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GENERAL ORTHOPAEDICS

The association between preoperative COVID-19-positivity and acute postoperative complication risk among patients undergoing orthopedic surgery

A MATCHED COHORT ANALYSIS

M. R. Mercier,
R. Koucheki,
J. R. Lex,
A. Khoshbin,
S. S-H. Park,
T. R. Daniels,
M. M. Halai

From St. Michael's Hospital, Toronto, Canada

Aims

This study aimed to investigate the risk of postoperative complications in COVID-19-positive patients undergoing common orthopaedic procedures.

Methods

Using the National Surgical Quality Improvement Programme (NSQIP) database, patients who underwent common orthopaedic surgery procedures from 1 January to 31 December 2021 were extracted. Patient preoperative COVID-19 status, demographics, comorbidities, type of surgery, and postoperative complications were analyzed. Propensity score matching was conducted between COVID-19-positive and -negative patients. Multivariable regression was then performed to identify both patient and provider risk factors independently associated with the occurrence of 30-day postoperative adverse events.

Results

Of 194,121 included patients, 740 (0.38%) were identified to be COVID-19-positive. Comparison of comorbidities demonstrated that COVID-19-positive patients had higher rates of diabetes, heart failure, and pulmonary disease. After propensity matching and controlling for all preoperative variables, multivariable analysis found that COVID-19-positive patients were at increased risk of several postoperative complications, including: any adverse event, major adverse event, minor adverse event, death, venous thromboembolism, and pneumonia. COVID-19-positive patients undergoing hip/knee arthroplasty and trauma surgery were at increased risk of 30-day adverse events.

Conclusion

COVID-19-positive patients undergoing orthopaedic surgery had increased odds of many 30-day postoperative complications, with hip/knee arthroplasty and trauma surgery being the most high-risk procedures. These data reinforce prior literature demonstrating increased risk of venous thromboembolic events in the acute postoperative period. Clinicians caring for patients undergoing orthopaedic procedures should be mindful of these increased risks, and attempt to improve patient care during the ongoing global pandemic.

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Keywords: COVID, NSQIP, Perioperative complications, Trauma, Arthroplasty

Correspondence should be sent to Mansur M. Halai; email: mansur.halai@unityhealth.to

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Introduction

COVID-19 continues to pose additional burdens on already strained healthcare systems worldwide.[1,2] There is growing evidence demonstrating that COVID-19 is associated with an increased risk for morbidity and mortality in hospitalized patients, including respiratory failure, pneumonia,

cardiac events, venous thromboembolism, and longer lengths of stay.[3-11] Specifically in patients undergoing surgical and interventional procedures, COVID-19 positivity increases morbidity and mortality.[3,4,12] The correlation between preoperative COVID-19 positivity and increased rates of perioperative complications has been demonstrated in various surgical specialties, including trauma, cardiothoracic, hepatobiliary, obstetric, and vascular.[4,13] In the orthopaedic literature, some studies have investigated the relationship between COVID-19 positivity and perioperative complications in common orthopaedic injuries such as hip and ankle fractures.[13-17] However, large-scale studies based on robust national data registries, investigating the relationship of COVID-19 positivity and complications in different orthopaedic procedures, are lacking.

Furthermore, while various patient comorbidities such as diabetes, cardiovascular disease (CVD), chronic obstructive pulmonary disease (COPD), and obesity have been associated with increased risk of suffering from morbidities and mortality associated with COVID-19-positive patients,[18,19] the relationship of these comorbidities, COVID-19 positivity, and incidence of complications in the immediate postoperative period following orthopaedic procedures is not well studied.

An enhanced understanding of the relationship between COVID-19 positivity and perioperative complications across a wide spectrum of orthopaedic procedures allows for enhanced risk stratification, patient counselling and optimization, resource allocation, and care planning. This study aimed to understand the relationship between COVID-19-positivity in patients undergoing orthopaedic surgery and the risk of adverse outcomes using the National Surgical Quality Improvement Programme (NSQIP) 2021 database.

Methods

Data source. A retrospective cohort analysis was performed based on the NSQIP database on patients undergoing orthopaedic surgery. The date range evaluated was 1 January 2021 to 31 December 2021. The NSQIP database is a deidentified collection of patient records from over 680 participating hospitals across North America that reports on perioperative complications within a 30-day period recorded directly by the programme's trained nurses.[20,21] Hospital research ethics board approval was obtained for this study.

Study population. NSQIP data on surgical procedures are reported as Current Procedural Terminology (CPT) codes.[22] Using CPT codes, patients who underwent the most common orthopaedic surgery procedures in the NSQIP database as previously reported by Molina et al[23] were identified and extracted (Table I). Patient preoperative COVID-19 status was specified by a discrete preoperative COVID-19 diagnosis variable in the NSQIP database. Per database documentation, COVID-19 positivity was defined as an active diagnosis of COVID-19 within 14 days prior to the primary procedure which is confirmed by laboratory testing.[24] Laboratory testing could be performed before or after the primary procedure to confirm the preoperative diagnosis.

Patient data. Baseline demographic data on patient age, sex, BMI, race, American Society of Anesthesiologists (ASA) grade,[25] and type of surgery were extracted. Using International Classification of Diseases (ICD)-10 codes, patient comorbidities were also extracted. Investigated comorbidities included diabetes mellitus (DM), congestive heart failure (CHF), hypertension (HTN), severe COPD, dependence on ventilators, chronic steroid use, and history of smoking.

Additionally, 30-day postoperative adverse events were identified based on ICD-10 codes. Perioperative outcomes were classified into major, minor, and any adverse events. Major adverse events included: deep surgical site infection, mechanical ventilation > 48 hours, unplanned intubation, acute renal failure, sepsis, venous thromboembolism, stroke, cardiac arrest/myocardial infarction (MI), return to operating theatre, and death. Minor adverse events included: superficial surgical site infection, wound dehiscence, pneumonia, urinary tract infection, and *Clostridium difficile* infections. Any adverse event was tabulated when a patient experienced one of more of the predefined major or minor adverse events. In addition, data on other perioperative outcomes, such as blood transfusion, length of stay (≥ 3 days), and discharge to non-home facilities, were extracted.

Statistical analysis. NSQIP data files from 2021 were analyzed in a master file using SPSS version 28 (2021; IBM, USA). Patient demographics, comorbidities, and adverse events data were compared between COVID-19-positive and COVID-19-negative patients undergoing all-type orthopaedic surgery. Chi-squared tests were used to compare demographics and postoperative adverse events. Independent-samples *t*-tests were used to compare continuous variables (age and BMI). COVID-19-positive patients were then compared to a 1:10 matched COVID-19-negative cohort, and propensity score matching was conducted based on age, sex, and all examined comorbidities (listed above). Matching was performed using R package "Matchit" package.[26] Multivariable regression was then performed to identify association of COVID-19 positivity with 30-day adverse events. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated for each specific adverse event, adverse event group, and surgery type (Table I for procedure type classifications). Using univariate analysis, complications and adverse events occurring within the 30-day postoperative period were compared. These are expressed as percentages of the cohorts, summarized in Table II.

Table I. Incidence of preoperative COVID-19 positivity among patients undergoing the most common orthopaedic surgery procedures in the National Surgical Quality Improvement Programme database.

CPT code	Surgery type	Procedure	Patients, n	COVID-19 patients, n (% of COVID-19 cases)
			194,121 (100)	740 (0.38)
27447	Arthroplasty	TKA	58,277 (30.02)	73 (9.86)
27130	Arthroplasty	THA	40,978 (21.11)	78 (10.54)
27245	Trauma	Treatment of intertrochanteric, peritrochanteric, or subtrochanteric femoral fracture, with intramedullary implant	12,670 (6.53)	224 (30.27)
63047	Spine	Laminectomy, single vertebral segment, lumbar	9,722 (5.01)	20 (2.70)
63030	Spine	Laminotomy (hemilaminectomy), with decompression of nerve root, lumbar	8,554 (4.41)	19 (2.57)
27236	Trauma	Open treatment of femoral fracture, proximal end, neck, internal fixation or prosthetic arthroplasty	8,306 (4.28)	134 (18.11)
29881	Sports	Arthroscopy knee (chondroplasty), with meniscectomy (medial or lateral)	7,125 (3.67)	9 (1.22)
29827	Shoulder	Shoulder arthroscopy, rotator cuff repair	6,879 (3.54)	7 (0.95)
23472	Shoulder	Total shoulder arthroplasty	5,804 (2.99)	12 (1.62)
22612	Spine	Arthrodesis lumbar	4,389 (2.26)	7 (0.95)
29888	Sports	Arthroscopically aided ACL	3,577 (1.84)	2 (0.27)
27487	Arthroplasty	Revision of TKA, both femoral and tibial components	3,097 (1.60)	5 (0.68)
27814	Trauma	Open treatment of bimalleolar ankle fracture, including internal fixation	2,604 (1.34)	23 (3.11)
27125	Arthroplasty	Hemiarthroplasty, hip, partial (eg, femoral stem prosthesis, bipolar arthroplasty)	2,576 (1.33)	46 (6.22)
22630	Spine	Arthrodesis, posterior interbody technique, including laminectomy and/or discectomy to prepare interspace, single interspace; lumbar	2,241 (1.15)	4 (0.54)
27134	Arthroplasty	Revision of THA	2,205 (1.14)	14 (1.89)
29880	Sports	Arthroscopy, knee (chondroplasty), with meniscectomy (medial or lateral)	2,187 (1.13)	4 (0.54)
27446	Sports	Arthroplasty, knee, condyle and plateau; medial or lateral compartment	1,793 (0.92)	1 (0.14)
27792	Trauma	ORIF of distal fibular fracture (lateral malleolus), including internal fixation	1,615 (0.83)	16 (2.16)
27486	Arthroplasty	Revision of TKA, with or without allograft; 1 component	1,548 (0.80)	5 (0.68)
27244	Trauma	ORIF intertrochanteric femur fracture with plate and screw	1,471 (0.76)	26 (3.51)
29806	Shoulder	Arthroscopy, shoulder, surgical; capsulorrhaphy	1,454 (0.75)	4 (0.54)
29877	Sports	Arthroscopy knee, débridement/shaving of articular cartilage (chondroplasty)	1,074 (0.55)	5 (0.68)
29807	Shoulder	Arthroscopy, shoulder, surgical; repair of slap lesion	781 (0.40)	0 (0)
23412	Shoulder	Repair of ruptured musculotendinous cuff (e.g. rotator cuff), open; chronic	700 (0.36)	0 (0)
29826	Shoulder	Arthroscopy, shoulder, surgical; decompression of subacromial space with partial acromioplasty, with coracoacromial ligament (i.e. arch) release	675 (0.35)	1 (0.14)
22554	Spine	Arthrodesis, anterior interbody technique, including minimal discectomy to prepare interspace, cervical below C2	537 (0.28)	0 (0)
23470	Shoulder	Arthroplasty, glenohumeral joint; hemiarthroplasty	273 (0.14)	1 (0.14)
63075	Spine	Discectomy, anterior, cervical, single interspace	269 (0.14)	0 (0)

ACL, anterior cruciate ligament; CPT, Current Procedural Terminology; ORIF, open reduction and internal fixation; THA, total hip arthroplasty; TKA, total knee arthroplasty.

Results

Patient population. Of 194,121 included patients who underwent orthopaedic surgery in 2021, 740 (0.38%) were identified as COVID-19-positive. Table I demonstrates the incidence of preoperative COVID-19 positivity among patients undergoing the most common orthopaedic surgery procedures in the NSQIP database. Trauma patients undergoing hip hemiarthroplasty had the highest rate of COVID-19 positivity at 1.79% (46/2,576). Among the included patients undergoing orthopaedic surgery, 108,902 (56.1%) underwent hip/knee arthroplasty surgery, 27,089 (14.0%) trauma surgery, 25,762 (13.3%) spine surgery, 15,777 (8.1%) sports surgery, and 16,591 (8.6%) shoulder surgery.

COVID-19 patient demographic data and comorbidities. Compared to COVID-19-negative patients, COVID-19-positive patients were older (mean age 71.1 years (standard deviation (SD)) 16.5 vs 64.7 years (SD 14.8); $p < 0.001$), had lower mean BMI (26.5 kg/m^2 (SD 9.0) vs 29.9 (SD 8.6); $p < 0.001$), were from different race groups,

Table II. Comparison of postoperative adverse events between COVID-19-positive (+) and the 1:10 propensity score matched COVID-19-negative (-) cohort. Data are expressed as number (%).

Variable	COVID-19 (+) cohort	COVID-19 (-) cohort	p-value	1:10 propensity matched COVID-19 (-) cohort	p-value
Patients, n	740 (9.09)	193,381 (99.62)		7,400 (90.91)	
Any adverse event	155 (20.95)	11,871 (6.14)	< 0.001	771 (10.42)	< 0.001
Major adverse event	112 (15.14)	7,611 (3.94)	< 0.001	537 (7.26)	< 0.001
Deep SSI	4 (0.54)	330 (0.17)	0.015	24 (0.32)	0.338
Mechanical ventilation > 48 hrs	11 (1.49)	219 (0.11)	< 0.001	23 (0.31)	< 0.001
Unplanned reintubation	19 (2.57)	448 (0.23)	< 0.001	45 (0.61)	< 0.001
Acute renal failure	4 (0.54)	118 (0.06)	< 0.001	9 (0.12)	0.007
Sepsis/septic shock	32 (4.32)	1,078 (0.56)	< 0.001	71 (0.96)	< 0.001
Venous thromboembolism	18 (2.43)	1,692 (0.87)	< 0.001	95 (1.28)	0.011
Stroke	6 (0.81)	291 (0.15)	< 0.001	27 (0.36)	0.069
Cardiac arrest/MI	19 (2.57)	1,108 (0.57)	< 0.001	96 (1.30)	0.005
Return to operating theatre	23 (3.11)	2,964 (1.53)	< 0.001	133 (1.80)	0.013
Death	49 (6.62)	1,611 (0.83)	< 0.001	193 (2.61)	< 0.001
Minor adverse event	84 (11.35)	5,876 (3.04)	< 0.001	339 (4.58)	< 0.001
Superficial SSI	9 (1.22)	2,040 (1.05)	0.668	85 (1.15)	0.870
Wound dehiscence	1 (0.14)	454 (0.23)	0.576	12 (0.16)	0.861
Pneumonia	50 (6.76)	1,362 (0.70)	< 0.001	103 (1.39)	< 0.001
Urinary tract infection	27 (3.65)	2,060 (1.07)	< 0.001	144 (1.95)	0.002
C. difficile infection	1 (0.14)	232 (0.12)	0.905	15 (0.20)	0.692
Readmission	62 (8.38)	6,658 (3.44)	< 0.001	396 (5.35)	< 0.001
Blood transfusion	98 (13.24)	7,841 (4.05)	< 0.001	695 (9.39)	< 0.001
Length of stay > 3 days	498 (67.30)	48,076 (24.86)	< 0.001	2,996 (40.49)	< 0.001
Discharge to non-home facility	336 (45.41)	26,486 (13.70)	< 0.001	2,156 (29.14)	< 0.001

MI, myocardial infarction; SSI, surgical site infection.

more commonly white, (p < 0.001) and had higher ASA grades (p < 0.001) (Table III). Incidence of patient comorbidities are demonstrated in Table IV. Comparison of comorbidities demonstrated that COVID-19-positive patients had higher rates of DM (9.2% vs 4.4%; p < 0.001), CHF (10.0% vs 3.0%; p < 0.001), history of severe COPD (10.27% vs 4.20%; p < 0.001), ventilator dependency (0.3% vs 0.0%; p < 0.001), and had higher rates of chronic steroid use (6.5% vs 4.2%; p = 0.002).

Propensity score matching to create a 1:10 COVID-19-negative cohort was constructed based on demographics and comorbidities of the COVID-19-positive cohort. After propensity matching, there were no statistically significant differences between most demographics and all comorbidities between the COVID-19-positive and -negative groups (Table III, Table IV). The demographics that were significantly different despite propensity score matching were patient race, and type of surgery.

Adverse events. Using univariate analysis, complications and adverse events occurring within the 30-day postoperative period were compared (Table II). Based on univariate analyses of the full groups, COVID-19-positive patients had higher rates of any adverse events (21.0% vs 6.1%; p < 0.001), major adverse events (15.1% vs 3.9%; p = 0.013), minor adverse events (11.4% vs 3.0%; p < 0.001), readmission (8.4% vs 3.4%; p < 0.001), blood transfusion (13.2% vs 4.1%; p < 0.001), longer lengths of stay (67.3% vs 24.9%; p < 0.001), and discharge to non-home facilities (45.4% vs 13.7%; p < 0.001).

More specifically, COVID-19-positive patients had higher rates of complications, including mechanical ventilation (1.5% vs 0.1%; p < 0.001), unplanned intubation (2.6% vs 0.2%; p < 0.001), sepsis (4.3% vs 0.6%; p < 0.001), venous thromboembolism (2.4% vs 0.9%; p < 0.001), pneumonia (2.4% vs 0.7%; p < 0.001), and death (6.6% vs 0.8%; p < 0.001) (Table II). COVID-19-positive patients undergoing hip/knee arthroplasty and trauma surgery had significantly higher rates of overall adverse events compared to COVID-19-negative patients (Table V).

After propensity score matching and controlling for all preoperative variables, multivariable analysis found that COVID-19-positive patients were at increased risk of 30-day postoperative complications, including: any adverse events (OR 2.3 (95% CI 1.9 to 2.8); p < 0.001), major adverse events (OR 2.3 (95% CI 1.8 to 2.9); p < 0.001), and minor adverse events (OR 2.6 (95% CI 2.0 to 3.3); p < 0.001). Specifically, risk of death (OR 2.6 (95% CI 1.9 to 3.7); p < 0.001), venous thromboembolism (OR 1.8 (95% CI 1.1 to 3.0); p < 0.001), and pneumonia (OR 4.91 (95% CI 3.4 to 7.0); p < 0.001) were also increased. COVID-19-positive patients undergoing total hip/knee arthroplasty (OR 2.6 (95% CI 1.7 to 3.9); p < 0.001) and trauma surgery (OR 1.8 (95% CI 1.4 to

Table III. Comparison of basic demographics between COVID-19-positive (+) and -negative (-) patients.

Variable	Total	COVID-19 (+)	COVID-19 (-)	p-value	1:10 propensity matched COVID-19 (-) cohort	p-value
Patients, n (%)	194,121 (100.00)	740 (0.38)	193,381 (99.62)		7,400 (90.91)	
Mean age, yrs (SD)	64.74 (14.81)	71.12 (16.48)	64.71 (14.80)	< 0.001	71.02 (13.71)	0.874
Male sex, n (%)	87,425 (45.04)	301 (40.68)	87,124 (45.05)	0.057	2,927 (39.55)	0.798
Mean BMI, kg/m^2 (SD)	29.91 (8.58)	26.51 (9.00)	29.92 (8.58)	< 0.001	26.21 (10.85)	0.393
Race, n (%)				< 0.001		< 0.001
White	127,488 (65.67)	580 (78.38)	126,908 (65.63)		5,803 (78.42)	
Black or African-American	15,672 (8.07)	43 (5.81)	15,629 (8.08)		387 (5.23)	
Other	8,194 (4.22)	37 (5.00)	8,157 (4.22)		172 (2.32)	
Unknown/Not reported	42,767 (22.03)	80 (10.81)	42,687 (22.07)		1,038 (14.03)	
ASA grade, n (%)				< 0.001		0.537
I	8,841 (4.55)	16 (2.16)	8,825 (4.56)		120 (1.62)	
II	84,344 (43.45)	160 (21.62)	84,184 (43.53)		1,725 (23.31)	
III	91,971 (47.38)	435 (58.78)	91,536 (47.33)		4,261 (57.58)	
IV+	8,557 (4.41)	129 (17.43)	8,428 (4.36)		1,284 (17.35)	
Case acuity, n (%)				< 0.001		< 0.001
Elective	171,365 (88.28)	427 (57.70)	170,938 (88.39)		5,723 (77.34)	
Urgent	8,730 (4.50)	116 (15.68)	8,614 (4.45)		610 (8.24)	
Emergent	14,026 (7.23)	197 (26.62)	13,829 (7.15)		1,067 (14.42)	
Surgery type, n (%)				< 0.001		< 0.001
Hip/knee arthroplasty	108,902 (56.10)	221 (29.86)	108,681 (56.20)		3,562 (48.14)	
Trauma	27,089 (13.95)	423 (57.16)	26,666 (13.79)		2,142 (28.95)	
Spine	25,762 (13.27)	50 (6.76)	25,712 (13.30)		863 (11.66)	
Sports	15,777 (8.13)	21 (2.84)	15,756 (8.15)		323 (4.36)	
Shoulder	16,591 (8.55)	25 (3.38)	16,566 (8.57)		510 (6.89)	

ASA, American Society of Anesthesiologists; SD, standard deviation.

Table IV. Comparison of comorbidities of interest between COVID-19-positive (+) and -negative (-) patients. Data are presented as number (%).

Variable	Total	COVID-19 (+)	COVID-19 (-)	p-value	1:10 propensity matched COVID-19 (-) cohort	p-value
Patients, n	194,121 (100.00)	740 (0.38)	193,381 (99.62)		7,400 (90.91)	
Smoking history	21,427 (11.04)	76 (10.27)	21,351 (11.04)	0.504	792 (10.70)	0.716
Diabetes				< 0.001		0.643
Insulin	8,615 (4.44)	68 (9.19)	8,547 (4.42)		644 (8.70)	
Non-insulin	22,665 (11.68)	84 (11.35)	22,581 (11.68)		922 (12.46)	
No	162,841 (83.89)	588 (79.46)	162,253 (83.90)		5,834 (78.84)	
Congestive heart failure	5,927 (3.05)	74 (10.00)	5,853 (3.03)	< 0.001	782 (10.57)	0.631
Hypertension	106,362 (54.79)	412 (55.68)	105,950 (54.79)	0.628	4,045 (54.66)	0.597
Ventilator-dependent	49 (0.03)	2 (0.27)	47 (0.02)	< 0.001	16 (0.22)	0.765
History of severe COPD	8,201 (4.22)	76 (10.27)	8,125 (4.20)	< 0.001	825 (11.15)	0.468
Chronic steroid use	8,191 (4.22)	48 (6.49)	8,143 (4.21)	0.002	498 (6.73)	0.801

COPD, chronic obstructive pulmonary disease.

Table V. Comparison of postoperative adverse events between COVID-19-positive (+) and -negative (-) patients based on surgery type.

Surgery type	COVID-19 (+) cohort	COVID-19 (-) cohort	p-value	1:10 propensity matched COVID-19 (-) cohort	p-value
Hip/knee arthroplasty, n (%)	35 (15.84)	5,414 (4.98)	< 0.001	251 (7.05)	< 0.001
Trauma, n (%)	114 (26.95)	4,100 (15.38)	< 0.001	421 (19.65)	< 0.001
Spine, n (%)	5 (10.00)	1,665 (6.48)	0.312	75 (8.69)	0.750
Sports, n (%)	0 (0)	334 (2.12)	0.500	9 (2.79)	0.438
Shoulder, n (%)	1 (4.00)	358 (2.16)	0.528	15 (2.94)	0.762

2.3); p < 0.001) were at increased risk of 30-day adverse events. With regard to other postoperative outcomes,

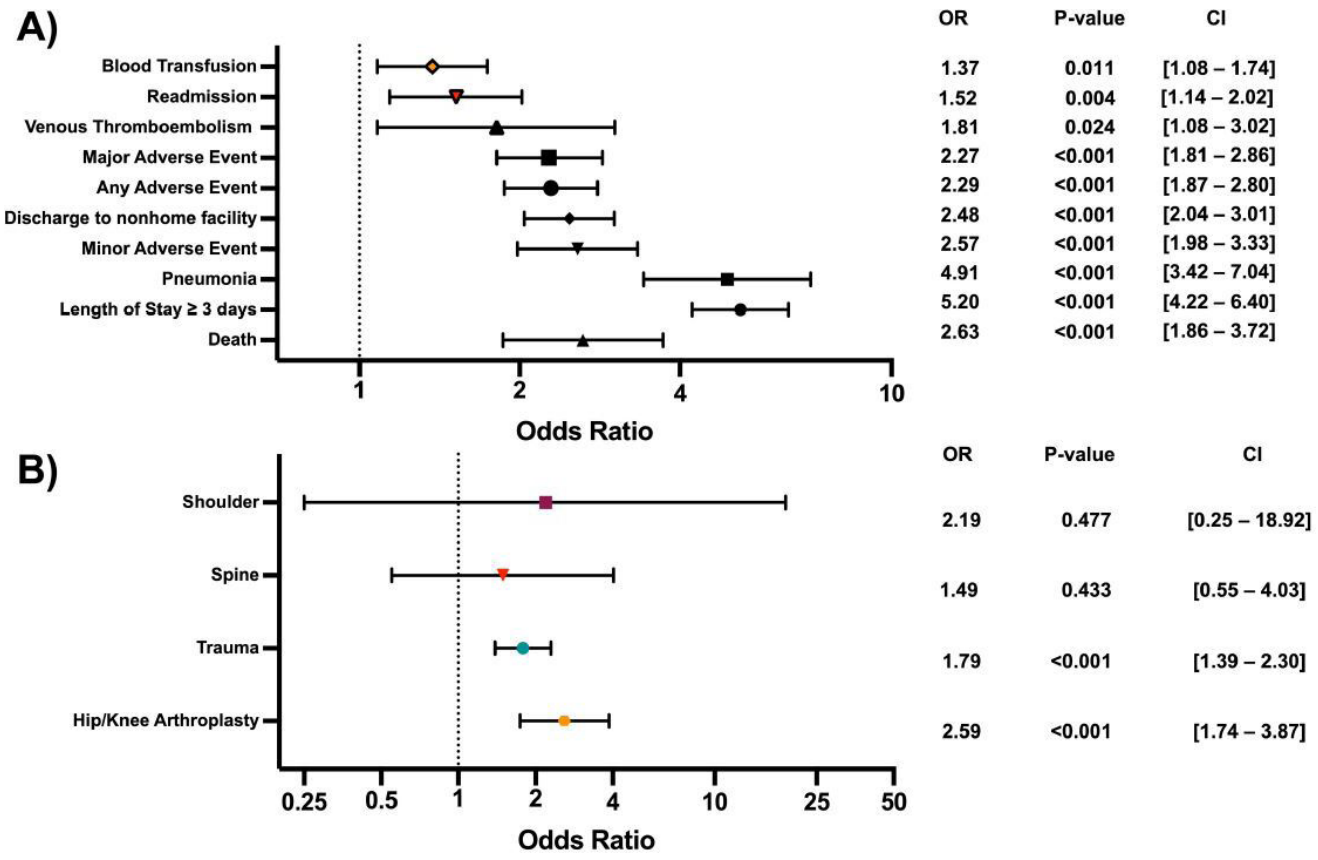

Fig. 1

Association of COVID-19 positivity with 30-day adverse events: multivariate analysis (controlling for age, sex, race, BMI, and American Society of Anesthesiologists grade). CI, confidence interval; OR, odds ratio.

COVID-19-positive patients were at increased risk for: longer lengths of stay (OR 5.2 (95% CI 4.2 to 6.4); $p < 0.001$), discharge to non-home facilities (OR 2.5 (95% CI 2.0 to 3.0); $p < 0.001$), and readmission (OR 1.5 (95% CI 1.1 to 2.0); $p = 0.004$) (Figure 1).

Discussion

Since the start of the COVID-19 pandemic, hospitals, medical institutions, and healthcare systems have experienced unprecedented levels of stress: the American Hospital Association estimates a financial impact of $50.7 billion per month in lost revenue for America's hospitals and healthcare systems.[2]

From a surgical perspective, early evidence from 2020 indicated that COVID-19 positivity was associated with increased rates of perioperative morbidity and mortality.[3] Furthermore, due to the pandemic, in 2020 healthcare facilities suspended elective and non-urgent surgical procedures, leading to massive backlogs and loss of projected revenue.[27] In 2021, as elective and non-urgent procedures resumed, the complications associated with COVID-19 positivity during the immediate perioperative period were further documented. With the recent release of 2021 data from NSQIP, we were able to assess the impact of COVID-19 positivity on perioperative adverse outcomes. We conducted a matched cohort analysis to identify patient risk factors independently associated with the occurrence of 30-day postoperative adverse events. We demonstrated that COVID-19-positive patients undergoing orthopaedic surgery had increased odds of many 30-day postoperative complications, with hip/knee arthroplasty and trauma surgery being the most high-risk procedures.

The rate of COVID-19 positivity in this cohort was found to be 0.38%. In the literature, reported rates of COVID-19 positivity have varied widely, from approximately 0.5% to 15% depending on patient cohort, timing since the start of the pandemic, variant surges, and geographical location.[15,28–34] In this analysis, COVID-19 positivity was defined based on lab-confirmed diagnosis. While these rates may be underestimating the true COVID-19 positivity rate among patients undergoing orthopaedic surgery, considering the small number of potential missed cases, it would be unlikely to alter the findings of our study.

At baseline, we demonstrated that COVID-19-positive patients were significantly older, had lower BMIs, and higher ASA grades. When comparing patient

comorbidities, we identified that COVID-19-positive patients had higher rates of DM, CHF, and severe COPD, were more likely to be ventilator-dependent, and had higher rates of chronic steroid use. The largest difference between rates of comorbidities between COVID-19-positive and -negative patients was found to be for history of CHF and severe COPD. These findings regarding comorbidities are consistent with previous reports.[5,15,35–37]

After propensity matching and controlling for all preoperative variables, multivariable analysis found that COVID-19-positive patients were at increased risk of several postoperative complications, including any adverse events, major adverse events, minor adverse events, and death. Our findings are consistent with multiple previous studies investigating COVID-19 positivity in perioperative patients. Large multicentre studies have demonstrated increased rates of pulmonary complications and 30-day mortality in COVID-19-positive patients undergoing a variety of surgical procedures.[4,38] However, our findings are in contrast to a recently published population-based cohort study of 71,144 Canadian patients undergoing major non-cardiac surgery, in which COVID-19 positivity was not associated with death, major adverse cardiovascular events, or rehospitalization following elective major non-cardiac surgery.[34] These variations may be partly explained by the quality of the database and retrospective nature of both analyses.

Based on the multivariable analysis, we also demonstrated that COVID-19-positive patients undergoing orthopaedic procedures have almost a two-fold increase in odds of venous thromboembolism and a five-fold increase in odds of perioperative pneumonia. Numerous studies have established COVID-19 as a risk factor for deep vein thrombosis, pulmonary embolism, and bleeding, due to the endothelial dysfunction and the subsequent procoagulative state caused by endotheliitis.[10,39–41] Increased risk of symptomatic perioperative pneumonia associated with COVID-19 positivity is rather expected, either caused by progression of the upper respiratory viral infection, worsening of a pre-existing pneumonia, or development of a secondary superimposed bacterial pneumonia.[42]

In this analysis, we also demonstrated that among COVID-19-positive cases, a higher proportion were deemed urgent or emergent trauma. This is likely due to the preoperative screening and isolation protocols implemented by many hospitals prior to elective surgery. Moreover, it has been demonstrated that the rate of morbidity and mortality in COVID-19-positive patients are higher after emergency surgery compared with elective surgery, possibly due to the nature related to the associated acute, emergent diagnosis.[4] The COVIDSurg Collaborative conducted a multicentre prospective cohort study on patients undergoing emergent and elective surgery, demonstrating a four-fold increased odds of 30-day mortality in COVID-19-positive patients compared to those without infection at the time of surgery.[43]

To better risk-stratify the orthopaedic surgical population, patients were further stratified by type of orthopaedic procedure; among the included patients, the most common procedures were hip and knee arthroplasty followed by trauma, spine, sports, and finally, shoulder surgery. We demonstrated an increased risk of 30-day adverse events in COVID-19-positive patients undergoing hip and knee arthroplasty and trauma surgery. While there appears to be consensus on increased risk of perioperative complications in trauma surgery in COVID-19-positive patients,[16,27,44,45] our results with regard to joint arthroplasty are in contrast to some recent reports arguing COVID-19 positivity does not significantly increase risk of respiratory, infectious, cardiac, and thromboembolic complications.[46,47] These differences may again be explained by the quality and size of studied databases and retrospective nature of analyses.

Finally, with regard to other postoperative outcomes, we demonstrated that COVID-19-positive patients were at increased risk for longer lengths of stay, discharge to non-home facilities, and readmission. Our findings are consistent with another large population-based study on hip fracture patients, which demonstrated a two-fold increase in length of stay in COVID-19-positive patients.[17,48] Notably, multiple studies and a systematic review compared lengths of stay in hip fracture patients before and after the pandemic, and demonstrated reduced lengths of stay, likely due to an attempt to prevent nosocomial viral transmission to the patient or other hospitalized patients.[49] A previous study compared postoperative outcomes of hip fracture patients before and after the pandemic, and found no differences in rates of 30-day hospital readmission and a decrease in rates of patients placed in skilled nursing facilities. The decreased placement of patients in nursing facilities may be attributed to the lack of nursing resources, together with the burden of the pandemic on nurses and healthcare providers.[50]

Strengths of this study include its large sample size, use of propensity score matching to compare COVID-19-positive versus negative patients across a wide breadth of orthopaedic procedures, and use of a highly validated dataset across hundreds of participating hospitals across the USA and Canada. This is the first study to assess perioperative complications associated with COVID-19 positivity using the NSQIP database in orthopaedic surgery. NSQIP is a nationally validated, risk-adjusted, outcomes-based registry designed to measure and improve the quality of surgical care.[51] However, this study is not without limitations, and as such the results should be interpreted accordingly. Limitations of analysis using the NSQIP registry include the fact that this database only tracks 30-day morbidity and mortality after a surgical

procedure.[52] Furthermore, the NSQIP registry also does not provide data on severity of patient comorbidities or initial indications for surgeries.[52]

To conclude, in this matched cohort analysis, we demonstrated that COVID-19 positivity during orthopaedic surgery increases odds of major and minor 30-day postoperative complications, with hip/knee arthroplasty and trauma surgery being the highest-risk procedures. Furthermore, these data reinforce prior literature demonstrating increased risk of mortality and venous thromboembolic events in the acute postoperative period. Clinicians caring for patients undergoing orthopaedic procedures should be mindful of these increased risks and attempt to improve patient care during the ongoing global pandemic.

Take home message

- Preoperative COVID-19 positivity is a relatively rare occurrence among patients undergoing orthopaedic surgery in the NSQIP dataset.
- COVID-19-positive patients undergoing orthopaedic surgery have higher rates of diabetes, heart failure, and pulmonary disease, as well as higher rates of several postoperative adverse events, including death, venous thromboembolism, and pneumonia.
- COVID-19-positive patients undergoing hip/knee arthroplasty and trauma surgery were at increased risk of adverse events.

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Author information:
- M. R. Mercier, MD, Orthopaedic Surgical Resident, University of Toronto Division of Orthopaedic Surgery, Toronto, Canada.
- R. Koucheki, MD, MEng, Orthopaedic Surgery Resident, University of Toronto Faculty of Medicine, Toronto, Canada; Institute of Biomedical Engineering, University of Toronto, Toronto, Canada.
- J. R. Lex, MBChB, MASc, Orthopaedic Surgery Resident
- S. S-H. Park, MD, MASc, FRCSC, Orthopaedic Surgeon
  University of Toronto Division of Orthopaedic Surgery, Toronto, Canada; Institute of Biomedical Engineering, University of Toronto, Toronto, Canada.
- A. Khoshbin, MD, MSc, FRCSC, Orthopaedic Surgeon
- T. R. Daniels, MD, FRCSC, Professor, Head of Orthopaedic Surgery
- M. M. Halai, MD, FRCSC, Orthopaedic Surgeon
  University of Toronto Division of Orthopaedic Surgery, Toronto, Canada; Department of Orthopaedic Surgery, St Michael's Hospital, Toronto, Canada.

Author contributions:
- M. R. Mercier: Conceptualization, Methodology, Data curation, Writing – original draft, Project administration.
- R. Koucheki: Methodology, Formal analysis, Investigation, Writing – original draft, Visualization.
- J. R. Lex: Methodology, Validation, Writing – review & editing.
- A. Khoshbin: Writing – review & editing, Conceptualization, Supervision.
- S. S. Park: Writing – review & editing, Validation, Supervision.
- T. R. Daniels: Supervision, Writing – review & editing.
- M. M. Halai: Project administration, Data curation, Writing – review & editing, Supervision.

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