



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.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.JournalofSurgicalResearch.com

Clinical Outcomes of 2019 COVID-19 Positive Patients Who Underwent Surgery: A New York City Experience

Neil M. Vranis, MD,¹ Jonathan M. Bekisz, MD, MSci,¹
David A. Daar, MD, MBA, Ernest S. Chiu, MD, FACS,
and Stelios C. Wilson, MD*

Hansjörg Wyss Department of Plastic Surgery, New York University School of Medicine, New York, New York

ARTICLE INFO

Article history:

Received 6 July 2020

Received in revised form

24 September 2020

Accepted 31 October 2020

Available online 23 November 2020

Keywords:

COVID-19

SARS-Cov-2

Surgery

Incubation period

ABSTRACT

Background: The coronavirus disease 2019 (COVID-19) global pandemic has led to a halt in elective surgeries throughout the United States and many other countries throughout the world. Early reports suggest that COVID-19 patients undergoing surgery have an increased risk of requiring intensive care unit (ICU) admission and overall mortality.

Materials and methods: A retrospective review was performed of all COVID-19, positive with polymerase chain reaction confirmation, patients who had surgery between February 17, 2020 and April 26, 2020 at a major New York City hospital. Clinical characteristics and outcomes including ICU admission, ventilator requirement, and mortality were analyzed. **Results:** Thirty-nine COVID-19 surgical patients were identified. Mean age was 53.9 y, and there were more men than women in the cohort (56.4% versus 43.6%). Twenty-two patients (56.4%) had a confirmed positive COVID-19 test preoperatively, and the remainder tested positive after their procedure. The majority (59%) of patients had an American Society of Anesthesiologists (ASA) class of 3 or higher. Postoperatively, 7 patients (17.9%) required ICU level care with a mean length of stay of 7.7 d. There were 4 deaths (10.3%) in this patient population, all of which occurred in patients who were ASA class 3 or 4.

Conclusions: This study represents the largest study to date, that objectively analyzes the outcomes of COVID-19 positive patients who underwent surgery. Overall, ICU admission rates and mortality are similar to reported rates in the literature for nonsurgical COVID-19 patients. Notably, in COVID-19 patients with ASA 1 or 2, there was a 0% mortality rate in the postoperative period.

© 2020 Elsevier Inc. All rights reserved.

Introduction

The 2019 novel coronavirus disease (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has evolved from an outbreak in Wuhan, China to a

worldwide pandemic.¹⁻³ In response, many countries have instituted various international travel restrictions, post-exposure quarantine protocols, and community social distancing guidelines, as well as other public health measures to protect citizens and offset the pressures of overburdened

* Corresponding author. Hansjörg Wyss Department of Plastic Surgery, New York University School of Medicine, 222 E. 41st St. 6th Floor New York, NY 10017. Tel./fax: 1-760-280-0236.

E-mail address: Stelios.Wilson@gmail.com (S.C. Wilson).

¹ This symbol denotes equal contribution to the content of this work.

0022-4804/\$ – see front matter © 2020 Elsevier Inc. All rights reserved.

<https://doi.org/10.1016/j.jss.2020.10.032>

health care systems.^{4,5} In the United States, the surgeon general put a pause on all elective or nonemergent surgery in an attempt to aid in the conservation of resources, minimize unnecessary exposures, and help slow the spread of disease.⁶

Early reports show that most patients infected with SARS-CoV-2 remain asymptomatic or have only mild symptoms. In contrast, a smaller, but striking, percentage of individuals develop severe respiratory compromise that can rapidly deteriorate to acute respiratory distress syndrome (ARDS) and even multisystem organ failure (MOF).¹ Reported symptoms include fever, cough, sore throat, headache, fatigue, dyspnea, malaise, diarrhea, arthralgias, or myalgias which will typically present within 14 d of infectivity.^{1,2,7} However, reports of longer “incubation periods,” up to 24 d, have been cited in the literature.⁸

Prior studies suggest an increased risk of mortality for COVID-19 positive patients who undergo surgery. The earliest report from Iran describes three patients who had routine intra-abdominal procedures during the presumed viral incubation period, two of whom died from ARDS and MOF. The third patient had an extended hospital course but ultimately recovered from their respiratory symptoms and was discharged home.⁹ More recently, a study published from Wuhan, China, analyzed 34 asymptomatic patients who underwent surgery during the incubation period of COVID-19.¹⁰ The group found that 44% of the patients were admitted to the intensive care unit (ICU) with a 20.5% mortality rate.¹⁰ These findings prompted the authors to suggest that undergoing surgery during the incubation period may contribute to the high rate of ICU admission and mortality. However, they acknowledge that procedural complexity and having multiple comorbidities were associated with a worse prognosis. Theories to explain the observed trends include ventilator-associated barotrauma, hypercoagulable state from the COVID-19 disease process and/or anesthesia, a systemic cytokine response secondary to surgical insult, or even the mere additional exposures to nosocomial COVID-19 strains and other infectious organisms.^{5,8,11-13}

As the number of confirmed cases, hospital admissions, the volume of COVID-19–associated mortality decline, and restrictions for performing elective surgeries are expected to be lifted. Understanding the virus, disease process, and complications that can arise from operating on patients with active COVID-19 or asymptomatic patients during the incubation period will help guide best practices during these uncertain times. To that end, this study was designed to describe the surgical experience at a single institution, located in a large, densely populated urban area at the height of the COVID-19 pandemic, to help determine the effect of surgery, including the use of general anesthesia, on patients with COVID-19 or asymptomatic patients who subsequently tested positive for SAR-CoV-2.

Materials and methods

Study design and participants

After obtaining institutional review board approval (i20-00644) and a waiver of informed consent given the nature of

the study, a retrospective review was performed of all patients who had surgery performed between March 6, 2020 and April 26, 2020 at Bellevue Hospital Center (New York, NY). It is the oldest public hospital in the United States and serves the most affected city in the world during the COVID-19 pandemic. This time period included the time leading up to the apex of COVID-19 positive cases in New York City, the apex, and the presumed decline. Individuals were included for analysis if they had surgery and also found to be SARS-CoV-2 positive by nasopharyngeal swab polymerase chain reaction (PCR) up to 14 days preoperatively or 24 days postoperatively. For the purpose of this study, patients who had a bedside surgical procedure directly related to COVID-19 sequelae and care, including but not limited to tracheostomy tube placement, gastrostomy tube placement, and insertion of peritoneal dialysis catheters, were excluded from the study. Patients were also excluded if their surgery was performed for COVID-19–related infection or other sequelae.

Data collection

All patients required a documented positive COVID-19 test. Testing related to this study was performed by PCR confirmation through the Bellevue Hospital laboratory and approved outside vendors using nasopharyngeal swab samples. The two primary tests used were the COVID-19 reverse transcription-PCR assay developed by Bio-Reference Laboratories (Bio-Reference Laboratories, Inc, Elmwood Park, NJ) for which information related to sensitivity and specificity is not yet available, and the Cepheid Xpert Xpress SARS-CoV-2 rapid test (Cepheid Inc, Sunnyvale, CA) reported to have a sensitivity of 95% and a specificity of 100%.¹⁴

Demographic data, patient comorbidities, and procedural information were collected. Surgical outcomes including operative details, escalation to ICU level care, or need for prolonged postoperative ventilation were recorded. Dates of symptoms onset, emergency room visits, surgery, and hospital admission and discharge were systematically captured. Patients were classified by the American Society of Anesthesiologists (ASA) physical status presurgical classification¹⁵ (Fig. 1).

<p>ASA Class 1 – Normal, healthy patient Ex: Healthy, mild alcohol use, non-obese, non-smoking</p>
<p>ASA Class 2 – Mild systemic disease Ex: Active smoker, pregnancy, obesity, well-controlled diabetes or hypertension</p>
<p>ASA Class 3 – Severe systemic disease Ex: Morbid obesity, COPD, poorly-controlled diabetes or hypertension, renal failure on hemodialysis</p>
<p>ASA Class 4 – Severe systemic disease that is a constant threat to life Ex: Recent myocardial infarction or cerebrovascular accident, cardiac disease with severely reduced ejection fraction, sepsis, renal failure not on hemodialysis</p>

Fig. 1 – American Society of Anesthesiologists (ASA) physical status classification system. (Color version of figure is available online.)

Table 1 – Patient demographics, comorbidities, and preoperative COVID-19 course.

Characteristics	n (%)	Symptoms/Comorbidities	n (%)
Patients	39	Preoperative symptoms	
Gender		Any preoperative COVID-19 symptoms	20 (51.3%)
Male	22 (56.4%)	Cough	10 (25.6%)
Female	17 (43.6%)	Objective fever	10 (25.6%)
Age (years)*	53.92 ± 20.30	Fatigue/malaise	4 (10.3%)
BMI (kg/m ²)*	26.89 ± 8.19	Shortness of breath	5 (12.8%)
Race/ethnicity		Myalgia or arthralgia	1 (2.6%)
Caucasian	6 (15.4%)	Anosmia or abnormal smell	0
African American	5 (12.8%)	Ageusia or abnormal taste	1 (2.6%)
Hispanic/Latinx	18 (46.2%)		
Asian	0		
Other/not reported	10 (25.6%)	Preoperative testing/workup	
Living situation		Preoperative positive COVID-19 test	22 (56.4%)
House/apartment	28 (71.8%)	Preoperative admission for COVID-19	3 (7.7%)
Shelter-domiciled/homeless	6 (15.4%)	Preoperative ICU for COVID-19	1 (2.6%)
Long-term facility	3 (7.7%)	Radiologic evidence of pneumonia	
Incarcerated	2 (5.1%)	X-ray	15 (38.5%)
Tobacco use		CT scan	6 (15.4%)
Active	3 (8.8%)	Time from symptom onset to surgery (days)*	14 ± 6 (range: 1-22)
Former	5 (14.7%)	Time from positive COVID-19 test to surgery (days)*	2.5 ± 12 (range: -33-24) [†]
Hypertension	18 (46.2%)		
Congestive heart failure	3 (7.7%)		
Coronary artery disease	5 (12.8%)	Pharmacologic management	
Cerebrovascular accident	2 (5.1%)	Azithromycin	13 (33.3%)
COPD	5 (12.8%)	Hydroxychloroquine	17 (43.6%)
Diabetes mellitus	4 (10.3%)	Other antibiotics (excluding peri-operative)	28 (71.8%)
Chronic kidney disease	5 (12.8%)	Lopinavir-ritonavir	3 (7.7%)
Hemodialysis	4 (10.3%)	Remdesivir	0
Active malignancy	1 (2.6%)	Tocilizumab	0
History of malignancy	2 (5.1%)	Steroids	1 (2.6%)
Autoimmune disorder	1 (2.6%)	Immunoglobulin	0

BMI = body mass index; COPD = chronic obstructive pulmonary disease.

*Mean ± Standard Deviation.

[†]Only 1 patient in deceased group placed on ventilator postoperatively.

Statistical analysis

Statistical analysis was performed using SPSS statistical software package, version 25 (IBM, Armonk, NY). Descriptive statistics and frequencies were calculated for the entire patient population and each subgroup analyzed. For comparisons between groups, the appropriate parametric or nonparametric tests were conducted based on the nature of variable and included the Student's t-test, the Mann-Whitney U test, and the chi-squared or Fischer's exact test. For the

purpose of two-tailed univariate analysis, the cutoff for statistical significance was set at an alpha (α) of 0.05.

Results

Demographics of patient population

A total of 39 PCR-confirmed COVID-19 symptomatic patients underwent a surgical procedure at Bellevue Hospital Center

from March 6, 2020 to April 26, 2020. The mean age was 53.9 y (range 9-91 y), and there was a predominance of male patients in the cohort, with 22 men (56.4%) compared with 17 women (43.6%). Many racial and ethnic backgrounds were represented, however, nearly half were identified as having Hispanic or Latin ethnicity (46.2%). The majority (71.8%) were domiciled in a house or an apartment; the remainder were either homeless or shelter-domiciled (15.4%), resided in a long-term care facility (7.7%), or were incarcerated in the New York City correctional system (5.1%) (Table 1).

Baseline health and medical comorbidities

With respect to the general health of this patient cohort before COVID-19 infection, the mean body mass index (BMI) was 26.89. Nearly a quarter had a history of current or prior tobacco use (8.8% active, 14.7% former). Hypertension was the most common comorbidity, present in 18 patients (46.2%), followed by coronary artery disease, chronic obstructive pulmonary disease (COPD), and chronic kidney disease in 5 patients (12.8%) each. 4 individuals (10.3%) had renal failure at

baseline and were on hemodialysis before the COVID-19 pandemic (Table 1).

COVID-19 infection in preoperative and perioperative periods

Among these 39 patients, 22 (56.4%) had a confirmed positive COVID-19 test before surgery. Three individuals required hospital admission for treatment of their COVID-19 infection preoperatively with 1 needing escalation to the ICU. For those patients with an unknown viral status preoperatively, the mean number of days between a SARS-CoV-2 positive test result and surgery was 5.6 (range 0-33). It must be noted that the individual who initially tested positive more than 30 d out from surgery had a repeat positive test 2 d before being taken to the operating room. For patients whose viral testing was performed subsequently to surgery, testing occurred at an average of 12.88 d (range 0-24) after their procedure (Table 1).

Twenty patients (51.3%) had documented evidence of at least one COVID-19 symptom in the preoperative period. Cough and objective fever were the most commonly cited

Table 2 – Operative details, outcomes, and complications.

	n (%)		n (%)
Operative characteristics		Operative outcomes	
Surgical service		COVID-related inability to extubate in OR	3 (7.7%)
Trauma	3 (7.7%)	New postoperative COVID-related ICU requirement	7 (17.9%)
General	8 (20.5%)	Postoperative ICU length of stay (days)*	7.7 ± 4.1
Cardiothoracic/interventional cardiology	4 (10.3%)	Respiratory support	
Vascular	4 (10.3%)	Supplemental oxygen	9 (23.1%)
Orthopedic/hand	8 (20.5%)	CPAP/BiPAP	1 (2.6%)
Neurosurgery	4 (10.3%)	Intubation	5 (13.2%)
Plastic/OMFS	3 (7.7%)	Extubated	3 (60%)
Pediatric	2 (5.1%)	Days on ventilator*	10.2 ± 3.3
OB-Gyn	1 (2.6%)	COVID-related severe complications	
Podiatry	2 (5.1%)	ARDS	5 (12.8%)
ASA classification		Shock requiring pressors	6 (15.4%)
1	4 (10.3%)	Acute kidney injury	6 (15.4%)
2	12 (30.8%)	New dialysis requirement	0
3	15 (38.5%)	ECMO	0
4	8 (20.5%)	Pulmonary embolism	0
Procedure length (mins)*	177.3 ± 115.1	Deep venous thrombosis	0
Type of anesthesia		Other ischemic or thrombotic complication	1 (2.6%)
General	35 (89.7%)	Secondary infection	5 (13.2%)
IV sedation/local	4 (10.3%)	Disposition	
Airway management		Hospital length of stay (days)*	20.9 ± 29.1
Endotracheal tube	34 (87.2%)	Discharged from hospital	26 (66.7%)
Laryngeal mask airway	2 (5.1%)	Remain admitted to hospital	9 (23.1%)
Nasal cannula oxygen or N/A	3 (7.7%)	Deceased	4 (10.3%)

ASA = American Society of Anesthesiologists.

* Mean ± Standard Deviation.

Table 3 – Characteristics of deceased patients.

Age, Gender	Comorbidities	Preopp COVID-19 symptoms or findings	COVID-19 test date	Surgery date	Procedure (length)	ASA class	Date of death	COVID-related complications	Cause of death
57, F	Active smoker, HTN, COPD, CKD on dialysis, HIV, hepatitis B, hepatitis C	Pneumonia on X-ray	3/30/2020	November 3, 2020	Arteriovenous fistula revision, graft placement (178)	4	May 4, 2020	Secondary infection	Unknown, found unresponsive
86, M	Former smoker, HTN, CHF, CAD, COPD, Parkinson's disease	Pneumonia on X-ray	3/29/2020	3/13/2020	Open reduction and internal fixation of hip (130)	3	3/31/2020	ARDS, shock requiring pressors, acute kidney injury	Multiorgan failure
54, F	HTN, CKD on dialysis, mitral valve endocarditis, hyperparathyroidism	Fever, pneumonia on X-ray	August 4, 2020	January 4, 2020	Mitral valve replacement (330)	4	4/22/2020	ARDS, shock requiring pressors	Bradycardiac arrest
65, M	Former smoker, COPD, CKD, HIV, hepatitis B, hepatitis C, IV drug use, cirrhosis with hepatopulmonary syndrome	None	4/16/2020	December 4, 2020	Arthroscopic irrigation and debridement for pyogenic arthritis of knee (93)	3	4/19/2020	Secondary infection	Unknown, found unresponsive

($n = 10$, 25.6%) followed by shortness of breath in 5 individuals (12.8%). Symptoms began an average of 14 d (range 1-22) before surgery (Table 1).

Surgical interventions and outcomes in the setting of COVID-19 infection

These 39 patients underwent a total of 42 procedures in the operating room over the duration of this study. For the purposes of statistical analysis, only the primary procedure to address their underlying problem was included (e.g., an initial amputation was selected over subsequent revision or debridement). Nearly, all cases were performed for emergent or urgent indications. General surgery and orthopedic/hand surgery were responsible for treating the largest percentages of these patients ($n = 8$, 20.5%), followed by neurosurgery, vascular surgery, and cardiothoracic surgery/interventional cardiology ($n = 4$, 10.7%) (Table 2).

Mean procedure length was approximately 177.3 min, and nearly, 90% of patients received general anesthesia ($n = 35$) with endotracheal intubation ($n = 34$). The ASA class was 3 or higher in 59% of the population, including 8 (20.5%) patients meeting criteria for class 4 (Table 2).

The anesthesiologists were unable to extubate 3 patients (7.7%) at the immediate conclusion of the procedure, secondary to difficulty weaning oxygen and ventilatory support requirements in 2 individuals and the presence of a hemothorax in another, while 7 (17.9%) patients were found to have COVID-related ICU needs that had not been present preoperatively, with an average postoperative ICU length of stay of 7.7 d (range 2-15 d [The patient admitted for 15 d remains in the ICU as of the time of manuscript submission]). Preoperatively, no patient was noted to have supplemental oxygen requirements nor were any patients on ventilators. Twenty-six (66.7%) patients remained on room air postoperatively and did not require any respiratory intervention, whereas approximately one quarter ($n = 9$) were unable to maintain adequate oxygen saturation requirements that improved with supplemental oxygen. Overall, 5 patients (13.2%) were intubated at some point in their postoperative course, with a mean duration of time on the ventilator of 10.2 d. Three of these patients have successfully been extubated at the time of manuscript submission, another remains intubated, and the last expired while on the ventilator (Table 2).

Severe complications of COVID-19 developed in 10 patients (25.6%). Shock requiring pharmacologic blood pressure support and acute kidney injury was the most common, occurring in 6 individuals each (15.4%). ARDS and secondary infection were also seen in 5 patients each. One patient suffered from a vaso-occlusive complication in the form of acute lower extremity ischemia secondary to an undetermined but likely embolic or *in situ* thrombotic etiology (Table 2).

At the time of manuscript submission, 9 patients (23.1%) remain admitted to the hospital, whereas 26 (66.7%) have been discharged home or to rehabilitation facilities (Table 2). All patients who had been discharged had confirmed proof of life with documented follow-up within the Bellevue Hospital Center system within 10 d of the final review of the clinical chart. There were 4 deaths (10.3%) among this cohort, all of

Table 4 – Comparison of patient characteristics and surgical outcomes among different ASA classes.

Characteristics	ASA class 1/2	ASA class 3/4	P-value
Patients	16	23	-
Demographics			
Age (years)*	46.5 ± 22.3	59.1 ± 17.5	0.056
BMI (kg/m ²)*	24.75 ± 5.5	28.35 ± 9.46	0.193
Race/ethnicity			0.420
Caucasian	3 (18.8%)	3 (13%)	
African American	1 (6.3%)	4 (17.4%)	
Hispanic/Latinx	10 (62.5%)	8 (34.8%)	
Asian	0	0	
Other/not reported	2 (12.5%)	8 (34.8%)	
Comorbidities			
Tobacco use			
Active	2 (14.3%)	1 (5%)	0.555
Former	0	5 (25%)	0.063
Hypertension	4 (25%)	14 (60.9%)	0.049
Congestive heart failure	0	3 (13%)	0.255
Coronary artery disease	0	5 (21.7%)	0.066
Cerebrovascular accident	0	2 (8.7%)	0.503
COPD	0	5 (21.7%)	0.066
Diabetes mellitus	1 (6.3%)	3 (13%)	0.631
Chronic kidney disease	0	5 (21.7%)	0.066
Hemodialysis	0	4 (17.4%)	0.130
Preoperative clinical course			
Any preoperative COVID-19 symptoms	8 (50%)	12 (52.2%)	0.894
Preoperative positive COVID-19 test	12 (75%)	10 (43.5%)	0.099
Preoperative admission for COVID-19	0	3 (13%)	0.255
Time from symptom onset to surgery (days)*	15.3 ± 4.5	17.7 ± 6.4	0.666
Time from positive COVID-19 test to surgery (days)*	0.3 ± 8.5	4 ± 14	0.358
Surgical outcomes			
Procedure length (mins)*	171.3 ± 99	181.5 ± 127.1	0.789
COVID-related inability to extubate in OR	1 (6.3%)	2 (8.7%)	1.000
New postoperative COVID-related ICU requirement	2 (12.5%)	5 (21.7%)	0.678
Postoperative ICU length of stay (days)*	6 ± 5.7	8.1 ± 4.0	0.667
Intubation	1 (6.3%)	4 (18.2%)	0.374
Days on ventilator*	10 [†]	10.3 ± 3.8	1.000
Hospital length of stay (days)*	6.6 ± 6.7	30.8 ± 34.3	0.008
Remain admitted to hospital	2 (12.5%)	7 (30.4%)	0.262
Deceased	0	4 (17.4%)	0.130

Bold indicates $P < 0.05$.

ASA = American Society of Anesthesiologists.

* Mean ± Standard Deviation.

[†] Only 1 patient in ASA class 1/2 placed on ventilator postoperatively.

which occurred in patients who were ASA class 3 or 4 (Table 3). Each death occurred at least a week after surgery, and 75% were in patients who had been admitted to the ICU, with the date of ICU admission coming a minimum of 12 d postoperatively. The causes of death have only been determined for 2 of these individuals (multiorgan system failure and secondary to cardiac arrest) (Table 3).

Differences in baseline characteristics and surgical outcomes among different ASA classes

Patients were grouped as per low (1 or 2) or high (3 or 4) ASA class and compared on the basis of demographics, health history, COVID-19 infection course, and surgical outcomes (Table 4). There were 16 patients in the low ASA class group

Table 5 – Comparison of living and deceased patients across all ASA classes and only ASA class 3/4.

Characteristics	Deceased	All alive	P-value [†]	ASA class 3/4 alive	P-value [‡]
Patients	4	35	-	19	-
Demographics					
Age (years)*	65.5 ± 14.4	52.6 ± 20.6	0.195	57.7 ± 18.1	0.409
BMI (kg/m ²)*	21.3 ± 3.2	27.57 ± 8.38	0.103	29.9 ± 9.7	0.042
Race/ethnicity			0.876		0.671
Caucasian	2 (50%)	4 (11.4%)		1 (5.3%)	
African American	0	5 (14.3%)		4 (21.1%)	
Hispanic/Latinx	0	18 (51.4%)		8 (42.1%)	
Asian	0	0		0	
Other/not reported	2 (50%)	8 (22.9%)		6 (31.6%)	
Comorbidities					
Tobacco use					
Active	1 (25%)	2 (6.7%)	0.322	0	0.200
Former	2 (50%)	3 (10%)	0.094	3 (18.8%)	0.249
Hypertension	3 (75%)	15 (42.9%)	0.318	11 (57.9%)	1.000
Congestive heart failure	1 (25%)	2 (5.7%)	0.284	2 (10.5%)	0.453
Coronary artery disease	1 (25%)	4 (11.4%)	0.436	4 (21.1%)	1.000
Cerebrovascular accident	0	2 (5.7%)	1.000	2 (10.5%)	1.000
COPD	3 (75%)	2 (5.7%)	0.004	2 (10.5%)	0.021
Diabetes mellitus	0	4 (11.4%)	1.000	3 (15.8%)	1.000
Chronic kidney disease	3 (75%)	2 (5.7%)	0.004	2 (10.5%)	0.021
Hemodialysis	2 (50%)	2 (5.7%)	0.045	2 (10.5%)	0.125
Preoperative clinical course					
Any preoperative COVID-19 symptoms	1 (25%)	19 (54.3%)	0.342	11 (57.9%)	0.317
Preoperative positive COVID-19 test	0	22 (62.9%)	0.029	10 (52.6%)	0.104
Preoperative admission for COVID-19	0	3 (8.6%)	1.000	3 (15.8%)	1.000
Time from symptom onset to surgery (days)*	12.7 ± 6.7	14.3 ± 6.1	0.712	14 ± 6.6	0.840
Time from positive COVID-19 test to surgery (days)*	11.5 ± 7.1	1.4 ± 12.1	0.066	2.4 ± 14.6	0.218
Surgical outcomes					
Procedure length (mins)*	182.8 ± 104.1	176.7 ± 117.7	0.806	181.2 ± 133.9	0.845
COVID-related inability to extubate in OR	0	3 (8.6%)	1.000	2 (10.5%)	1.000
New postoperative COVID-related ICU requirement	2 (50%)	5 (14.3%)	0.141	3 (15.8%)	0.194
Postoperative ICU length of stay (days)*	5.7 ± 3.1	8.7 ± 4.4	0.381	10 ± 3.8	0.229
Intubation	1 (25%)	4 (11.8%)	0.446	3 (16.7%)	1.000
Days on ventilator*	9	10.5 ± 3.7	0.800	10.7 ± 4.5	1.000
Hospital length of stay (days)*	13.3 ± 15.3	21.7 ± 30.3	0.639	34.5 ± 36.2	0.054

Bold indicates $P < 0.05$.

ASA = American Society of Anesthesiologists.

*Mean ± Standard Deviation.

[†]P-values for comparison of deceased and all patients who remain alive.

[‡]P-values for comparison of deceased and patients with ASA class 3 or 4 who remain alive.

and 23 in the high ASA class group. Those in the low ASA class group tended to be younger (mean age 46.5 versus 59.1 y, $P = 0.056$) and have lower mean BMI 24.75 versus 28.35, $P = 0.193$), although neither comparison yielded statistical significance. Patients in the high ASA class group had significantly higher rates of hypertension (60.9% versus 25%, $P = 0.049$), whereas the rates of coronary artery disease, COPD, and chronic kidney disease were not significant. There was no

discernible difference in the rates patients experienced preoperative COVID-19 symptoms (low ASA = 50% versus high ASA = 52.2%, $P = 0.894$). Patients in the low ASA class group more frequently had a known positive COVID-19 test before surgery (75% versus 43.5%, $P = 0.099$), but this difference was not statistically significant.

Regarding postoperative outcomes, no statistically significant differences were detected with respect to a new COVID-

related need for ICU management (low ASA = 12.5% versus high ASA = 21.7%, $P = 0.678$) or ICU length of stay (low ASA = 6 days versus high ASA = 8.1 d, $P = 0.667$). However, patients in the low ASA class group had significantly shorter durations of their overall hospital length of stay, with a mean of 6.6 d compared with 30.8 d ($P = 0.008$). Finally, there was a 17.4% mortality rate ($n = 4$) in the high ASA class group, compared with zero deaths in the low ASA class group ($P = 0.130$).

Comparison of baseline characteristics between living and deceased patients

To better understand mortality in the postoperative patient with COVID-19, the patient population was divided on the basis of whether or not they remained alive at the time of manuscript submission ($n = 35$) or were deceased ($n = 4$). Patients who ultimately died were on average older (65.5 versus 52.6 y, $P = 0.195$) and had lower BMIs (21.3 versus 27.6, $P = 0.103$) although neither of these comparisons reached statistical significance. They had higher rates of every comorbidity with the exception of diabetes mellitus and a history of cerebrovascular accident, and these rates were statistically significantly different with respect to COPD (75% versus 5.7%, $P = 0.004$), chronic kidney disease (75% versus 5.7%, $P = 0.004$), and being hemodialysis-dependent (50% versus 5.7%, $P = 0.045$). It bears noting that none of the deceased patients were known to be COVID-19 positive preoperatively, compared with 62.9% of those who remain alive ($P = 0.029$) (Table 5).

The cohort of survivors was then further stratified to include only those with ASA class 3 or 4 status. A significant difference in BMI was identified, as those who remained alive were had a mean BMI 8 points higher than the deceased (29.9 versus 21.3, $P = 0.042$). In addition, patients who died had significantly higher rates of COPD (75% versus 10.5%, $P = 0.021$) and chronic kidney disease (75% versus 10.5%, $P = 0.021$) (Table 5).

Discussion

As the number of confirmed COVID-19 cases decreases, surgeons, anesthesiologists, infectious disease experts, and hospital administrators will have the challenging task of determining when elective surgery can safely recommence. Here, we present clinical data on the potential additional surgical risk of operating on COVID-19 patients or asymptomatic patients who are hypothetically in the incubation period of the disease.

The suggested notion that a patient undergoing surgery who is either asymptomatic or subsequently infected by a coronavirus is not novel. In 2015, the Middle East region experienced a similar, albeit much smaller scale, coronavirus outbreak.^{2,8} Coined Middle East respiratory syndrome coronavirus, this similar respiratory virus exhibited high fatality and transmissibility characteristics. In one hospital where a Middle East respiratory syndrome coronavirus mini-outbreak occurred, the cardiac ward was preferentially susceptible, and ultimately, 5 of the 6 patients who had

undergone recent cardiac surgery died secondary to respiratory failure.¹⁶

Currently, studies in the literature associating COVID-19 and increased surgical risk with poorer outcomes are limited to small case reports or make generalized conclusions that are not supported by the data. Recently, a multihospital study from Wuhan China reported 20% mortality rate in 34 patients.¹⁰ However, it lacks a comparison group and most of the patients who died had multiple comorbidities or underwent index procedures that involved thoracic surgery, suggesting that many of these patients had some degree of respiratory compromise at baseline. Publishing these data during these challenging times on a novel virus is quite valuable. However, generalized conclusions regarding COVID-19 and its associated perioperative risk for otherwise healthy patients that fall in the ASA 1 or 2 category should not be made based off such studies alone. In our cohort of patients who underwent surgery, all patients in the ASA 1 or 2 class have survived. In a recent meta-analysis of over 650 patients, the authors found that 20% of hospitalized, infected COVID-19 patients required an ICU admission and 14% of the hospital patients had fatal outcomes.⁷ Our data, composed of surgical patients (18% ICU admission rate and 10% mortality), aligns with the results these authors present, suggesting that patients undergoing surgery do not appear to have a significantly increased risk of mortality.

Each surgical subspecialty has a cohort of medically indicated, high priority procedures that are not considered emergent. For the months during which the COVID-19 was at its peak in New York City, these procedures were either discouraged or prohibited by hospital institutions. With limited understanding of the surgical and/or anesthetic impact on the physiology of those infected with SARS-CoV-2, this can be challenging for surgeons, patients, and their families.¹⁷ During these times of uncertainty, there is a moral and ethical obligation for surgeons to remain current on the evolving literature and best practices. It is imperative health care providers clearly convey the risks associated with each procedure while acknowledging the potential for additional contributing factors such as COVID-19 that may alter the risk profile for that procedure or the subsequent postoperative care. Conversely, although the timeline of societal recovery from this pandemic is uncertain, and many anticipate that the slow return to "normal" may take several more months. During this time period, the potential repercussions from improper, generalized cancellation or delay of all non-emergent surgeries may yield significant pain, distress, and morbidity for patients and society.⁶ Therefore, careful consideration, risk stratification, and preoperative patient counseling are imperative as bans lift on elective surgery.

As with all studies, this study has its limitations. First, it is a retrospective review from a single hospital. However, given the severity of this pandemic and the rapidly evolving health care regulations regarding elective surgery, the authors believe that publishing these results adds value to the medical community as we begin to evaluate the future of elective surgery in the near term. While many patients in our cohort were confirmed SARS-CoV-2 positive before surgery, there were several patients in the early part of this study, when testing kits were unavailable or their use was not widespread,

that were presumed to be in the incubation period based on the estimated time from the day they subsequently tested positive for the virus on PCR-based testing. We included all patients who tested positive up to 14 d before their surgery or up to 24 d after their surgery, based on the longest incubation time that has been reported to date in an effort to ensure that we captured all infected patients who underwent surgery at our institution.⁸ As a tertiary care center in New York City, the epicenter of the COVID-19 pandemic in the United States, our institution is in a unique position to perform this study. Despite the intermission on elective cases, longstanding referral and transfer patterns from other city hospitals contributed to the constant but low volume of emergent operative cases at our institution. The overwhelming majority, 80% of our reported cases, had surgery dates after the New York State mandate to cancel of elective surgery in New York City. Therefore, elective procedures are inherently underrepresented, however, it remains the largest reported series published to date on this topic. While a majority of cases included were for urgent or emergent indications, they represent a wide variety of surgical procedures commonly performed as part of care in a level 1 trauma center (e.g., open reduction internal fixation of hip fractures, coronary artery bypass grafting, laparoscopic cholecystectomy, appendectomy, etc.). Nonetheless, it must be acknowledged that with the constraints of the cancellation of elective cases as well as a hesitancy to operate on patients with confirmed or suspected COVID-19 infection, it was necessary for the purposes of this study to group procedures of varying complexity from all surgical specialties, stratifying patients only by ASA class. Ideally, as the COVID-19 pandemic evolves and more data become available both within New York City as well as the country and the world at large, coordinated efforts can be made between centers to pool outcomes and further refine our understanding of the interplay between COVID-19 and postoperative outcomes.

Finally, our intention is to determine the impact of COVID-19 with postoperative complication and mortality. Unfortunately, a recently implemented New York City moratorium limits the performance of autopsies during this COVID-19 pandemic. The cause of death for 3 of the 4 patients is presumed to be attributed to COVID-19. One patient, a 65-year-old SARS-Cov-2 positive, drug dependent, active smoker was diagnosed with pyogenic arthritis, underwent knee wound irrigation and debridement and expired unexpectedly 8 d after surgery while recovering on the floor. Patients with severe COVID-19 illness have a propensity for a hypercoagulable state, however, an autopsy could not be performed. Although he had tested positive for SARS-CoV-2, he remained asymptomatic during his hospitalization and was only tested because his roommate had been found to be positive for COVID-19. Further, this patient received none of the treatments being used at that time to combat the virus, including hydroxychloroquine, tocilizumab, or corticosteroids, and thus the true cause of death remains unknown. We included this patient in the analysis, despite significant contemplation that the cause of death was unrelated to COVID-19, which would only strengthen our findings and conclusions. While this study would indeed be strengthened by comparing this COVID positive cohort to a matched control of patients undergoing

surgery who were COVID negative, we are limited by the study period (a <2 mo duration) and single-institution setting. This prevented our ability to obtain a properly matched cohort of control patients with similar patient and operative characteristics. Nevertheless, our case series is valuable in its size and timeliness as we continue to battle the COVID-19 pandemic today.

Conclusions

We have critically analyzed the hospitalizations and postoperative outcomes for 39 PCR-confirmed SARS-Cov-2 patients who underwent surgery during the apex of the COVID-19 epidemic in a large volume New York City hospital. The rate of ICU admission and mortality of these patients appears to be similar to nonsurgical COVID-19 patients who have been reported in the literature. It was encouraging to find that none of the patients with ASA 1 or 2 scores died in the immediate postoperative period. These findings support the risk stratification of elective surgery algorithms that Dr Stahel presents in his recent editorial.⁶ We encourage all researchers to work together and continue accruing objective data, so that health care professionals and hospitals are better able to risk stratify COVID-19 positive surgical candidate patients to achieve safe clinical outcomes.

Disclosure

The authors have no financial interest to declare in relation to the content of this work.

Author's contributions

The project idea and study design were conceptualized and put forth by N.M.V., J.M.B., and S.C.W. Refinement of this study design was performed by S.C.W., D.A.D., and Chiu. Data collection was performed by N.M.V., J.M.B., S.C.W., with data analysis performed by J.M.B. Manuscript writing was performed by N.M.V., J.M.B., D.A.D., and S.C.W., with manuscript editing being performed by all members of the team. Figures were generated by D.A.D. and J.M.B. Chiu served as PI for the study and oversaw the project.

REFERENCES

1. Burhan E, Prasenoahadi P, Rogayah R, Isbaniyah F, Reisa T, Dharmawan I. Clinical Progression of COVID-19 patient with extended incubation period, delayed RT-PCR time-to-positivity, and potential Role of chest CT-scan. *Acta Med Indones.* 2020;52:80–83.
2. Chakraborty C, Sharma AR, Sharma G, Bhattacharya M, Lee SS. SARS-CoV-2 causing pneumonia-associated respiratory disorder (COVID-19): diagnostic and proposed therapeutic options. *Eur Rev Med Pharmacol Sci.* 2020;24:4016–4026.
3. *Coronavirus live Updates: W.H.O. Declares pandemic as number of infected countries Grows.* New York, NY: The New York Times; 2020.
4. Doussot A, Heyd B, Lakkis Z. We asked the experts: How do we maintain surgical quality standards for enhanced

- recovery programs after cancer surgery during the COVID-19 outbreak? *World J Surg.* 2020;44:2051–2052.
5. Lepre L, Costa G, Virmo VA, et al. Acute care surgery and postoperative COVID-19 pneumonia: a surgical and environmental challenge. *ANZ J Surg.* 2020;90:1160–1161.
 6. Stahel PF. How to risk-stratify elective surgery during the COVID-19 pandemic? *Patient Saf Surg.* 2020;14:8.
 7. Rodriguez-Morales AJ, Cardona-Ospina JA, Gutierrez-Ocampo E, et al. Clinical, laboratory and imaging features of COVID-19: a systematic review and meta-analysis. *Trav Med Infect Dis.* 2020:101623.
 8. Wang Y, Wang Y, Chen Y, Qin Q. Unique epidemiological and clinical features of the emerging 2019 novel coronavirus pneumonia (COVID-19) implicate special control measures. *J Med Virol.* 2020;92:568–576.
 9. Aminian A, Safari S, Razeghian-Jahromi A, Ghorbani M, Delaney CP. COVID-19 outbreak and surgical practice: Unexpected fatality in perioperative period. *Ann Surg.* 2020;272:e27–e29.
 10. Lei S, Jiang F, Su W, et al. Clinical characteristics and outcomes of patients undergoing surgeries during the incubation period of COVID-19 infection. *EClinicalMedicine.* 2020:100331.
 11. Ben Abdallah I, La Collegiale A, Coscas R, et al. Early experience in Paris with the impact of the Covid-19 pandemic on Vascular surgery. *J Vasc Surg.* 2020;72:373.
 12. Connors JM, Levy JH. Thromboinflammation and the hypercoagulability of COVID-19. *J Thromb Haemost.* 2020;18:1559–1561.
 13. Spiezia L, Boscolo A, Poletto F, et al. COVID-19-Related severe hypercoagulability in patients admitted to intensive care Unit for acute respiratory failure. *Thromb Haemost.* 2020;120:998–1000.
 14. Loeffelholz MJ, Alland D, Butler-Wu SM, et al. Multicenter evaluation of the Cepheid Xpert Xpress SARS-CoV-2 test. *J Clin Microbiol.* 2020;58:e00926-20.
 15. ASA Physical Status Classification System; 2019. Available at: <https://www.asahq.org/standards-and-guidelines/asa-physical-status-classification-system>. Accessed January 5, 2020.
 16. Nazer RI. Outbreak of Middle East respiratory syndrome-coronavirus causes high fatality after cardiac Operations. *Ann Thorac Surg.* 2017;104:e127–e129.
 17. Milner R, Roggin KK, Angelos P, J.B M. Unknown unknowns: surgical consent during the COVID-19 pandemic. *Ann Surg.* 2020:229–233.