Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Systematic Review and Meta Analysis

Making a Joint Decision Regarding the Timing of Surgery for Elective Arthroplasty Surgery After Being Infected With COVID-19: A Systematic Review

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ABSTRACT

Background: The Coronavirus Disease 2019 (COVID-19) pandemic has caused a substantial number of patients to have their elective arthroplasty surgeries rescheduled. While it is established that patients with COVID-19 who are undergoing surgery have a significantly higher risk of experiencing postoperative complications and mortality, it is not well-known at what time after testing positive the risk of postoperative complications or mortality returns to normal.

Methods: PubMed (MEDLINE), Excerpta Medica dataBASE, and professional society websites were systematically reviewed on March 7, 2022 to identify studies and guidelines on the optimal timeframe to reschedule patients for elective surgery after preoperatively testing positive for COVID-19. Outcomes included postoperative complications such as mortality, pneumonia, acute respiratory distress syndrome, septic shock, and pulmonary embolism.

Results: A total of 14 studies and professional society guidelines met the inclusion criteria for this systematic review. Patients with asymptomatic COVID-19 should be rescheduled 4-8 weeks after testing positive (as long as they do not develop symptoms in the interim), patients with mild/moderate COVID-19 should be rescheduled 6-8 weeks after testing positive (with complete resolution of symptoms), and patients with severe/critical COVID-19 should be rescheduled at a minimum of 12 weeks after hospital discharge (with complete resolution of symptoms).

Conclusions: Given the negative association between preoperative COVID-19 and postoperative complications, patients should have elective arthroplasty surgery rescheduled at differing timeframes based on their symptoms. In addition, a multidisciplinary and patient-centered approach to rescheduling patients is recommended. Further study is needed to examine the impact of novel COVID-19 variants and vaccination on timeframes for rescheduling surgery.

The Coronavirus Disease 2019 (COVID-19) pandemic has caused unimaginable levels of disruption for patients undergoing orthopedic procedures and healthcare professionals providing care worldwide [1,2]. Surgeons and patients are faced with rapidly changing regulations at local and national levels as COVID-19 case volumes peak and trough with novel variants of concern. Patients suffering from debilitating conditions such as hip and knee osteoarthritis have had elective procedures such as total hip and knee arthroplasty canceled due to numerous reasons, including national

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lockdowns, inadequate medical staffing, personal protective equipment shortages, and positive COVID-19 tests during pre-admission testing [3,4].

A less common reason for surgical cancelations was patients having positive COVID-19 tests during pre-admission testing, with pre-admission testing positivity rates ranging from 0.21% to 0.79% [5,6]. However, during the past few months, there was a spike of COVID-19 cases due to the Omicron variant, with the daily number of new cases in the United States peaking at 1,302,179 on January 10, 2022 [7]. This surge of COVID-19 resulted in an increasing number of patients incidentally testing positive for COVID-19 during pre-admission testing, leading to cancelation of elective surgeries. Needless to state, these cancelations resulted in immense inconvenience to patients and disruption of care [8–10].

The most important issue, however, relates to the lack of a concrete protocol regarding rescheduling of these patients. It is well-established that patients with COVID-19 who are undergoing surgery have a substantially higher risk of experiencing postoperative complications and increased risk of mortality [11–18]. However, it is not well-known at what time point after testing positive the risk of postoperative complications or mortality returns to normal in COVID-19 positive patients, as many of the current guidelines for rescheduling surgery at hospitals are primarily focused on reducing infection transmission and not focused on the risks of the patient undergoing the procedure. Therefore, we conducted this systematic review to determine the optimal timeframe to reschedule patients for elective arthroplasty surgery after being diagnosed with COVID-19 preoperatively, focusing on timeframes that decrease their risk of experiencing postoperative complications such as pneumonia, respiratory failure, and mortality back to the baseline risk. We hypothesized that patients who test positive for COVID-19 preoperatively should be rescheduled for elective arthroplasty surgery, 1-3 months after their positive COVID-19 test, depending on the presence of symptoms and symptom severity.

Methods

In an effort to provide orthopedic surgeons and healthcare systems with evidence-based recommendations regarding preoperative COVID-19 testing and timeframes to reschedule elective surgery after having a positive COVID-19 test preoperatively, we conducted a systematic review in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines, which was registered with the International Prospective Register of Systematic Reviews (PROSPERO) [CRD42022314816].

Search Methodology

A comprehensive literature search with PubMed (MEDLINE) and Excerpta Medica dataBASE (EMBASE) was conducted on March 7, 2022 using the search terms in Appendix 1. In addition, professional society websites were searched for guidelines and consensus statements regarding the perioperative management of patients undergoing elective surgery during the COVID-19 pandemic. Professional societies included the International Consensus Group (ICM), the American Association of Hip and Knee Surgeons (AAHKS), the American Academy of Orthopaedic Surgery , the American Society of Anesthesiologists (ASA), the American Patient Safety Foundation (APSF), the Association of Anaesthetists (AA), the Center for Peri-operative Care, the Federation of Surgical Specialty Association, the Royal College of Anaesthetists, the Royal College of Surgeons of England (RCS), the European Society of Sports Traumatology, Knee Surgery, and Arthroscopy (ESSKA), and the European Hip Society (EHS) and European Knee Associates.

Study Selection Criteria

Three authors (IAK, MBZ, PAG) independently screened titles and abstracts from the literature search. When questions arose about study inclusion, three authors (IAK, MBZ, PAG) discussed the query and came to a consensus. After the title and abstract screening, full-text review was conducted by three authors (IAK, MBZ, PAG), who convened with the principal investigator (YAF) to discuss discrepancies and arrive at a consensus about final study inclusion.

This systematic review included randomized controlled trials, prospective non-randomized studies, and retrospective cohort studies. To be considered for inclusion, all studies must have examined the impact of being diagnosed with COVID-19 preoperative in humans undergoing elective surgery, report the amount of time that patients were diagnosed with COVID-19 before undergoing surgery, and include a comparison group of patients who were not diagnosed with COVID-19, preoperatively. Studies were excluded if they were case reports and case series, if they examined the impact of COVID-19 in non-human species, and if they had no comparison group of COVID-19 negative patients.

Data Extraction

The primary outcomes for this study were the odds of experiencing postoperative pneumonia, postoperative respiratory failure, and postoperative mortality. Secondary outcomes include postoperative deep vein thrombosis, pulmonary embolism, arrhythmia, urinary tract infection, sepsis, or any postoperative complication. For each outcome, the odds ratios (OR) will be examined for experiencing those complications between different timeframes of when patients were diagnosed with COVID-19 before surgery, and compared to patients who were COVID-19 negative.

Given the limited number of studies expected to be published on this topic, a qualitative synthesis of the data was planned, with no meta-analysis. Three authors (IAK, MBZ, PAG) conducted the qualitative data extraction and synthesis, which was reviewed by the principal investigator (YAF) for accuracy and completeness.

Qualitative Analysis

The qualitative synthesis was conducted by examining what timeframes patients underwent surgery after being diagnosed with COVID-19 (0-2 weeks, 2-3 weeks, 3-4 weeks, 4-5 weeks, 5-6 weeks, 6-7 weeks, 7-8 weeks, >8 weeks). After doing that, complication rates were examined in each timeframe, and it was determined whether patients were at an increased risk of sustaining complications during a specific timeframe when compared to COVID-19 negative patients undergoing surgery. Statistical significance was defined as the OR for sustaining a complication being >1, with the entire 95% confidence interval being >1.

Figures were constructed to display the results of the qualitative analysis at various time points when two or more studies evaluated specific complications and their likelihood to occur within the different timeframes. Within the figures, red downward-pointing arrows signified statistically significant results indicating an increased risk of suffering complications, black dots signified no significant difference in the results, and green upward-pointing arrows signified statistically significant results indicating a decreased risk of suffering complications.

Risk of Bias Assessment

The articles in this systematic review were reviewed independently by 3 authors (IAK, ZBM, PAG) using the Newcastle-Ottawa risk-of-bias tool to evaluate for risk of bias [19]. The three authors convened to reach consensus on the designations for risk-of-bias assessments. Disagreements between the authors were resolved by the principal investigator (YAF).

Results

The literature search yielded 2,364 unique publications (Fig. 1). After title and abstract screening and full-text review by three authors, 8 studies and 7 professional society guidelines provided guidance on the topic of this systematic review and were included in the qualitative synthesis (Fig. 1) [20–34]. The risk-of-bias assessments can be found in Appendix 2. The following sections summarize the information synthesized from the systematic review, with each section having a specific focus.

Preoperative Screening for Patients Undergoing Elective Arthroplasty Surgery

The use of preoperative COVID-19 screening protocols are effective, with major components including pre-admission testing, symptom questionnaires, and temperature checks [35]. For pre-admission testing, the literature supports using Reverse Transcription Polymerase Chain Reaction (RT-PCR) testing to preoperatively screen all patients [28,36–39]. A recent meta-analysis found that antigen testing has variable sensitivity for asymptomatic patients (58.1%; 95% CI: 40.2%-74.1%) and may not identify asymptomatic patients with COVID-19 [39]. Multiple studies show that most patients who test positive for COVID-19 preoperatively are asymptomatic [40–42]. Therefore, it is essential to use a screening technique that will identify COVID-19 positive patients, functioning to protect patients from the deleterious impacts of COVID-19, and to protect healthcare workers by limiting exposure to COVID-19. Regarding the timing of testing, professional societies have previously recommended testing patients 48-72 hours before the surgery [33,34], providing healthcare teams enough time to receive the results and act accordingly.

Timeframes for Rescheduling Patients Who Test Positive During Pre-admission Testing

The COVIDSurg Collaboration Group conducted an international multi-institutional study including 3,127 patients who were COVID-19 positive and 137,104 patients who were COVID-19 negative undergoing any type of surgery [22]. They found that patients diagnosed with COVID-19 during pre-admission testing who were undergoing elective surgery had an increased odds of 30-day mortality and pulmonary complications (pneumonia, acute respiratory distress syndrome, or unexpected ventilation) when undergoing surgery within 0-6 weeks of being infected with

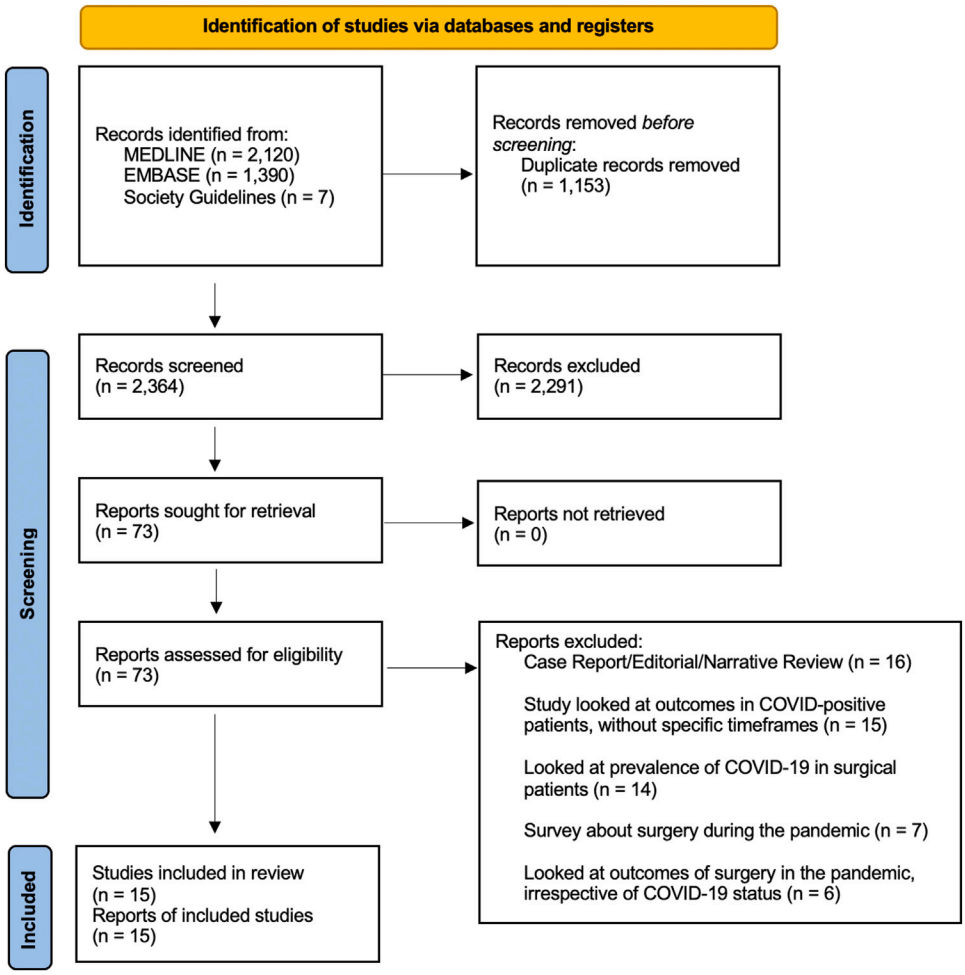

Fig. 1. PRISMA flow diagram.

Table 1
Study-specific Complications for Various Timeframes.

Study	Complication	Timeframes (Vary for Each Study)					
		Control	0-2 wk	3-4 wk	5-6 wk	7-8 wk	More than 8 wk
Butyrskii et al.	Mortality	Reference	20%[a]	25%[a]	18.1%[a]	8.3%[a]	1.5%
		Control	0-2 wk	3-4 wk	5-6 wk	7 or More wk	
COVIDSurg et al.	Pulmonary Complications	Reference	3.77 [2.53-5.62][a]	4.58 [3.09-6.78][a]	3.57 [2.17-5.88][a]	1.09 [0.71-1.69]	
	Mortality	Reference	5.50 [3.24-9.34][a]	3.95 [2.18-7.15][a]	4.14 [2.05-8.33][a]	1.03 [0.50-2.09]	
		Control	0-4 wk	4-8 wk	8 or More wk		
Deng et al.	Pneumonia	Reference	6.46 [4.06-10.27][a]	2.44 [1.20-4.96][a]	1.15 [0.66-2.01]		
	Respiratory Failure	Reference	3.36 [2.22-5.10][a]	1.23 [0.62-2.47]	1.09 [0.71-1.67]		
	Pulmonary Embolism	Reference	2.73 [1.35-5.53][a]	1.05 [0.31-3.60]	1.49 [0.76-2.95]		
	Sepsis	Reference	3.67 [2.18-6.16][a]	1.87 [0.87-4.01]	1.01 [0.56-1.81]		
	DVT	Reference	1.44 [0.78-2.66]	1.04 [0.43-2.51]	1.24 [0.75-2.06]		
	Arrhythmia	Reference	0.79 [0.42-1.50]	1.88 [0.99-3.60]	1.39 [0.88-2.18]		
	Renal Failure	Reference	1.77 [1.11-2.81][a]	0.93 [0.45-1.91]	1.12 [0.75-1.67]		
	Urinary Tract Infection	Reference	1.15 [0.70-1.89]	0.92 [0.48-1.78]	0.99 [0.67-1.46]		
	Any Postoperative Complication	Reference	1.72 [1.33-2.21][a]	1.15 [0.81-1.64]	0.92 [0.74-1.16]		
		Control	0-10 d	11-30 d	>30 d		
Lal et al.	Pneumonia	Reference	7.7 [4.4-13.3][a]	6.2 [3.7-10.1][a]	2.7 [1.8-4.1][a]		
	Mechanical Ventilation	Reference	3.1 [1.3-6.4][a]	3.1 [1.5-5.9][a]	1.3 [0.7-2.3]		
	ARDS	Reference	4.0 [2.2-7.2][a]	4.5 [2.7-7.5][a]	2.0 [1.3-3.0][a]		
	Septic Shock	Reference	3.4 [1.8-6.2][a]	2.7 [1.5-4.8][a]	1.7 [1.1-2.6][a]		
	Myocardial Infarction	Reference	2.2 [0.6-5.7]	1.6 [0.5-4.0]	1.7 [0.8-3.2]		
	Ischemic Stroke	Reference	1.0 [0.2-3.3]	3.4 [1.5-7.0][a]	1.8 [0.9-3.4]		

Butyrskii et al. reported the odds ratio as a percentage. COVIDSurg et al., Deng et al., and Lal et al. reported odds ratios.
Pulmonary Complications (COVIDSurg Study) = Pneumonia, ARDS, and Unexpected Mechanical Ventilation.
DVT, deep vein thrombosis; ARDS, acute respiratory distress syndrome.
[a] Statistical Significance Difference Compared to the Control.

COVID-19, which diminished when undergoing surgery 7 weeks or more after being infected with COVID-19 (Table 1, Figs. 2 and 3). Patients undergoing surgery 7 weeks or longer after being diagnosed with COVID-19 infection who were symptomatic at the time of surgery also had an increased odds of 30-day mortality and pulmonary complications [22]. The findings of this study held true when subgroup analyzing asymptomatic patients [22].

Deng et al. conducted a multi-institutional study using the Symphony Health COVID-19 Database [43], including 5,479 patients who underwent major elective surgery during one of four timeframes: prior to the pandemic (pre-COVID), within 0-4 weeks of a positive polymerase chain reaction (PCR) test (peri-COVID), within 4-8 weeks of a positive PCR test (early post-COVID), and more than 8 weeks after a positive PCR test (late post-COVID). When comparing the odds of postoperative complications amongst the 4 cohorts, patients in the peri-COVID group had a significantly higher odds of pneumonia, respiratory failure, pulmonary embolism, sepsis, renal failure, and any complication, compared to the pre-COVID group (Table 1, Figs. 3 and 4). Patients in the early post-COVID group had a higher risk of pneumonia compared to the pre-COVID group (Table 1, Fig. 3), while patients in the late post-COVID group had no increased risk of any complication (Table 1).

Butyrskii et al. conducted a multi-center prospective cohort study in Russia to determine the optimal timeframe for patients to undergo elective surgery after testing positive for COVID-19 preoperatively [21]. Among the 682 patients in this study, 32 were COVID positive, and 650 were COVID negative. The main outcome for this study was 30-day postoperative mortality. The authors found that patients had increased odds of mortality when having surgery 0-8 weeks after being diagnosed with COVID-19, which decreased for patients who underwent surgery more than 8 weeks after a positive COVID-19 test (Table 1, Fig. 2). However, patients who underwent surgery more than 8 weeks after a positive COVID-19 test and still had active symptoms had increased odds of mortality.

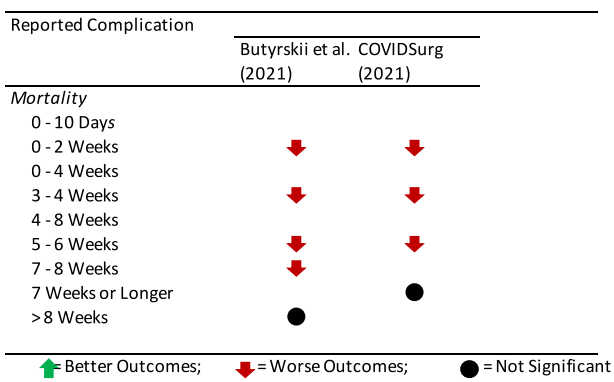

Fig. 2. Mortality qualitative assessment.

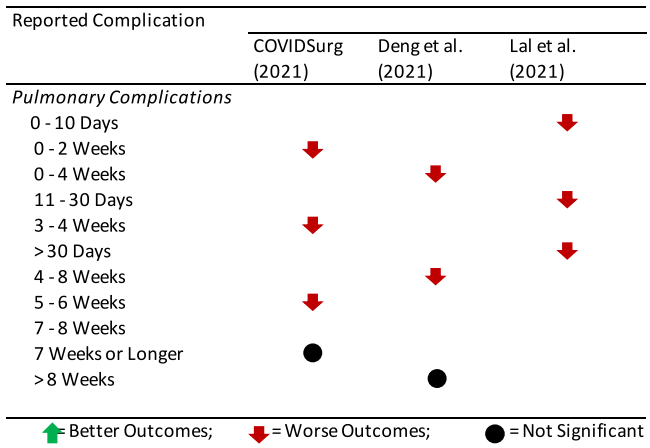

Fig. 3. Pulmonary complications qualitative assessment.

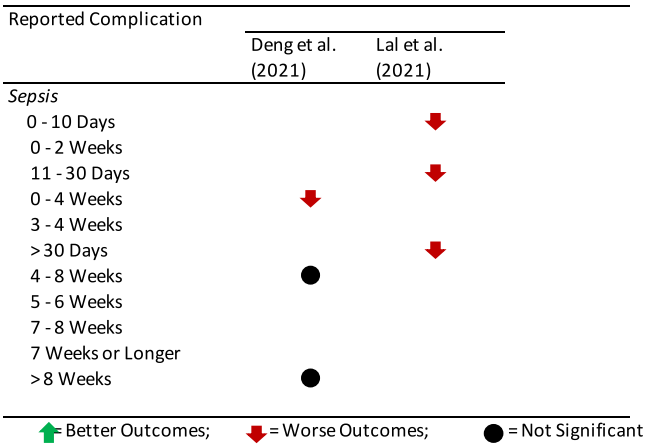

Fig. 4. Sepsis qualitative assessment.

While these results support the previous studies, 2 significant limitations include the study had a low number of COVID-19 positive patients, and we were only able to access the abstract due to the full-text being written in Russian.

The study by Lal et al., using the Department of Veterans Affairs Database, corroborates the findings of the 3 studies discussed above [25]. In a matched cohort study design, 30-day postoperative outcomes of patients undergoing elective and emergency surgery who tested positive for COVID-19 via RT-PCR (432 patients) versus COVID-19 negative patients (1,256 patients) were compared. The study further stratified outcomes in COVID-19 positive patients by timeframes relating to surgery: surgery within 10 days of the positive test, surgery 11-30 days after the positive test, and surgery >30 days after the positive test. The study found that patients who had surgery >30 days after their positive test still had an increased risk of pneumonia, acute respiratory distress syndrome , and septic shock compared to COVID-19 negative patients (Table 1, Figs. 3 and 4).

When rescheduling patients who required treatment in the hospital for severe/critical COVID-19, there is no clear supporting literature. The study by Deng et al. included patients with severe/critical COVID-19, although they only made up 0.9% of the COVID-19 positive cohort and no subgroup analysis was performed for those patients. Fortini et al. found that 3-6 months following hospitalization for COVID-19 [44], 22% of patients had complete resolution of their symptoms (including fatigue, loss of taste/smell, etc.), while, 78% of patients still experienced symptoms attributable to COVID-19, a finding supported by multiple studies [45,46].

Summary of the Professional Organization Statements/Guidelines

The AA/RCS consensus statements suggested waiting 7 weeks after testing positive for COVID-19 to schedule elective surgery (Table 2) [31,32]. The ESSKA guidelines suggest waiting a minimum of 8 weeks after testing positive for COVID-19 to reschedule elective surgery (Table 2) [34]. These recommendations differ from the ASA/APSF guidelines, which recommended rescheduling elective surgery after 4 weeks for asymptomatic patients, 6 weeks for with mild/moderate symptoms, and 12 weeks for severe/critical COVID-19 (Table 2) [30]. The ASA/APSF guidelines used a limited number of studies with small sample sizes to support their recommendation [30]. The EHS and European Knee Associates guidelines mentioned no specific timeframe for postponement in patients with a positive COVID-19 RT-PCR test, while suggesting waiting 3 weeks was a reasonable time, with no supporting evidence (Table 2). The ICM/AAHKS Guidelines and American Academy of Orthopaedic Surgery Recommendation mentioned to use the Center for Disease Control and Prevention time-based approach or symptom-based approach for rescheduling patients [28,29], without recommending specific rescheduling timeframes (Table 2).

Discussion

Based on information synthesized from the aforementioned studies and professional organization guidelines, the following timeframes should be considered for rescheduling patients who are undergoing elective arthroplasty surgery after testing positive for COVID-19 preoperatively (Fig. 5), based on their COVID-19 severity (Table 3):

- Asymptomatic Disease: 4-8 weeks after testing positive, as long as there is no development of symptoms in the interim.
- Mild/Moderate Disease: 6-8 weeks after testing positive, as long as all symptoms are resolved.
- Severe/Critical Disease Requiring Hospitalization: 12 weeks minimum after hospital discharge, with complete resolution of symptoms.

Rationale for the Timeframes Recommended in This Systematic Review

The studies conducted by the COVIDSurg Collaboration Group [22], Deng et al. [43], Butyrskii et al. [21], and Lal et al. [25] support utilization of the timeframes established in this systematic review for patients with asymptomatic disease and mild/moderate disease. In

Table 2
Professional Society Guidelines and Position Statements Summary.

Professional Society	Timeframe Recommendations Based on COVID-19 Severity (if Applicable)		
ESSKA	Severity of COVID-19 Not Considered	8 wk	
AA/RCS	Asymptomatic COVID-19 7 wk	Mild/Moderate COVID-19 7 wk	Severe/Critical COVID-19 Patient-Specific
ASA/APSF	Asymptomatic COVID-19 4 wk	Mild/Moderate COVID-19 6 wk	Severe/Critical COVID-19 12 wk
EHS/EKA	Severity of COVID-19 Not Considered CDC Time-Based Approach Recommended; Stated Approximately 3 wk To Reschedule Surgery		
ICM/AAHKS	Severity of COVID-19 Not Considered CDC Time-Based Approach Recommended; No Specific Timeframe Recommended		
AAOS	Severity of COVID-19 Not Considered CDC Time-Based Approach Recommended; No Specific Timeframe Recommended		

ESSKA, European Society of Sports Traumatology, Knee Surgery, and Arthroscopy; AA, Association of Anaesthetists; RCS, Royal College of Sugeons; ASA, American Society of Anesthesioologists; APSF, American Patient Safety Foundation; EHS, European Hip Society; EKA, European Knee Associates; ICM, International Consensus Meeting; AAHKS, American Association of Hip and Knee Sugeons; AAOS, American Academy of Orthopedic Surgeons; CDC, Centers for Disease Control and Prevention.

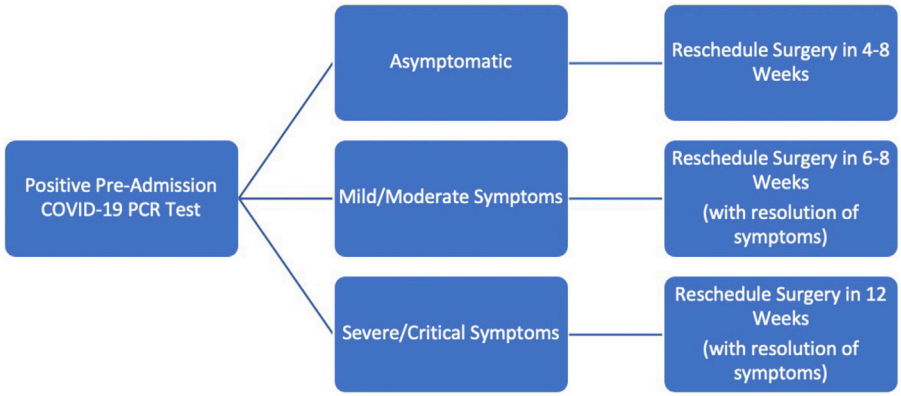

Fig. 5. Flowchart for rescheduling COVID positive patients for elective arthroplasty cases.

addition, these timeframes are similar to those recommended by the AA/RCS consensus statements [31]. Regarding patients with severe/critical COVID-19, since patients may be asymptomatic 12 weeks after having severe/critical COVID-19 [44], we are proposing that patients with severe/critical COVID-19 who have a complete resolution of symptoms can be rescheduled for elective arthroplasty surgery at a minimum of 12 weeks after hospital discharge. This timeframe should be modified according to each patient's condition, since some patients may be symptomatic 12 weeks after hospital discharge and may be experiencing "Long-COVID". In addition, while symptoms such as exertional dyspnea are indicative of decreased pulmonary function [44], which may impact patients undergoing elective surgery, the impact of non-specific symptoms such as anosmia, ageusia, and fatigue is unclear and their presence should not be an absolute contraindication for undergoing elective surgery. Patients with severe/critical COVID-19 should undergo multidisciplinary surgical clearance and preoperative optimization to determine when elective arthroplasty surgery should be performed.

Studies Proposing Shorter Timeframes and Their Limitations

A few studies proposed shorter timeframes for patients to undergo surgery after testing positive for COVID-19. Kothari et al. found that patients undergoing elective cancer surgery who waited a minimum of 20 days after testing positive with RT-PCR and underwent surgery did not have an increased risk of postoperative complications. While they proposed 20-days is a safe timeframe, the average time patients in the study had surgery postponed was 52 days (range: 20-202). Pandrowala et al. and Baiocchi et al. found that COVID-19 positive patients who had surgery delayed for 14 days and underwent surgery after having a negative re-test were not at an increased risk of mortality [20,27]. They proposed a 14-day delay is safe for patients. However, patients must be asymptomatic and have a negative RT-PCR test before undergoing surgery. Since some patients may have a positive RT-PCR test for an extended period of time after being infected [48], this may cause unnecessary surgical delays. Finally, Larsen et al. studied ambulatory surgical patients who were asymptomatic and found that patients with no delay in surgery had no increased reported 30-day re-admission or complications compared to patients with surgical delay [26]. However, their sample size was limited, and no statistical analysis was done.

Patient Risk Stratification and Preoperative Optimization

Evidence supports those patients with specific comorbidities are at a higher risk of experiencing postoperative complications and mortality when they have a positive preoperative COVID-19 test. The COVIDSurg Collaboration Group found that amongst patients diagnosed with COVID-19 preoperatively, predictors for 30-day mortality were being male (OR 2.37) and having an ASA of 3-5 (OR 4.67) [49], while predictors for 30-day pulmonary complications were having an ASA of 3-5 (OR 9.78) [49]. Clement et al. found that patients who develop COVID-19 postoperatively had a significantly higher risk for postoperative mortality, with patients who are over the age of 77 and patients having a higher ASA score having an elevated risk of developing COVID-19, postoperatively [15]. In addition, the ICM/AAHKS, ESSKA, and EHS/EKS recommended that patients with comorbidities placing them at a higher risk of COVID-19 such as increasing age, diabetes mellitus, obesity, obstructive sleep apnea, chronic obstructive pulmonary disease, uncontrolled hypertension, heart disease, kidney disease, and being immunocompromised should have risk-stratification and optimization [28,33,34]. It will be important to ensure patients with the aforementioned risk factors for morbidity and mortality undergo thorough multidisciplinary optimization before undergoing elective arthroplasty [50].

Patient-Surgeon Shared Decision-Making

Orthopedic surgeons should engage in shared decision-making with their patients regarding the decision to reschedule surgery when patients test positive for COVID-19 during pre-admission

Table 3
COVID-19 Severity Definitions [47].

COVID-19 Severity	Symptoms
Asymptomatic Disease	Patients with none of the symptoms listed below
Mild Disease	Fever, dry cough, sore throat, fatigue, anosmia, ageusia, body aches, abdominal pain, nausea, vomiting, or diarrhea.
Moderate Disease	Persistent fever and cough, without experiencing hypoxemia.
Severe Disease	Pneumonia with hypoxemia (an oxygen saturation under 92%).
Critical Disease	ARDS along with septic shock, encephalopathy, heart failure, acute kidney injury, and coagulation defects.

ARDS, acute respiratory distress syndrome.

testing. It is vital for patients to feel that they are making the decision to reschedule their surgery together with their orthopedic surgeon [51]. While engaging in shared decision-making, an invitation to partner together to make the decision must be made, and then information exchange must take place between the orthopedic surgeon and patient, especially as it pertains to the published literature regarding postoperative complications and mortality after being diagnosed with COVID-19, preoperatively. Various decision aids can be used during this step to help educate patients about the published literature, including brochures and videos. Finally, the patient's preferences for their care must be elicited, while delicately balancing their preferences and values with the principle of beneficence [51]. By going through these steps and engaging in shared decision-making, patients will feel better informed and are more likely to be satisfied and have better outcomes [52].

Limitations and Considerations for Future Research

There are important limitations to consider about the recommendations assembled in this systematic review. All of the studies examining perioperative morbidity and mortality in this systematic review were conducted during prior waves of the COVID-19 pandemic, with a high prevalence of COVID-19 variants of concern other than the Omicron variant. While preliminary studies show that Omicron has a milder disease course with a lower odds of patients being hospitalized and having severe disease, and a blunted impact on the lungs compared to other variants [53–56], this has not been explored in patients undergoing elective surgery. Therefore, it remains unclear what impact the Omicron variant will have on perioperative morbidity and mortality, especially in asymptomatic patients, and as a result, what impact it will have on timeframes to safely reschedule patients after being infected with COVID-19, preoperatively.

Another limitation is that no previous studies have examined the impact of COVID-19 vaccination status on timeframes to safely perform surgery after being infected with COVID-19, preoperatively. A study by Prasad et al. found that patients who have been vaccinated for COVID-19 (with 2 doses) more than 2 weeks before undergoing surgery had significantly lower rates of postoperative COVID-19, pulmonary and thrombotic complications, and decreased length of stay [57]. Therefore, as an increasing percentage of the population becomes vaccinated, further study is needed to assess what impact COVID-19 vaccination status has on timeframes for rescheduling elective arthroplasty surgery.

Finally, this systematic review provides recommendations for timeframes to reschedule elective arthroplasty cases based on patient safety, functioning to minimize perioperative morbidity and mortality due to a prior COVID-19 infection. This differs from infection control policies designed to mitigate the transmission of COVID-19 from infected patients to healthcare workers and other patients [58]. Given their goal, infection control policies are typically shorter than the timeframes in this systematic review, although they vary institutionally. It is important to consult your respective local infection control policies to attenuate the spread of COVID-19, and to consider the timeframes mentioned in this systematic review to optimize patient safety.

Therefore, these guidelines may conflict with your local hospital or healthcare systems policy, and it is important to note that each surgeon and patient should consult with their local system's guidelines as variability may exist based on emerging data, local trends, and preferences. The timeframes mentioned in this systematic review have been recommended based on the literature as of March 7, 2022. These timeframes are subject to modification as new evidence emerges on this topic.

Conclusion

The ideal timeframe for rescheduling elective arthroplasty surgery, with the goal of minimizing the risk of morbidity and mortality following surgery after a positive COVID-19 test, is not well-defined. Based upon the best available evidence and professional organization recommendations, we sought to provide timeframe recommendations for rescheduling patients who are undergoing elective arthroplasty surgery following a positive COVID-19 test. Surgeons and patients will likely be confronted with differing guidelines from local, state, and federal governments as well as policies from their local hospital or health system. We hope that through an awareness of the current best available evidence and understanding of its limitations, surgeons are equipped to help patients determine the optimal time to reschedule surgery that helps to account for each patient's individual circumstance.

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Appendix

Appendix 1
MEDLINE (PubMed) and EMBASE Literature Searches.

Database	Search Terms	Number of Results
MEDLINE (PubMed)	Performing Surgery COVID-19 Positive Patients	971
MEDLINE (PubMed)	Elective Surgery After COVID Infection	395
MEDLINE (PubMed)	Timing of Surgery After COVID-19	231
MEDLINE (PubMed)	Surgery Delay COVID Positive Patients	219
MEDLINE (PubMed)	Surgery AND Preoperative AND COVID AND Positive AND Patients	200
MEDLINE (PubMed)	Surgery Rescheduling COVID	91
MEDLINE (PubMed)	Positive COVID-19 Preadmission Testing	13
EMBASE	Elective Surgery After COVID Infection	630
EMBASE	Surgery AND Preoperative AND COVID AND Positive AND Patients	260
EMBASE	Surgery Delay COVID Positive Patients	176
EMBASE	Timing of Surgery After COVID-19	166
EMBASE	Performing Surgery COVID-19 Positive Patients	102
EMBASE	Surgery Rescheduling COVID	45
EMBASE	Positive COVID-19 Preadmission Testing	11

COVID-19, Coronavirus Disease 2019.

Appendix 2
Risk of Bias Assessment (Newcastle-Ottawa Scale).

Author	Study Type	Selection (Max ****)	Comparability (Max **)	Exposure/Outcome (Max ***)	Total Stars
Baiocchi 2020	Cohort	****	**	*	7
Butyrskii 2021	Cohort	-	-	-	-
COVIDSurg 2021	Cohort	****	**	***	9
Deng 2021	Cohort	****	**	***	9
Kothari 2021	Cohort	****	**	***	9
Lal 2021	Cohort	****	**	***	9
Larsen 2021	Cohort	***		**	5
Pandrowala 2021	Cohort	****		**	6

*Not applicable due to not having the full-text in English.