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Original Research

Robotic-assisted Total Knee Arthroplasty Reduces Radiographic Outliers for Low-volume Total Knee Arthroplasty Surgeons

Connor Byrne, MD *, Caleb Durst, BS, Kevin Rezzadeh, MD, Zachary Rockov, MD, Charles Moon, MD, Sean Rajaee, MD

Cedars Sinai, Los Angeles, CA, USA

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Background: Most studies evaluating robotic-assisted total knee arthroplasty (RA TKA) analyzed the advantages offered to high-volume surgeons. This study aims to determine if RA TKA improves radiographic or clinical outcomes for low-volume, non—arthroplasty-trained surgeons.

Methods: Radiographic and early clinical outcomes of 19 RA TKAs and 41 conventional TKAs, all performed by a single, non—arthroplasty-trained orthopaedic surgeon, were compared. Radiographic outliers were based on surgeon targets and defined as tibial posterior slope outside of 0°-5°, tibial tray varus outside of 0°-3°, and the presence of notching. Clinical outcomes included inpatient narcotic usage, length of stay, range of motion, and Patient-Reported Outcome Measurement Information System scores.

Results: There was a significant decrease in tibial slope outliers (RA TKA 0% vs non-RA TKA 22%, $P = .024$) and notching incidence (RA TKA 0% vs non-RA TKA 19.5%, $P = .044$) in the RA group. Tibial tray varus/valgus outliers trended lower in the RA TKA group (10.0% vs 26.8%, $P = .189$). Length of stay was significantly shorter in RA patients (48.0 hours [standard deviation: 25.5] vs 67.7 hours [34.3], $P = .038$). RA patients trended toward lower in postoperative inpatient total mean morphine equivalents usage (79.9 [89.2] vs 140.1 [169.3], $P = .142$) and inpatient mean morphine equivalents usage per day (30.36 [26.9] vs 45.6 [36.7], $P = .105$). There was no significant difference in Patient-Reported Outcome Measurement Information System scores or range of motion at first and second postoperative follow-up within 3 months.

Conclusions: RA TKA reduced the incidence of radiographic outliers when compared to conventional TKA for a low-volume arthroplasty surgeon.

Introduction

There has been a steady increase in robotic-assisted (RA) total knee arthroplasties (TKAs) performed in the United States. RA-TKAs allow for potential improvements in precision and accuracy of executing a surgical construct, but its use is associated with a learning curve that can last up to 1 year in high-volume surgeons [1]. Some studies have suggested an initial learning curve lasting only 6-20 cases [2,3]. This learning curve has been shown to be affected by surgical volume, with higher-volume surgeons having slightly shorter learning curves [2]. However, there are little data addressing early clinical and radiographic outcomes in low-volume surgeons performing RA TKA.

Interest surrounding RA TKA has been increasing secondary to improved surgical precision, less soft-tissue disruption, and higher patient satisfaction [4]. Robotic TKAs have been shown to be associated with improved patient-reported outcome scores, specifically pain and physical function [5–8]. Studies have shown lower postoperative pain scores and decreased analgesia requirements with robotic TKA [9], as well as decreased opioid prescription requirements [10]. Robotic TKAs have demonstrated improved early survivorship and equivalent long-term survival [4,11] and potential decreased overall costs [12] when compared to conventional TKAs.

Given the potential benefits that RA TKA can provide, there is likely a strong interest in this field, even amongst surgeons who

* Corresponding author. 444 South San Vicente Boulevard, Beverly Hills, CA 90211, USA. Tel.: +1 925 451 6455.

E-mail address: Connor.byrne@cshs.org

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perform only a small percentage of TKAs as part of their practice. Even though there are data showing improved clinical outcomes and improved component positioning with robotics [13], there is a paucity of literature describing if these potential benefits also translate to lower-volume surgeons. As such, the purpose of this study was to evaluate early patient and radiographic outcomes for a single low-volume arthroplasty surgeon performing RA TKA compared to conventional TKAs performed by the same surgeon. We hypothesized that there would be fewer radiographic outliers in the RATKA cohort compared to the conventional TKA cohort and that this would translate to improved clinical outcomes.

Material and methods

Inclusion/exclusion criteria

After receiving approval from a institutional review board (#00001723), we performed a retrospective review of all patients who underwent either RA TKA using the ROSA Knee System (Zimmer Biomet, Montreal, Quebec, Canada) or conventional TKA between June 2018 and December 2021 by a single low-volume arthroplasty surgeon. The surgeon in this study is a fellowship-trained trauma specialist and, on average, performs approximately 30 TKAs per year. The surgeon did not perform any RA TKA cases prior to the study period. No patients were excluded from this study and all procedures were performed for the indication of degenerative osteoarthritis.

Surgical techniques

Patients were separated into either RA (n = 19) or non-RA (NRA) TKA (n = 41) cohorts. All procedures in the RA TKA cohort were performed using the ROSA Knee System. Every patient included underwent the procedure to address primary osteoarthritis.

All cases were performed using a standard midline approach with a medial parapatellar arthrotomy, followed by osteophyte debridement and then soft tissue releases based off preoperative alignment. For the conventional group, the surgeon always aimed to create a neutral mechanical axis, utilizing posterior referencing and manual flexion/extension gap balancing. For the ROSA knee group, the navigation software was used to create balanced gaps. Both groups received a pericapsular injection of lidocaine, Marcaine and Toradol at the end of the case, and then received an equivalent postoperative pain regimen while inpatient.

The mean polyethylene liner thickness was 11.75 mm and 10.66 mm for the RA and conventional cohorts respectively. The majority of patients included in this study received cruciate retaining polyethylene liners. Of the 43 patients who received a cruciate retaining liner, 15 were in the RA cohort and 32 were in the conventional cohort. The 7 patients who received posterior stabilized liners were all in the conventional cohort, while all 4 of the patients who received medial congruent liners were in the RA cohort. The constrained posterior stabilized and TC3 liners were each used once in the conventional cohort, while the constrained condylar knee was selected for a single patient in the RA cohort who was found to have an incompetent medial congruent liner intraoperatively.

Outcomes

Radiographic assessments were made independently by 2 orthopaedic surgeons measuring initial postoperative radiographs for tibial tray sagittal alignment (posterior slope), tibial tray coronal alignment, and the presence of notching. Ranges for acceptable radiographic outcomes were $0°$-$5°$ for the posterior tibial slope and $0°$-$3°$ of varus for tibial tray coronal alignment. Operative time and length of stay were collected for both RA TKA and NRA TKA. Range of motion taken from preoperative and first and second postoperative visits was collected. Narcotics usage in mean morphine equivalents (MME) was also recorded. Finally, each patient had been requested to complete Patient-Reported Outcomes Measures Information System (PROMIS) surveys across 3 domains (pain, function, mood) at each postoperative visit, and these data were collected retrospectively. PROMIS surveys have been shown to reliably and accurately assess outcomes from orthopaedics interventions in terms of a patient's functional ability, pain, and depression levels [14,15].

Table 1
Demographics statistics in robot-assisted and not robot-assisted total knee arthroplasty groups.

Variable	Robot-assisted	Conventional	*P* value
Age (y)	70.1 [7.2]	65.4 [9.0]	.047
Sex (%F)	70.0%	58.5%	.386
BMI	31.0 [5.9]	32.2 [6.1]	.447

Values reported as percentage or mean, followed by standard deviation in brackets.
BMI, body mass index.

Statistical analysis

Independent samples T-test was used for normally distributed continuous variables and Mann-Whitney U test was used for continuous variables that were not normally distributed as determined by a significant Kolmogorov-Smirnov test. Fisher's exact test was used to compare categorical variables, including the percent of outliers regarding targets for accuracy. Cohen's kappa was computed to assess the agreement between 2 raters in the measurements of radiographic outcomes. The threshold for statistical significance was $P = .05$. Outcomes were reported as percentages or means followed by standard deviations in brackets in the same units.

Results

There were a total of 62 patients that met the inclusion criteria for the study. Patient demographics are listed in Table 1. The RA TKA group was significantly older on average than the NRA TKA group (70.1 years [7.2] vs 65.4 years [9.0]). Seventy percent of RA TKA patients were female relative to 58.5% of patients in the NRA TKA group ($P = .417$). Body mass index was slightly lower in RA TKA patients than NRA TKA patients (32.24 [6.05] vs 30.99 [5.87]). There was poor agreement between the raters for posterior slope (kappa = 0.20 [95% confidence interval: −0.7, 0.47], $P = .148$). There was fair to good agreement for both varus for tibial tray coronal alignment (kappa = 0.47 [95% confidence interval: 0.22, 0.73], P value<.001) and notching (kappa = 0.65 [95% confidence interval: 0.42, 0.87], $P < .001$).

There was a significant decrease in tibial slope outliers in RA TKA vs NRA TKA (0% vs 22%, $P = .024$). There was also a significant

Table 2
Perioperative statistics in robotically assisted and not robotically assisted total knee arthroplasty groups.

Variable	Robot-assisted	Conventional	*P* value
Surgery time	76.8 [27.6]	76.6 [20.4]	.389
Length of stay	2.3 [1.2]	2.8 [1.4]	.038
Total MME	79.9 [89.2]	140.1 [169.3]	.142
MME/day postoperatively	30.4 [27.0]	45.6 [36.8]	.105

MME, mean morphine equivalents.
Values reported as percentage or mean, followed by standard deviation in brackets.

Table 3
Range of motion (ROM) preoperatively (pre-op), at first postoperative visit 6 weeks after surgery (Post-op 1), and at second postoperative visit 12 weeks after surgery (Post-op 2).

Variable	Robot assisted	Conventional	*P*-value
Pre-op ROM	118.0 [15.5]	113.8 [16.6]	.406
Post-op 1 ROM	95.6 [15.4]	88.5 [18.5]	.162
Post-op 2 ROM	106.8 [11.3]	105.0 [23.6]	.613
Early change ROM[a]	−21.1 [23.0]	−27.8 [23.6]	.328
Late change ROM[b]	−11.2 [17.7]	−6.9 [16.5]	.326

Values reported as percentage or mean, followed by standard deviation in brackets.
[a] There were 18/20 robot-assisted patients and 36/41 not robot-assisted patients with documented 6-week postoperative ROM measures.
[b] There were 17/20 robot-assisted patients and 34/41 not robot-assisted patients with documented 12-week postoperative ROM measures.

difference in the incidence of notching with 0% of patients identified to have notching in RA TKA compared to roughly 20% in NRA TKA ($P = .044$). Tibial tray coronal alignment (varus/valgus) outliers also trended lower in the RA TKA group but did not reach statistical significance (10.0% vs 26.8%, $P = .189$).

Operative time was similar between groups (RA: 76.8 minutes [27.6] vs NRA: 76.6 minutes [20.4], $P = .389$). Length of stay was significantly shorter in RA patients (48.0 hours [SD: 25.5] vs 67.7 hours [34.3], $P = .038$).

RA patients had lower opiate use with a postoperative total MME of 79.9 [89.2] vs 140.1 [169.3] in the NRA TKA group, though this was not statistically significant ($P = .142$). The mean MME usage per day was also lower in RA TKA vs NRA TKA (30.36 [26.9] vs 45.6 [36.7], $P = .105$), but again, this was not statistically significant. The above findings are summarized in Table 2.

The preoperative range of motion was 118.0 degrees [15.5] in RA TKA patients and 113.8 in NRA TKA patients ($P = .406$). The final postoperative range of motion at 12 weeks was 106.76 [11.31] for RA TKA patients and 104.97 [23.63] for NRA TKA patients ($P = .613$). There were no significant differences in range-of-motion change between cohorts from preoperative baseline to 6-week follow-up (RA: −21.1 degrees [23.04] vs NRA: −27.8 degrees [23.6], $P = .328$) or 12-week follow-up (−11.2 degrees [SD: 17.7] vs −6.9 degrees [16.5], $P = .326$). These findings are summarized in Table 3.

Preoperative PROMIS score baselines in pain, function, and depression were comparable between RA TKA and NRA TKA (Table 4). There were no significant differences between RA TKA and NRA TKA in change in PROMIS scores from preoperative baseline to either postoperative visit (Table 4). By the 12-week postoperative visit, RA TKA patients had PROMIS pain scores decrease 5.4 units [15.4] and NRA TKA patients had pain scores decrease 4.0 units [6.6] ($P = .812$).

At the 2-year follow-up, the all-cause reoperation rate was 10.0% (n = 2) in the RA group and 12.2% (n = 5) in the NRA group. ($P = .800$) Two patients in the RA group underwent single component revision for instability and patellar impingement, respectively. In the NRA group, 3 patients (7.1%) underwent full component revision for periprosthetic joint infection, and 2 patients (4.8%) underwent arthroscopy for soft-tissue impingement. Additionally, 2 patients (4.8%) in the NRA group required manipulation under anesthesia. There were no manipulations under anesthesia in the RA group.

Discussion

As more arthroplasty surgeons implement robotic surgery into their practice, reservations exist amongst non−arthroplasty-trained surgeons who use this technology infrequently. Given the highly specialized nature of this procedure and potential difficulty with utilizing this technology, especially on a nonroutine basis, it is fair to question whether it is appropriate for these surgeons to employ robotic TKAs in their practice. Previous studies have shown that robotic TKAs performed by lower-volume surgeons have been associated with longer hospital length of stay, higher complication rates, inferior patient-reported outcomes, and longer procedure times [16]. Our study, in contrast, showed that RA TKA performed by a low-volume surgeon had a significant decrease in radiographic outliers and notching, with similar operating times, lower MMEs, a shorter length of stay, and no difference in PROMIS measures.

Previous studies have demonstrated the increased reliability and accuracy of performing bony cuts when performing RA TKA [17] and that high-volume arthroplasty surgeons can achieve fewer radiographic outliers when aiming to achieve a neutral mechanical axis [18]. However, it has yet to be established how this translates to surgeons who perform these procedures as just a small percentage of their overall practice. Our study suggests that these benefits can also be seen in these low-olume surgeons, as we specifically found a significantly lower incidence of radiographic outliers.

We also found no significant differences between RA and NRA TKAs when looking at operative time. This demonstrates that low-volume surgeons can adopt this robotic system into their surgical workflow with very little learning curve and achieve time neutrality. What the specific learning curve and average timeline still remains to be seen for this specific demographic of surgeons. Prior studies have also demonstrated longer surgical times between robotic and conventional TKA during the initial learning curve; however, studies have shown that operative times when first using the robotic technique continue to decrease both at 6 months and 1 year of use, and there is a potential for time neutrality once the surgeon has entered into a proficiency phase [1,3,19]. Our study demonstrated no difference in the operative time between the 2 techniques, suggesting that this proficiency phase with time neutrality is both achievable and sustainable for a low volume

Table 4
The change in patient reported outcome measurement information system (PROMIS) scores in pain, depression, and function from preoperative baseline to early (~1 month) or late follow-up (~3 months) in Robotic-Assisted (RA) and Non Robotic-Assisted (NRA) groups.

Robotic-Assisted			Conventional		
Early			Early		
Pain (10)[a]	Depression (10)	Function (10)	Pain (25)[a]	Depression (24)	Function (25)
3.0 (10.3)	−1.0 [6.8]	−0.20 [7.0]	−2.92 [7.3]	0.08 [9.8]	1.2 [7.8]
Late			Late		
Pain (7)	Depression (7)	Function (7)	Pain (23)	Depression (22)	Function (23)
−5.4 [15.4]	−2.3 [5.8]	3.7 [8.5]	−4.0 [6.6]	1.0 [6.9]	4.4 [6.1]

Values reported as percentage or mean, followed by standard deviation in brackets.
The number following PROMIS measure refers to the number of patients with both baseline and follow-up PROMIS scores for that measure at a given follow-up.
[a] The difference in change of pain PROMIS scores from baseline to early follow-up between the RA and NRA groups approached statistical significance ($P = .063$).

surgeon, and thus should not necessarily be a deterrent for adopting this technique into a general practice where it will be only performed sporadically.

We also found equivalent post-operative range of motion measurements between the 2 groups at all follow-up time points. Previous studies have also demonstrated equivalent range of motion measurements after undergoing robotic-assisted [20], while others have suggested improved early ROM [21].

Additionally, we found that RA TKA patients had numerically lower opiate usage during their hospital stay, a finding that has been previously reported [22,23]. We found no significant difference in early patient-reported outcome scores between the robotic and nonrobotic groups, suggesting similar recovery time, which has been previously described [24]. These patients can expect to see a similar improvement in their physical function ability, pain levels,and overall mood compared to patients undergoing conventional TKA.

Our study does have a several limitations. First, this review was performed retrospectively and as such carries with it the limitations associated with its design. Additionally, this study examined just 1 surgeon performing these procedures, and thus further studies involving more surgeons should be performed prior to extrapolating our findings to the general population. Finally, the external validity of the study is limited by the selection bias of patients included in this study.

Conclusions

Our data demonstrate that a low-volume TKA orthopaedic surgeon can expect to see the benefits of improved accuracy with no changes to their operative times and similar or improved early outcomes associated with RA TKA. Further studies analyzing long-term benefits of RA TKA in both high- and low-volume orthopaedic surgeons will be valuable to the orthopaedic community.

Conflicts of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2023.101303.

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