Arthroplasty Today 27 (2024) 101348

Contents lists available at ScienceDirect

Arthroplasty Today

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

Original Research

The Impact of the Coronavirus Disease 2019 Pandemic on US Total Knee and Hip Arthroplasty Procedures in 2020

Matthew R. Barnes, BA [a,*], Alexandra B. Zagaria, MPH [b], Paul M. Werth, PhD [b], David S. Jevsevar, MD, MBA [c]

[a] Geisel School of Medicine at Dartmouth, Hanover, NH, USA
[b] Department of Orthopaedics, Dartmouth-Hitchcock Medical Center, Lebanon, NH, USA
[c] OrthoVirginia, North Chesterfield, VA, USA

ARTICLE INFO

Article history:
Received 13 September 2023
Received in revised form
12 January 2024
Accepted 5 February 2024
Available online xxx

Keywords:
COVID-19
Total knee arthroplasty
Total hip arthroplasty
Elective surgery

ABSTRACT

Background: The coronoavirus disease 2019 (COVID-19) pandemic had profound impact on elective procedures in the United States. We characterized the longer-term decline and recovery of hip and knee arthroplasty procedures following the onset of the COVID-19 pandemic in the United States.
Methods: We conducted a retrospective analysis of patients undergoing primary and revision total knee and hip arthroplasty (TKA and THA) in the United States between 2014 and 2020 using claims from a large national commercial payer data set contaivning deidentified information from patients with commercial health coverage. We calculated the percentage of cases lost by month using a forecast model to predict TKA and THA volumes in the absence of COVID-19. We then calculated the association between COVID-19 positivity rates and THA/TKA procedures by state and month.
Results: There was a large initial decline in procedures, with primary TKA and THA volumes declining by 93.2% and 87.1% in April 2020, respectively, with revisions seeing more modest declines. Cases quickly recovered with volumes exceeding expected levels in summer months. However, cumulative 2020 volumes remained below expected with 9.7% and 7.5% of expected primary TKA and THA cases lost, respectively. Higher state COVID-19 positivity rates were associated with lower primary TKA, THA, and revision knee procedure rates.
Conclusions: After the initial decline in March and April, knee and hip arthroplasty cases resumed quickly; however, by the end of 2020, the annual procedure volume had still not recovered fully. The loss in case volume within states was worse in months with higher COVID-19 positivity rates.

Introduction

The coronoavirus disease 2019 (COVID-19) outbreak was declared a pandemic by the World Health Organization on March 11, 2020 [1]. On March 13, 2020, the American College of Surgeons recommended postponing or canceling electively scheduled procedures, with the Centers for Medicare and Medicaid Services releasing a similar recommendation 5 days later [2,3]. By March 24, 2020, 30 states released guidances recommending or mandating discontinuation of elective procedures with varying levels of specificity [4]. The effect of these guidances were swift, as an initial Medicare claims analysis comparing average weekly procedure volumes in the period from January 1, 2020 to March 17, 2020 to the period from March 18, 2020 to March 31, 2020, found a 94% drop in primary total knee arthroplasty (TKA) and 92% drop for primary total hip arthroplasty (THA) without fracture [5]. Another study analyzing inpatient primary elective TKA and THA through 2020 showed a decrease in procedure volumes of 46.5% and 47.7%, respectively, compared to 2017-2019 averages [6].

Procedure cancellations and delays represented a major impact to hospital finances [7-9]. Prior to the pandemic, elective orthopaedic procedures were estimated to account for 13% of total hospital reimbursement and 23% of total hospital net income nationwide [7]. While Medicare is the major insurance provider for patients receiving TKA and THA, commercial payers tend to offer

* Corresponding author. Geisel School of Medicine, 66 College Street, Hinman 7000-13, Hanover, NH 03755, USA. Tel.: +1 978 460 3467.
E-mail address: matthew.r.barnes.med@dartmouth.edu

https://doi.org/10.1016/j.artd.2024.101348

significantly higher reimbursement rates [8]. Given the importance of elective procedures such as TKA and THA to the financial stability of hospital systems and orthopedic practices, it is crucial to understand both the initial drop in procedure volumes, as well as the longer-term impact as the pandemic progressed and restrictions on elective procedures were lifted. We specifically focused on the patient population with commercial coverage to better characterize these trends on the procedures with highest impact to hospital and surgeon revenues.

In this study, we identified the impact of the initial drop in procedures and hypothesize that not all the lost case volume will have recovered by the end of 2020. In addition, we hypothesize that this effect was greater both in regions with higher COVID-19 caseloads and with older patients more at risk from COVID-19.

Material and methods

We conducted a retrospective analysis of patients from a large national commercial payer data set undergoing primary and revision TKA and THA in the United States supplied by the Health Intelligence Company, LLC. We analyzed claims data for knee and hip osteoarthritis diagnoses and arthroplasty surgeries from January 1, 2014, through December 31, 2020.

Patients who underwent TKA and THA procedures were identified using Current Procedural Terminology (CPT) codes and were grouped into 4 cohorts: primary total knee CPT 27447; primary total hip CPT 27130-27132; revision knee CPT 27486-27487; revision hip CPT 27134-27138. There was a total of 439,369 primary total knee, 292,250 primary total hip, 32,510 revision knee, and 18,593 revision hip surgeries in this database during the time period analyzed. Patients with diagnoses of knee and hip osteoarthritis (OA) were identified using International Classification of Diseases 9 and 10 Clinical Modification codes provided in the Appendix Table S1 (see Supplementary Data). Inclusion criteria were patients with an International Classification of Diseases-9/10-Clinical Modification code for knee or hip OA or those with a diagnosis of unspecified OA plus a diagnosis of knee or hip pain [9].

Patient demographics

Mean age and sex demographics were calculated for all arthroplasty procedures occurring an equal number of days before and after the American College of Surgeons recommendation on March 13. The 292 days between May 26, 2019, through March 13, 2020, represented the prepandemic period and the 292 days between March 14, 2020, through December 31, 2020, represented the postpandemic period. A Welch 2-sample t-test was used to determine significant differences in the age and sex demographic distributions of the procedures in these 2 time periods.

Seasonal Autoregressive Integrated Moving Average time series forecast

We used seasonal Autoregressive Integrated Moving Average (seasonal ARIMA) models to predict 2020 monthly arthroplasty volumes in the absence of COVID-19. The model analyzed year-over-year and seasonal trends and random variations in the monthly arthroplasty volumes from January 2014 through February 2020 to calculate expected values for procedure volume from March 2020 to December 2020. ARIMA(0,0,0)(0,1,0)[12] with drift, ARIMA(1,0,0)(0,1,0)[12] with drift, ARIMA(0,0,0)(0,1,1)[12] with drift, and ARIMA(0,0,0)(1,0,0)[12] with nonzero mean models were selected as the best models for primary TKA, primary THA, revision knee, and revision hip, respectively.

COVID-19 positivity mixed effects

We also analyzed the relationship between state COVID-19 positivity rates and prevalence of arthroplasty surgery using a mixed-effect model with random intercepts and random slopes. For this model, the months from May to December 2020 were the observational covariates, COVID-19 positivity rates were the covariate, and arthroplasty prevalence rates represented the outcome variable.

State-level COVID-19 testing data were obtained from the Johns Hopkins Coronavirus Resource center to construct state-level positivity rates [10]. Arthroplasty prevalence was calculated by dividing 2020 monthly procedure volumes by monthly OA diagnoses in the prior year. 2020 OA diagnosis volumes were not used as a baseline as these displayed a similar decline during the initial months of the pandemic. The model used data from May through December 2020. March and April were excluded from this analysis due to limited testing availability during the early months of the pandemic [10-14].

Results

Patient demographics

Prepandemic and postpandemic age and sex demographics were similar. Primary TKA had a decline in mean age from 59.5 to 58.9 years ($P = .01$). Age distributions for the other procedures and sex demographics for all procedures did not show significant differences before and after the start of the pandemic (Table 1).

ARIMA time series forecast

Based on historical trends of year-over-year growth and seasonal fluctuations in arthroplasty procedures (Fig. 1), we projected 2020 case volumes in this patient population had the COVID-19 pandemic not occurred. We estimated that 72,597 primary TKA,

Table 1
Arthroplasty incidence, prevalence, and patient demographics.

Volume, prevalence, and demographics	Primary total knee	Primary total hip	Knee revision	Hip revision
Total volume per year				
2014	53,458	34,267	3818	2746
2015	57,503	37,804	4090	2655
2016	62,508	40,391	4533	2552
2017	64,470	42,322	4718	2582
2018	66,659	44,637	5058	2757
2019	69,221	46,921	5288	2644
2020	65,550	45,908	5005	2657
Prevalence rate (per 100,000 diagnosed)[a]				
2014	599.8	4350.5	42.8	348.6
2015	606.2	4479.5	43.1	314.6
2016	611.4	4677.3	44.3	295.5
2017	603.5	4742.9	44.2	289.4
2018	599.7	4890.7	45.5	302.1
2019	591.9	5001.4	45.2	281.8
2020	617.4	5347.4	47.1	309.5
Mean age				
Pre-COVID-19	59.5[b]	58.0	59.1	58.1
Post-COVID-19	58.9[b]	57.6	59.0	57.3
Mean Female (%)				
Pre-COVID-19	54.6	49.2	50.8	46.5
Post-COVID-19	55.5	49.5	47.2	49.9

[a] Prevalence rate expressed as number of procedures over number of members diagnosed with relevant knee or hip osteoarthritis.
[b] $P < .05$.

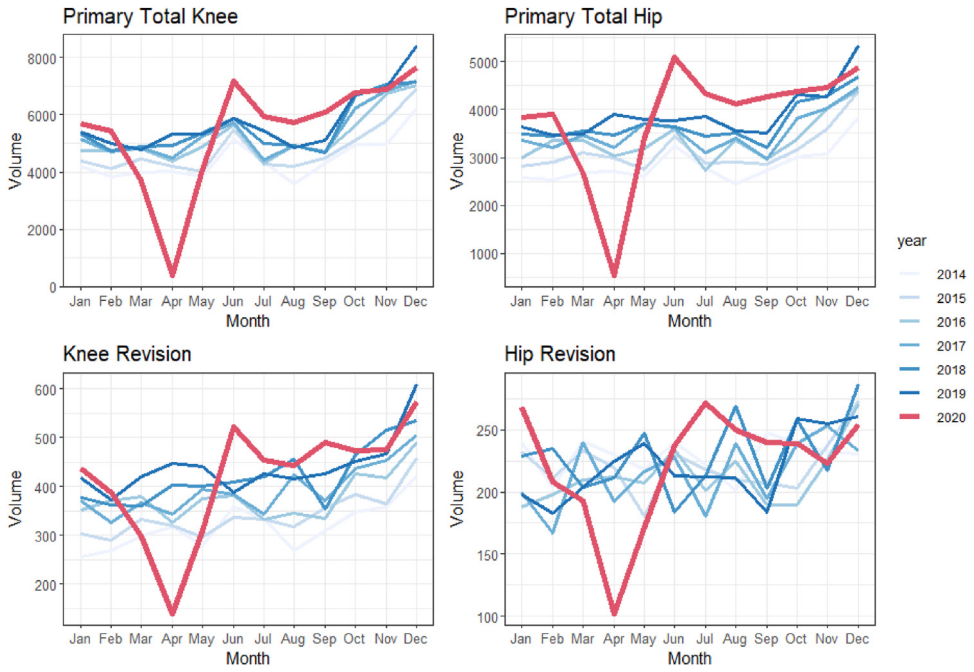

Figure 1. Observed volumes of primary TKA, primary THA, revision, knee, and revision hip procedures from 2014 through 2020.

49,639 primary THA, 5587 revision knee, and 2716 revision hip procedures would have taken place in the absence of COVID-19. April 2020 was the first full month with cancellation procedures in effect and saw the largest monthly case declines, with declines compared to expected volumes of 93.2% in primary TKA, 87.1% in primary THA, 69.3% in knee revision, and 54.4% in hip revision (Table 2). There was an initial rapid recovery in cases with observed primary and revision TKA and THA volumes exceeding expected in the summer months (Fig. 2). However, the cumulative volumes of the last 10 months of 2020 were still below expected with 11.5% of primary TKA, 8.9% of primary THA, and 12.2% of revision knee procedures lost (Table 2). Revision hip procedures did not experience a significant cumulative decline by the end of 2020.

COVID-19 positivity mixed effects

When comparing between states, higher COVID-19 positivity rates were associated with lower procedure rates. From May to December 2020, every 1% increase in monthly COVID-19 positivity was associated with an average of 20.1, 135.9, and 2.2 fewer cases per state of primary TKA, primary THA, and knee revision procedures per 100,000 osteoarthritis diagnoses (Table 3). This effect was most pronounced during the early months of the COVID-19 pandemic for primary and revision knee procedures, with the effect waning over time (Fig. 3). The decline in hip revision procedures was not significantly correlated with COVID-19 positivity rates.

Discussion

The start of the COVID-19 pandemic had a major impact on elective musculoskeletal procedures in the United States. April 2020 represented the greatest drop in monthly surgical volumes of primary TKA and THA. This is in line with studies of the early impact of COVID-19 in the US and abroad [5,15,16]. Revision procedures showed a more modest decline with just over half of revision knee and hip cases being lost, suggesting prioritization of higher acuity

Table 2
Percent of forecasted procedure volumes lost for last 10 months of 2020 by procedure type.

Forecast models by procedure	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Total knee											
Forecasted cases lost (%)	−27.2	−93.2	−26.8	17.0	4.5	12.1	12.9	−2.8	−5.1	−11.7	−11.5
95 Lo	−18.2	−92.4	−18.7	28.7	15.9	25.8	25.9	5.6	2.8	−5.6	−2.6
95 Hi	−34.4	−93.8	−33.4	7.3	−4.8	1.1	2.3	−10.0	−11.9	−17.1	−18.8
Total hip											
Forecasted cases lost (%)	−26.5	−87.1	−15.1	27.6	6.4	9.2	14.8	−3.3	−0.4	−11.8	−8.9
95 Lo	−18.8	−85.9	−6.8	40.1	16.7	20.7	27.0	5.1	8.2	−5.7	−0.4
95 Hi	−32.8	−88.1	−22.1	17.1	−2.2	−0.2	4.7	−10.4	−7.8	−17.2	−16.1
Knee revision											
Forecasted cases Lost (%)	−31.9	−69.3	−32.6	19.7	0.6	−4.4	12.0	−4.4	−7.9	−5.7	−12.2
95 Lo	−21.9	−65.0	−23.2	37.3	14.9	8.8	28.4	7.9	3.3	3.9	−0.5
95 Hi	−39.6	−72.7	−39.9	6.0	−10.5	−14.7	−0.7	−14.1	−17.0	−13.7	−21.5
Hip revision											
Forecasted cases lost (%)	−10.7	−54.4	−25.2	8.1	24.2	14.4	14.8	1.4	−4.8	7.5	−2.7
95 Lo	13.7	−42.4	−6.1	37.1	57.6	45.2	47.6	26.3	18.8	33.8	22.8
95 Hi	−26.5	−62.2	−37.8	−10.8	2.5	−5.7	−6.1	−15.3	−20.5	−10.2	−19.4
COVID-19 positivity rate	16.96	16.01	6.17	4.94	7.40	5.73	4.38	5.20	9.27	11.37	

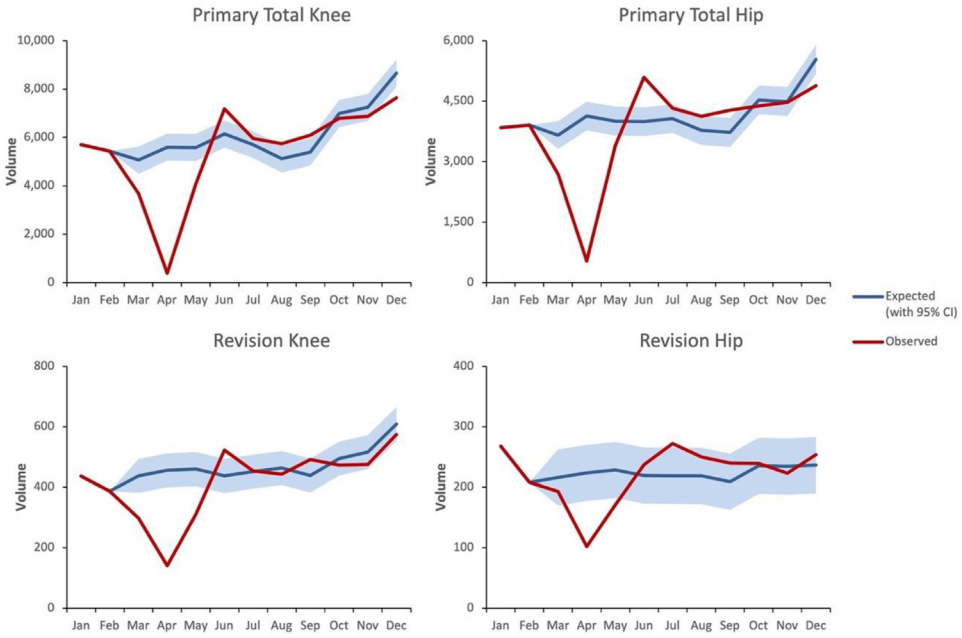

Figure 2. Observed cases vs ARIMA time series forecast of 2020 primary TKA, primary THA, revision knee and revision hip procedures.

procedures. Primary and revision procedures quickly recovered with an overshoot in the early summer with monthly volumes exceeding expected volumes. However, this rebound did not last as a second increase in COVID-19 positivity in November and December resulted in fewer than expected primary TKA/THA cases.

By the end of 2020, there was still a deficit in total procedures performed, representing a net loss of over 11,000 arthroplasty procedures in this payer population alone, or 10.3% of expected cases between March through December 2020. The study by Heckmann et al. [6] showed higher year end procedure deficits at 46.5%-47.7% for primary TKA and THA, respectively, however this study analyzed only inpatient cases. In particular, this study found a similar initial drop in procedures in the "first wave" from March to April but significantly greater declines in later waves throughout the year than this analysis. This suggests that following the first wave of the pandemic, there was a larger continued impact on inpatient procedures, accelerating the trend toward outpatient surgery. This trend toward outpatient surgery has been demonstrated in both THA and TKA with no significant difference to short-term patient outcomes or complications rates [17-19].

In addition, there also may have been some prioritization of patients with commercial coverage given higher reimbursements in this population. An analysis of Medicare claims from April to September 2020 found THA volumes decreased by 16% compared to the April to September 2019 [18]. In our private payer data set, the volume of THA procedures decreased by only 2.9% over the same period, however, a more thorough study comparing the 2 payer populations would be required to demonstrate this effect more reliably.

Table 3
Mixed effects models: association between COVID-19 positivity rate and state case prevalence rates per month in 2020.[a]

Variables	Total knee arthroplasty		Total hip arthroplasty		Knee revision		Hip revision	
	Estimates (CI)	*P*	Estimates (CI)	*P*	Estimates (CI)	*P*	Estimates (CI)	*P*
Predictors								
(Intercept)	532.9 (*483.4 to 582.4*)	**<.001**	5857.6 (*5241.9 to 6473.4*)	**<.001**	42.3 (*35.8 to 48.7*)	**<.001**	465.6 (*340.8 to 590.5*)	**<.001**
Month	41.7 (*31.4 to 52.0*)	**<.001**	127.1 (*34.5 to 219.8*)	**.007**	3.5 (*1.5 to 5.5*)	**.001**	7.9 (*−10.6 to 26.5*)	.403
Positivity	−20.1 (*−28.5 to −11.8*)	**<.001**	−135.9 (*−226.1 to −45.7*)	**.003**	−2.2 (*−3.8 to −0.7*)	**.004**	−10.4 (*−29.8 to 9.1*)	.296
State	5.8 (*−5.2 to 16.8*)	.305	102.7 (*−33.3 to 238.6*)	.139	−1.1 (*−2.6 to 0.4*)	.135	5.6 (*−22.1 to 33.4*)	.691
Interactions								
Month * Positivity	3.6 (*2.0 to 5.1*)	**<.001**	20.0 (*3.4 to 36.6*)	**.018**	0.3 (*0.1 to 0.6*)	**.019**	1.2 (*−2.4 to 4.7*)	.517
Month * State	2.3 (*0.0 to 4.5*)	**.049**	8.6 (*−11.9 to 29.2*)	.409	0.3 (*−0.1 to 0.8*)	.144	0.4 (*−3.8 to 4.7*)	.838
N	51		51		51		51	
Observations	408		408		358		321	
Marginal R^2/Conditional R^2	0.386/NA		0.180/NA		0.076/NA		0.022/NA	

Intercept is the variability of case prevalence associated with the fixed-effects terms and represents an overall "typical" response of a state. Month represents the slope of case prevalence over the course of May-December 2020. Positivity measures the variability due to COVID positivity rates between states (ie, to what extent states with differing positivity rates behave differently) and represents the change in procedure rate for every 1% difference in positivity. State refers to the variability due to individual state differences (ie, states behaving differently despite similar positivity rates). A * represents the interaction between predictors. N refers to the 50 states plus the District of Columbia.

Confidence Intervals are shown in italics and bolded values indicate statistical significance.

[a] All rates expressed as volume per 100,000 members with relevant osteoarthritis diagnoses. Months evaluated included May through Dec 2020. Mar-Apr were omitted due to volatility in COVID positivity rates due to lack of testing availability. 2019 monthly diagnosis volumes were used as the denominator for obtaining 2020 monthly prevalence rates. This was done to mitigate the impact of reduced diagnoses due to lower visit volumes.

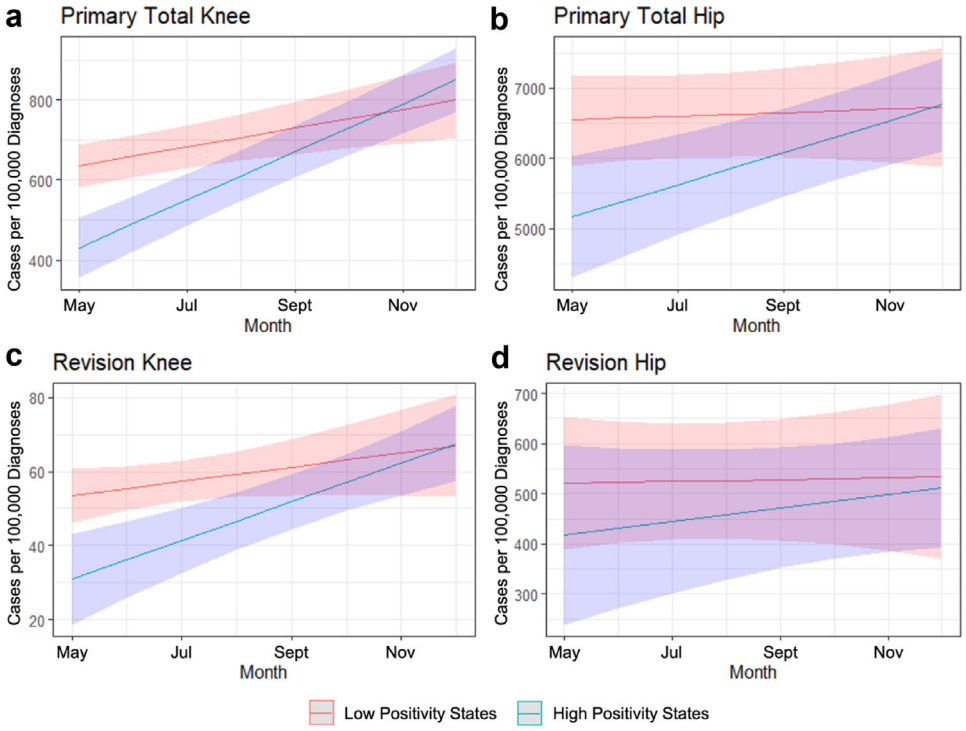

Figure 3. Marginal effects of COVID-19 positivity on arthroplasty procedure rate variation. High and low positivity states refer to states at one standard deviation above or below the mean positivity rate in a given month. States with higher positivity rates were found to have relatively lower rates of arthroplasty procedures, though this effect wanes by the end of 2020.

Prior studies modeling the timeline of working through the expected COVID-19 backlog suggest this deficit continued well into 2021 if not longer [20]. Additional surges of COVID-19 in 2021 and the rise of more infectious variants such as Delta and Omicron may have resulted in additional cancellations, prolonging the time to work through the backlog of cases.

Additionally, we found that within states, there was a greater decline in arthroplasty prevalence as COVID-19 positivity rates rose. This effect was greatest in the early months of the pandemic though became less significant as the pandemic progressed. We did not find a significant difference in arthroplasty prevalence between states, meaning we did not find that states with similar rates of COVID-19 positivity behaved differently. Future studies could examine specific COVID-19 policies, rates of vaccination, and other factors to investigate differences in behavior of arthroplasty cancellation between states.

There are several limitations with this study. First, this study is limited to claims from patients covered by the large national payer which provided the data, which excludes Medicare, Medicare Advantage, state Medicaid, military, and uninsured populations. Second, rising unemployment during the pandemic may affect this analysis given that it is focused on patients with private insurance. While the payer does cover patients throughout the United States, this analysis may be affected by the size of its presence in each state. In addition, given that the data used ends in December 2020, this study does not reflect the effects of vaccines and emergence of new COVID-19 variants on the speed of procedure recovery. Follow-up studies will be required to understand the impact of these factors on elective surgeries.

Conclusions

The COVID-19 pandemic was an unprecedented challenge to healthcare systems, especially in the context of elective primary and revision THA and TKA. The initial mandate to restrict elective procedures had a profound impact on volumes and expected arthroplasty case volumes for 2020 were not achieved. Additionally, states with higher levels of COVID-19 infections had lower arthroplasty prevalence, and increased COVID-19 rates in November and December again led to decreasing arthroplasty procedures. There is opportunity for future research on the effect that surgical cancellations had on both postoperative patient outcomes and on the financial implications to healthcare institutions.

Conflicts of interest

David S. Jevsevar declares research support from DePuy/Mitek and is a member of AAHKS: Evidence Based Medicine Committee and AAOS: Research and Quality Council. All other authors declare there are no conflicts of interest. For full disclosure statements refer to https://doi.org/10.1016/j.artd.2024.101348.

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Appendix TableS1
ICD-9 and ICD-10 CM codes for OA diagnosis.

Diagnosis	ICD-9-CM	ICD-10-CM
Osteoarthritis of Knee	715.x6	M17.0, M17.10, M17.11, M17.12, M17.2, M17.30, M17.31, M17.32, M17.4, M17.5, M17.9
Osteoarthritis of Hip	715.x5	M16.0, M16.10, M16.11, M16.12, M16.2, M16.30, M16.31, M16.32, M16.4, M16.50, M16.51, M16.52, M16.6, M16.7, M16.9
Osteoarthritis Unspecified	715.00, 715.09, 715.10, 715.18, 715.20, 715.28, 715.30, 715.38, 715.80, 715.89, 715.90, 715.98	M15.0, M15.1, M15.2, M15., M15.9, M19.90, M19.91, M19.92, M19.93
Pain in the Knee	719.46	M25.561, M25.562, M25.569
Pain in the Hip	719.45	M25.551, M25.552, M25.559