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Article

Trends and Patterns of Robotic Total Knee Arthroplasty: 2016–2019

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Abstract: This study investigates the trends and patterns of robotic-assisted total knee arthroplasty (RA-TKA) from 2016 to 2019. Using data from the Nationwide Inpatient Sample (NIS), we analyzed demographics, prevalence of comorbidities, total cost, and length of stay (LOS) for 88,415 RA-TKA cases identified during this period. Our analysis revealed a significant increase in RA-TKA procedures, from 5,330 in 2016 to 39,495 in 2019. Patients undergoing RA-TKA were slightly younger, with an average age of 66.2 years. The average hospital stay was 1.89 days, and total charges averaged \$65,891. We also examined various comorbidities and demographic factors, including race, median household income, and hospital teaching status. The results show that RA-TKA usage in the US has grown substantially, with specific demographic and clinical patterns. Further studies on the long-term outcomes of RA-TKA are needed to fully understand the benefits of this technology.

Keywords: robotic surgery; total knee arthroplasty; robotic knee surgery; big data

1. Introduction

Robotic-assisted total knee arthroplasty (RA-TKA) has been increasingly adopted in orthopedic surgery, driven by its potential to enhance precision and improve patient outcomes. The use of robotic systems in surgery allows for more accurate implant positioning and alignment, potentially leading to better functional outcomes and longer implant longevity. Studies suggest long-term advantages of RA-TKA, including faster recovery and improved knee mobility [1–4]. Despite these benefits, the need for RA-TKA and its full benefits remain under discussion, particularly regarding cost-effectiveness and accessibility.

When evaluating RA-TKA, immediate postoperative benefits such as reduced complications, hospital costs, and shorter hospital stays are crucial. Knee arthroplasty is a common and financially impactful procedure, with 718,000 hospitalizations in the US in 2011 alone [5,6]. The economic burden associated with knee arthroplasty is significant, necessitating an evaluation of newer technologies like RA-TKA to determine their value in healthcare systems.

The number of TKAs has been rising and is projected to reach 3.48 million annually in the U.S. by 2030 [7]. This increase is driven by an aging population, rising obesity rates, and higher patient expectations for mobility and quality of life. Despite advancements in TKA techniques and materials, up to 20% of patients remain dissatisfied postoperatively [8–10]. This dissatisfaction is often due to persistent pain, limited function, and complications. Improvements in surgical precision, such as those offered by RA-TKA, may enhance outcomes and reduce these dissatisfaction rates.

The integration of robotic systems in TKA aims to minimize human error, improve reproducibility, and enhance the precision of bone cuts and implant positioning. By facilitating better

alignment and balance of the knee joint, RA-TKA may lead to improved functional outcomes and patient satisfaction. However, the adoption of robotic technology in knee arthroplasty is associated with higher initial costs, which include the purchase and maintenance of robotic systems, as well as training for surgical teams [11–13].

Research Questions

This study aims to address the following research questions: What are the demographic and clinical characteristics of patients undergoing RA-TKA? How has the adoption of RA-TKA changed from 2016 to 2019? What are the prevalence rates of comorbidities among patients undergoing RA-TKA? What are the trends in total cost and length of stay (LOS) for patients undergoing RA-TKA?

2. Methods

Data Source

This study utilized the Nationwide Inpatient Sample (NIS), the largest publicly available all-payer inpatient care database in the United States. The dataset comprised 88,415 RA-TKA cases from January 1, 2016, to December 31, 2019.

Patient Identification and Exclusions

RA-TKA procedures were identified using specific ICD-10-PCS codes. Clinical outcomes, including in-hospital mortality, length of stay, complications, and hospitalization costs, were analyzed.

Outcome Measures

RA-TKA procedures were identified using specific ICD-10-PCS codes. Clinical outcomes, including in-hospital mortality, length of stay, and hospitalization costs, were analyzed.

Ethical Considerations

The study was conducted under exempt status granted by the institutional review board, and the requirement for informed consent was waived due to the de-identified nature of the NIS dataset.

3. Results

Demographics of Cohort Population

The demographic analysis of the RA-TKA cohort is summarized in Table 1. The average age of RA-TKA patients was 66.2 ± 9.46 years. The gender distribution showed that 58.8% of the patients were female. Payer distribution indicated that 54.4% were covered by Medicare, 3.1% by Medicaid, 38.2% by private insurance, and 4.2% by other sources, including self-pay.

Table 1. Demographics of the RA-TKA cohort population.

Parameter	RA-TKA (%)
Total Surgeries	88,415
Average Age (years)	66.2 ± 9.46
Female	58.8
Payer - Medicare	54.4
Payer - Medicaid	3.1
Payer - Private	38.2
Payer - Other (including self-pay)	4.2

Trend Analysis of RA-TKA Procedures by Year

The trend analysis revealed a significant increase in RA-TKA procedures from 2016 to 2019. In 2016, there were 5,330 RA-TKA procedures, increasing to 39,495 by 2019. This demonstrates a growing adoption

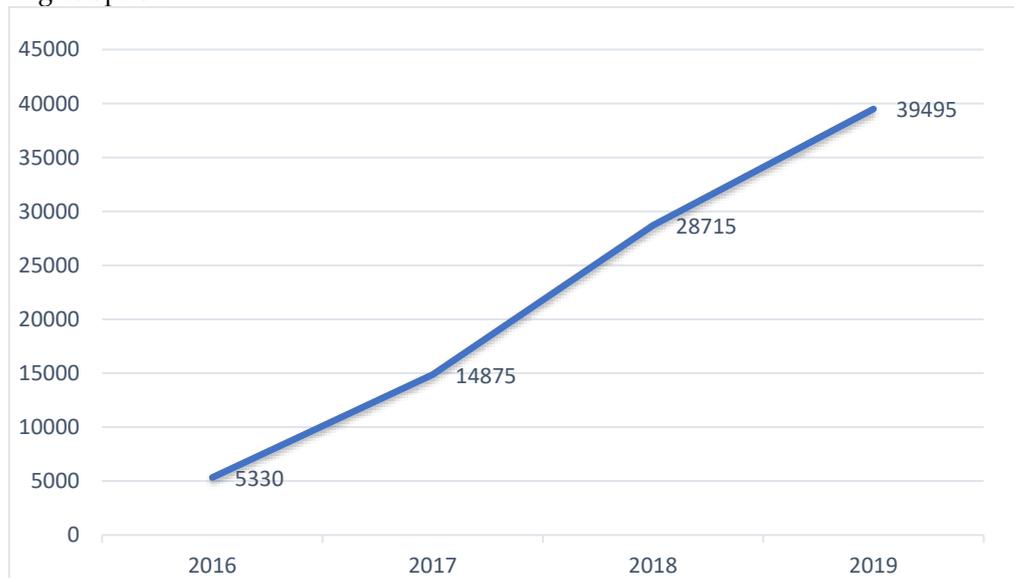


Figure 1. Trend Analysis of RA-TKA Procedures by Year.

Prevalence of Comorbidities in Patients Who Underwent RA-TKA

The prevalence of various comorbidities in the RA-TKA cohort is shown in Table 2. The most common comorbidities included hypertension (57.6%), dyslipidemia (44.1%), and Type 2 diabetes (19.2%).

Table 2. Prevalence of comorbidities in patients who underwent RA-TKA.

Comorbidity	RA-TKA (%)
Hypertension	57.6
Dyslipidemia	44.1
Sleep Apnea	13.8
Chronic Anemia	4.9
Alcohol Abuse	0.7
Osteoporosis	3.7
Mental Disorders	27.9
Parkinson Disease	0.5
Type 2 Diabetes	19.2
Renal Disease	5.5
Congestive Heart Failure	1.2
Chronic Lung Disease	5

Race Distribution

The race distribution among RA-TKA patients is summarized in Table 3. The majority of patients were White (83.8%), followed by Black (6.2%), Hispanic (5.3%), and other races.

Table 3. Race distribution in the RA-TKA cohort.

	Frequency	Percent
White	71,800	81.2
Black	5,355	6.1
Hispanic	4,560	5.2
Asian or Pacific Islander	1,200	1.4
Native American	945	1.1
Other	1,820	2.1

Total	85,680	96.9
Missing	2,735	3.1
Total	88,415	100

Median Household Income National Quartile for Patient ZIP Code

The distribution of median household income for RA-TKA patients is shown in Table 4. Patients were evenly distributed across income quartiles.

Table 4. Median household income national quartile for patient ZIP Code.

Income Quartile	Frequency	Percent
0-25th percentile	17,970	20.3
26th to 50th percentile (median)	22,315	25.2
51st to 75th percentile	23,740	26.9
76th to 100th percentile	23,080	26.1
Total	87,105	98.5
Missing	1,310	1.5
Total	88,415	100

Location/Teaching Status of Hospital

The distribution of hospital location and teaching status for RA-TKA procedures is shown in Table 5. The majority of procedures were performed in urban teaching hospitals (61.0%).

Table 5. Location and teaching status of hospitals performing RA-TKA procedures.

Hospital Type	Frequency	Percent
Rural	5,805	6.6
Urban non-teaching	28,705	32.5
Urban teaching	53,905	61
Total	88,415	100

Total Cost and Length of Stay (LOS)

The average length of stay for patients undergoing RA-TKA was 1.89 days, with an average total cost of \$65,891.

Table 6. Total cost and length of stay for RA-TKA procedures.

Metric	Value
Length of stay (days)	1.89 ± 1.70
Total charges (\$)	65,891 ± 41,042

4. Discussion

The study found that RA-TKA has seen significant growth from 2016 to 2019. The demographic analysis shows that the majority of patients are White, covered by Medicare, and treated in urban teaching hospitals. The prevalence of common comorbidities and the associated costs and length of stay were also detailed.

The trends indicate a shift towards the adoption of robotic technology in knee arthroplasty, likely driven by the potential benefits of enhanced precision and better clinical outcomes [14,15]. Despite the higher initial costs, RA-TKA may be cost-effective in the long term due to reduced postoperative complications and shorter hospital stays [16,17]. The reduced length of stay can alleviate bed occupancy pressures in hospitals and decrease the risk of hospital-acquired infections [18].

Furthermore, the study highlights that RA-TKA patients tend to be younger, which may reflect a preference for using advanced technology in patients with potentially longer life expectancy and higher activity demands. The lower prevalence of certain comorbidities in the RA-TKA cohort

suggests that this population may be healthier overall, which could contribute to the observed outcomes [19,20].

The distribution of RA-TKA procedures across different types of hospitals reveals that urban teaching hospitals are more likely to adopt this technology. This could be due to the higher availability of resources and specialized surgical teams in teaching hospitals [21]. Additionally, the even distribution of median household income among RA-TKA patients indicates that this technology is accessible to a broad socioeconomic spectrum [22].

However, several limitations exist in this study. The NIS dataset is limited to in-hospital data and does not capture long-term outcomes [23–26], which are crucial for evaluating the full impact of RA-TKA. Additionally, the retrospective nature of the study and reliance on administrative data may introduce coding errors and biases [27,28].

Despite these limitations, the study provides valuable insights into the adoption and impact of RA-TKA. As robotic technology continues to evolve, ongoing research and long-term follow-up studies are necessary to fully understand its benefits and cost-effectiveness in knee arthroplasty [29,30].

5. Conclusions

RA-TKA usage in the US has increased significantly from 2016 to 2019, with specific demographic and clinical patterns. The adoption of robotic technology in knee arthroplasty shows promising trends, with potential benefits in precision, reduced complications, and shorter hospital stays. Further studies on both short- and long-term outcomes of RA-TKA are needed to fully understand the benefits of this technology.

List of Abbreviations (A-Z)

HCUP: Healthcare Cost and Utilization Project
ICD-10: International Classification of Diseases, 10th Revision
LOS: Length of Stay
NIS: Nationwide Inpatient Sample
SPSS: Statistical Package for the Social Sciences
TKA: Total knee Arthroplasty

Conflict of interest: None.

Funding: None.

Ethical approval: The study was conducted under exempt status granted by the institutional review board, and the requirement for informed consent was waived due to the de-identified nature of the NIS dataset.

Informed consent: Irrelevant.

Acknowledgements: Irrelevant.

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