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Original Article

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Retrospective analysis of robotic unicompartmental and total knee arthroplasties: patient demographics and outcomes

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Abstract

Context: With the growing number of robotic knee arthroplasties being performed, new outcomes must be analyzed to provide a database for comparing robotic and nonrobotic surgeries. These results can be utilized in the future to properly assess the significance of utilizing robotic technology in the operating room regarding patient outcomes and cost.

Objectives: The aims of this study are to: (1) analyze adverse outcomes from robotic-assisted knee arthroplasty and its relation to sex, body mass index (BMI), and age; and (2) explore any possible differences in outcomes among robotic-assisted unicompartmental knee arthroplasty (UKA) and robotic-assisted total knee arthroplasty (TKA). It is hypothesized that sex, BMI, and age will play a role in adverse events experienced among robotic-assisted knee arthroplasty. It is hypothesized that adverse outcomes will differ in robotic-assisted TKA v UKA.

Methods: A retrospective analysis was performed utilizing 1,300 patient cases from a single surgeon that underwent robotic-assisted UKA or TKA utilizing a robotic surgical system. Demographics were sorted by age, sex, and BMI. Outcomes were sorted by the type of adverse event. The most common adverse event was further statistically analyzed by age, sex, and BMI and then compared to the total cohort. The most common adverse event was also broken down by TKA vs. UKA.

Results: The average age of the individuals undergoing this procedure was 63.6 years, with 52.3 % being female. The average BMI was 32.2. Of the 87 patients who experienced adverse events, 111 total events were documented. Manipulation under anesthesia (MUA) was the highest experienced adverse event. Among the MUA events, 79.5 % had a BMI over 30 (p=0.067), 72.8 % were female (p=0.014), and the average age was 59 years (p=0.019). Among the MUA adverse events, 76.9 % (n=30) were following a TKA and 23.1 % were following a UKA. When considering the entire sample (n=1,300), there was a statistically significant 12.6 times greater odds that an MUA occurred among those who had a TKA vs. UKA (p<0.001). Similar results were discovered when only considering those who had experienced an adverse event (n=87) because the odds of an MUA occurring among those who underwent a TKA was 4.67 times greater than those who underwent a UKA (p<0.001).

Conclusions: MUA was the most common adverse event in this cohort of robotic-assisted knee arthroplasties. The other adverse events did not yield large enough cohort sizes to analyze statistically in relation to specific patient demographics. Younger patients and females were at significantly greater odds of needing MUA. A BMI over 30 was not found to have a statistically significant risk of needing an MUA after robotic-assisted knee arthroplasty. Among the total cohort, those who underwent a TKA were at a 12.6 times greater odds of needing an MUA than those who received a UKA.

The number of knee arthroplasties performed in the United States is growing each year. A population-based logistic regression model of 7.8 million primary total knee arthroplasties (TKAs) predicted that TKAs alone are projected to increase 143.0 % between 2012 and 2025 [1]. With the number of cases increasing, it is pertinent to continue to analyze outcomes to ensure high-quality results. Adding robotic assistance into surgery is a new factor that needs to be

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considered. Predictions from a prior study of 112,161 patients utilizing multivariable logistic regression models estimated that 50.0 % of TKAs in the United States will be technology-assisted by 2032 [2]. With an enhanced wave of enthusiasm for utilizing robots in surgery, orthopedic robotic-assisted arthroplasties require more data and analysis to determine the robot's outcomes and significance, especially in regard to different patient demographics.

Currently, there is limited data on the long-term outcome differences between robotic and traditional knee arthroplasty procedures due to the relatively recent addition of robotic surgeries. Some data suggest that there are short-term differences, but it lacks generalizability. However, a retrospective case control study with 340 patients comparing outcomes between traditional and robotic-assisted knee arthroplasties found the two to be comparable methods with small differences noted with TKAs specifically. It was noted that the robotic-assisted TKA had a shorter length of stay and quicker time to home discharge, but the manual TKAs had shorter operative times, increased maximum flexion at 90 days, and required less postoperative physical therapy visits [3].

A systematic review of nine comparative studies consisting of 1,159 patients demonstrated that robotic-assisted TKA improved surgical accuracy, precision, and correction in alignment [4]. Another finding in a retrospective cohort analysis with 811,852 patients was that unicompartmental knee arthroplasties (UKAs) had higher odds of one- and two-year revision but lower odds of 1-year manipulations under anesthesia (MUAs) than the TKAs, which led to the hypothesis that is challenged in this study as well [5].

The aims of this study are to: (1) analyze adverse outcomes from robotic-assisted knee arthroplasty and its relation to sex, body mass index (BMI), and age; and (2) explore any possible differences in outcomes among robotic-assisted UKA and robotic-assisted TKA. It is hypothesized that sex, BMI, and age will play a role in the adverse events experienced among robotic-assisted knee arthroplasty. It is hypothesized that adverse outcomes will differ in robotic-assisted TKA vs. UKA. This study consists of an analysis of age, sex, and BMI in relation to adverse events in robotic-assisted TKA and UKA.

Methods

Ethical approval

Before initiating the study, the Mount Carmel Institutional Review Board (IRB) expedited review approval was obtained (study #210525-4). No funding was received for this study nor was a clinical trial registry needed. An IRB-approved waiver for informed consent was received, and no patient compensation was provided.

Data collection

A retrospective analysis was completed, including 1,300 robotic-assisted UKAs and TKAs from 2012 to 2021. All nonrobotic cases were excluded. The cases studied were all performed by a single surgeon utilizing the CORI® (formerly NAVIO®) surgical system (Smith+Nephew, Watford England). Patient characteristics including age, sex, and BMI were collected utilizing both electronic databases and paper medical records and inserted into a Google Sheets spreadsheet without any patient identifiers. The data on sex and age were gathered utilizing patient chart review of individual identification cards, such as driver's licenses, that had been scanned into the chart just before the primary surgical procedure. BMI was gathered through a chart review of preoperative clearances.

Cases of adverse events were identified based on follow-up clinical documentation. The adverse events were sorted into 14 categories by type of event that had occurred. The categories included MUA, ruptured quadriceps tendon, ruptured patellar tendon, patellar fracture, irrigation and debridement with polyethylene change, irrigation and debridement without polyethylene change, deep vein thrombosis, revision, arthrotomy, wound dehiscence, periprosthetic fracture, infection, cellulitis, and wound drainage.

For the purpose of this study, all adverse events that led to an MUA were classified under the umbrella category of "MUA" due to the inability of the review to pinpoint the exact indication for each MUA performed. These adverse events may have included contracture, patient quality-of-life expectations, and decreased range of motion (ROM). An MUA is a procedure performed to correct a contracture of soft tissue after TKA or partial knee arthroplasty to improve the ROM in the joint. ROM less than 90 degrees of flexion at 6 weeks may indicate MUA. Other indications may be the patient's quality-of-life expectations.

Other data points collected that were not utilized in this study are insurance, previous surgeries to the surgical knee, hospital where the surgery was performed, surgical side, surgery duration, anesthesia duration, blood loss, fluids needed, vendor, femur component size, tibial component size, patella size, polyethylene size, days between bilateral surgery if performed, days after surgery that physical therapy was started, number of physical therapy visits, preoperative flexion and extension ROM, initial postoperative flexion and extension ROM, and final postoperative flexion and extension ROM.

Data analysis

The average age, sex, and BMI of the cohort were found. The most common adverse event was identified, and among those who had experienced this event, the average age, sex, and percentage of BMI over 30 were found. The patient demographics of the total cohort were then compared to those of the most common adverse event utilizing statistical analysis (Ohio University Statistical Core for Health and Medicine). Age was analyzed utilizing a Mann–Whitney U test. Sex and BMI, and MUA in TKA vs. UKA, were analyzed utilizing chi-square analysis. A threshold p value of <0.05 was considered significant.

Results

Total cohort

The 1,300 patient cohort from 2012 to 2021 consisted of 1,005 UKAs, 294 TKAs, and 1 conversion from UKA to TKA. The average age of the total cohort was 64 years (range, 32–92 years). The total cohort sex consisted of 681 females (52.3 %), 618 males (47.5 %), and 1 unidentified sex. The average BMI of the total cohort was 32 kg/m^2 (range, 15–54 kg/m^2).

Adverse events

There were 111 total adverse events experienced among 87 patients (Table 1). The most experienced adverse event was requiring an MUA postoperatively, which was 39 out of 111 adverse events experienced (35.1 %). A ruptured quadriceps tendon was the next most experienced event at 13 out of 111 events (11.7 %). Irrigation and debridement with polyethylene change was next at 9 out of 111 events (8.1 %), and revision also had 9 out of the 111 events (8.1 %). Arthrotomy was found to have 8 out of the 111 events (7.2 %). Wound dehiscence was accountable for 7 of the 111 events (6.3 %), and deep vein thrombosis was accountable for 6 out of 111 events (5.4 %). The three categories of ruptured patellar tendon, periprosthetic fracture, and infection each accounted for 4 of the 111 events (3.6 % each). Irrigation and debridement without polyethylene change accounted for 3 out of 111 events (2.7 %), and cellulitis also accounted for 3 out of 111 events (2.7 %). Finally, the two separate events of wound drainage and patellar fracture each had 1 instance out of 111 (0.9 % each).

Table 1: Adverse events experienced postoperatively by category.

Adverse event	Events experienced (n=111)	Percentage of total events
Manipulation under anesthesia	39	35.1 %
Ruptured quadriceps tendon	13	11.7 %
Irrigation and debridement with poly change	9	8.1 %
Revision	9	8.1 %
Arthrotomy	8	7.2 %
Wound dehiscence	7	6.3 %
Deep vein thrombosis	6	5.4 %
Ruptured patellar tendon	4	3.6 %
Periprosthetic fracture	4	3.6 %
Infection	4	3.6 %
Irrigation and debridement without poly change	3	2.7 %
Cellulitis	3	2.7 %
Wound drainage	1	0.9 %
Patellar fracture	1	0.9 %

MUA demographics

When examining the group of patients who experienced MUA (n=39), the average age was 59 years (age range 32–80 years). The sex of the individuals who experienced an MUA was 71.8 % female (n=28 out of 39). The percentage of those in this group with a BMI more than 30, which is considered obese by the NIH, was 79.5 % (n=31 out of 39).

Total cohort vs. MUA

Overall, 39/1,300 individuals (0.03 %) underwent an MUA. The results of the total cohort were then compared to the subset of individuals who experienced an MUA. Utilizing chi-square analysis, the odds of MUA occurring among females was found to be 2.36 times greater than the odds of MUA occurring among males (p=0.014). Mann–Whitney U testing found that those experiencing MUAs were statistically significantly younger than the larger patient cohort (p=0.019, U=19,173.50). BMI was analyzed with a chi-square analysis, and although those with a BMI above 30 had 1.99 times greater odds of needing an MUA, these results were not found to be statistically significant (p=0.067, OR=1.99, CI 95 %). Of MUA adverse events, 76.9 % (n=30) were following a TKA and 23.1 % were following a UKA. When considering the entire sample (n=1,300), there was a statistically significant 12.6 times greater odds that an MUA occurred among those who had a TKA vs. UKA (p<0.001). After analysis of only those who had experienced an adverse event (n=87), similar results were found in that patients who underwent a TKA had 4.67 times greater odds of needing an MUA than those who underwent a UKA (p<0.001).

Discussion

Robot-assisted knee arthroplasty will continue to play a large role in the field of orthopedics for various reasons, but the outcomes must continue to be analyzed to seek out room for improvement. This 1300-patient retrospective review found that MUA was the most experienced adverse event among this cohort of robotic-assisted knee arthroplasties. Younger patients and females were at a statistically higher risk of needing an MUA, but obese BMI was not found to have statistical significance in relation to needing an MUA.

The fact that only a single surgeon's cases were utilized helped to reduce the effects of variance in technique and threshold for MUA determinants. Performing these cases utilizing a single robot interface further standardized the study.

As stated, females were found to be at a statistically significant higher risk of needing an MUA after robotic knee arthroplasty. The muscular and pelvic structure of the female anatomy must be considered in these results.

Younger patients may have been at a higher risk of requiring an MUA due to decreased muscular laxity compared to that of older patients. This result has also been seen in a nonrobotic study, in which 1729 TKA patients were reviewed and the average age for those who needed an MUA was 55.2 years compared to the cohort age of 65.3 years ($p<0.001$) [6].

Regarding BMI, the relationship between having an obese BMI and an increased need for MUA postoperatively has varied in nonrobotic studies [6]. Interestingly, the lack of statistical significance in this study could suggest that there may be a protective component in those with an obese BMI, potentially avoiding the need for an MUA following knee arthroplasty if a robot is utilized. However, to elucidate this, further studies would be required.

TKAs were found to have led to a higher odds of needing an MUA than UKAs, which as previously mentioned was discovered in a previous study [5].

Osteopathic considerations

Future osteopaths should utilize this data to help determine if there is any role for osteopathic manipulative medicine to aid in the reduction of MUAs following robotic-assisted arthroplasty because this was the most common adverse event in this study. Creating standardized protocols focusing on the hip, knee, and ankle may be beneficial in preventing the adverse events that require an MUA.

For example, a pre-posttest randomized experiment of 50 patients discovered that myofascial release played a significant role in decreasing myofascial trigger points in postoperative total knee replacement patients [7]. Additionally, a prospective, single-blinded, two-group, match-controlled outcome study of 76 patients provided postoperative osteopathic manipulative treatment (OMT) on days 2 through 5 and discovered a 20.0 % earlier time to stair climbing and a 43.0 % farther ambulation on day 3 when compared to a control group [8]. Incorporating both myofascial release and other OMT treatment into patient populations in whom this study found to have a higher odds of needing an MUA, females and younger individuals, may be a way to help decrease this incidence.

Limitations

The generalization of this study may be limited by the variation of physicians' thresholds for determining whether a patient needs an MUA postoperatively. Thresholds to perform an MUA may be based on decreased ROM, contracture, patient therapy participation, and the patient's goals for quality of life postoperatively. A standard threshold protocol established for determining a patient's need for an MUA would decrease this variability.

The nature of this study as a retrospective analysis was also a limitation on numerous factors. Physical therapy requirements were not standardized across patients in this study, therefore potentially impacting the need for an MUA. Additionally, race was not taken into consideration for this study due to the lack of data being obtained for all of the patients at the point of care. Future studies should consider formulating a standardized physical therapy program as well as exploring the impact of other demographic factors such as race.

Because there was no comparison nonrobotic group utilized in this study, future studies may benefit from adding this to perform a true comparison. When looking to compare this study to previous studies looking at MUA incidence rates, a problem commonly encountered was the lack of specification as to the composition of whether the study was robotic, nonrobotic, or a combination of the two.

Another limitation of this study includes the cohort patient size of n=1,300. This is something that must be considered when applying these results to a larger scale population. This led to a small (n=39) for those who experienced an MUA and even fewer for the other adverse events. This small sample size limited the analysis to those who experienced an MUA. Future studies evaluating a larger population of patients experiencing adverse events may be able to better analyze these undesirable outcomes requiring follow-up procedures like a MUA.

Additionally, selection bias may have played a significant role based on surgeon selection of patients when determining whether or not a knee arthroplasty was needed or whether or not robotic assistance was utilized.

Finally, when utilizing these results in the future, one must also consider the cost-to-benefit ratio of investing in a robotic system vs. the cost burden of patients experiencing an adverse event such as additional surgical procedures like an MUA or extending hospital stay for additional treatment.

Conclusions

There were 111 adverse events experienced among 1,300 patients who underwent knee arthroplasty, either UKA or TKA, performed by a single surgeon with a standardized robotic surgical system. MUA was the most experienced adverse event. Females and younger patients were at a statistically significant higher risk of needing an MUA. Those with a BMI less than 30, however, were not found to have a statistically significant risk of needing an MUA after robotic-assisted knee arthroplasty. Out of the entire cohort, those who received a TKA were at 12.6 times greater odds of needing an MUA postoperatively than those who received a UKA ($p<0.001$).

Further research is needed to determine the potential for robotic-assisted knee arthroplasty to contribute to a reduction in the need for MUA in those with a BMI over 30 in comparison to nonrobotic surgeries. Further studies may also compare the number and type of adverse events for this robotic study to those of nonrobotic cases to see if this technology contributed to a reduction in adverse events. Finally, as the need for MUA was the most notable postoperative intervention examined in this study, there may be a significant role of OMT in reducing its necessity. Future studies should examine this potential.

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