



Original Research

An Updated Estimate of Total Hip and Total Knee Arthroplasty Inpatient Case Volume During the 2020 COVID-19 Pandemic in the United States

Nathanael D. Heckmann, MD^{a,*}, Cory K. Mayfield, MD^a, Mary K. Richardson, BS^a, Kevin C. Liu, BS^a, Jennifer C. Wang, MD^a, Amit S. Piple, MD^a, Jeffrey B. Stambough, MD^b, Daniel A. Oakes, MD^a, Alexander B. Christ, MD^a, Jay R. Lieberman, MD^a

^a Department of Orthopaedic Surgery, Keck School of Medicine of USC, Los Angeles, CA, USA

^b Department of Orthopaedic Surgery, University of Arkansas for Medical Sciences, Little Rock, AR, USA

ARTICLE INFO

Article history:

Received 7 April 2023

Received in revised form

24 October 2023

Accepted 27 January 2024

Available online xxx

Keywords:

Total joint arthroplasty

COVID-19 pandemic

Case volume

ABSTRACT

Background: Inpatient total hip arthroplasty (THA) and total knee arthroplasty (TKA) practices were dramatically affected in the United States in 2020 as elective surgeries were paused in response to the COVID-19 pandemic. This study sought to provide an updated estimate of inpatient total joint arthroplasty (TJA) case volumes in the United States in 2020.

Methods: A retrospective cohort study was performed by identifying all adult patients who underwent primary, elective TJA from January 1st, 2017 to December 31st, 2020, using the National Inpatient Sample. Monthly and annual case volumes were reported with descriptive statistics. Baseline case volumes were established by taking the average number of monthly cases performed in 2017, 2018, and 2019. These monthly averages were compared to 2020 values.

Results: From 2017 to 2019, the average case volume was 1,056,669 cases per year (41.0% THA, 59.0% TKA) and 88,055 cases per month. In 2020, 535,441 cases were identified (45.4% THA, 54.6% TKA), corresponding to a 49.3% reduction from the 2017-2019 annual average. Monthly cases decreased to 4515 in April during the “first wave” of COVID-19, corresponding to a 94.8% decrease from prior years. In June, cases rebounded to 55,520 before decreasing again in July to 50,100 during the “second wave” of COVID-19. During the “third wave,” COVID-19 cases decreased month-over-month from October through December (56.5% decrease).

Conclusions: This updated estimate identified a 49.3% decrease in inpatient TJA cases in 2020 compared to prior years. This is similar to the 46.5-47.7% decrease in case volume previously reported.

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Introduction

Orthopedic surgery practices were substantially impacted in the United States in 2020 as a result of the COVID-19 pandemic. In particular, elective surgical procedures, including primary total hip arthroplasty (THA) and total knee arthroplasty (TKA), were among the first to be postponed as hospital resources were reallocated to

accommodate rising COVID-19 cases [1-3]. While a marked reduction in elective inpatient total joint arthroplasty (TJA) cases has been reported throughout the literature, the accuracy of these estimates remains in question [4-9].

Our previous work utilized the Premier Healthcare Database (PHD) to estimate 2020 THA and TKA inpatient case volumes [4]. The PHD was the first large database to report inpatient surgical data for the entire 2020 calendar year, and it was used to generate these prior estimates. Unfortunately, the National Inpatient Sample (NIS), which is considered the gold standard for quantifying national trends in surgical volume, was not yet available for 2020 at the time of our prior publication. As such, 2 case volume models were created: one using PHD data and the second using NIS-

* Corresponding author. Department of Orthopaedic Surgery, Keck Medical Center of USC, 1520 San Pablo Street, Ste 2000, Los Angeles, CA 90033, USA. Tel.: +1 323 704 6363.

E-mail address: nate.heckmann@gmail.com

derived weights applied to the PHD model [4]. Both models produced similar estimates of 46.5% and 47.7% fewer cases compared to the 2017–2019 average, respectively.

A commentary questioned the validity of our previous estimates due to the “unorthodox methodology” of combining 2 databases [9]. Therefore, the purpose of this study was to use 2020 data from the NIS to provide an updated estimate of inpatient TJA case volume in the United States in 2020. We hypothesize that this updated NIS estimate will be similar to the estimates we reported previously using the PHD.

Material and methods

Data source and study population

A retrospective cohort study was performed by identifying all adult patients who underwent primary, elective THA, or TKA from January 1st, 2017 through December 31st, 2020, using the NIS database [10]. The NIS database contains all-payer data on inpatient hospitalizations, covering approximately 98% of the U.S. population. It contains an approximate 20% weighted representative sampling of all hospital inpatient discharges [10]. As such, researchers and policymakers commonly utilize this database to make estimates of national healthcare trends [11]. This study was exempt from institutional review board review as all patient information was deidentified in accordance with the Health Insurance Portability and Accountability Act.

Patients who underwent primary, elective TJA were identified using International Classification of Diseases–Tenth Revision (ICD-10) codes. All patients <18 years old and those who underwent TJA for nonelective and nonprimary indications were excluded. (Supplemental Table 1) Patient demographic data collected included age, sex, race, length of stay, total cost, and insurance type. Hospital characteristics evaluated were hospital bed size, urban vs rural setting, teaching status, geographic region, and ownership (government, private).

TJA case volume modeling

The NIS database was queried for primary, inpatient, and elective TJA cases from January 2017 to December 2020. As these records represent a stratified sampling of United States community hospitals, NIS weighting was then applied to these data to generate nationally representative annual models (2017 NIS, 2018 NIS, 2019 NIS, 2020 NIS). The NIS weights are ratios of true total discharges to those captured in the NIS sampling strategy, and application of these multipliers allows for estimation of national trends [12]. Monthly and annual trends of primary, inpatient, and elective TJA were reported with descriptive statistics. The baseline elective TJA case volume was established by taking the average of the number of cases in 2017, 2018, and 2019 for each calendar month. Next, the difference between the number of TJAs performed in each month of 2020 and the average number performed from 2017–2019 was calculated.

The 2020 NIS model was compared with 2 previously published 2020 estimates by our group: a weighted model using 2020 data from the PHD alone (Prior Model 1) and a second model with NIS-derived weights applied to 2020 PHD data (Prior Model 2). For each calendar month in 2020, percent differences relative to the current 2020 NIS model were calculated for Prior Model 1 and Prior Model 2.

Statistical analysis

Differences in patient and hospital characteristics from 2017–2020 were evaluated via analysis of variance and chi-square analysis for continuous and categorical variables, respectively. All

statistical analyses were performed using STATA (version 16.1; StataCorp, College Station, Texas).

Results

Patient demographics and hospital characteristics

In total, 3,507,449 TJA (41.7% THA, 58.3% TKA) cases were recorded from January 2017 to December 2020. From 2017 to 2019, the average annual case volume was 1,056,669 cases per year (41.0% THA, 59.0% TKA). Statistically significant but clinically unremarkable differences in age, sex, and race were found in 2017 through 2020. (Table 1) Differences in hospital characteristics were small but statistically significant. (Table 2) When analyzed individually, trends in THA and TKA cases were similar to the overall TJA cohort. (Supplemental Tables 2 and 3)

Modeling of 2020 TJA case volume

After applying weighting factors, the 2020 NIS model demonstrated an annual total of 535,441 TJA cases, corresponding to 521,228 fewer cases (a 49.3% decrease) than the NIS model for 2017–2019, which averaged 1,056,669 cases per year (Table 3). Prior Model 1 demonstrated an annual total of 525,661 cases in 2020, corresponding to a 1.8% difference from the 2020 NIS model. In April 2020, Prior Model 1 reported 1585 TJAs, which represented a 64.9% deviation from the 2020 NIS estimate (4515 TJAs). The remaining monthly estimates were similar between the 2 models (range of absolute differences: 0.0–10.5%). (Fig. 1) Overall, Prior Model 2 reported a total of 538,256 cases in 2020, representing a 0.5% difference from the 2020 NIS model. In April 2020, Prior Model 2 reported 1619 TJA cases, representing a 64.2% difference from the 2020 NIS model (4515 TJAs). Otherwise, the remaining months demonstrated similar case volumes (range of absolute differences: 0.5–7.7%) (Fig. 1).

Monthly TJA case volume in 2020 vs 2017–2019

From March to April 2020, TJA case volume declined from 39,540 to 4515 cases, which represented a 94.8% decrease from the 2017–2019 average for April. This downtrend corresponded to the “first wave” of COVID-19. (Fig. 2a) Subsequently, TJA case volume steadily increased from May to June, reaching a 2020 peak of approximately 55,000 cases, corresponding to a 36.8% decrease from the 2017–2019 June average. This resurgence in TJA case volume correlated with the moderate decrease in COVID-19 cases at the conclusion of the “first wave.” (Fig. 2b) Overall, the “first wave” of COVID-19 was associated with a 189,000-case reduction from March to May 2020 compared to 2017–2019 monthly averages (Fig. 3).

The “second wave” of COVID-19 began in June, peaked in July, and stabilized throughout August and September of 2020. As COVID-19 cases climbed, TJA case volume declined, reaching approximately 50,000 surgeries in July and 47,000 surgeries in August, correlating to a 39.3% and 45.1% reduction from the respective 2017–2019 monthly averages. (Fig. 2c) In total, the “second wave” of COVID-19 cases was associated with 137,000 fewer cases from June to September of 2020 compared to 2017–2019 averages (Fig. 3).

From October to December of 2020, COVID-19 case volumes increased steeply, representing a third surge in cases. An inverse relationship was observed between COVID-19 infections and TJA case volume with approximately 47,000 surgeries performed in October, 40,000 in November, and 36,000 in December 2020. (Fig. 2d) These monthly volumes corresponded to a 52.6%, 55.8%,

Table 1
Patient characteristics and demographic information from 2017-2020 in the NIS-HCUP database.

Variable	2017 (N = 1,152,374)	2018 (N = 1,040,468)	2019 (N = 977,166)	2020 (N = 535,441)	P-value
Average age (years)	66.3 ± 10.1	66.5 ± 10.2	66.9 ± 10.2	66.8 ± 10.3	<.0001
Length of stay (days)	2.3 ± 1.8	2.1 ± 1.9	2.0 ± 2.1	2.1 ± 2.4	<.0001
Total cost (\$)	61,322.83 ± 40,126.75	63,473.04 ± 39,271.61	65,214.18 ± 43,298.15	70,382.53 ± 52,175.20	<.0001
Male sex N (%)	466,065 (40.4)	422,374 (40.6)	397,146 (40.6)	221,811 (41.4)	<.0001
Race N (%)					<.0001
Caucasian	911,854 (82.7)	833,614 (82.4)	792,886 (83.4)	429,266 (82.5)	
African American	88,905 (8.1)	81,125 (8.0)	77,180 (8.1)	43,010 (8.3)	
Hispanic	59,510 (5.4)	57,384 (5.7)	46,040 (4.8)	27,645 (5.3)	
Asian or Pacific Islander	14,880 (1.4)	13,175 (1.3)	12,630 (1.3)	6675 (1.3)	
Native American	4265 (0.4)	4620 (0.5)	4025 (0.4)	2355 (0.5)	
Other	23,135 (2.1)	21,665 (2.1)	18,385 (1.9)	11,500 (2.2)	
Payer category N (%)					<.0001
Medicare	650,960 (56.6)	587,939 (56.6)	563,631 (57.7)	298,646 (55.8)	
Medicaid	53,090 (4.6)	47,920 (4.6)	44,425 (4.6)	26,685 (5.0)	
Private	408,940 (35.5)	366,499 (35.3)	331,286 (33.9)	186,131 (34.8)	
Self	6125 (0.5)	6060 (0.6)	7555 (0.8)	3930 (0.7)	
No charge	615 (0.1)	530 (0.1)	375 (0.0)	275 (0.1)	
Other	31,200 (2.7)	30,510 (2.9)	29,220 (3.0)	19,275 (3.6)	
Month N (%)					<.0001
January	100,605 (8.7)	95,850 (9.2)	90,085 (9.2)	73,230 (13.7)	
February	93,240 (8.1)	84,665 (8.1)	81,725 (8.4)	64,185 (12.0)	
March	97,465 (8.5)	84,960 (8.2)	78,140 (8.00)	39,540 (7.4)	
April	88,080 (7.6)	86,665 (8.3)	86,295 (8.83)	4515 (0.8)	
May	99,010 (8.6)	88,200 (8.5)	80,055 (8.19)	29,925 (5.6)	
June	97,875 (8.5)	86,810 (8.3)	78,920 (8.08)	55,520 (10.4)	
July	84,540 (7.3)	82,385 (7.9)	80,840 (8.27)	50,100 (9.4)	
August	96,670 (8.4)	85,065 (8.2)	75,850 (7.76)	47,155 (8.8)	
September	87,370 (7.6)	77,740 (7.5)	76,890 (7.87)	47,265 (8.8)	
October	110,100 (9.6)	100,785 (9.7)	91,810 (9.40)	47,765 (8.9)	
November	104,145 (9.0)	89,775 (8.6)	79,025 (8.09)	40,230 (7.5)	
December	93,275 (8.1)	77,570 (7.5)	77,530 (7.93)	36,010 (6.7)	

and 56.5% reduction compared to the 2017-2019 averages for October, November, and December, respectively. During these final months of 2020, 151,000 fewer TJA surgeries were performed compared to the 2017-2019 average.

Discussion

This study found a marked decrease in elective THA and TKA cases in 2020 during the COVID-19 pandemic with an estimated 521,000 fewer inpatient cases performed compared to the annual average from 2017-2019. This corresponded to a 49.3% decrease, similar to the 46.5-47.7% decrease in 2020 case volumes we reported previously using the PHD [4]. However, the current model has the benefit of utilizing 2020 NIS data, which contains a 20%

representative sampling of all U.S. inpatient cases and is well-acknowledged as the gold standard for quantifying nationwide surgical case volume [10,11]. The current results confirm the accuracy of our prior models of decreased inpatient cases related to the COVID-19 pandemic. The 2020 data demonstrated 470,457 fewer cases were performed in the inpatient setting, which is similar to the 467,642-480,237 fewer cases reported in our prior publication.

The results of the current study provide more accurate historical trends of inpatient TKA and THA case volume during the 2020 COVID-19 pandemic compared to prior studies. Several studies have been published in the past that have estimated the decrease in the number of elective TKA and THA in the United States during 2020 as a result of the COVID-19 pandemic [5-7]. A prior study from

Table 2
Hospital characteristics from 2017-2020 in the NIS-HCUP database.

Variable	2017	2018	2019	2020	P-value
Bed size N (%)					<.0001
Small	355,515 (30.84)	336,703 (32.35)	339,131 (34.69)	199,086 (37.16)	
Medium	325,614 (28.25)	292,215 (28.07)	268,570 (27.47)	199,086 (36.37)	
Large	471,670 (40.92%)	411,940 (39.58)	369,840 (37.83)	195,390 (36.47)	
Urban vs Rural, Teaching Status N (%)					<.0001
Rural	110,370 (9.57)	98,314 (9.45)	92,740 (9.49)	53,841 (10.05)	
Urban, nonteaching	313,835 (27.22)	265,384 (25.50)	223,021 (22.81)	123,990 (23.14)	
Urban, teaching	728,595 (63.20)	677,159 (65.06)	661,780 (67.70)	357,930 (66.81)	
Region N (%)					<.0001
Northeast	214,110 (18.57)	200,689 (19.28)	195,431 (19.99)	126,636 (23.64)	
Midwest or North Central	300,860 (26.10)	267,854 (25.73)	249,230 (25.50)	125,651 (23.45)	
South	405,000 (35.13)	365,806 (35.14)	347,625 (35.56)	187,615 (35.02)	
West	232,829 (20.20)	206,510 (19.84)	185,255 (18.95)	95,860 (17.89)	
Ownership N (%)					<.0001
Government, nonfederal	96,689 (8.39)	87,400 (8.40)	82,804 (8.47)	44,845 (8.37)	
Private, not-profit	870,815 (75.54)	773,965 (74.36)	729,570 (74.63)	385,005 (71.86)	
Private, invest-own	185,295 (16.07)	179,493 (17.24)	165,167 (16.90)	105,911 (19.77)	

Table 3
Estimated TJA volume in 2020.

Month	NIS	Prior model 1	Prior model 2	2017-2019 NIS average
January	73,230	68,510	70,183	95,513
February	64,185	59,095	60,968	86,543
March	39,540	39,925	41,098	86,855
April	4515	1585	1619	87,013
May	29,925	28,451	28,973	89,088
June	55,520	57,490	58,513	87,868
July	50,100	49,621	50,792	82,588
August	47,155	49,672	50,792	85,862
September	47,265	49,957	50,363	80,667
October	47,765	47,756	48,672	100,898
November	40,230	41,361	42,936	90,982
December	36,010	32,238	33,348	82,792
Total	535,441	525,661	538,256	1,056,669

“Prior Model 1” represents weighted values using 2020 PHD data, while “Prior Model 2” represents estimates extrapolated from 2020 PHD data using NIS weighting. [4] “2020 NIS” represents weighted case volumes using the 2020 NIS database. “2017-2019 NIS Average” are monthly average case volumes from 2017-2019 as recorded in the NIS database.

our group utilized Premier data to estimate the decrease in inpatient case volume [4]. This prior study included 574 hospitals’ monthly data available from January 2017 through December 2020. These data were weighed against NIS-derived national estimates of monthly volume for years 2017 and 2018, as the 2019 and 2020 NIS files were not available at that time. With these overlapping years of NIS and Premier data, an NIS-derived weight was computed and applied to the 2020 Premier data to provide a secondary estimate. These 2 prior models gave similar estimates of 525,661 and 538,256 cases, which differed from our updated estimate of 535,441 cases by 1.8% and 0.5%, respectively.

The prior commentary included concerns regarding the validity of our prior estimates given the novel methodology employed [9]. While these concerns may be well-founded, the present study’s findings support the accuracy of these prior estimation strategies. In addition, it was suggested that there was little to no value in reporting inpatient case numbers without taking into account outpatient case volume trends [9]. While this opinion seems convincing on face value, it is at odds with the

sheer existence of the NIS as a stand-alone database, as this dataset is designed to only report on nationwide inpatient trends without taking into account surgeries performed in the ambulatory setting. Furthermore, inpatient surgical trends, even if reported in the absence of outpatient surgical trends, are of interest to orthopedic surgeons, hospital systems, and policymakers given the implications related to inpatient costs and resource allocation. Nevertheless, we acknowledge the importance of investigating outpatient TJA surgery trends during and following the COVID-19 pandemic and have made this the subject of ongoing research within our group.

This study has several limitations that warrant further discussion. First, as with all administrative databases, the NIS may be prone to coding errors. However, the current study sought to evaluate surgical case volumes and did not rely on granular comorbidity or complication data to support our findings. Comorbidities such as obesity are much more likely to be missed or miscoded than common surgeries such as TKA, given the larger financial implications associated with miscoding a surgical intervention. Second, the retrospective observational nature of the NIS database limits our ability to make any type of causal inference. As such, the findings reported in the present study are simply descriptive in nature. Despite these limitations, the data presented in this current study is of value as it provides updated 2020 inpatient TJA case volumes and addresses concerns expressed previously about the accuracy and validity of prior estimates. These data allow surgeons, policymakers, and healthcare stakeholders to better understand the historical impact of the COVID-19 pandemic on TJA practice patterns in the United States in 2020.

This study has notable strengths. First, the NIS is a nationwide inpatient representative sampling of approximately 20% of all discharges in the United States. As such, the data presented in the current study includes all hospital types, all payer types, and all geographical regions within the United States, making our findings generalizable. The large representative sampling of the NIS is also reassuring regarding the accuracy of our findings, as the dataset would have to be systematically flawed to render our findings inaccurate in an epidemiologically material way. Lastly, the findings in the present study are similar in quantity to the estimates reported previously with a <2.5% difference across all 3 estimates

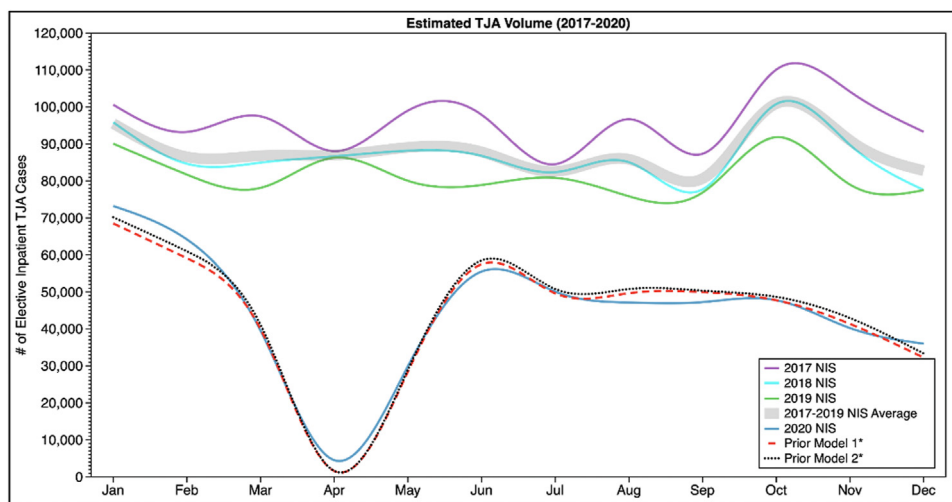


Figure 1. Weighted estimates of monthly case volumes from 2017 through 2020 using the NIS database. The “Prior Model 1” represents weighted values using 2020 PHD data, while “Prior Model 2” represents estimates extrapolated from 2020 PHD data using NIS weighting. The 2020 NIS estimate indicates weighted case volumes using the 2020 NIS database. *Denotes 2020 TJA case volume estimates from Heckmann et al. 2022 [4].

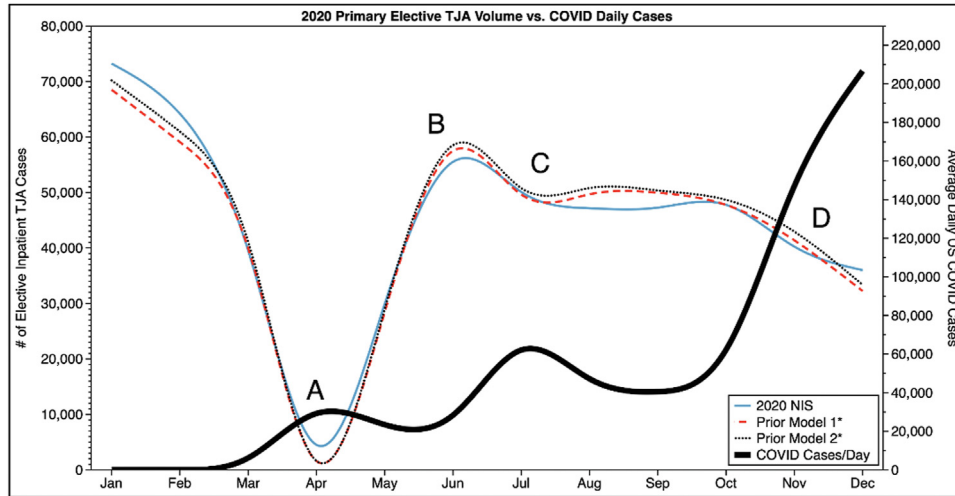


Figure 2. Three estimates of monthly primary, elective TJA volume plotted with average daily new COVID-19 cases in the United States. (a) Steep decline in TJA case volume corresponds to the first wave of COVID-19, resulting in an elective surgery suspension from March to April 2020. (b) Resurgence of TJA case volume as average daily COVID-19 cases fell from May to June 2020. (c) Second decline in TJA case volume in conjunction with the second wave of COVID-19 cases in July 2020. (d) Sharp increase in COVID-19 cases corresponds to another decline in TJA case volume from October to December 2020. *Denotes 2020 TJA case volume estimates from Heckmann et al. 2022 [4].

reported in this study and in our previous report [4]. The consistent findings across all 3 estimates are reassuring regarding the accuracy of these values.

Conclusions

The present study offers an updated estimate of inpatient TJA cases performed in the United States in 2020 during the COVID-19 pandemic. We estimated 535,441 inpatient TKA and THA surgeries were performed in 2020, representing a 49.3% decrease compared to previous years. This estimate is similar to our previous estimates of 525,661-538,256 inpatient TJAs.

Conflicts of interest

A. Christ is a paid consultant for Intellijoint Surgical and Smith & Nephew and is a board/committee member of AAOS, the Musculoskeletal Tumor Society, and the Orthopaedic Research Society. N. Heckmann receives royalties from Corin; is a paid consultant for Intellijoint Surgical, MicroPort Orthopedics, Corin U.S.A., and Zimmer; has stock options in Intellijoint Surgical; and is a board/committee member of AAOS, AJRR, and AAHKS. J. Lieberman receives royalties from DePuy; is a paid consultant for DePuy; has stock options in BD Surgiphor and Hip Innovations Technologies; receives financial/material support from Saunders/Mosby-Elsevier; holds board/committee appointments with the AAOS, Hip Society, Musculoskeletal Transplant Foundation, and Western Orthopaedic

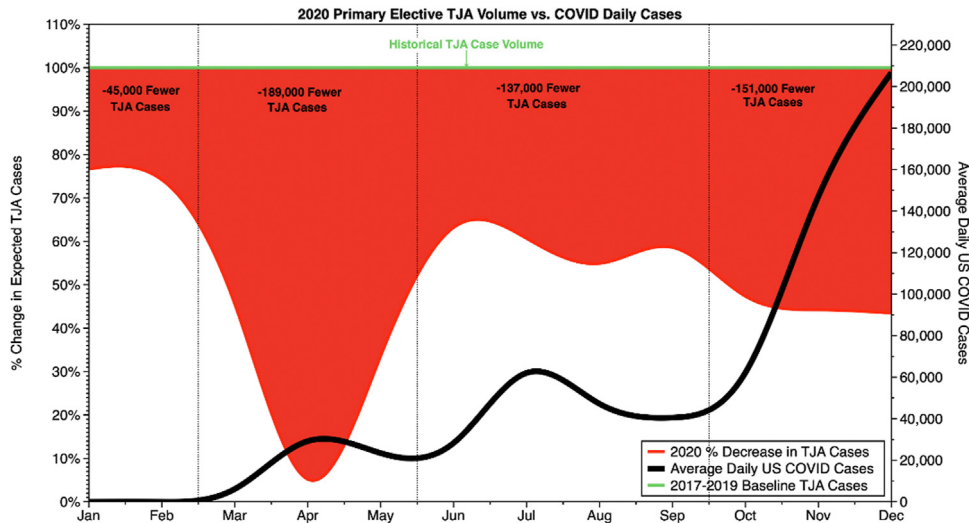


Figure 3. Estimated percentage change in primary, elective, inpatient TJA cases (red line, left y axis) performed in 2020 by month relative to the historical monthly averages from 2017-2019 (green line, left y axis) and the average daily COVID-19 cases in the U.S. by month in 2020 (black line, right y axis). The estimated decrease in TJA volume is represented by the red-shaded area between the green and red lines. These estimates represent the month-to-month differences between the 2020 weighted NIS estimates of TJA volume and the average estimates of TJA volume for 2017-2019, as derived from the NIS database. In total, approximately 522,000 patients were either delayed or unable to undergo elective inpatient arthroplasty in 2020.

Association. D. Oakes is a paid consultant and receives royalties from LimaCorporate. J. Stambough receives royalties from Signature Orthopaedics; is a speaker bureau member of CurveBeam; is a paid consultant for Medacta and Smith & Nephew; receives financial or material support from Smith & Nephew; is an editorial/governing board member of the *Journal of Arthroplasty*; and is a board/committee member of AAHKS and AJRR. All other authors declare no potential conflicts of interest.

For full disclosure statements refer to <https://doi.org/10.1016/j.artd.2024.101336>.

CRediT authorship contribution statement

Nathanael D. Heckmann: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Cory K. Mayfield:** Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Mary K. Richardson:** Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Kevin C. Liu:** Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Jennifer C. Wang:** Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Amit S. Piple:** Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Jeffrey B. Stambough:** Conceptualization, Formal analysis, Supervision, Writing – review & editing. **Daniel A. Oakes:** Conceptualization, Formal analysis, Supervision, Writing – review & editing. **Alexander B. Christ:** Conceptualization, Formal analysis, Supervision, Writing – review

& editing. **Jay R. Lieberman:** Conceptualization, Formal analysis, Supervision, Writing – review & editing.

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Appendix

Supplemental Table 1

List of ICD-10 codes used.

ICD-10 description	ICD-10 codes
TJA	0SR90- + 0SRB0-; TKA: 0SRC0- + 0SRD0-
Neoplasm	C40.2, C40.8, C40.9, C41.4, C41.9, C76.3, C76.5, C79.5, C80.9
Trauma	M80.05, M80.06, M80.85, M80.86, M84.35, M84.36, M84.45, M84.46, M84.65, M84.66, M84.75, S32.3, S32.4, S32.5, S32.6, S32.8, S72, S79.0, S79.1, S82.0, S82.1, S82.2, S82.3, S82.4, S82.8, S82.9, S89.0, S89.1, S89.2, S89.3, M96.65, M96.66, M96.67, M96.69
Periprosthetic fracture	M97.0, M97.1
Complications of orthopedic implants	T84.0, T84.116, T85.117, T84.124, T84.125, T84.126, T84.127, T84.194, T84.195, T84.196, T84.197, T84.218, T84.228, T84.3, T84.4, T84.8, T84.9

Supplemental Table 2

Total hip arthroplasty (THA) patient characteristics, demographic information, and hospital characteristics from 2017–2020 in the NIS-HCUP database.

Variable	2017 (N = 422,875)	2018 (N = 430,649)	2019 (N = 446,586)	2020 (N = 243,145)	P-value
Average age (y)	65.54 ± 11.25	65.88 ± 11.14	66.27 ± 11.02	66.48 ± 11.26	<.0001
Length of stay (d)	2.22 ± 2.03	2.07 ± 2.11	1.96 ± 2.35	2.17 ± 2.95	<.0001
Total cost (\$)	62,894.99 ± 43,676.57	64,743.15 ± 41,315.27	66,267.46 ± 47,062.40	72,713.29 ± 55,392.37	<.0001
Male sex N (%)	187,620 (44.34)	190,680 (44.25)	195,465 (43.75)	106,070 (43.59)	.008
Race N (%)					<.0001
Caucasian	345,695 (85.25)	356,155 (85.12)	373,581 (85.94)	201,081 (84.98)	
African American	31,905 (7.87)	32,440 (7.75)	34,495 (7.94)	18,885 (7.98)	
Hispanic	15,625 (3.85)	17,195 (4.11)	14,140 (3.25)	8950 (3.78)	
Asian or Pacific Islander	3735 (0.92)	3970 (0.95)	4190 (0.96)	2180 (0.92)	
Native American	1160 (0.29)	1400 (0.33)	1445 (0.33)	870 (0.37)	
Other	7380 (1.82)	7250 (1.73)	6845 (1.57)	4660 (1.97)	
Payer category N (%)					<.0001
Medicare	229,180 (54.27)	239,125 (55.57)	255,405 (57.23)	135,135 (55.62)	
Medicaid	21,505 (5.09)	21,455 (4.99)	22,220 (4.98)	13,495 (5.55)	
Private	158,330 (37.49)	155,105 (36.04)	152,760 (34.23)	84,305 (34.70)	
Self	2925 (0.69)	3380 (0.79)	4170 (0.93)	2205 (0.91)	
No charge	340 (0.08)	245 (0.06)	160 (0.04)	190 (0.08)	
Other	10,019 (2.37)	11,040 (2.57)	11,560 (2.59)	7630 (3.14)	
Month N (%)					<.0001
January	35,620 (8.42)	37,065 (8.61)	38,005 (8.51)	31,125 (12.80)	
February	34,640 (8.19)	34,705 (8.06)	36,005 (8.06)	27,975 (11.51)	
March	36,305 (8.59)	35,675 (8.28)	34,970 (7.83)	17,790 (7.32)	
April	32,905 (7.78)	35,340 (8.21)	38,945 (8.72)	3360 (1.38)	
May	36,740 (8.69)	37,030 (8.60)	37,020 (8.29)	15,585 (6.41)	
June	35,670 (8.44)	35,330 (8.20)	36,055 (8.07)	26,300 (10.82)	
July	31,565 (7.46)	35,070 (8.14)	37,880 (8.48)	23,340 (9.60)	
August	36,535 (8.64)	36,305 (8.43)	36,450 (8.16)	21,810 (8.97)	
September	31,100 (7.35)	32,225 (7.48)	34,870 (7.81)	20,920 (8.60)	
October	39,080 (9.24)	40,835 (9.48)	41,520 (9.30)	20,785 (8.55)	
November	37,660 (8.91)	37,230 (8.65)	37,055 (8.30)	17,895 (7.36)	
December	35,055 (8.29)	33,840 (7.86)	37,810 (8.47)	16,260 (6.69)	
Bed Size N (%)					<.0001
Small	127,370 (30.10)	137,599 (31.93)	148,085 (33.14)	86,795 (35.67)	
Medium	117,380 (27.74)	118,900 (27.59)	123,305 (27.60)	63,685 (26.17)	
Large	178,380 (42.16)	174,400 (40.47)	175,405 (39.26)	92,860 (38.16)	
Urban vs Rural, Teaching Status N (%)					<.0001
Rural	34,710 (8.20)	34,940 (8.11)	38,250 (8.56)	21,465 (8.82)	
Urban, nonteaching	109,595 (25.90)	105,400 (24.46)	98,175 (21.97)	53,395 (21.94)	
Urban, teaching	278,825 (65.90)	290,560 (67.43)	310,370 (69.47)	168,480 (69.24)	
Region N (%)					<.0001
Northeast	84,980 (20.08)	84,570 (19.63)	86,915 (19.45)	58,110 (23.88)	
Midwest or North Central	108,530 (25.65)	109,910 (25.51)	113,700 (25.45)	56,700 (23.30)	
South	141,450 (33.43)	146,500 (34.00)	155,255 (34.75)	83,985 (34.51)	
West	88,170 (20.84)	89,920 (20.87)	90,925 (20.35)	44,545 (18.31)	
Ownership N (%)					<.0001
Government, nonfederal	35,900 (8.48)	35,665 (8.28)	37,745 (8.45)	20,740 (8.52)	
Private, not-profit	325,805 (77.00)	329,345 (76.43)	341,745 (76.49)	179,570 (73.79)	
Private, invest-own	61,425 (14.52)	65,889 (15.29)	67,306 (15.06)	43,030 (19.68)	

Supplemental Table 3

Total knee arthroplasty patient characteristics, demographic information, and hospital characteristics from 2017-2020 in the NIS-HCUP database.

Variable	2017 (N = 729,374)	2018 (N = 609,764)	2019 (N = 530,526)	2020 (N = 292,226)	P-value
Average age (y)	66.74 ± 9.37	66.93 ± 9.38	67.33 ± 9.35	67.04 ± 9.49	<.0001
Length of stay (d)	2.29 ± 1.58	2.19 ± 1.75	2.10 ± 1.95	2.00 ± 1.82	<.0001
Total cost (\$)	60,401.91 ± 37,863.86	62,563.44 ± 37,693.16	64,321.12 ± 39,820.22	68,427.61 ± 49,233.32	<.0001
Male sex N (%)	278,395 (38.16)	231,674 (37.99)	201,645 (38.00%)	115,710 (39.58%)	<.0001
Race N (%)					<.0001
Caucasian	566,074 (81.22)	477,429 (80.49)	419,261 (81.19)	228,121 (80.39)	
African American	56,990 (8.18)	48,680 (8.21)	42,685 (8.27)	24,125 (8.50)	
Hispanic	43,875 (6.30)	40,180 (6.77)	31,900 (6.18)	18,690 (6.59)	
Asian or Pacific Islander	11,145 (1.60)	9205 (1.55)	8440 (1.63)	4495 (1.58)	
Native American	3105 (0.45)	3220 (0.54)	2580 (0.50)	1485 (0.52)	
Other	15,745 (2.26)	14,410 (2.43)	11,540 (2.23)	6840 (2.41)	
Payer Category N (%)					<.0001
Medicare	421,725 (57.89)	348,789 (57.27)	308,180 (58.13)	163,465 (56.00)	
Medicaid	31,580 (4.33)	26,450 (4.34)	22,205 (4.19)	13,185 (4.52)	
Private	250,555 (34.39)	211,380 (34.71)	178,515 (33.67)	101,805 (34.88)	
Self	3200 (0.44)	2680 (0.44)	3385 (0.64)	1725 (0.59)	
No charge	275 (0.04)	285 (0.05)	215 (0.04)	85 (0.03)	
Other	21,170 (2.91%)	19,470 (3.20)	17,660 (3.33)	11,645 (3.99)	
Month N (%)					<.0001
January	64,970 (8.91)	58,775 (9.64)	52,070 (9.81)	42,090 (14.40)	
February	58,585 (8.03)	49,955 (8.19)	45,715 (8.62)	36,210 (12.39)	
March	61,150 (8.38)	49,280 (8.08)	43,165 (8.14)	21,750 (7.44)	
April	55,165 (7.56)	51,325 (8.42)	47,345 (8.92)	1155 (0.04)	
May	62,265 (8.54)	51,170 (8.39)	43,030 (8.11)	14,340 (4.91)	
June	62,195 (8.53)	51,475 (8.44)	42,865 (8.08)	29,215 (10.00)	
July	52,965 (7.26)	47,310 (7.76)	42,960 (8.10)	26,740 (9.15)	
August	60,115 (8.24)	48,750 (7.99)	39,400 (7.43)	25,335 (8.67)	
September	56,265 (7.71)	45,510 (7.46)	42,015 (7.92)	26,340 (9.01)	
October	71,005 (9.74)	59,950 (9.83)	50,290 (9.48)	26,975 (9.23)	
November	66,480 (9.11)	52,545 (8.62)	41,955 (7.91)	22,335 (7.64)	
December	58,215 (7.98)	43,720 (7.17)	39,715 (7.49)	19,740 (6.76)	
Bed Size N (%)					<.0001
Small	228,080 (31.26)	199,088 (32.64)	191,035 (36.00)	112,271 (38.40)	
Medium	208,215 (28.54)	173,300 (28.41)	145,255 (27.37)	77,570 (26.53)	
Large	293,250 (40.20)	237,515 (38.94)	194,400 (36.63)	102,510 (35.06)	
Urban vs Rural, Teaching Status N (%)					<.0001
Rural	75,640 (10.37)	63,364 (10.39)	54,475 (10.26)	32,371 (11.07)	
Urban, nonteaching	204,225 (27.99)	159,975 (26.23)	124,826 (23.52)	70,565 (24.14)	
Urban, teaching	449,680 (61.64)	386,565 (63.38)	351,390 (66.21)	189,415 (64.79)	
Region N (%)					<.0001
Northeast	129,100 (17.70)	116,104 (19.04)	108,501 (20.45)	68,510 (23.43)	
Midwest or North Central	192,300 (26.36)	157,929 (25.89)	135,525 (25.54)	68,941 (23.58)	
South	263,500 (36.12)	219,295 (35.96)	192,355 (36.25)	103,600 (35.44)	
West	144,645 (19.83)	116,575 (19.11)	94,310 (17.77)	51,300 (17.55)	
Ownership N (%)					<.0001
Government, nonfederal	60,774 (8.33)	51,725 (8.48)	45,055 (8.49)	24,100 (8.24)	
Private, not-profit	544,930 (74.69)	444,580 (72.89)	387,785 (73.07)	205,390 (70.25)	
Private, invest-own	123,840 (16.97)	113,599 (18.63)	97,851 (18.44)	62,861 (21.50)	