Arthroplasty Today 21 (2023) 101152

Contents lists available at ScienceDirect

Arthroplasty Today

journal homepage: http://www.arthroplastytoday.org/

Original Research

Projections and Epidemiology of Revision Hip and Knee Arthroplasty in the United States to 2040-2060

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ARTICLE INFO

Article history:
Received 1 October 2022
Received in revised form
29 March 2023
Accepted 23 April 2023
Available online xxx

Keywords:
Revision total joint arthroplasty
Total hip arthroplasty
Total knee arthroplasty
Projections
CMS Medicare Part-B

ABSTRACT

Background: National projections of future joint arthroplasties are useful in understanding the changing burden of surgery and related outcomes on the health system. The aim of this study is to update the literature by producing Medicare projections for revision total joint arthroplasty procedures from 2040 through 2060.

Methods: The study uses 2000-2019 data from the CMS Medicare Part-B National Summary and combines procedure counts using CPT codes for revision total joint arthroplasty procedures. In 2019, revision total knee arthroplasty (rTKA) and revision total hip arthroplasty (rTHA) procedures totaled 53,217 and 30,541, respectively, forming a baseline from which we generated point forecasts between 2020 and 2060 and 95% forecast intervals (FI).

Results: On average, the model projects an annual growth rate of 1.77% for rTHAs and 4.67% for rTKAs. By 2040, rTHAs were projected to be 43,514 (95% FI = 37,429-50,589) and rTKAs were projected to be 115,147 (95% FI = 105,640-125,510). By 2060, rTHAs was projected to be 61,764 (95% FI = 49,927-76,408) and rTKAs were projected to be 286,740 (95% FI = 253,882-323,852).

Conclusions: Based on 2019 total volume counts, the log-linear exponential model forecasts an increase in rTHA procedures of 42% by 2040 and 101% by 2060. Similarly, the estimated increase for rTKA is projected to be 149% by 2040 and 520% by 2060. An accurate projection of future revision procedure demands is important to understand future healthcare utilization and surgeon demand. This finding is only applicable to the Medicare population and demands further analysis for other population groups.

Introduction

Modern total joint arthroplasty (TJA) has been largely successful, providing patients with improved function and quality of life. Primary TJA has become one of the most performed procedures by orthopedic surgeons, with the number of procedures performed continuing to increase [1–4]. Indications and patient demographics of patients undergoing primary TJA have changed over the decades with improvements in implant survivorship [1,5]. Given the overall success of primary TJA procedures, the number of these procedures has increased and is expected to continue increasing [1,4,6].

Sloan et al. utilized the National Inpatient Sample (NIS) from 2000 to 2014 to project the number of primary TJAs that would be performed by the year 2030. The study found an increasing number of primary TJAs performed from the sample data. The authors projected that by 2030, primary total hip arthroplasties (THAs) would grow to 635,000 procedures per year, while primary total knee arthroplasties (TKAs) would grow to 1.26 million procedures per year in the United States [4]. Between 1988 and 2000, only 8 to 28 states reported inpatient discharges to the NIS, limiting previous studies based upon the NIS database [7]. Moreover, there has been increasing evidence that outpatient aseptic revision TJA (rTJA) is a

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https://doi.org/10.1016/j.artd.2023.101152

safe option for patients without an increased risk of complications [8]. Therefore, these outpatient rTJA patients may not be accounted for in the NIS database and would lead to lower projection rates. The Medicare Part B database includes claims data from all states and includes outpatient encounters, which would account for outpatient aseptic rTJA [9].

Although modern primary TJA have shown excellent implant survivorship and patient-reported outcomes, they are not without risk of requiring revision surgery. As the indications for primary TJA have expanded, revision rates are projected to increase in the future [1,10]. Numerous studies have examined projections of primary TJA, but there is a paucity of literature on future rTJA projections. Kurtz et al. utilized NIS data to form projections of rTJA. They reported that compared to 2005, the number of hip revision procedures is projected to double by 2026, while the demand for knee revisions is expected to double by 2015 [1]. Schwarz et al. more recently examined NIS data from 2002-2014 for rTJA. They projected that revision THA (rTHA) would increase between 43% and 70%, while revision TKA (rTKA) would increase from 78% to 182% between 2014 and 2030 [10]. Compared to primary TJA, rTKAs have increased rates of complications, longer length of stay, prolonged surgical time, higher blood loss, increased need for transfusion, and higher rates of prosthetic joint infections [11–13]. These burdens of revision surgery may lead to increased resource utilization, cost of care, and stress on healthcare systems [14–17]. As we begin to approach the boundaries of these previous projections in 2030, an updated rTJA projection relying on recent national data is needed to better and more accurately quantify the number of future rTJA.

The purpose of this study is to update the literature by producing Medicare projections for rTJA procedures until 2040 and 2060 by using past utilization data from the Center for Medicare and Medicaid Services (CMS) Medicare Part B National Summary. We hypothesized that the demand for rTHA and rTKA in the United States will increase substantially over the next 4 decades.

Material and methods

This study utilized 2000-2019 data from the CMS Medicare/Medicaid Part B National Summary [18]. We identified rTHA and rTKA procedures using current procedural terminology (CPT) codes previously used in the literature. [19–21] The CPT codes used were divided into 2 key categories: (1) rTHAs and (2) rTKAs (Appendix 1). Each procedure with the listed CPT codes was recorded for every year from 2000 to 2019 (Appendix 2). Since these procedure counts included only fee-for-service (FFS) patients and not Medicare Advantage (MA) patients, we uplifted numbers from the Part B National Summary using a ratio of FFS to MA patients provided by the Kaiser Family Foundation [22]. Uplifting was done by utilizing the ratio of FFS to MA to extrapolate the total number of procedures performed. The number of revision procedures collected for each year is recorded in Appendix 3.

Following this adjustment, we used the 20-year period of procedure counts from 2000 to 2019 for rTHA and TKA to generate log-linear (exponential growth) time series forecasts between 2020 and 2060. Kurtz et al. assessed projections from 2005 to 2030 utilizing data from 1990 to 2003 [1]. Since we utilized a wider range of data from 2000 to 2019, our projection model was used to forecast revision rates until 2060. We generated point forecasts and 95% forecast intervals (FI) for each year over the forecasted time period. This model replicates similar methods used in the projection of future rTJA volume [4,10]. The year 2020 was excluded from our baseline procedure counts due to the COVID-19 pandemic's effects on surgical volume. Therefore, the projections in this study can be considered prepandemic. General linear model methods in the form of Poisson and negative binomial regression as well as autoregressive integrated moving average (ARIMA) were used for validation. When comparing these models to our ordinary least square (OLS) regression model, the OLS model had the best fit. We utilized the total procedure counts for rTHAs and rTKAs to generate log-linear projected yearly growth rates. The yearly growth rates were used to predict yearly growth over 5-year periods. Revision procedure projections were calculated and recorded over 5-year periods.

Statistical analysis was performed using the R programming environment version 4.1.2 (R Core Team 2021). R: a language and environment for statistical computing. Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900,051-07-0, URL http://www.R-project.org/.

Results

Utilizing the log-linear regression model yielded annual projections and growth rates for both rTHA and rTKA. Between the years 2000 and 2019, the number of rTHAs in the Medicare population increased from 22,313 to 30,541, which represents a 36.87% cumulative increase. Medicare patients undergoing rTKAs saw a more drastic increase during the same time period, with 21,923 procedures in 2000 and 53,217 procedures in 2019, which represented a 142.74% increase. These results are further elaborated in Table 1. Based on our log-linear regression model demonstrated in Table 2, rTHAs were projected to increase by 1.77% (95 FI = 1.41%-2.12%) annually. rTKAs were projected to increase by 4.67% (95% FI = 4.46%-4.88%) annually. A comparison of our models and the models utilized by Kurtz et al. and Schwartz et al. are highlighted in Appendix 4.

Table 3 demonstrates the projected increase in rTHAs and rTKAs from 2020 to 2060 in 5-year periods. Based on the yearly projected increase for rTHAs, an estimated increase of 9.15% is expected for each 5-year period after 2020. Similarly, based on yearly projected increases for rTKAs, the projected increase for each 5-year period after 2020 is 25.62%. By 2040, the demand for rTHAs was projected to be 43,514 (95% FI = 37,429-50,589) with a cumulative growth of 41.94% when compared to 2020 projections.

Table 1
Revision THAs and TKAs volumes with percentage change and cumulative growth over 5-year periods.

Year (5-year intervals)[a]	Revision THAs			Revision TKAs		
	Adjusted volume	% Change between each 5-year period	Cumulative growth (base = 2000)	Adjusted volume	% Change between each 5-year period	Cumulative growth (base = 2000)
2000	22,313	-	-	21,923	-	-
2005	22,852	2.41%	2.41%	28,887	31.76%	31.76%
2010	24,495	7.19%	9.78%	35,412	22.59%	61.53%
2015	28,249	15.33%	26.60%	42,333	19.54%	93.09%
2019[a]	30,541	8.11%	36.87%	53,217	25.71%	142.74%

[a] 2015-2019 represents a 4-year period.

Table 2
Log-linear OLS regression estimates and growth rates with 95% confidence intervals (formulated using normal approximation).

Procedure type	Intercept	Trend estimate	Standard error	Projected annual growth (%) − confidence intervals obtained by normal approximation.		
y	$\widehat{\beta_0}$	$\widehat{\beta_1}$	$s.e.\ of\ \widehat{\beta_1}$	$Average = (\exp(\widehat{\beta_1}) - 1)*100$	$95\%\ CI\ (lower) = (\exp(\widehat{\beta_1} - (1.96*\widehat{SE})))*100$	$95\%\ CI\ (upper) = (\exp(\widehat{\beta_1} + (1.96*\widehat{SE})))*100$
No. of revision THAs	9.9629	0.0175	0.0018	1.77%	1.41%	2.12%
No. of revision TKAs	9.7836	0.0456	0.0010	4.67%	4.46%	4.88%

During this time period, the demand for rTKAs was projected to be 115,147 (95% FI = 105,640-125,510) with a cumulative growth of 149.02% compared to 2020 projections.

By 2060, the demand for rTHAs was projected to be 61,764 (95% FI = 49,927-76,408), with a cumulative growth of 101.47% when compared to 2020 projections. Similarly, the demand for rTKAs was projected to be 286,740 (95% FI = 253,882-323,852) with a cumulative growth of 520.11% compared to 2020 projections. The relative difference in rate of growth between rTHA and rTKA from 2000 to 2060 can be appreciated in Figure 1.

Discussion

Over the last several years, the demand for rTJAs has continued to increase and is expected to continue increasing through 2030 [1,10]. When using our model, the number of rTHAs in the Medicare population is expected to double by 2060 while the number of rTKAs is expected to double by 2040 compared to 2020 rates. These drastic increases over the coming decades will place a heavy burden on the healthcare system and existing arthroplasty surgeons [17]. During the data collection timeframe of 2000 to 2019, there was a cumulative increase in the number of rTJAs performed. Although no single cause can be attributed to the increase in rTJAs, changing patient demographics could play a factor in this increase. As modern implants have improved, there has been an increase in the number of younger patients undergoing TJAs [23]. With a younger population receiving TJAs, implants can be subject to the higher activity level of this patient demographic compared to older patients. This increased activity level can cause early failure of implants and lead to an increased risk of undergoing rTJA in the future [24–26]. With the majority of revision procedures occurring in patients over 65 years old and life expectancy in the United States increasing over the last few decades, we can expect this number to rise in the future as younger patients undergoing TJAs have implant failures [23,27–29]. Similarly, an increased number of patients with obesity or preoperative opioid use have undergone primary TJAs. Both of these patient groups have an increased risk of requiring revision surgeries, likely further increasing the demand for rTJAs [30–36].

Similar trends in rTJA have been noted in other studies [1,10]. These studies examined the projections of rTJA in the future using the NIS database. While these studies demonstrated similar trends to our study, they have limitations. Although the NIS database allowed these studies to assess patients under 65 years old, it is limited since its sample represents only 20% of nonfederal hospital discharges in the United States. To extrapolate nationally, this data had to be scaled, which may introduce error. In addition, in 1990, only 11 states participated in the NIS. This number has grown to 37 states that were participating by 2005, which has since grown to 48 states in 2018 [37,38]. Although the number of participating states has grown, previous studies such as Kurtz et al. that relied on earlier data from the NIS were likely limited in their accurate representation of the number of rTJA across the country. In addition, studies using the NIS relied on International Classification of Diseases (ICD) coding, which has been shown to provide inaccurate details and may lead to misidentification of procedures [39,40]. Nearly 98% of US individuals ≥65 years of age receive Medicare insurance, which provides a more complete understanding of rTJA in this patient population [9]. Moreover, as ICD-9 and ICD-10 codes are incorporated into databases, they can hinder the accuracy of joint arthroplasty registries, which would not occur when identifying procedures by CPT codes [41].

Our study was able to utilize national data through the CMS Medicare Part B National Summary. Therefore, it was not necessary to scale our data. Additionally, we utilized the Kaiser Family

Table 3
Revision THAs and TKAs projections with low and high 95% confidence intervals and cumulative growth.

Year (5-year intervals)	Revision THAs			Revision TKAs		
	Projection	95% Forecast interval	Cumulative growth (base = 2020)	Projection	95% Forecast interval	Cumulative growth (base = 2020)
Forecast (OLS)						
2020	30,657	27,569-34,090	-	46,240	43,516-49,135	
2025	33,462	29,846-37,516	9.15%	58,087	54,408-62,014	25.62%
2030	36,524	32,237-41,381	19.14%	72,968	67,939-78,370	57.80%
2035	39,866	34,759-45,723	30.04%	91,663	84,750-99,140	98.23%
2040	43,514	37,429-50,589	41.94%	115,147	105,640-125,510	149.02%
2045	47,496	40,264-56,028	54.93%	144,648	131,604-158,984	212.82%
2050	51,842	43,280-62,099	69.11%	181,707	163,879-201,473	292.96%
2055	56,586	46,495-68,867	84.58%	228,260	204,002-255,403	393.64%
2060	61,764	49,927-76,408	101.47%	286,740	253,882-323,852	520.11%

Foundation data to adjust for MA patients in our population by utilizing the ratio of FFS to MA patients. This method allowed for a more accurate representation of the current number of rTJAs taking place in the United States for patients 65 years or older. Our model was based on Medicare data from 2000 to 2019. This 20-year span of data provided a robust cohort of patients compared to prior publications [1,10]. The large span of time over which the regression modeling was based upon will provide more accurate projections of rTJA.

Projecting the number of revision surgeries that will be needed in the future has several benefits. Projections allow for more accurate budgeting and allocation of resources to these procedures as they continue to increase in number. It is estimated that the projected cost of revision surgeries for prosthetic joint infections in the United States is over $1.6 billion and is expected to continue to increase [42]. Additionally, revision surgeries are labor-intensive and require additional expertise and resources to successfully perform. Revision surgeries are costly procedures with prolonged surgical time and longer length of stay compared to primary TJA and place a huge financial strain on the healthcare system [43,44]. By providing projections that show these surgeries will be increasing in number, stakeholders can better prepare and invest in future resources to match the increased demand [45,46]. Moreover, this projected increase in volume is important to consider as surgeon reimbursement continues to decrease while payments to hospitals continues to increase [47].

Although we aimed to produce an accurate projection of rTJA, our study possessed some limitations. We utilized the CMS Medicare database to extrapolate future demand for rTJA. While this database was able to assess a significant population undergoing TJA, it primarily accounted for patients over 65 years old. Younger patients have higher revision rates; thus, the CMS data may specifically underestimate revision numbers on the basis of excluding younger patients [48,49]. However, our trends match similar reports on rTJA, with rTKA outpacing the rate of rTHA [1]. These trends can be appreciated in Appendix 4 when comparing our rates to those of other papers. Our models were based on CMS data, while the remaining studies used the NIS database. Compared to our log-linear OLS model, Schwartz et al. demonstrated similar rates of growth when using a linear OLS model. Both Schwartz and Kurtz had higher rates of growth when comparing our general linear model model to theirs. Variations in rates seen between these 3 studies may be due to the database utilized for the regression models and our 20-year baseline data used for extrapolation compared to the 12 to 13-year baseline data used by other studies [1,10]. Importantly, our projection model did not directly measure changes in technology and evolving patient demographics. TJA technology has constantly evolved over the years with changes to polyethylene components, implant design, and evolving surgical techniques [50–53]. These changes have led to increased survivorship of TJA, which may affect the number of patients requiring rTJA in the future. These factors may lead to future variability and inaccuracies in our projection models when assessing projections 40 years into the future. Moreover, since we utilized CPT codes to identify TJA procedures in the CMS database, we are unable to distinguish between cemented and uncemented implants. Alternative models including the ARIMA were assessed in our study to partially account for the above phenomena. However, some literature suggests that including an extensive range of baseline raw data subdivided into smaller time periods may provide improved accuracy of the model [54,55]. We were able to use 20 years of nationwide data to extrapolate projections, which provides an indirect measure of these changes.

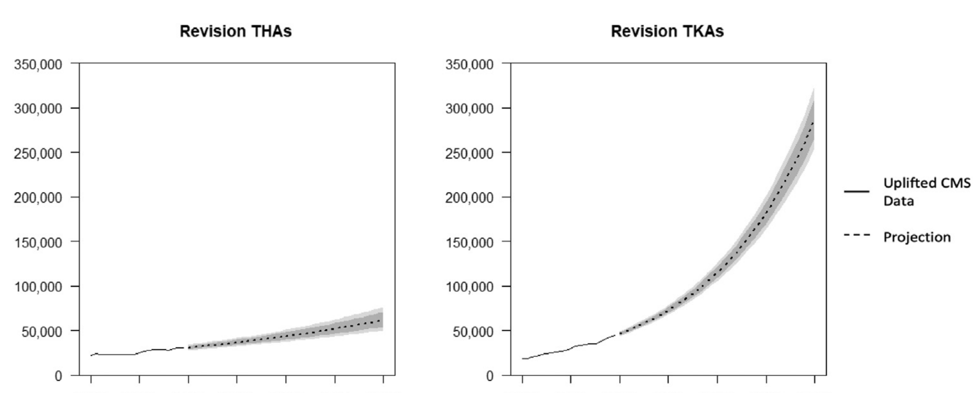

Figure 1. Revision THAs and TKAs projected between 2020 and 2060 using log-linear model. The black line represents uplifted CMS data from 2000-2019, the dotted line represents point forecast while the red area indicates the 95% confidence intervals.

Conclusions

Projecting the number of rTJAs is difficult given the constant changes in implant design, implant materials, and patient demographics. An accurate projection of future revision procedure demands is important to understand future healthcare utilization and surgeon demand. With an increasing demand for rTJA, the need for surgeons capable and willing to perform these procedures is of the utmost importance. Our study was able to build on previous methods used to form a comprehensive model to predict the future increase in rTJAs in the Medicare population. Future studies should examine the utility of other models, such as ARIMA, to possibly provide more accurate projections if given a more extensive range of baseline data.

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.2023.101152.

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Appendix 1
CMS revision CPT codes and associated description.

Revision THA CPT codes	CMS description
27138	Revision of total hip arthroplasty; femoral component only, with or without allograft
27134	Revision of total hip arthroplasty; both components, with or without autograft or allograft
27137	Revision of total hip arthroplasty; acetabular component only, with or without autograft or allograft
Revision TKA CPT codes	CMS description
27486	Revision of total knee arthroplasty, with or without allograft; 1 component
27487	Revision of total knee arthroplasty, with or without allograft; femoral and entire tibial component

Appendix 2
Revision total hip arthroplasty (THA) and revision total knee arthroplasty (TKA) volumes between 2000 and 2019 grouped by CMS CPT codes.

Year	Revision THAs			Revision TKAs		
	Volume (CPT: 27134 + 27137 + 27138)	YOY change	Annual percentage change	Volume (CPT: 27486 + 27487)	YOY change	Annual percentage change
2000 - CMS	18,520	-	-	15,103	-	-
2001 - CMS	20,546	2026	10.94%	15,851	748	4.95%
2002 - CMS	19,517	−1029	−5.01%	17,326	1475	9.31%
2003 - CMS	19,930	413	2.12%	18,229	903	5.21%
2004 - CMS	20,333	403	2.02%	20,033	1804	9.90%
2005 - CMS	19,881	−452	−2.22%	20,859	826	4.12%
2006 - CMS	19,017	−864	−4.35%	20,691	−168	−0.81%
2007 - CMS	18,779	−238	−1.25%	20,927	236	1.14%
2008 - CMS	18,175	−604	−3.22%	20,983	56	0.27%
2009 - CMS	17,982	−193	−1.06%	21,501	518	2.47%
2010 - CMS	18,616	634	3.53%	22,338	837	3.89%
2011 - CMS	20,109	1493	8.02%	24,239	1901	8.51%
2012 - CMS	20,272	163	0.81%	24,521	282	1.16%
2013 - CMS	20,608	336	1.66%	24,576	55	0.22%
2014 - CMS	20,292	−316	−1.53%	24,317	−259	−1.05%
2015 - CMS	19,492	−800	−3.94%	24,244	−73	−0.30%
2016 - CMS	19,368	−124	−0.64%	25,656	1412	5.82%
2017 - CMS	19,572	204	1.05%	26,668	1012	3.94%
2018 - CMS	19,563	−9	−0.05%	27,679	1011	3.79%
2019 - CMS	19,546	−17	−0.09%	28,269	590	2.13%

Appendix 3
Revision total hip arthroplasty (THA) and revision total knee arthroplasty (TKA) volumes adjusted for Medicare Advantage patients.

Year	Percentage of MA patients (r)[a]	Revision THAs			Revision TKAs		
		Adjusted Volume Vol/(1-r)	YOY change	Annual percentage change	Adjusted Volume Vol/(1-r)	YOY change	Annual percentage change
2000 (uplifted)	17%	22,313	-	-	18,196	-	-
2001 (uplifted)	15%	24,172	1859	8.33%	18,648	452	2.48%
2002 (uplifted)	14%	22,694	−1478	−6.11%	20,147	1498	8.03%
2003 (uplifted)	13%	22,908	214	0.94%	20,953	806	4.00%
2004 (uplifted)	13%	23,371	463	2.02%	23,026	2074	9.90%
2005 (uplifted)	13%	22,852	−520	−2.22%	23,976	949	4.12%
2006 (uplifted)	16%	22,639	−212	−0.93%	24,632	656	2.74%
2007 (uplifted)	19%	23,184	545	2.41%	25,836	1204	4.89%
2008 (uplifted)	22%	23,301	117	0.51%	26,901	1065	4.12%
2009 (uplifted)	23%	23,353	52	0.22%	27,923	1022	3.80%
2010 (uplifted)	24%	24,495	1141	4.89%	29,392	1469	5.26%
2011 (uplifted)	25%	26,812	2317	9.46%	32,319	2927	9.96%
2012 (uplifted)	26%	27,395	583	2.17%	33,136	818	2.53%
2013 (uplifted)	28%	28,622	1228	4.48%	34,133	997	3.01%
2014 (uplifted)	30%	28,989	366	1.28%	34,739	605	1.77%
2015 (uplifted)	31%	28,249	−739	−2.55%	35,136	398	1.14%
2016 (uplifted)	31%	28,070	−180	−0.64%	37,183	2046	5.82%
2017 (uplifted)	33%	29,212	1142	4.07%	39,803	2620	7.05%
2018 (uplifted)	35%	30,097	885	3.03%	42,583	2780	6.98%
2019 (uplifted)	36%	30,541	444	1.47%	44,170	1587	3.73%

[a] Proportion of Medicare Advantage patients relative to the total number of Medicare beneficiaries [19].

Appendix 4
Revision total hip arthroplasty (THA) and revision total knee arthroplasty (TKA) annual growth rates comparison.

Estimation method/procedure	Approximate annual growth rates in procedures					
	Current study		Schwartz et al.		Kurtz et al.	
	rTHA	rTKA	rTHA	rTKA	rTHA	rTKA
OLS (log-linear)	1.77%	4.67%	-	-	-	-
OLS (linear)	-	-	2.22%	3.65%	-	-
GLM (Poisson & negative binomial)	1.79%	4.62%	3.38%	6.68%	3.51%	8.10%
ARIMA (0,1,1)	1.65%	4.78%	-	-	-	-