postoperative follow-up by a single fellowship-trained arthroplasty surgeon at a high-volume joint center. Exclusion criteria included <6 month postoperative follow-up, incomplete chart information, inflammatory arthritis, and BMI >40. Demographics and post-operative outcomes, including length of stay (LOS), opioid consumption, duration of opioid use, and discharge status, were recorded.

Results: There were no significant differences in preoperative demographics between the two groups. A decrease in LOS (1.58 vs. 2.18 days, $p < 0.001$) and morphine equivalents (73.52 vs. 102.50, $p = 0.017$) was reported for the robotic TKA group compared to the control group. The robotic group also reported fewer patients at six weeks postoperatively requiring opioids compared to the control group (37 vs. 61, $p = 0.001$). Average KOOS Jr at 6-months postoperatively was 81.73 for the control group and 78.22 in the robotic group ($p = 0.039$).

Conclusion: Robotic-assisted TKA patients experienced significantly decreased LOS, morphine equivalents, and opioid usage at 6-week postoperatively, indicating that there are early clinical benefits of robotic-assisted TKA. No significant differences between the robotic and control groups were reported in pre-operative KOOS Jr. Although average 6-month postoperative KOOS Jr was slightly higher for the control group, the difference was clinically insignificant. Our average KOOS Jr for both cohorts was higher than the national 1-year postoperative average, 76.8.

Introduction

Technology continues to drive improvements in modern healthcare. Utilization trends for technology assistance in total joint arthroplasty have increased over the past decade. [1,2,3] Robotic-assisted surgery was introduced in

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the 1980's, and its use in joint arthroplasty has grown exponentially since then. [4,5,6] As a result of this growth, there is concern that the associated costs may outweigh the proposed benefits of this technology. Robotic-assisted total knee arthroplasty (TKA) has been used to improve clinical outcomes, implant survivorship, component alignment/positioning, bone preparation, and soft tissue balance and protection as well as decrease the 15-20 % of patients who were dissatisfied with their joint replacement. [7] It has been extensively reported in literature that robotic-assisted TKA yields more accurate and precise bone cuts, producing consistent and accurate post-operative mechanical alignment compared to manual instrumentation. [8-13]

The Mako robotic system [14] utilizes computerized tomography (CT) scan 3-dimensional data and modeling to generate a virtual pre-operative plan. This plan includes templated size of implants, planned resection measurements, and planned angular cut information in the coronal, sagittal, and axial planes. During the surgery, this pre-operative plan is manipulated in a virtual environment to balance the knee. The saw blade, at the end of the robotic arm, executes the plan. The robotic arm is "guided" by a haptic boundary. This haptic boundary prevents the saw blade from cutting outside the predetermined area and will shut down if this haptic area is breached. The use of the CT-enhanced data and information, paired with haptic controlled execution of the cuts during total knee arthroplasty, has been shown to improve accuracy and precision. [15,16]

As arthroplasties become more common, there is an increased awareness of opioid use and post-operative pain control. [17-24] Centers have become increasingly attentive to the dangers of opioid use and the need to limit post-operative opioid use given that opioids can cause increased medical complications, such as acute hypertension and kidney injury. [25] Consequently, the field of joint arthroplasty has changed over the last decade to include a variety of modalities to assist in post-operative pain control. [26,27,28]

Published literature supports the use of robotic-assisted arthroplasty, though there is still much to learn about the outcomes of this technology. Some reviews have shown decreased pain scores following robotic-assisted arthroplasty, but relatively few, with the exception of Bhimani et al., have reported on actual opioid consumption itself. [29,30,31] The purpose of this study was to evaluate inpatient post-operative and post-discharge outcomes of robotic-assisted TKA versus TKA using conventional manual instrumentation, measuring time to discharge, discharge status, and opioid consumption post-operatively.

Materials and Methods

After approval by the Institutional Review Board, patient outcomes after robotic-assisted TKA were reviewed retrospectively at a single high-volume joint institution. One hundred patients were identified that underwent robotic-assisted (R) primary TKA during a subsequent transition period from traditional to all robotic-assisted TKA. These procedures were done following a learning curve time period as outlined by Vermue et al. [32] A second matched group, based on diagnosis and procedure, was identified – control group (C) – consisting of 100 patients who underwent primary total knee arthroplasty with manual instrumentation immediately prior to transitioning to all robotic-assisted.

A total of 200 patients were reviewed, all of whom underwent primary TKA between 2016 and 2018 with the minimum of a 6-month follow-up. Patients were selected consecutively, excluding those that did not meet the study inclusion and exclusion criteria. The inclusion criteria for this study are as follows: (1) patients who were 18-79 years of age; (2) patients that underwent primary TKA between 2016 and 2018 with at least 6 months of clinical follow-up; (7) patients that had a Triathlon implant design. Exclusion criteria for this study are as follows: (1) patients less than 17 years of age or older than 79 years of age; (2) patients with a BMI greater than 40; (3) patients with inflammatory arthritis; (4) patients with an active infection or suspected latent infection in or about the knee joint; (5) patients who underwent simultaneous bilateral TKAs or staged bilateral TKAs performed less than 6 months apart; (6) patients involved in workers' compensation cases; (7) patients with inadequate bone stock to support fixation of the prosthesis. Patients older than 80 years of age were excluded due to a different pain protocol and varying morphine requirements when compared to an average patient.

All TKAs were performed by one fellowship trained arthroplasty surgeon (author J.H.). Group R was compared to group C. A single implant design (Triathlon; Stryker, Mahwah, NJ) was used for all patients in this study. Group R and group C patients received the same pre-operative counseling and preparation. Both groups were also managed with the same post-operative protocols. All patients at our institution receive spinal anesthesia with adductor canal block, periarticular injection consisting of bupivacaine mixed with ketorolac, and a limited opioid post-operative pain protocol. They all underwent cruciate retaining TKA with patella resurfacing. Group C underwent a measured resection technique. Patient-controlled analgesia, urinary catheters, and post-operative drains were not used in any patient. None of the patients in this study underwent bilat-

eral TKA. Post-operative pain scores were assessed and recorded per institution's post-operative protocols.

Demographic information was collected for every patient. Post-operative outcome measures included hospital length of stay (LOS), ability to walk > 50 feet during inpatient physical therapy, surgical time, pain scores, morphine equivalents, opioid status at 6 weeks postoperatively, and inpatient and post-discharge complications were collected, as well. Pre-operative and 6-month post-op Knee Injury and Osteoarthritis Outcome Scores for Joint Reconstruction (KOOS Jr) were calculated for both groups. Independent Samples t-Test and Chi-Square test were used to determine statistical significance. A power analysis was not performed. A p-value of < 0.05 was determined to be statistically significant for this study.

Results

Patient demographics were assessed for variance with no significant differences between the robotic-assisted and conventional TKA groups for pre-operative variables, including age, body mass index (BMI), and gender (Table 1). Insurance status was similar for each group, as well; 52 patients had Medicare in the control group and 51 in the robotic group. Group R demonstrated significantly reduced LOS ($p = <0.001$); LOS in group R was 1.58 days (SD=0.58) versus the control group at 2.18 days (SD=0.44), nearly half a day longer. Morphine equivalents for group C were nearly twice as great (M=102.50, SD=95.60) compared to group R (M=73.51, SD=69.78) (p=0.017). Post-operative opioid use at 6 weeks was significantly greater for group C with 61 patients still taking opioids compared with 37 patients in group R (p=0.001). The surgical (p=<0.013) and tourniquet (p=<0.019) times were statistically significantly greater for group R (155.17 and 46.68 min) compared to group C (147.86 and 42.74 min.) (Table 2). No other statistically significant differences were found between the two groups regarding 18-hour post-operative pain, patients who walked over 50 feet during inpatient physical therapy, or the number of inpatient and post-discharge complications. There was no statistically significant difference for the postoperative KOOS Jr. between the two groups (Table 2). Although the 6-month postoperative KOOS Jr. for group C was higher than group R (81.73 vs. 78.22), it is important to note that both were higher compared to the 1-year postoperative national average of 76.8 (Table 3) and that the difference was clinically insignificant based on the minimum clinically important difference (MCID). [33]

Discussion

Post-operative outcome measures are multifactorial with each potentially having an individual effect. Identifying such factors and determining if modifications can be made to improve patient care may not only serve to benefit the patient but also can have a ripple effect in our healthcare system. This study showed that robotic-assisted TKA patients experienced a significant decrease in LOS, morphine equivalents, and 6-week postoperative opioid use. Total surgical and tourniquet time, however, were longer when compared to the manual instrumented group.

Table 1. Demographic Data of Group R and Group C

	Robotic (R)	Standard Deviation	Control (C)	Standard Deviation	P Value
Demographics					
Age	65.59	8.57	66.01	8.15	> 0.05
Gender (M:F)	46:54		44:57		> 0.05
BMI	31.01	4.53	30.15	4.37	> 0.05

Table 2. Mean, Standard Deviation, and P Values of Data Metrics for Group R and Group C

	Robotic (R)	Standard Deviation	Control (C)	Standard Deviation	P Value
Length of Stay (days)	1.58	0.58	2.18	0.44	< 0.001
Morphine Equivalence	73.52	69.78	102.50	96.51	0.017
Opioid Use at 6 Weeks (Y:N)	37:63		61:39		0.001
Surgical Time (min)	155.17	18.98	147.86	22.00	0.013
Tourniquet Time (min)	46.68	9.80	42.74	13.00	0.019
Pre-Op KOOS Jr.	46.72	12.63	47.62	13.43	> 0.05*
6 Month Post-Op KOOS Jr.	78.22	20.44	81.73	18.90	0.039*

*compared combined cohort to National Scores in Table 2

Table 3. National KOOS Jr. Scores

	Mean Score
National Pre-Op KOOS Jr.	46.5
National 1 Year Post-Op KOOS Jr.	76.8

There was no clinically significant difference between the 6-month postoperative average KOOS Jr of the control versus that of the robotic group (81.73 versus 78.22). According to Lyman et al., the MCID, which reflects the minimum change that determines if a patient perceives a change in their health, of the KOOS Jr is from 7 to 36.33 The difference between the averages of our two groups is clinically insignificant and therefore, indicates that the difference in patient-reported postoperative function and pain for the robotic group versus the control group is negligible.

There was a notable difference in 6-week postoperative opioid use between the robotic and conventional TKA groups. 61% of the conventional TKA patients were taking opioids at 6 weeks postoperatively, whereas only 37% of robotic-assisted TKA patients were taking opioids. The use of robotic-assisted TKA resulted in a 60% overall reduction of opioid use in our patient population. This is a significant reduction in opioid use at a time when the opioid crisis is front and center in the field of arthoplasty. [17, 34]

Haddad et al. had similar results, demonstrating decreased post-operative pain, less time to discharge, and decreased analgesia requirements for robotic arm-assisted TKA patients compared to conventional TKA patients. [35] Two other studies by Marchand et al. and Bhimani et al. also reported significantly lower mean pain scores comparing robotic arm-assisted TKA to manual instrumentation TKA. [36,37] These findings may be due to the differences in surgical technique provided with robotic-assisted surgery such as limiting soft tissue releases, intramedullary violation, and reduced bone and periarticular soft tissue injury. Several studies have shown increased pain and delayed post-operative rehabilitation can result from even limited soft tissue releases which may promote changes in local and systemic inflammatory responses. [37-40] Decreasing opioid requirements can reduce cost, as well as minimize associated post-operative complications, to make a positive impact in the opioid crisis seen in healthcare today. [41,42]

There are several explanations for the longer surgical times in the robotic-assisted group. One reason is that this technique requires the surgeon to perform registration of key anatomic landmarks prior to performing the replacement, such as placing pins and arrays in both the femur and tibia. Although total operative time may be longer initially, surgeons can significantly decrease this time with experience. The learning curve has been reported to be 35 patients, decreasing surgical time by 13 minutes. [43] Another potential contributor to added operative time is robotic setup and registration. However, early data on robotic UKA vs. Oxford UKA shows time was saved with quicker trialing and reduced need to recut bone surfaces. [44] Even with a well-documented learning curve associated with robotic-assisted total knee arthroplasty, surgeons are able to consistently perform knee replacements with operative times under 60 minutes. This is both enabled and enhanced with the proper setup and operative team. [32,45]

As a non-randomized retrospective analysis, there are several limitations to this study. Given that confounding variables are difficult to control in a retrospective study, inherent selection bias must be taken into account when comparing outcomes since certain patients were selected to undergo robotic-assisted TKA. Patients were not blinded to which method of TKA they underwent, i.e. robotic-assisted versus conventional methods, which could have resulted in an inherent placebo bias and, consequently, decreased pain perception. This study is limited to short-term postoperative outcomes given that there was a fairly short follow-up of 6 months. In addition, this study does not comment on 6 month radiographic outcomes and does not compare alignment films of the two cohorts. Unfortunately, this was not a matched study but rather a retrospective examination of a single surgeon experience. As such, the cohorts were not matched for comorbidities and ASA. We were also unable to determine the relative rate of pre-operative opioid use in each cohort which may have altered our post-operative opioid use results. Despite these limitations, this is a retrospective single surgeon study using the same robotic platform, implant design, surgical approach, and post-operative pain and rehabilitation protocols.

Robotic-assisted TKA patients demonstrated a decrease in hospital LOS, morphine equivalents, and opioid usage at 6-weeks postoperatively. Though average KOOS Jr at 6-months postoperatively was slightly higher for the control group versus the robotic group, it is important to note that the KOOS Jr of both groups were higher when compared to the national average.

This study was not intended to be a cost-analysis of robotic-assisted arthroplasty, which is beyond the scope of this investigation. There have been several published examples of the cost-benefit analysis of robotic-assisted total knee arthroplasty. [46,47] Further long-term studies are needed to assess the financial and functional implications of robotic-assisted surgery. This study provides early clinical support that robotic-assisted surgery may contribute to an overall opioid reduction strategy in addition to improved early post-operative outcomes.

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AUTHOR DISCLOSURES
- The authors declare that there is no conflict of interest in connection with this submitted article.