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Acute thrombotic manifestations of coronavirus disease 2019 infection: Experience at a large New York City health care system

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ABSTRACT

Background: Coronavirus disease 2019 (COVID-19) is a novel coronavirus that has typically resulted in upper respiratory symptoms. However, we have encountered acute arterial and venous thrombotic events after COVID-19 infection. Managing acute thrombotic events from the novel virus has presented unprecedented challenges during the COVID-19 pandemic. In our study, we have highlighted the unique treatment required for these patients and discussed the role of anticoagulation for patients diagnosed with COVID-19.

Methods: The data from 21 patients with laboratory-confirmed COVID-19 disease and acute venous or arterial thrombosis were collected. The demographics, comorbidities, home medications, laboratory markers, and outcomes were analyzed. The primary postoperative outcome of interest was mortality, and the secondary outcomes were primary patency and morbidity. To assess for significance, a univariate analysis was performed using the Pearson χ^2 and Fisher exact tests for categorical variables and the Student *t* test for continuous variables.

Results: A total of 21 patients with acute thrombotic events met our inclusion and exclusion criteria. Most cases were acute arterial events (76.2%), with the remainder venous cases (23.8%). The average age for all patients was 64.6 years, and 52.4% were male. The most prevalent comorbidity in the group was hypertension (81.0%). Several markers were markedly abnormal in both arterial and venous cases, including an elevated neutrophil/lymphocyte ratio (8.8) and D-dimer level (4.9 μg/mL). Operative intervention included percutaneous angiography in 25.00% of patients and open surgical embolectomy in 23.8%. Most of the patients who had undergone arterial intervention had developed a postoperative complication (53.9%) compared with a 0% complication rate after venous interventions. Acute kidney injury on admission was a factor in 75.0% of those who died vs 18.2% in the survivors ($P = .04$).

Conclusions: We have described our experience in the epicenter of the pandemic of 21 patients who had experienced major thrombotic events from infection with COVID-19. The findings from our cohort have highlighted the need for increased awareness of the vascular manifestations of COVID-19 and the important role of anticoagulation for these patients. More data are urgently needed to optimize treatment and prevent further vascular complications of COVID-19 infections. (J Vasc Surg 2021;73:789-96.)

Keywords: COVID-19; Thrombosis; Limb salvage

The 2019 novel coronavirus (COVID-19) has resulted in a pandemic that has overwhelmed many health care systems across the world.[1] As of June 21, 2020, >2 million cases had been diagnosed in the United States with >200,000 cases in New York City (NYC) alone.[2] NYC was the epicenter of the pandemic and had more COVID-19 cases than many other countries in the world.[3] The Mount Sinai Health System is in the heart of NYC and, as a result, has experienced a high volume of patients with COVID-19.

COVID-19 has a wide range of recognized presentations from asymptomatic carriers to those with upper respiratory symptoms. In severe cases, the virus can result in acute respiratory distress syndrome, sepsis, and death.[4] Increasing evidence has also shown that patients with COVID-19 infection appear to develop a virus-induced hypercoagulability that results in significant thrombotic events.[5] Initial reports showed that anticoagulation therapy can result in decreased mortality in patients with COVID-19,[6] presumably by reducing pulmonary

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embolism and thrombotic complications.[7] The mechanism of thrombosis is still incompletely elucidated but is thought to involve dysregulation of the clotting cascade, endothelial dysfunction,[8] and endotheliitis.[9]

At the start of the pandemic, we experienced a noticeable increase in the number of vascular surgery consultations at our institution for acute large vessel thrombosis in both the arterial and the venous circulation. We have described our experience with patients with laboratory-confirmed COVID-19 who had experienced an acute vascular event. Managing acute thrombotic events caused by this novel virus has presented unprecedented challenges during the COVID-19 pandemic. In the present study, we have highlighted the thrombotic complications of COVID-19, the unique treatment required for these patients, and discussed the role of anticoagulation therapy for patients diagnosed with COVID-19.

METHODS

Data source and selection of patients. Data were prospectively collected and maintained for all vascular surgery consultations in the Mount Sinai Health System. Data were collected from March 1, 2020 to April 15, 2020. Patients with laboratory-confirmed COVID-19 infections using polymerase chain reaction testing were selected. Patients who had tested negative for COVID-19 despite the presence of respiratory symptoms were excluded. Any patient with chronic respiratory symptoms without an acute component occurring within 2 weeks were excluded. Mild COVID-19 infection was defined as a hospitalized patient with an oxygen saturation >94% and no radiographic evidence of pneumonia. Moderate COVID-19 infection was defined as a hospitalized patient with hypoxia (oxygen saturation ≤94%) or radiographic evidence of pneumonia. Severe COVID-19 infection was defined as a patient requiring more than a nasal cannula to maintain oxygen saturation or mechanical ventilation. These definitions were modified from established classifications.[10,11] The thrombotic events were subdivided into arterial and venous classifications.

Statistical analysis. The patients' demographics, comorbidities, home medications, laboratory markers, and outcomes were analyzed. The primary postoperative outcome of interest was mortality. The secondary postoperative outcomes of interest were primary patency and morbidity. To assess for significance in the patient demographics, comorbidities, home medications, laboratory markers, and outcomes, univariate analysis was performed using the Pearson χ^2 and Fisher exact tests for categorical variables and the Student *t* test for continuous variables. $P < .05$ was considered to be statistically significant. All analyses were performed using SAS, version 9.4 (SAS Institute, Cary, NC). The institutional review board approved the present study.

ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center, retrospective cohort study
- **Key Findings:** Acute arterial (76.2%) and venous (23.8%) thrombotic complications of the peripheral circulation occurred in 21 patients with coronavirus disease 2019. Operative intervention included percutaneous angiography in 25.0% of the patients and open surgical embolectomy in 23.8%. Most arterial interventions had resulted in a postoperative complication (53.9%) vs a 0% complication rate in venous interventions. Acute kidney injury on admission and the use of general anesthesia were independent risk factors of mortality ($P < .05$).
- **Take Home Message:** The findings from our cohort have highlighted the need for increased awareness of vascular manifestations of coronavirus disease 2019 and outcomes of operative intervention and anticoagulation in these patients.

RESULTS

The daily number of hospitalized patients with COVID-19 in the health care system during the study period ranged from 900 to 2000 patients. Of these hospitalized patients with COVID-19, >30 had received vascular consultations. Of those patient, 21 had experienced an acute thrombotic event and met our inclusion and exclusion criteria (Table I). Of the 21 patients, 14 (66.7%) had been admitted for a thrombotic event and found to have COVID-19 and seven had been admitted initially for COVID-19 and subsequently developed a thrombotic event. Most cases were acute arterial events (76.2%), with the remainder, venous cases (23.8%). The average age of all patients was 64.6 years, and 52.4% were male. Most patients were either white (28.6%), African American (28.6%), or Hispanic (28.6%). No Asian patient had presented with arterial events (0% vs 60%; $P = .008$). A trend was seen toward more venous events in women (60% vs 40%; $P = .70$). Most of the patients had been taking an antiplatelet (76.2%) or anticoagulant (19.1%) agent before admission, with 23.8% of patients receiving clopidogrel before admission and 52.4% taking aspirin. The indications for preoperative anticoagulation included atrial fibrillation and a history of deep vein thrombosis. All patients who had undergone revascularization had had anticoagulation therapy started preoperatively. Of the four patients who had died, two had been receiving subcutaneous heparin at 5000 U every 12 hours after surgery. One had been receiving enoxaparin at 40 mg daily for 3 days. The final patient had been treated with apixaban at home.

The most prevalent comorbidity in the 21 patients was hypertension (81.0%; Table II). Other common presenting medical problems included hyperlipidemia (66.7%),

Table I. Patient demographics and preoperative medications

Factor	All patients	Arterial cases	Venous cases	*P* value
Total patients, No. (%)	21 (100)	16 (76.2)	5 (23.8)	NA
Age, years	64.6	63.3	78.0	.08
Female gender, No. (%)	11 (52.4)	8 (50)	3 (60)	.70
Ethnicity, No. (%)				
White	6 (28.6)	6 (37.5)	0 (0)	.11
Hispanic	6 (28.6)	6 (37.5)	0 (0)	.11
African American	6 (28.6)	4 (25.0)	2 (40.0)	.52
Asian	3 (14.3)	0 (0)	3 (60.0)	<.01
Medications before admission, No. (%)				
Plavix	5 (23.8)	5 (31.3)	0 (0)	.15
Aspirin	11 (52.4)	10 (62.5)	1 (20.0)	.10
ACE inhibitor or ARB	7 (33.3)	5 (31.3)	2 (40.0)	.72
Anticoagulant	4 (19.1)	3 (18.8)	1 (20.0)	.95

ACE, Angiotensin-converting enzyme; *ARB*, angiotensin II receptor blocker; *NA*, not applicable.

Table II. Medical comorbidities and coronavirus disease 2019 (*COVID-19*) severity

Medical comorbidity	All patients	Arterial cases	Venous cases	*P* value
Hypertension	17 (81.0)	14 (87.5)	3 (60.0)	.17
Hyperlipidemia	14 (66.7)	12 (75.0)	2 (40.0)	.14
Peripheral vascular disease	6 (28.6)	6 (37.5)	0 (0)	.11
Diabetes mellitus	10 (47.6)	9 (56.3)	1 (20.0)	.16
Acute kidney injury	10 (47.6)	7 (43.8)	3 (60.0)	.53
Chronic kidney injury	2 (9.5)	2 (12.5)	0 (0)	.41
ESRD requiring HD	1 (4.8)	1 (6.3)	0 (0)	.57
Coronary artery disease	6 (28.6)	5 (31.3)	1 (20)	.63
Congestive heart failure	4 (19.1)	3 (18.8)	1 (20)	.95
CVA	4 (19.1)	3 (18.8)	1 (20)	.95
Body mass index, kg/m^2	31.5	33.6	26.05	.54
COPD	2 (9.5)	2 (12.3)	0 (0)	.41
Smoking status				
Never	10 (47.6)	6 (37.5)	4 (80)	.10
Former	7 (33.3)	6 (37.5)	1 (20)	.47
Current	2 (9.5)	2 (12.5)	0 (0)	.41
COVID-19 severity				
Mild	8 (38.1)	7 (43.8)	1 (20)	.34
Moderate	10 (47.6)	7 (43.8)	3 (60)	.53
Severe	3 (14.3)	2 (12.5)	1 (20)	.38

COPD, Chronic obstructive pulmonary disease; *CVA*, cerebrovascular accident; *ESRD*, end-stage renal disease; *HD*, hemodialysis.
Data presented as number (%), unless noted otherwise.

diabetes mellitus (47.5%), acute renal failure (47.6%), and current or former smoking (81.0%). No statistically significant differences were found in comorbidities between the arterial and venous cases. The average body mass index was high at 31.5 kg/m^2. Most patients had had either mild (38.1%) or moderate (47.6%) COVID-19 infections.

Several laboratory values were markedly abnormal for both arterial and venous cases, including an elevated neutrophil/lymphocyte ratio (NLR; 8.8), and D-dimer (4.9 μg/mL), fibrinogen (634.1 mg/dL), ferritin (929.1 ng/mL), and lactate dehydrogenase (516.6 U/L) levels (Table III). The procalcitonin levels had differed

Table III. Preoperative laboratory markers and imaging studies

Variable	All patients	Arterial cases	Venous cases	*P* value
Laboratory marker				
Hematocrit, %	38.8	38.4	40.1	.49
White blood cell count, $10^3/\mu L$	12.4	13.1	10.4	.90
Platelet count, $10^3/\mu L$	331	367	217	.27
NLR	8.8	10.4	6.5	.18
INR	1.2	1.25	1.1	.27
PTT, seconds	35.7	36.0	34.8	.79
Creatinine, mg/dL	1.5	1.4	1.6	.88
D-dimer, μg/mL	4.9	4.0	7.2	.32
Fibrinogen, mg/dL	634.1	654.3	593.7	.45
Procalcitonin, ng/mL	14.1	19.3	0.08	< .01
Ferritin, ng/mL	929.1	1004.5	627.3	.15
Lactate dehydrogenase, U/L	516.6	558.9	403.7	.68
Erythrocyte sedimentation rate	92.2	92.9	87	.93
C-reactive protein, mg/L	76.7	82.7	56.9	.20
Lactate dehydrogenase, mmol/L	1.6	1.7	0.8	.30
Troponin, ng/mL	0.05	0.06	0.04	.55
Preoperative imaging study, No. (%)				
Arterial or venous duplex ultrasonography	5 (23.8)	4 (25)	1 (20)	.82
Preoperative computed tomography angiography	7 (33.3)	4 (25)	3 (60)	.15

INR, International normalized ratio; *NLR*, neutrophil/lymphocyte ratio; *PTT*, partial thromboplastin time.

significantly between the arterial and venous groups (19.34 ng/mL vs 0.08 ng/mL; $P < .01$). Finally, 85.7% of the 21 patients had presented with lymphopenia on admission.

The most frequently involved arterial segment was the femoropopliteal region (38.1%; Table IV). Two patients had undergone thrombolysis (Table IV). One of the two patients had undergone thrombolysis for radial and ulnar artery thrombosis, and the second for catheter-directed thrombolysis on postoperative day 0, followed by embolectomy the next day. Seven patients (33.3%) were treated conservatively and two patients (9.5%) had required primary amputation (Table V). The four patients who had required general anesthesia were intubated for the operation. The remaining patients had undergone revascularization with either percutaneous angiography (25.0%) or open surgical embolectomy (23.8%). Most of those who had undergone arterial intervention had developed a postoperative complication (53.9%) compared with none of the patients who had undergone venous intervention (0%; Table V). The postoperative complications included pneumonia (41.7%), shock (41.7%), acute renal failure (33.3%), cardiac arrest (33.3%), and myocardial infarction (16.7%) in the arterial group. The in-hospital primary patency rate was 100% and the major amputation rate was 0% during the study period. The mortality rate was 33.3% in the arterial group and 0% in the venous group. Of the four patients who had died, the cause of death was hypoxic respiratory failure leading to cardiac arrest in three and septic shock in one patient. Three of the four patients who had died had been receiving anticoagulation therapy. The hospital length of stay was 8.33 days for all patients.

The risk factors that were more prevalent in the patients with COVID-19 who had died included general anesthesia (50.0% vs 18.18%; $P = .22$) and acute kidney injury on admission (75.0% vs 18.2%; $P = .04$). All four patients who had died were women (100% vs 45.5%; $P = .057$) and were >55 years old (100% vs 45.5%; $P = .057$; Table VI).

DISCUSSION

Given our findings, patients with COVID-19 infection will have a viral-induced hypercoagulability and are at high risk of arterial and venous thromboembolism. More than 30 thrombotic complications occurred during the study period. In contrast, during the 45-day period preceding the present study, only nine interventions had been required for acute thrombotic events, of which seven were arterial and two were venous cases. This translates to more than a threefold increase in the rate of thrombotic events. Increasing evidence has shown that patients with COVID-19 are prone to thrombotic complications.[12] Some investigators have postulated that these events can potentially be explained by disseminated intravascular coagulation, which is

Table IV. Anatomic and procedural information

Anatomic location	All patients, No. (%)	Intervention	Postoperative anticoagulation	Outcome
Aortoiliac or inferior vena cava	1 (4.76)	—	—	—
Iliofemoral	3 (18.75)	—	—	—
Femoropopliteal	8 (38.10)	—	—	—
Infrageniculate	2 (9.52)	—	—	—
Upper extremity	10 (47.62)	—	—	—
Pathologic entity (Rutherford classification)	—			
Upper extremity DVT		Palliative care	NA	Deceased
Lower extremity DVT		Conservative	Apixaban	Alive
Common femoral artery thrombosis (3)		Left above-the-knee guillotine amputation	Enoxaparin	Deceased
Peroneal artery thrombosis (2a)		Angiogram with peroneal angioplasty	Apixaban	Deceased
Radial artery thrombosis (2a)		Conservative	Enoxaparin	Alive
Superficial femoral artery thrombosis (2a)		Thrombolysis (POD 0); open surgical embolectomy (POD 1)	Warfarin	Alive
PT artery thrombosis (2a)		Balloon angioplasty and stenting of PT	Apixaban	Deceased
Unknown		Below-the-knee amputation	Apixaban	Alive
Superficial femoral artery thrombosis (1)		Conservative	Rivaroxaban	Alive
Iliofemoral DVT		Percutaneous mechanical thrombectomy with venoplasty and stenting	Apixaban	Alive
Superficial femoral artery thrombosis with reconstitution of peroneal artery (2b)		Percutaneous thrombectomy with thrombolysis	Apixaban	Alive
Common iliac artery, popliteal artery, and anterior tibial artery thrombosis (2b)		Surgical embolectomy with fasciotomies	Intravenous unfractionated heparin	Alive
Unknown (3)		Above-the-knee amputation	Apixaban	Deceased
Radial and ulnar artery thrombus (unknown)		Conservative	Intravenous unfractionated heparin (admitted)	Deceased
Superficial femoral and popliteal artery thrombosis (3)		Below-the-knee amputation	Intravenous unfractionated heparin	Alive
Lower extremity DVT		IVC filter	Rivaroxaban (on discharge)	Alive
Axillary artery occlusion (unknown)		Surgical embolectomy	Enoxaparin	Alive
Popliteal and tibial artery thrombosis (2b)		Surgical embolectomy	Apixaban	Alive
Radial and ulnar artery thrombosis (2b)		Angiogram with thrombolysis	Enoxaparin	Alive
External iliac artery occlusion (unknown)		Surgical embolectomy	Rivaroxaban	Alive
Iliofemoral and femoropopliteal DVT		Conservative	Intravenous unfractionated heparin	Alive

DVT, Deep vein thrombosis; *IVC,* inferior vena cava; *NA,* not applicable; *POD,* postoperative day; *PT,* posterior tibial.

Table V. Perioperative information and complications

Variable	All patients, No. (%)	Arterial cases, No. (%)	Venous cases, No. (%)	*P* value
Procedure type				
Percutaneous angiography	4 (25.0)	2 (40.0)	6 (28.6)	.52
Open surgery or bypass	5 (23.8)	5 (31.3)	0 (0)	.15
Primary major amputation	2 (9.5)	2 (12.5)	0 (0)	.41
Conservative or palliative treatment	7 (33.3)	4 (25.0)	3 (60.0)	.15
Anesthesia type				
General	4 (19.1)	4 (25.0)	0 (0)	.21
MAC	8 (38.1)	6 (37.5)	2 (40.0)	.92
Complications				
Any postoperative complication	8 (57.1)	8 (66.7)	0 (0)	.078
Deep vein thrombosis	0 (0)	0 (0)	0 (0)	.98
Pulmonary embolism	0 (0)	0 (0)	0 (0)	.98
Myocardial infarction	2 (14.3)	2 (16.7)	0 (0)	.53
Pneumonia	6 (42.9)	5 (41.7)	0 (0)	.83
Stroke	1 (7.1)	1 (8.3)	0 (0)	.67
Acute renal failure	4 (28.6)	4 (33.3)	0 (0)	.33
Acute liver injury	2 (14.3)	2 (16.7)	0 (0)	.53
Intubation/reintubation	4 (28.6)	4 (33.3)	0 (0)	.33
Shock/sepsis	5 (35.7)	5 (41.7)	0 (0)	.25
Cardiac arrest	4 (28.6)	4 (33.3)	0 (0)	.33
Death	4 (28.6)	4 (33.3)	0 (0)	.33
Major amputation	0 (0)	0 (0)	0 (0)	.98
Primary patency	14 (100)	12 (100)	2 (100)	.98
Reintervention	2 (14.3)	2 (16.7)	0 (0)	.53
Hospital length of stay, days	8.3	8.9	5.5	.47

MAC, Monitored anesthesia care.

Table VI. Factors associated with postoperative mortality on univariate analysis

Factor	*P* value
Female gender	.057
Age >55 years	.057
General anesthesia	.217
Acute kidney injury on admission	.039

thought to contribute to thrombotic complications in critically ill septic patients with COVID-19.[13] However, in 38.1% of our thrombotic cases, the patients had only had a mild COVID-19 infection and no evidence of disseminated intravascular coagulation. In addition, the initial presentation for five patients (23.8%) was an acute thrombotic event without upper respiratory symptoms. These patients had incidentally been found to have laboratory-confirmed COVID-19 infection. Thus, we suspect another underlying mechanism might exist for hypercoagulability in these patients that might not correlate with the severity of COVID-19 infection. It has been suggested that the severity of the inflammatory response correlates with the severity of COVID-19.[14] However, we observed a greater number of thrombotic events in patients with mild COVID-19 symptoms, which suggests that the hypercoagulability risk of COVID-19 might not correlate with the degree of the inflammatory response alone. Increasing evidence has shown the presence of viral-induced endotheliitis, which could also contribute to the hypercoaguability.[15]

We identified several prevalent comorbidities in patients with thrombotic events, including hypertension, hyperlipidemia, diabetes mellitus, and acute renal failure. These comorbidities were much more prevalent in our cohort compared with other reported cases of COVID-19 in the reported data and might be significant risk factors for thrombotic events.[16] All four patients in our cohort who had died were women and >55 years. Both female gender and older age have been shown to be a poor prognostic factor after vascular surgery interventions.[17] Thus, both risk factors are also likely poor prognostic factors for ischemic events after COVID-19 infection.

Numerous studies have shown that patients with COVID-19 will have multiple laboratory abnormalities, including decreased antithrombin levels, elevated

D-dimer levels, decreased partial thromboplastin time, elevated fibrin-degradation products, and increased fibrinogen.[10] In our patients, several laboratory values were markedly elevated, including D-dimer, fibrinogen, and lactate dehydrogenase. Although more data are needed, perhaps elevated D-dimer and fibrinogen levels can be used as markers to indicate patients with a high risk of thrombotic complications from COVID-19. Another notable laboratory finding was a very high NLR of 8.83. Other studies have correlated a high NLR as a predictor for progression of COVID-19 infection.[18] In line with this finding, our cohort had had a high postoperative sepsis and mortality rate of 35.7% and 28.6%, respectively. This might have resulted from the progression of the COVID-19 infection. It has been hypothesized that the virus acts on T lymphocytes and that downstream sequelae could be important factors in clot formation and propagation.[10] Furthermore, we found elevated levels of procalcitonin only in the patients with arterial thrombosis and not in those with venous events. Studies have shown an association between procalcitonin and COVID-19 disease severity[19,20]; however, the mechanism of this association has remained unclear.

The acute vascular presentations of COVID-19 have resulted in several unique considerations and important management strategies. First, all patients during the pandemic who present with thrombotic events should undergo COVID-19 testing because its presence could be a major risk factor. This is especially important for patients who are young or who have no significant risk factors for thrombosis. Additionally, based on our experience and current available data, we would recommend that anticoagulation therapy should strongly be considered for hospitalized patients with COVID-19 infections and high-risk patients in the outpatient setting. Recent studies have demonstrated the benefits of anticoagulation for patients with COVID-19–induced sepsis.[12] Most studies evaluating anticoagulation for patients with COVID-19 have used heparin-based therapy.19 At present, heparin-based therapies are recommended because they (1) bind strongly to the COVID-19 spike proteins[20,21] and (2) downregulate elements of the inflammatory process, including interleukin-6.[22]

The decision to intervene for patients with COVID-19 and an acute thrombotic event must be carefully evaluated. The threshold to intervene will depend on the patient's respiratory status, severity of ischemia, and overall prognosis. Although various rates have been reported, the risk of mortality after COVID-19 infections has been ~3.7%.[23] In our cohort, the mortality rate for arterial thrombosis was high at 33.3%, although only a few patients had had severe COVID-19 infection at presentation. All mortalities and complications occurred after arterial thrombosis, although the two groups had not had significant difference in comorbidities, suggesting patients with venous thrombosis will have a much better prognosis. Most of the patients with arterial thrombosis had also experienced significant complications, including pneumonia, intubation or reintubation, myocardial infarction, and acute renal failure. However, the short-term primary patency was 100%, with no reoperations for major amputation. Thus, although acute arterial thrombotic events are a poor prognostic marker for complications and mortality, the short-term patency and limb salvage rates remained high**.** The risk factors we identified for mortality, which included age >55 years, preoperative acute kidney injury, and female gender, should also be considered when determining the optimal management. Additionally, mortality might be reduced if local or regional anesthesia is used to avoid intubation. In early reports, the mortality rate for patients with COVID-19 who required intubation was >80%.[17,24] In our study, 19.1% of the patients who had undergone general anesthesia. We found a much greater mortality rate (50.0% vs 18.1%; $P = .22$) for the patients who had required intubation. These patients had been intubated for the procedure in the operating room; thus, avoiding general anesthesia for these patients might be critical to reducing perioperative mortality.

Our study had several limitations. First, the number of acute thrombotic events at our institution was likely greater than that reported in the present study. In part, this might have resulted from false-negative test results with nasal swabs, which had been routinely used in our institution during the study period. The rate of false-negative results from polymerase chain reaction COVID-19 testing can exceed 30%.[25] Thus, patients with symptoms consistent with COVID-19 but with negative testing results were excluded from the present study. Additionally, patient data were obtained through vascular surgery consultation in the health care system. It is likely that a significant portion of patients with thrombotic events had been treated by the primary team without vascular surgery consultation, in particular, in the case of deep vein thrombosis. Patients with COVID-19 who developed thrombotic complications might have been critically ill, with only a palliative route pursued by the primary team. Furthermore, although we had no control group, we had seen a markedly increased rate of acute ischemic and venous thrombotic consultations at the start of the pandemic. Most of these thrombotic events had occurred in patients with COVID-19 who had been comparatively younger and without significant risk factors. The increased rates of thrombotic events also emphasize the importance of having a vascular surgeon and interventionalist readily available during the pandemic. Finally, the incidence of thrombotic events in the present study might have been underreported because patients had chosen to stay at home and had not presented until after the study period.

CONCLUSIONS

COVID-19 infection will typically present with respiratory symptoms such as fever, cough, or shortness of breath. However, increasing evidence has shown the presence of a viral-induced hypercoagulability in COVID-19 infections that might not correlate with the severity of infection. We have described our experience in the epicenter of the pandemic with 21 patients who had experienced major thrombotic events from COVID-19. The results from our study have highlighted the need for increased awareness of the vascular manifestations of COVID-19 and the important role of anticoagulation therapy for these patients. More data are urgently needed to optimize treatment and prevent further vascular complications from COVID-19 infection.

AUTHOR CONTRIBUTIONS

Conception and design: NI, AR
Analysis and interpretation: NI, AR
Data collection: NI, AR, SS, AV, JP, MB, WT, KS, DH, RT, MM, PF
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