Robotic-Assisted Total Knee Arthroplasty is Safe in the Ambulatory Surgery Center Setting

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KEYWORDS

• Robotic TKA • Ambulatory surgery center • Outpatient total knee arthroplasty
• ROSA knee system • Outcomes

KEY POINTS

• Robotic-assisted total knee arthroplasty may be safely performed in the ambulatory surgery center setting.

LEVEL OF EVIDENCE: III

Background

Total knee arthroplasty (TKA) is one of the most performed procedures in the United States. With TKA removed from the Medicare-designated inpatient-only list, there has been an increasing trend toward outpatient TKA in ambulatory surgery centers (ASCs), with acceptable safety profiles.[1–3] Robotic assistance in TKA has been increasing in popularity as well, with the releases of multiple robotic platforms over the past decade. Many of these platforms have shown improved implant alignment as well as short-term patient-reported outcomes and patient satisfaction compared with conventional instrumentation[4–10]; less soft-tissue injury and lower perioperative analgesia requirements also have been reported.[7] Approximately 20% of patients receiving a TKA with conventional instrumentation report dissatisfaction,[11] but there is hope that with robotic technology, implant longevity, functional outcomes, and patient satisfaction will improve.

There are several differences in the robotic platforms available, which can be classified as active, semi-active, and passive. Active robotics can independently complete a task after appropriate input from the surgeon. Semi-active platforms allow the robot to perform a task while the surgeon has active haptic feedback to avoid deviation from the preoperative plan. Last, passive platforms are under direct control of the surgeon. Various platforms require different imaging requirements. Some systems require advanced imaging studies such as a computed tomography (CT), MRI, or specialized radiographs. Several systems are imageless and rely on accurate intraoperative anatomic landmark mapping[12,13]

The implementation of robotic platforms in the ASC has not been widely studied. There have been a couple studies on the use of robotics in unicondylar knee arthroplasty in the outpatient setting,[14,15] but few have looked at robotic-assisted TKA (RA-TKA) in the ASC. The purpose of this study was to evaluate the results of implementing RA-TKA in a free-standing ASC. We hypothesized that RA-TKA would have similar complication rates and patient-reported outcomes to conventional TKA in an outpatient setting.

This article represents original work and has not been previously published.
Funding: None.
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Orthop Clin N Am 54 (2023) 153–159
https://doi.org/10.1016/j.ocl.2022.11.001

MATERIALS AND METHODS

Upon approval from an institutional review board, a retrospective chart review identified patients who underwent conventional outpatient primary TKA and RA-TKA at a free-standing ASC from January 1, 2020 to August 18, 2020 and August 24, 2020 to January 11, 2021, respectively, performed by the same surgeon at the same ASC. As a retrospective study, informed consent was waived. Patients undergoing revision surgery were excluded. The robotic system used in the study was the Robotic Surgical Assistant (ROSA) Knee System (Zimmer-Biomet, Warsaw, Indiana), a semi-active platform in which an imageless technique is used. After the initial establishment of the robot at the ASC, all subsequent primary TKAs were performed using the robotic system.

Patient Selection

All patients in the cohort were evaluated by the operating surgeon and had a diagnosis of knee arthritis. In each patient conservative management had failed, and patients were deemed appropriate candidates for TKA. A thorough history and physical examination was performed to evaluate patients' suitability for outpatient TKA. Patients with risk factors were cleared preoperatively by the patient's internist and/or cardiologist. Those with excessive risk factors (ie, coronary artery disease, diabetes, body mass index (BMI) greater than 40, peripheral vascular disease, chronic obstructive pulmonary disease (COPD), congestive heart failure, cirrhosis, or chronic kidney disease) did not undergo TKA in the ASC and were not included in this study. All patients underwent a preoperative workup, including review of medical records, blood work, electrocardiogram, and chest radiograph. Preoperatively, patients were evaluated by anesthesia to assess suitability for outpatient TKA at the surgery center. Patients who were good candidates for outpatient TKA, attended a "prehab" educational session with physical therapy before surgery.

Surgical Technique

All procedures were done by the same board-certified orthopedic surgeon at a single free-standing ASC. Patients received spinal anesthesia or general anesthesia when the spinal anesthesia could not be administered and an adductor canal block preoperatively. All patients received antibiotics (cephazolin and vancomycin, unless contraindicated by allergies) prior to incision. Intravenous tranexamic acid was used if not contraindicated. A nonsterile tourniquet was used, and the knee was exposed through a standard medial parapatellar approach.

Patients in the conventional TKA group underwent instrumentation with a gap-balancing technique to prepare the femur and tibia. The robotic knee system was used to aid in preparing the bone cuts and balancing the knee. Cemented femoral and tibial components were then implanted. The patella was resurfaced when bone stock allowed.

Postoperative Protocol

Postoperative protocols remained the same between the two cohorts. A multi-modal pain composed of acetaminophen, gabapentin, meloxicam, tramadol, and oxycodone regimen was used. Venous thromboembolism (VTE) prophylaxis of aspirin, 81 mg twice per day, was used for 6 weeks unless alternative anticoagulation was indicated. Patients received 3 days of oral clindamycin upon discharge.

All patients were discharged from the ASC the same day of surgery after working with physical therapy and after deemed safe for discharge. Patients participated in physical therapy for at least 6 weeks postoperatively. Patients were followed routinely with appointments at 2 weeks, 6 weeks, and 12 weeks postoperatively. The Knee Injury and Osteoarthritis Outcome Score short form (KOOS JR) and visual analog scale (VAS) score for pain were obtained at these appointments to assess patient-reported outcomes.

Statistics

Prior to this study, a power analysis was performed. For a power of 80%, α of 0.05, and β of 0.2, a 10% difference in complications or 8-point difference in KOOS JR scores would be detected for a cohort of 170 patients. Statistics were performed using SPSS software (IBM Corporation, Armonk, New York). *T*-tests were performed for continuous variables; Fisher exact tests and chi-squared analysis were performed for categorical variables.

RESULTS

Eighty-six patients who underwent a primary RA-TKA were identified, and 86 consecutive patients who underwent primary conventional TKA prior to implementation of the robot at the ASC were identified for comparison.

The whole cohort was composed of 96 female (55.8%) and 76 male (44.2%) patients, with a mean age of 62.3 years and an average BMI of

Table 1
Cohort demographics

	Robotic-Assisted (N = 86)	Conventional (N = 86)
Sex (%)		
Male	44 (51.2)	32 (37.2)
Female	42 (48.8)	54 (62.8)
Mean age (SD)	61.3 (7.3)	63.2 (7.3)
Mean BMI, kg/m2 (SD)	31.2 (5.9)	32.6 (6.3)
ASA score (%)		
I	10 (11.6)	9 (10.5)
II	58 (67.4)	48 (55.8)
IIIa	18 (20.9)	29 (33.7)
Laterality (%)		
Left	45 (52.3)	35 (40.7)
Right	41 (47.7)	51 (59.3)

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; SD, standard deviation.

31.9 kg/m2 (Table 1). There were no statistical differences between robotic and conventional instrumentation groups regarding age ($p = 0.1$), gender ($p = 0.06$), race ($p = 0.84$), American Society of Anesthesiologists (ASA) score ($p = 0.17$), tobacco use ($p = 0.7$), or alcohol use ($p = 0.4$).

In both groups, all patients were successfully discharged on the day of surgery. No patients required an overnight stay or transfer to a hospital facility. Three patients (3.5%) in the RA-TKA group and five patients (5.8%) in the conventional TKA group had immediate postoperative complications of nausea, lightheadedness, hypertension, shortness of breath, or pain, but all patients were successfully discharged the day of surgery after treatment of their symptoms (Table 2).

A total of five patients (5.8%) in the RA-TKA group required a return trip to the operating room (OR), all for manipulation under anesthesia (MUA) for arthrofibrosis. No patient in the conventional TKA group required MUA. Two patients (2.3%) in the conventional TKA group required a return trip to the OR: one patient for superficial wound necrosis that was treated with debridement and negative pressure wound therapy, and the second patient for a patellar fracture that necessitated open reduction internal fixation. None of the patients had deep infections, deep venous thrombosis, or required readmission to the hospital within 90 days after surgery. Intraoperative complications included a single medial epicondylar fracture in the RA-TKA group, which was fixed with a screw intraoperatively. There was only one visit to the emergency room (ER) in the 90 days after surgery in the conventional TKA group; the patient went to the ER for chest pain and was diagnosed with an anxiety attack and treated appropriately. There were no differences in total complications, delayed discharges, intraoperative complications, return visits to the OR, ER visits, or readmissions (see Table 2).

Surgical outcomes were assessed in both the RA-TKA and conventional TKA groups (Table 3). Blood loss, surgical time, total time in the OR, time in postanesthesia care unit (PACU), and total length of stay were assessed. Estimated blood loss (EBL) was similar between the two cohorts with no significant difference. Patient-reported outcomes of KOOS Jr. score and VAS were obtained at 2, 6, and 12 weeks postoperatively. There were no statistically significant differences in pain scores preoperatively, at discharge, or at the 2-, 6-, or 12-week follow-up appointments. Similarly, KOOS JR scores preoperatively, and at 2, 6, and 12 weeks showed no statistically significant differences between the two groups (see Table 3).

The surgical times were on average 4 min longer, with an average of 7 min more total OR time in the RA-TKA group compared with the conventional TKA group. These times reached statistical significance with *p*-values of 0.017 and 0.021, respectively. Time in PACU was slightly longer in the RA-TKA but was not statistically significant. The total length of stay was significantly longer in the RA-TKA group than the conventional group: 468 min versus 412 min ($p < 0.0001$) (see Table 3).

The cohort was separated into quartiles to compare surgical times over the length of the study. The average surgical time decreased over time in the RA-TKA group from 85 min in the first quarter of cases to 72 min in the fourth quarter, reaching statistical significance ($p = 0.003$). The average surgical time slightly decreased in the conventional TKA group from 78 to 75 min, not reaching statistical significance ($p = 0.35$) (Table 4).

DISCUSSION

This study supports our hypothesis that RA-TKA has comparable outcomes and low complication rates as conventional TKA performed in a free-standing ASC. KOOS JR and VAS pain scores preoperatively and postoperatively were similar between our two treatment groups. Outpatient

Table 2
Perioperative complications of the cohort (N = 172)

	Robot-Assisted (N = 86)	Conventional (N = 86)	*P*-value
Postsurgical event in PACU delaying discharge	3	5	0.720
Nausea	1	4	0.368
Pain	0	1	1.00
Hypertension	1	0	1.00
Shortness of breath	1	0	1.00
ER visits	0	1	1.00
Hospital admissions	0	0	
Intraoperative complications	1	0	1.00
Intraoperative medial epicondyle fracture	1	0	1.00
Postoperative complications	6	4	0.746
Dermabond allergy	0	1	1.00
Saphenous neuropathy	1	0	1.00
ER visits	0	1	1.00
Return trip to OR	5	2	0.44
Arthrofibrosis requiring Manipulation	5	0	0.059
Superficial wound	0	1	1.00
Patellar fracture	0	1	1.00
Deep infection	0	0	
Total complications	10	10	1.00

Abbreviations: ER, emergency room; PACU, postanesthesia care unit.

TKA has increased significantly over the past decade, with the coronavirus disease-2019 (COVID-19) pandemic acting as an additional catalyst. Many hospitals implemented outpatient total joint programs to help reduce the number of patients in the hospitals as well as potential patient exposure on the wards.[16] Studies have continued to show low complications with outpatient TKA,[3,17] and it has been shown that the removal of TKA from the Medicare inpatient-only list has not increased complications.[18] Robotic-assisted TKA also has become increasingly popular over the past decade. With appropriate patient selection, improved perioperative management, and surgical techniques, many patients are discharged home on the same day of surgery. Both groups of patients in this study were able to be discharged on the day of surgery and had similar functional outcomes. These findings are consistent with other studies evaluating RA-TKA.[19,20] Most of the literature on RA-TKA, however, is on the Mako robotic system (Stryker Orthopaedics, Mahwah, New Jersey), with minimal literature published on ROSA Knee System. The Mako system differs from the ROSA system in that there is a requirement for a preoperative CT scan.

Robotic platforms pose some challenges for implementation. They require space in the OR, they are expensive, and they may initially increase surgical times. Several studies have discussed the cost of implementation of robotic assistance in surgery.[21,22] Robotics require large upfront and maintenance costs, and many robotic systems have additional disposable instrumentation costs. There also is the consideration of the costs for advanced imaging (ie, CT and MRI) for some systems. In the environment of cost reduction and bundled payments, many surgeons, hospitals, and surgery centers are likely hesitant to implement robotics for this reason. Despite increased costs in these areas, several studies have shown lower total 90-day cost with RA-TKA. The lower total cost was attributed

Table 3
Estimated blood loss, operative time, and patient reported outcomes

	Robot-Assisted (N = 86)	Conventional (N = 86)	*P*-value
EBL (mL)	106.8 ± 11.4	108.14 ± 11.8	0.87
Surgical time (min)	79 ± 3	75 ± 1	0.017
Total OR time (min)	117 ± 3	110 ± 3	0.021
Time in PACU (min)	220 ± 11	206 ± 14	0.12
Total Length of Stay (min)	468 ± 15	412 ± 15	<0.0001
Preop VAS (mm)	52.4 ± 4.4	50.5 ± 4.7	0.55
Preop KOOSJR	44.6 ± 2.8	46.9 ± 2.4	0.23
Discharge VAS (mm)	37.6 ± 4.7	32.7 ± 4.8	0.19
2-week VAS (mm)	36.7 ± 4.3	34.9 ± 3.5	0.55
2-week KOOSJR	60.1 ± 2.3	58.8 ± 2.1	0.42
6-week VAS (mm)	26.1 ± 4.3	20.9 ± 3.0	0.064
6-week KOOSJR	67.1 ± 2.5	70.1 ± 2.2	0.089
12-week VAS (mm)	18.6 ± 4.3	13.7 ± 3.0	0.11
12-week KOOSJR	72.2 ± 3.1	73.0 ± 2.6	0.72

Abbreviations: EBL, estimated blood loss; KOOSJR, Knee Injury and Osteoarthritis Outcomes Score Short Form; OR, operating room; PACU, post-anesthesia care unit; VAS, visual analog scale.

to shorter hospital stays and lower readmission rates in the RA-TKA groups.[23,24] The current study did not examine or compare costs.

A learning curve is associated with the implementation of RA-TKA, which is reflected in this study. There was a significant difference in surgical times (79 min with RA-TKA versus 75 min with conventional TKA, $p = 0.02$). The average surgical time of the first quarter of cases with robotic assistance was 85 min, which dropped to 83 min in the second quarter, 78 min in the third quarter, and 72 min in the last quarter of patients. The surgical times after completing 64 cases were on average faster than conventional TKA but were not significant. Our findings are consistent with previous studies concerned with the learning curve with RA-TKA. Kayani and colleagues[25] found a learning curve of only 7 cases with continued improvement in surgical times throughout 60 cases. Sodhi and colleagues[26] similarly found a significant decrease in operative times between the first 20 and final 20 cases in their cohort. All studies showed that after the initial learning curve, operative times were similar to those of conventional instrumentation techniques once proficiency in the new system was achieved.[27] With the implementation of this new technology in the ASC, it remains unclear if the learning curve is associated with patient functional outcomes or complications.

Table 4
Surgical times (min)

	RA-TKA	Conventional TKA	*P*-value
First quarter (N = 21)	85	78	0.06
Second quarter (N = 22)	83	76	0.06
Third quarter (N = 21)	76	70	0.1
Fourth quarter (N = 22)	72	75	0.3
Full cohort (N = 86)	79	75	0.02

Abbreviations: RA-TKA, robotic-assisted total knee arthroplasty; TKA, total knee arthroplasty.

This study is not without limitations. The retrospective nature of the study has its inherent limitations, with possible bias in each cohort. This study evaluated consecutive cases from a single surgeon at a single ASC performing the same surgery. This reduces the risk of confounding factors but can only be generalizable to surgeons with similar patient selection and perioperative protocols. The study has a relatively small number of patients and short-term follow-up of RA-TKA performed in an

ASC. Many of the proposed benefits of RA-TKA, such as accuracy of component positioning, decreased soft-tissue injury, and component longevity were outside the scope of this study. Last, the COVID-19 pandemic may have influenced our study. There was a period of no elective surgery during the latter part of the conventionally instrumented TKA group. In addition, a small subset of patients in the RA-TKA contracted COVID-19 in the weeks after their surgery. None of the patients were hospitalized, but this reduced their ability to attend and participate in physical therapy and other postoperative care. Restrictions in services as well as patient hesitancy to attend sessions limited the number of therapy sessions some patients received. This change is a plausible contributing factor in the five cases (5.8%) requiring MUA in the RA-TKA group, although the increased number of cases was not statistically significant. In a separate study evaluating outpatient TKA at our same institution, there was an overall rate of arthrofibrosis of 3.0%, which was similar to the overall rate of arthrofibrosis in our study (2.9%).[3] The difference seen in this study is likely multifactorial, with contributions of circumstances surrounding the COVID-19 pandemic, potentially over-tightening knees with robotic-assistance, and standard sample error.

SUMMARY

The short-term results were comparable between RA-TKA and conventional TKA performed in the ASC. There were similar outcomes in terms of complications, re-operations, patient pain scores, and KOOS JR scores. One can conclude from our study that RA-TKA can be safely and effectively performed in a free-standing ASC. Long-term follow-up is necessary to determine implant survival and long-term patient-reported outcomes. With larger studies and longer follow-up, potential benefits and disadvantages of RA-TKA in the ASC can be further elucidated.

FINANCIAL DISCLOSURE

W. Mihalko has the following disclosures outside of this work: Aesculap/B.Braun, DOD, Myoscience Inc., NIH, Pacira Biosciences, Pacira Inc, Zimmer; P.C. Toy has the following disclosures outside of this work: Biomet, Innomed, Medtronic, Smith and Nephew. T. Eason has no disclosures. The authors report no conflicts of interest in regard to this work. Ethical Review Institutional review board approval by the University of Tennessee Health Science Center. Informed consent was waived by the IRB.

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