



## Original Research

# Early Postoperative Complications in Total Hip and Knee Arthroplasties Before and During the COVID-19 Pandemic: A Retrospective Analysis of 38,234 Patients

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## ABSTRACT

**Background:** The outcomes of total joint arthroplasty during the coronavirus disease 2019 (COVID-19) pandemic are unknown. We sought to compare early postoperative complications in total hip arthroplasty (THA) and total knee arthroplasty (TKA) prior to and during the COVID-19 pandemic.

**Methods:** Patients in the American College of Surgeons National Surgical Quality Improvement Program database who had THA or TKA in the latter halves (July to December) of 2019 and 2020 were identified. Patients were divided into pre-COVID-19 (2019) and during-COVID-19 (2020) cohorts. Propensity score matching and logistic regression were used to detect correlations between operative period and outcomes. Statistical significance was set at  $\alpha = 0.05$ .

**Results:** A total of 38,234 THA and 61,956 TKA patients were included. There was a significantly higher rate of outpatient procedures in 2020 than that in 2019 for both THA (41.68% vs 6.59%,  $P < .001$ ) and TKA (41.68% vs 7.56%,  $P < .001$ ). On matched analysis, surgery in 2020 had lower odds of hospital stay for >1 day (THA: odds ratio [OR] 0.889;  $P < .001$ ) (TKA: OR 0.644;  $P < .001$ ) and nonhome discharge (THA: 0.655;  $P < .001$ ) (TKA: 0.497;  $P < .001$ ). There was also increased odds of superficial surgical site infection in THA (OR 1.272;  $P = .040$ ) and myocardial infarction in TKA patients (OR 1.488;  $P = .042$ ) in 2020 compared to those in 2019. There was no difference in the 15 other outcomes assessed.

**Conclusions:** Total joint arthroplasty surgery remains safe despite the COVID-19 pandemic. A statistically significant increase was detected in superficial surgical site infection and myocardial infarction risk during 2020 compared to 2019; however, the clinical significance of this is questionable. A shift away from inpatient stay was also present, possibly reflecting efforts to minimize nosocomial exposure to COVID-19.

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## Introduction

The first case of coronavirus disease 2019 (COVID-19) in the United States was reported in January 2020 [1]. During this first wave, entities such as the American College of Surgeons and American Academy of Orthopaedic Surgeons published guidelines recommending that nonemergent surgeries be deferred and resources be redirected to critical care efforts and personnel to

accommodate incoming COVID-19 patients [2–4]. Fields with predominantly elective procedures, such as orthopaedic surgery, were most significantly affected [5], with a recent study by Mattingly et al. reporting a 64% decrease in musculoskeletal procedures during the initial 2020 shutdown [6]. Of these, joint arthroplasty procedures were the most impacted with an alarming surgical volume decrease of 89.5% [6].

With such significant decreases in joint arthroplasty procedures during the initial 2020 shutdown [6], patients requiring joint replacement surgeries were left with disabling pain and limited mobility [7–10]. Although there was clearly a necessity to resume elective orthopaedic procedures such as total joint replacements, there was also unease about the repercussions of performing

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surgery during the initial phase of the COVID-19 pandemic [11,12]. During the peak of the pandemic in 2020, some authors reported increased morbidity and mortality in COVID-19 patients, with acute respiratory distress syndrome being the most common postoperative complication [11–13]. This, in addition to the risk of infection transmission to staff and other patients, made resumption of elective procedures controversial [14]. Several authors and organizations drafted guidelines to minimize these risks as elective surgeries resumed [15,16]. Recommendations included only accommodating COVID-19 patients if the institution had sufficient staff and resources. Additionally, patients diagnosed or exposed to COVID-19 should have their surgeries rescheduled and follow the appropriate Centers for Disease Control and Prevention recommendations [15–17]. Despite the measures taken to ensure that only COVID-19-free patients undergo elective orthopaedic surgery, it is plausible that patient outcomes could have been affected during the COVID-19 pandemic.

To this end, the aim of this study was to evaluate the short-term postoperative outcomes of patients that underwent elective total joint arthroplasty (TJA) during the COVID-19 pandemic. We hypothesized that the rate of early postoperative complications in elective TJA surgery will not differ significantly between the pre-COVID-19 and during-COVID-19 pandemic cohorts.

## Material and methods

This study did not require institutional review board approval or exemption as it was an analysis of publicly available, deidentified data.

### Data source

We utilized the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database for this study. NSQIP is a multicenter, national, risk-adjusted database containing prospectively collected preoperative, intraoperative, and postoperative variables and outcomes [18].

### Patient selection

We included patients with Current Procedural Terminology codes for total hip arthroplasty (THA) (27130) and/or total knee arthroplasty (TKA) (27447) and *International Classification of Disease-Tenth Revision* codes for osteoarthritis of the hip (M16, M160–M165, M169) and/or knee (M170–M175, M179). We excluded patients with Current Procedural Terminology codes for revision arthroplasty (27486, 27487, 27138, 27137, 27134).

For each procedure, we compared outcomes in 2020 (during-COVID-19) to outcomes in 2019 (pre-COVID-19). To capture the period after which elective surgery resumed in 2020, we only included patients undergoing procedures in quarters 3 and 4 of both years (July–December).

### Preoperative and perioperative characteristics

Preoperative variables collected were demographic data (age, gender, weight, and height) and comorbidities including smoking, hypertension, diabetes mellitus, chronic obstructive pulmonary disease (COPD), congestive heart failure, end-stage renal disease, diabetes mellitus, disseminated cancer, preoperative steroid or immunosuppressant use, bleeding disorder, preoperative anemia, preoperative transfusion, and American Society of Anesthesiology (ASA) Classification. Body mass index (BMI) was calculated for all patients. We classified preoperative anemia as hematocrit less than 36 and 39 for females and males, respectively. According to NSQIP,

diabetes mellitus is defined as being on insulin or a noninsulin antidiabetic agent. Perioperative variables assessed were wound classification and inpatient vs outpatient procedure.

### Postoperative outcomes

The ASC-NSQIP database documents postoperative outcomes and complications up to 30 days following surgery. Postoperative outcomes assessed included the following adverse events: superficial surgical site infection (SSI), deep SSI, wound dehiscence, pneumonia, unplanned reintubation, pulmonary embolism, deep venous thrombosis or thrombophlebitis, failure to extubate, urinary tract infection, cerebrovascular accident, cardiac arrest, myocardial infarction (MI), sepsis, acute kidney injury, unplanned reoperation, prolonged hospital stay (>30 days), unplanned readmission, and 30-day mortality. We also evaluated for differences in hospital stay for more than 1 day and discharge to rehab or acute care facility.

### Statistical analysis

Descriptive analyses were performed for preoperative and perioperative variables and outcomes. Univariate analysis, including Student's t-test and Pearson's chi-square test, was used to identify differences in continuous and categorical variables, respectively. Since we were investigating the safety of arthroplasty, we wanted to increase the sensitivity of our analysis. Therefore, we set statistical significance at  $\alpha = 0.05$  rather than 0.01.

To compare outcomes between 2020 and 2019, propensity score matching was performed. TKA and THA cohorts were analyzed separately. The propensity score was derived from a logistic regression model. All preoperative and perioperative variables were included in the propensity score model. We performed a nearest neighbor one-to-one matching between the 2020 and 2019 cohorts with no replacement. To compare postoperative outcomes, we then performed a bivariate logistic analysis of the unmatched cohorts and a multivariable logistic regression analysis of the matched cohorts. All preoperative and perioperative variables which were different between the matched cohorts at a  $P$  value < .1 were included in the multivariate model. All statistical analyses were performed using Stata (StataCorp. 2019. Stata Statistical Software: Release 16.1.; StataCorp LP, College Station, TX).

### Source of funding

No funding was received or used for this project.

## Results

### Study samples

In the latter half of 2020, 17,805 THA and 26,970 TKA cases were performed, compared to 20,429 THA and 34,976 TKA cases in 2019. Notably, 41.68% of THA cases and 45.20% of TKA cases were performed on an outpatient basis in 2020 compared to 6.59% of THA cases ( $P < .0001$ ) and 27.95% of TKA ( $P < .0001$ ) in 2019. ASA classification and proportion of outpatient procedures were significantly different between the unmatched THA cohorts, while age, proportion of patients with hypertension, proportion of patients with COPD, and proportion of outpatient procedures were significantly different between the unmatched TKA cohorts. Detailed demographic and preoperative data are presented in [Table 1](#) and [Table 2](#).

**Table 1**  
Total hip arthroplasty patient and procedure characteristics.

Variable	Unmatched cohort (N = 38,234)			Matched cohort (N = 35,604)		
	2019 (N = 20,429)	2020 (N = 17,805)	P value	2019 (N = 17,802)	2020 (N = 17,802)	P value
Age, mean [SD]	66.08 [10.61]	66.01 [10.50]	.528	67.07 [10.47]	66.01 [10.50]	<b>.000</b>
Female, n (%)	11,163 (54.65%)	9573 (53.77%)	.085	9825 (55.19%)	9571 (53.76%)	<b>.007</b>
BMI, mean [SD]	30.55 [6.12]	30.52 [6.16]	.568	30.75 [6.34]	30.52 [6.16]	<b>.001</b>
Smoker, n (%)	2222 (10.88%)	1918 (10.77%)	.743	1974 (11.09%)	1918 (10.77%)	.342
HTN, n (%)	11,257 (55.10%)	9778 (54.92%)	.716	10,169 (57.12%)	9775 (54.91%)	<b>.000</b>
CHF, n (%)	72 (0.35%)	77 (0.43%)	.210	72 (0.40%)	77 (0.43%)	.681
COPD, n (%)	954 (4.67%)	769 (4.32%)	.099	904 (5.08%)	769 (4.32%)	<b>.001</b>
ESRD, n (%)	33 (0.16%)	32 (0.18%)	.667	32 (0.18%)	32 (0.18%)	1.000
Bleeding disorder, n (%)	367 (1.80%)	296 (1.66%)	.317	323 (1.81%)	296 (1.66%)	.274
Disseminated cancer, n (%)	47 (0.23%)	42 (0.24%)	.906	38 (0.21%)	42 (0.24%)	.654
Diabetes, n (%)	2537 (12.42%)	2257 (12.68%)	.448	2419 (13.59%)	2254 (12.66%)	<b>.010</b>
Preoperative anemia, n (%) <sup>a</sup>	3143 (15.38%)	2827 (15.88%)	.186	3033 (17.04%)	2826 (15.87%)	<b>.003</b>
Transfused preoperatively, n (%)	8 (0.04%)	4 (0.02%)	.358	1 (0.01%)	4 (0.02%)	.180
Steroid/immunosuppressant use, n (%)	617 (3.02%)	557 (3.13%)	.541	610 (3.43%)	557 (3.13%)	.115
Wound classification, n (%)			.554			.714
Clean	20,379 (99.76%)	17,752 (99.70%)		17,754 (99.73%)	17,749 (99.70%)	
Clean/contaminated	43 (0.21%)	46 (0.26%)		41 (0.23%)	46 (0.26%)	
Contaminated	7 (0.03%)	6 (0.03%)		7 (0.04%)	6 (0.03%)	
Dirty/infected	0	1 (0.01%)		0	1 (0.01%)	
ASA class, n (%)			<b>.015</b>			<b>.000</b>
1	649 (3.18%)	523 (2.94%)		353 (1.98%)	523 (2.94%)	
2	10,473 (51.27%)	9073 (50.96%)		8150 (45.78%)	9073 (50.97%)	
3	8977 (43.94%)	7850 (44.09%)		8696 (50.38%)	7847 (44.08%)	
4	330 (1.62%)	359 (2.02%)		330 (1.85%)	359 (2.02%)	
Outpatient procedure, n (%)	1346 (6.59%)	7422 (41.68%)	<b>.000</b>	1345 (7.56%)	7420 (41.68%)	<b>.000</b>

CHF, congestive heart failure; ESRD, end-stage renal disease; HTN, hypertension; SD, standard deviation.

Significant values are in bold.

<sup>a</sup> Anemia was defined as hematocrit less than 36 and 39 for females and males, respectively.

### Matched samples

The matched THA samples included 17,802 cases in 2020 and 17,802 cases in 2019. The matched TKA samples included 26,970 cases in 2020 and 26,970 cases in 2019. Age, gender, BMI, ASA class, and certain comorbidities (hypertension, COPD, diabetes,

preoperative anemia) remained statistically different between the matched THA cohorts, with the 2020 cohort having lower age, BMI, number of females, and comorbidities. Meanwhile, age, ASA class, and proportion of hypertensive patients remained statistically different between the matched TKA cohorts, with age, proportion of hypertensive patients, and ASA classes 1 and 2 being higher in

**Table 2**  
Total knee arthroplasty patient and procedure characteristics.

Variable	Unmatched cohort (N = 61,956)			Matched cohort (N = 53,940)		
	2019 (N = 34,976)	2020 (N = 26,970)	P value	2019 (N = 26,970)	2020 (N = 26,970)	P value
Age, mean [SD]	67.47 [9.09]	66.90 [9.16]	<b>.000</b>	66.67 [9.26]	66.90 [9.16]	<b>.004</b>
Female, n (%)	21,285 (60.86%)	16,223 (60.15%)	.076	16,240 (60.22%)	16,223 (60.15%)	.881
BMI, mean [SD]	32.93 [6.46]	33.00 [6.57]	.182	33.09 [6.57]	33.00 [6.57]	.115
Smoker, n (%)	2591 (7.41%)	1954 (7.24%)	.440	1981 (7.35%)	1954 (7.24%)	.655
HTN, n (%)	22,314 (63.79%)	16,723 (61.99%)	<b>.000</b>	16,320 (60.51%)	16,723 (61.99%)	<b>.000</b>
CHF, n (%)	162 (0.46%)	109 (0.40%)	.270	100 (0.37%)	109 (0.40%)	.533
COPD, n (%)	1988 (5.68%)	1399 (5.19%)	<b>.007</b>	1371 (5.08%)	1399 (5.19%)	.585
ESRD, n (%)	62 (0.18%)	55 (0.20%)	.449	61 (0.23%)	55 (0.20%)	.577
Bleeding disorder, n (%)	619 (1.77%)	483 (1.79%)	.844	450 (1.67%)	483 (1.79%)	.279
Disseminated cancer, n (%)	53 (0.15%)	42 (0.16%)	.895	43 (0.16%)	42 (0.16%)	.914
Diabetes, n (%)	6528 (18.66%)	4848 (17.98%)	.029	4770 (17.69%)	4848 (17.98%)	.380
Preoperative anemia, n (%) <sup>a</sup>	5677 (16.23%)	4396 (16.30%)	.821	4528 (16.79%)	4396 (16.30%)	.126
Transfused preoperatively, n (%)	7 (0.02%)	8 (0.03%)	.444	7 (0.03%)	8 (0.03%)	.796
Steroid/immunosuppressant use, n (%)	1138 (3.25%)	937 (3.47%)	.131	1000 (3.71%)	937 (3.47%)	.145
Wound classification, n (%)			<b>.019</b>			.533
Clean	34,872 (99.69%)	26,921 (99.80%)		26,919 (99.81%)	26,921 (99.80%)	
Clean/contaminated	93 (0.27%)	40 (0.15%)		41 (0.15%)	40 (0.15%)	
Contaminated	14 (0.04%)	12 (0.04%)		10 (0.04%)	12 (0.04%)	
Dirty/infected	2 (0.01%)	2 (0.01%)		0	2 (0.01%)	
ASA Class, n (%)			.471			<b>.001</b>
1	540 (1.54%)	417 (1.55%)		347 (1.29%)	417 (1.55%)	
2	16,271 (46.51%)	12,397 (45.96%)		12,098 (44.86%)	12,397 (45.96%)	
3	17,585 (50.27%)	13,683 (50.72%)		13,997 (51.90%)	13,683 (50.72%)	
4	585 (1.67%)	478 (1.77%)		528 (1.96%)	478 (1.77%)	
Outpatient procedure, n (%)	9777 (27.95%)	12,192 (45.20%)	<b>.000</b>	9777 (36.25%)	12,192 (45.20%)	<b>.000</b>

CHF, congestive heart failure; ESRD, end-stage renal disease; HTN, hypertension; SD, standard deviation.

Significant values are in bold.

<sup>a</sup> Anemia was defined as hematocrit less than 36 and 39 for females and males, respectively.

the 2020 sample. For both the TKA and THA matched cohorts, the ratio of outpatient procedures was significantly higher in 2020. Detailed demographic and preoperative data of the matched cohorts are presented in Table 1 and Table 2.

### Postoperative outcomes

The incidence of the various postoperative outcomes is presented in Table 3. The overall complication rate for the THA cohort was 5.17% and 5.10% in 2019 and 2020, respectively, ( $P = .743$ ). The overall complication rate for the TKA cohort was 5.48% and 5.25% in 2019 and 2020, respectively, ( $P = .212$ ). There was no difference between 2020 and 2019 in the rates of any adverse event assessed (Table 3). However, patients treated in 2020 had a significantly lower rate of hospital stay for >1 day (THA: 28.78% vs 42.46%;  $P < .001$ ) (TKA: 32.72% vs 48.98%;  $P < .001$ ) and nonhome discharge (THA: 5.25% vs 8.86%;  $P < .001$ ) (TKA: 4.83% vs 9.13%;  $P < .001$ ). Bivariate logistic regression of the unmatched samples also showed lower odds of hospital stay for >1 day and nonhome discharge for both THA and TKA cohorts in 2020 with no difference in any of the analyzed adverse events (Table 4).

As the matched cohorts had significant differences in baseline characteristics, we performed a multivariate logistic regression of the matched cohorts controlling for all statistically different baseline characteristics. The multivariate models are outlined in Table 5. The multivariate analysis demonstrated increased odds of superficial SSI in THA patients (odds ratio [OR] 1.272; confidence interval [CI] [1.101–1.602];  $P = .040$ ) and MI in TKA patients (OR 1.488; CI [1.014–2.184];  $P = .042$ ) that underwent surgery in 2020 compared to 2019. There was also a decreased odds of hospital stay for >1 day (THA: OR 0.889; CI [0.847–0.935];  $P < .001$ ) (TKA: OR 0.644; CI [0.620–0.669];  $P < .001$ ) and discharge to rehab or acute care facility (THA: OR 0.655; CI [0.589–0.731];  $P < .001$ ) (TKA: OR 0.497; CI [0.455–0.543];  $P < .001$ ) in 2020. No other significant associations were present.

### Discussion

As we continue to learn about COVID-19, experts are increasingly suspecting the evolution of this virus into an endemic

pathogen [19]. With that in mind, it is important to assess the safety of orthopaedic surgery during the COVID-19 era. In this analysis of TJA postoperative outcomes before and after the COVID-19 pandemic, we found no difference in the 18 postoperative complications assessed on unmatched bivariate analysis. Matched multivariable analysis demonstrated a small increase in superficial SSI and MI rates in THA and TKA in 2020.

Overall, our results suggest that short-term complications in TJA surgery were not significantly different before and during the COVID-19 pandemic. Several previous studies have reported increased mortality in COVID-19 patients undergoing surgical treatment [11–13,20]. Kayani et al. found a 20% increase in mortality rates in patients with COVID-19 that underwent THA for hip fractures [13]. Haffner et al. analyzed 10,940 patients undergoing various procedures and found that COVID-19 patients were twice as likely to die postoperatively compared to their healthy counterparts [20]. Nonetheless, as opposed to these studies which analyzed COVID-19 patients specifically, we found no increase in postoperative mortality in 2020 among all patients who underwent arthroplasty. This suggests that guidelines and safety precautions, such as preoperative COVID-19 screening, were successful in mitigating complications associated with performing surgery on COVID-19 patients. Furthermore, our findings support a previous study by Kader et al. which estimated that the overall probability of a patient admitted for elective orthopaedic surgery having a false-negative preoperative test leading to postoperative mortality would be around 1 in every 7000 (or 0.01%) [21]. This small rate of mortality would also help explain why we did not find an increase in mortality in patients undergoing TJA in 2020. Furthermore, the risk of postoperative death by nosocomial COVID-19 infection has also been shown to be low in several clinical studies [22,23].

We found a slightly increased risk of superficial SSI in patients undergoing THA in 2020 compared to 2019. To our knowledge, there is no literature directly associating COVID-19 infection with an increased risk of SSI. One explanation may be decreased follow-up of patients undergoing hip replacement during the COVID-19 pandemic. It is known that clinical outpatient visits decreased during the start of the pandemic due in part to patients' fear of contracting COVID-19 [24,25]. The decreased clinical supervision could have led to inappropriate wound care by patients. Even

**Table 3**  
Incidence of adverse events in unmatched cohorts.

Complications	Total hip arthroplasty			Total knee arthroplasty		
	2019 (N = 20,429)	2020 (N = 17,805)	P value	2019 (N = 34,976)	2020 (N = 26,970)	P value
Any adverse event	5.17%	5.10%	.743	5.48%	5.25%	.212
Superficial SSI	0.86%	0.97%	.238	1.29%	1.19%	.265
Deep SSI	0.12%	0.15%	.441	0.07%	0.08%	.672
Dehiscence	0.14%	0.15%	.805	0.19%	0.26%	.063
Pneumonia	0.23%	0.17%	.151	0.26%	0.24%	.687
Reintubation	0.08%	0.08%	.875	0.09%	0.08%	.565
Pulmonary embolism	0.20%	0.23%	.465	0.37%	0.32%	.279
DVT/thrombophlebitis	0.34%	0.28%	.319	0.58%	0.62%	.606
Failure to extubate	0.04%	0.02%	.199	0.04%	0.04%	.995
Urinary tract infection	0.69%	0.62%	.421	0.63%	0.65%	.682
Stroke/CVA	0.07%	0.08%	.578	0.08%	0.05%	.146
Arrest	0.04%	0.06%	.596	0.05%	0.06%	.946
Myocardial infarction	0.18%	0.19%	.923	0.18%	0.24%	.140
Sepsis	0.19%	0.14%	.228	0.18%	0.13%	.150
Unplanned reoperation	1.70%	1.60%	.432	0.97%	0.94%	.674
Unplanned 30-d readmission	3.01%	2.88%	.456	2.76%	2.58%	.175
30-D mortality	0.07%	0.10%	.356	0.07%	0.09%	.541
Acute kidney injury	0.03%	0.03%	.976	0.03%	0.04%	.414
Hospital stay >1 d	42.46%	28.78%	<b>.000</b>	48.98%	32.72%	<b>.000</b>
Discharge to rehab or acute care facility	8.86%	5.25%	<b>.000</b>	9.13%	4.83%	<b>.000</b>

CVA, cerebral vascular accident; DVT, deep venous thrombosis. Significant values are in bold.

**Table 4**  
Bivariate logistic regression models of unmatched cohorts (2020 vs 2019).

Complications	Total hip arthroplasty			Total knee arthroplasty		
	OR	95% CI	P value	OR	95% CI	P value
Any adverse event	0.985	[0.899- 1.079]	.743	0.956	[0.891- 1.026]	.891
Superficial SSI	1.136	[0.919-1.402]	.442	0.921	[0.798-1.064]	.265
Deep SSI	1.243	[0.713-2.166]	.441	1.135	[0.632-2.039]	.672
Dehiscence	1.068	[0.632-1.805]	.805	1.378	[0.981-1.933]	.064
Pneumonia	0.717	[0.454-1.131]	.153	0.936	[0.680-1.289]	.687
Reintubation	0.945	[0.465-1.917]	.875	0.851	[0.491-1.476]	.566
Pulmonary embolism	1.176	[0.761-1.819]	.465	0.861	[0.656-1.129]	.279
DVT/thrombophlebitis	0.831	[0.577-1.196]	.319	1.055	[0.859-1.296]	.606
Failure to extubate	0.430	[0.114-1.622]	.213	0.997	[0.437-2.275]	.995
Urinary tract infection	0.902	[0.703-1.158]	.421	1.042	[0.854-1.272]	.682
Stroke/CVA	1.229	[0.593-2.548]	.578	0.625	[0.330-1.184]	.150
Arrest	1.275	[0.518-3.138]	.597	1.023	[0.520-2.015]	.946
Myocardial infarction	1.023	[0.640-1.637]	.923	1.297	[0.917-1.835]	.141
Sepsis	0.735	[0.444-1.215]	.230	0.741	[0.492-1.116]	.151
Unplanned reoperation	0.937	[0.802-1.099]	.432	0.965	[0.820-1.137]	.674
Unplanned 30-d readmission	0.955	[0.849-1.077]	.456	0.934	[0.846-1.031]	.175
30-D mortality	1.394	[0.687-2.830]	.358	1.193	[0.677-2.102]	.541
Acute kidney injury	0.983	[0.547-2.408]	.976	1.423	[0.605-3.359]	.416
Hospital stay > 1 d	0.548	[0.525-0.572]	<b>.000</b>	0.507	[0.490-0.524]	<b>.000</b>
Discharge to rehab or acute care facility	0.570	[0.525-0.619]	<b>.000</b>	0.505	[0.472-0.539]	<b>.000</b>

CVA, cerebral vascular accident; DVT, deep venous thrombosis.  
Significant values are in bold.

**Table 5**  
Multivariate logistic regression models of matched cohorts (2020 vs 2019).

Complications	Total hip arthroplasty			Total knee arthroplasty		
	OR	95% CI	P value	OR	95% CI	P value
Any adverse event	1.048	[0.948-1.159]	.362	1.008	[0.935-1.089]	.821
Superficial SSI	1.272	[1.101-1.602]	<b>.040</b>	1.026	[0.877-1.200]	.746
Deep SSI	1.623	[0.884-3.003]	.118	1.180	[0.631-2.203]	.604
Dehiscence	1.114	[0.625-1.986]	.714	1.328	[0.924-1.907]	.125
Pneumonia	0.802	[0.492-1.310]	.379	1.056	[0.744-1.496]	.760
Reintubation	1.206	[0.578-2.517]	.618	0.959	[0.529-1.736]	.889
Pulmonary embolism	1.506	[0.937-2.418]	.091	0.952	[0.710-1.275]	.742
DVT/thrombophlebitis	0.998	[0.674-1.479]	.993	1.034	[0.831-1.286]	.764
Failure to extubate	0.471	[0.113-1.968]	.302	1.021	[0.424-2.462]	.962
Urinary tract infection	0.769	[0.580-1.019]	.068	1.058	[0.854-1.310]	.604
Stroke/CVA	1.571	[0.744-3.319]	.236	0.662	[0.338-1.297]	.230
Arrest	1.541	[0.597-3.975]	.371	1.214	[0.576-2.558]	.609
Myocardial infarction	1.217	[0.739-2.002]	.440	1.488	[1.014-2.184]	<b>.042</b>
Sepsis	0.778	[0.446-1.360]	.379	0.722	[0.469-1.113]	.140
Unplanned reoperation	0.997	[0.839-1.185]	.975	0.954	[0.802-1.134]	.597
Unplanned 30-d readmission	1.004	[0.879-1.145]	.955	0.949	[0.854-1.055]	.336
30-D mortality	1.449	[0.674-3.118]	.342	1.423	[0.746-2.716]	.284
Acute kidney injury	1.272	[0.411-3.937]	.676	1.294	[0.519-3.229]	.580
Hospital stay >1 d	0.889	[0.847-0.935]	<b>.000</b>	0.644	[0.620-0.669]	<b>.000</b>
Discharge to rehab or acute care facility	0.655	[0.589-0.731]	<b>.000</b>	0.497	[0.455-0.543]	<b>.000</b>

CVA, cerebral vascular accident; DVT, deep venous thrombosis.  
Significant values are in bold.

though telemedicine visits have been shown to be effective in diagnosing and following SSIs [26], they may have not been able to compensate for the decrease in outpatient visits. Patel et al. analyzed the visit patterns of almost 17 million commercial insurance enrollees and found that total outpatient visits, including in-person and telemedicine visits, decreased by 9.1%, with decreases in total visit rates by state ranging from 16% to 73% after expansion of telehealth coverage by Medicare [24]. Despite the statistical significance, the clinical significance of this increased superficial SSI risk is questionable as the magnitude of increase was minimal (OR 1.272), and superficial SSI is often treatable. Furthermore, the reporting of SSI may have been inconsistent, as many of these patients were treated on outpatient basis. With these considerations, this small increase may be interesting if reproducible but unlikely to be compelling or actionable at this time.

We also found an increased risk of MI in patients undergoing TKA in 2020. COVID-19 infection is strongly associated with a proinflammatory and prothrombotic state, leading to an increased theoretical risk of MI [27]. Our finding of increased postoperative MI incidence in 2020 could be related to a small percentage of patients with COVID-19 who were missed during preoperative screening. Furthermore, patients previously hospitalized with severe COVID-19 were found to have a high prevalence (40%) of occult cardiac ischemia/infarction on perfusion analysis even after complete recovery [27]. This could suggest that even recovered COVID-19 patients may have an increased predisposition for coronary syndromes when the heart is stressed with surgery. This could explain the increased risk of MI we found despite rigorous preoperative screening. However, it is difficult to make any conclusions without accounting for COVID-19 status in the analysis. Future studies should reevaluate this and focus on the long-term cardiovascular consequences of COVID-19, as this can have large implications on patient selection for elective, nonurgent procedures.

Interestingly, on both matched and unmatched analyses, the 2020 cohort was much more likely to undergo THA and TKA on an outpatient basis and was less likely to have nonhome discharge and hospital stay for >1 day. This probably is a result of efforts to decrease patient stay in locations, such as hospitals and rehab/care centers, where there is a possibility of COVID-19 exposure [28]. Additionally, utilization of outpatient centers such as ambulatory surgery centers has been recommended to allow isolation of healthy patients undergoing elective surgery from COVID-19 patients and to relieve some load from the COVID-19-strained hospital systems [29,30]. The Centers for Medicare and Medicaid Services also agreed to cover outpatient arthroplasty procedures as of January 2020 [31]. This shift to outpatient TJA surgery is supported by recent literature showing no increased complication rates compared to inpatient surgery [32].

This study has several limitations. First, as with any retrospective analysis, only association can be established and not causation. Second, we were limited by the variables recorded in NSQIP and could not determine the COVID-19 status of included patients or account for other confounders that may have affected our findings. Third, NSQIP only records complications within 30 days, resulting in underestimation of possible longer-term complications. Fourth, variability in reporting is likely present in any large database. As such, inaccuracies may have been introduced to our analysis due to reporting differences. Finally, we could not account for other consequences of the COVID-19 pandemic, such as decreased availability of health-care workers and supplies and economic decline, which could have affected patient outcomes. Despite these limitations, this is, to our knowledge, the first study to assess the safety of TJA during the COVID-19 pandemic using a large national database.

## Conclusions

Broadly, THA and TKA short-term complications remained largely similar to prepandemic rates during 2020. A statistically significant increase in superficial SSI and MI risk was present in 2020; however, further studies are required to determine the clinical significance and persistence of this finding. There was also a shift away from inpatient surgery in 2020, possibly reflecting efforts to avoid nosocomial exposure of patients to COVID-19. Our current findings suggest that TJA procedures may be safely carried out during the COVID-19 pandemic without a substantially increased risk of most short-term postoperative complications.

## Conflicts of interest

Julius K. Oni is an American Academy of Orthopaedic Surgeons Knee Program Committee board or committee member; American Association of Hip and Knee Surgeons Humanitarian Committee board or committee member; is a paid consultant for DePuy Synthes and Zimmer Biomet; receives fellowship support from Omega and Smith and Nephew. All other authors declare no potential conflicts of interest.

For full disclosure statements refer to <https://doi.org/10.1016/j.artd.2022.08.018>.

## References

- [1] Holshue ML, DeBolt C, Lindquist S, Lofy KH, Wiesman J, Bruce H, et al. First case of 2019 novel coronavirus in the United States. *N Engl J Med* 2020;382:929–36.
- [2] American College of Surgeons. COVID-19: guidance for triage of non-emergent surgical procedures. *Am Coll Surg* 2020;2019:1–38.
- [3] Guy D, Brocco JS. AAOS guidelines for elective surgery - American Academy of Orthopaedic Surgeons. <https://www.aaos.org/about/covid-19-information-for-our-members/aaos-guidelines-for-elective-surgery/> [accessed 23.01.22].
- [4] Centers for Medicare & Medicaid Services. CMS releases recommendations on adult elective surgeries, non-essential medical, surgical, and dental procedures during COVID-19 response | CMS. <https://www.cms.gov/newsroom/press-releases/cms-releases-recommendations-adult-elective-surgeries-non-essential-medical-surgical-and-dental> [accessed 23.01.22].
- [5] Meredith JW, High KP, Freischlag JA. Preserving elective surgeries in the COVID-19 pandemic and the future. *JAMA* 2020;324:1725–6.
- [6] Mattingly AS, Rose L, Eddington HS, Trickey AW, Cullen MR, Morris AM, et al. Trends in US surgical procedures and health care system response to policies curtailing elective surgical operations during the COVID-19 pandemic. *JAMA Netw Open* 2021;4:e2138038.
- [7] Pietrzak JRT, Maharaj Z, Erasmus M, Sikhali N, Cakic JN, Mokete L. Pain and function deteriorate in patients awaiting total joint arthroplasty that has been postponed due to the COVID-19 pandemic. *World J Orthop* 2021;12:152–68. <https://doi.org/10.5312/wjo.v12.i3.152>.
- [8] Morris JA, Super J, Huntley D, Ashdown T, Harland W, Anakwe R. Waiting lists for symptomatic joint arthritis are not benign. *Bone Jt Open* 2020;1:508–11.
- [9] Scott CEH, MacDonald DJ, Howie CR. 'Worse than death' and waiting for a joint arthroplasty. *Bone Joint J* 2019;101 B:941–50.
- [10] Kapstad H, Rustøen T, Hanestad BR, Moum T, Langeland N, Stavem K. Changes in pain, stiffness and physical function in patients with osteoarthritis waiting for hip or knee joint replacement surgery. *Osteoarthr Cartil* 2007;15:837–43.
- [11] Besnier E, Tuech JJ, Schwarz L. We asked the experts: covid-19 outbreak: is there still a place for scheduled surgery? "Reflection from pathophysiological data.". *World J Surg* 2020;44:1695–8.
- [12] Bhangu A, Nepogodiev D, Glasbey JC, Li E, Omar OM, Simoes JF, et al. Mortality and pulmonary complications in patients undergoing surgery with perioperative SARS-CoV-2 infection: an international cohort study. *Lancet* 2020;396:27–38.
- [13] Kayani B, Onochie E, Patil V, Begum F, Cuthbert R, Ferguson D, et al. The effects of COVID-19 on perioperative morbidity and mortality in patients with hip fractures. *Bone Joint J* 2020;102B:1136–45.
- [14] Anoushiravani AA, Barnes CL, Bosco JA, Bozic KJ, Huddleston JI, Kang JD, et al. Reemergence of multispecialty inpatient elective orthopaedic surgery during the COVID-19 pandemic: guidelines for a new normal. *J Bone Joint Surg Am* 2020;102:E79.
- [15] American College of Surgeons, American Society of Anesthesiologists. Association of perioperative registered nurses, American hospital association. Joint statement: roadmap for resuming elective surgery after COVID-19 pandemic. <https://www.facs.org/covid-19/clinical-guidance/roadmap-elective-surgery;> 2020 [accessed 23.01.22].
- [16] Newsroom April 2020: AAOS releases clinical considerations for resuming elective surgery. <https://www.aaos.org/aaos-home/newsroom/press-releases/>

- aaos-releases-clinical-considerations-for-resuming-elective-surgery/ [accessed 23.01.22].
- [17] CDC. About quarantine and isolation. Cdc. 2020. <https://www.cdc.gov/coronavirus/2019-ncov/your-health/quarantine-isolation.html>; 2008 [accessed 23.01.22].
- [18] American College of Surgeons. ACS national surgical quality improvement Program (ACS NSQIP). <https://www.facs.org/quality-programs/acs-nsqip> [accessed 23.01.22].
- [19] Phillips N. The coronavirus is here to stay - here's what that means. *Nature* 2021;590:382–4.
- [20] Haffner MR, Le HV, Saiz AM, Han G, Fine J, Wolinsky P, et al. Postoperative in-hospital morbidity and mortality of patients with COVID-19 infection compared with patients without COVID-19 infection. *JAMA Netw Open* 2021;4:e215697.
- [21] Kader N, Clement ND, Patel VR, Caplan N, Banaszkiwicz P, Kader D. The theoretical mortality risk of an asymptomatic patient with a negative SARS-CoV-2 test developing COVID-19 following elective orthopaedic surgery. *Bone Joint J* 2020;102-B:1256–60.
- [22] Kane AD, Paterson J, Pokhrel S, Berry SK, Monkhouse D, Brand JW, et al. Perioperative COVID-19 infection in urgent elective surgery during a pandemic surge period: a retrospective observational cohort study. *Anaesthesia* 2020;75:1596–604.
- [23] Sutherland L, Hastie J, Takayama H, Furuya Y, Hochman B, Kelley N, et al. Low rate of health care-associated transmission of coronavirus disease 2019 (COVID-19) in the epicenter. *J Thorac Cardiovasc Surg* 2021;161:e235–7.
- [24] Patel SY, Mehrotra A, Huskamp HA, Uscher-Pines L, Ganguli I, Barnett ML. Trends in outpatient care delivery and telemedicine during the COVID-19 pandemic in the US. *JAMA Intern Med* 2021;181:388–91.
- [25] Chatterji P, Li Y. Effects of the COVID-19 pandemic on outpatient providers in the United States. *Med Care* 2021;59:58–61.
- [26] McLean KA, Mountain KE, Shaw CA, Drake TM, Pius R, Knight SR, et al. Remote diagnosis of surgical-site infection using a mobile digital intervention: a randomised controlled trial in emergency surgery patients. *NPJ Digit Med* 2021;4:160.
- [27] Toscano O, Cosentino N, Campodonico J, Bartorelli AL, Marenzi G. Acute myocardial infarction during the COVID-19 pandemic: an update on clinical characteristics and outcomes. *Front Cardiovasc Med* 2021;8:648290.
- [28] Where are all the patients? Addressing covid-19 fear to encourage sick patients to seek emergency care | catalyst non-issue content. <https://catalyst.nejm.org/doi/full/10.1056/CAT.20.0193> [accessed 23.01.22].
- [29] Zeegen EN, Yates AJ, Jevsevar DS. After the COVID-19 pandemic: returning to normalcy or returning to a new normal? *J Arthroplasty* 2020;35:S37–41.
- [30] Gilat R, Haunschild ED, Tauro T, Cole BJ. Recommendations to optimize the safety of elective surgical care while limiting the spread of COVID-19: primum non nocere. *Arthrosc Sport Med Rehabil* 2020;2:e177–83.
- [31] CMS. January 2020. Update of the hospital outpatient prospective payment system (OPPS). Centers for Medicare and Medicaid Services. <https://www.cms.gov/files/document/mm11605.pdf>; 2020 [accessed 24.06.20].
- [32] DeMik DE, Carender CN, Kohler JG, An Q, Brown TS, Bedard NA. Recent increases in outpatient total hip arthroplasty have not increased early complications. *J Arthroplasty* 2022;37:325–329.e1.