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High Thrombus Burden in Patients With COVID-19 Presenting With ST-Segment Elevation Myocardial Infarction



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ABSTRACT

BACKGROUND Coronavirus disease-2019 (COVID-19) is thought to predispose patients to thrombotic disease. To date there are few reports of ST-segment elevation myocardial infarction (STEMI) caused by type 1 myocardial infarction in patients with COVID-19.

OBJECTIVES The aim of this study was to describe the demographic, angiographic, and procedural characteristics alongside clinical outcomes of consecutive cases of COVID-19-positive patients with STEMI compared with COVID-19-negative patients.

METHODS This was a single-center, observational study of 115 consecutive patients admitted with confirmed STEMI treated with primary percutaneous coronary intervention at Barts Heart Centre between March 1, 2020, and May 20, 2020.

RESULTS Patients with STEMI presenting with concurrent COVID-19 infection had higher levels of troponin T and lower lymphocyte count, but elevated D-dimer and C-reactive protein. There were significantly higher rates of multivessel thrombosis, stent thrombosis, higher modified thrombus grade post first device with consequently higher use of glycoprotein IIb/IIIa inhibitors and thrombus aspiration. Myocardial blush grade and left ventricular function were significantly lower in patients with COVID-19 with STEMI. Higher doses of heparin to achieve therapeutic activated clotting times were also noted. Importantly, patients with STEMI presenting with COVID-19 infection had a longer in-patient admission and higher rates of intensive care admission.

CONCLUSIONS In patients presenting with STEMI and concurrent COVID-19 infection, there is a strong signal toward higher thrombus burden and poorer outcomes. This supports the need for establishing COVID-19 status in all STEMI cases. Further work is required to understand the mechanism of increased thrombosis and the benefit of aggressive antithrombotic therapy in selected cases. (J Am Coll Cardiol 2020;76:1168-76) © 2020 by the American College of Cardiology Foundation.

Coronavirus disease-2019 (COVID-19) caused by the severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2) has been shown to result in coagulation abnormalities and predisposes patients to thrombotic disease, both in the venous and arterial circulations (1). This is believed to be secondary to inflammation, platelet activation, endothelial dysfunction, and stasis (2). Despite this exaggerated risk, reduced presentations with ST-segment elevation myocardial infarction (STEMI) and other thrombotic disorders such as cerebrovascular accident have been seen during the pandemic, mainly as a result of social isolation and behavioral changes. Furthermore, emergency cardiac



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catheterization reveals a variety of findings in patients with COVID-19 with ST-segment elevation, including classic type 1 myocardial infarction (obstructive coronary artery disease), angiographically normal epicardial coronary arteries, and/or left ventricular dysfunction due to myocarditis or stress-induced cardiomyopathy (3-5). Some institutions and opinion leaders have suggested thrombolytic therapy as the preferred initial mode of reperfusion to protect health care providers (6), although clinical bodies have advocated continuation of primary percutaneous coronary intervention (PCI) as the default strategy (7,8). There are limited reports of treating COVID-19-positive patients presenting with type I myocardial infarction leading to STEMI who receive primary PCI, highlighted by recent studies finding only 10 of 18 patients with STEMI on electrocardiogram having obstructive disease (4).

Understanding the natural history and treatment responses of patients with COVID-19 presenting with STEMI is essential to inform patient management decisions and protect health care workers. As the largest coronary intervention center in the United Kingdom, Barts Heart Centre is well placed to provide contemporary analysis of STEMI cases during the COVID-19 era. We describe the demographic, angiographic, and procedural characteristics as well as clinical outcomes in consecutive cases of COVID-19-positive patients with STEMI comparing outcomes with COVID-19-negative patients.

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METHODS

STUDY DESIGN AND PATIENT POPULATION. This was a single-center, observational study of 115 consecutive patients admitted with confirmed STEMI at Barts Heart Centre between March 1, 2020, and May 20, 2020. This study was designed to assess the incidence of COVID-19 among patients admitted with STEMI and to compare their baseline characteristics, and angiographic, procedural, and clinical outcomes with patients with STEMI who were COVID-19-negative. Patients were included if they were admitted to Barts Heart Centre via the London Ambulance Service either directly from home or via partner district hospitals with cardiac chest pain and STEMI (ST-segment elevation in 2 or more contiguous leads ≥ 0.2 mV) on their electrocardiogram (ECG) or patients admitted with an out-of-hospital cardiac arrest and ECG meeting diagnostic criteria for STEMI after return of spontaneous circulation. Angiographic confirmation of occlusive coronary disease was performed in all cases. Patients with out-of-hospital

cardiac arrest who did not achieve return of spontaneous circulation, and those with non-STEMI were excluded from the study.

INTERVENTIONAL PROCEDURES. All health care professionals involved in each of the procedures wore full personal protective equipment; this was hospital policy for all STEMI cases during the study period. The interventional strategy was at the discretion of the operator, including the use of direct stenting, pre-/post-dilatation, aspiration thrombectomy, and treatment of bystander noninfarct-related artery stenoses. All patients received a loading dose of aspirin 300 mg and either clopidogrel 600 mg or ticagrelor 180 mg before the procedure. All patients then received 75 mg aspirin per day plus either 75 mg clopidogrel per day or 90 mg ticagrelor twice-daily maintenance therapy. During primary PCI, unfractionated heparin was administered in a loading dose of 70 to 100 U/kg with the activated clotting time (ACT) maintained >250 s. ACTs were recorded at 10- to 15-min intervals after the initial dose of heparin. Glycoprotein (GP) IIb/IIIa inhibitors were used at the operator's discretion and according to local guidelines.

INVESTIGATIONS. All patients with STEMI had baseline serological samples before cardiac catheterization for full blood count, renal and liver function tests, C-reactive protein, D-dimer, fibrinogen, clotting, ferritin, lactate dehydrogenase, ferritin, creatine kinase, and high sensitivity (hs)-troponin T. Post-catheterization, all patients underwent routine nasal/pharyngeal swab for the SARS-CoV-2 virus using real-time reverse transcriptase-polymerase chain reaction (RT-PCR) irrespective of symptoms.

Patients with COVID-19 had a confirmed diagnosis based on the identification of SARS-CoV-2 on nasal/pharyngeal swab or, preceding COVID-19 symptoms alongside diagnostic radiological chest imaging. All of these patients were managed as COVID-19 positive as per center policy.

DATA COLLECTION. The following data fields were collected as part of our center's routine practice for the British Cardiovascular Intervention Society audit submissions, including patient age, sex, ethnicity, height, weight, cardiovascular risk factors, time of symptom onset, and time of arrival at primary PCI hospital. In addition, the following procedure-related data were collected prospectively: target vessel; number of diseased vessels; use of diagnostic devices such as intravascular ultrasound, optical coherence tomography, or pressure wire; use of aspiration thrombectomy; post-dilatation; and use of GP IIb/IIIa

ABBREVIATIONS AND ACRONYMS

- ACT** = activated clotting time
- COVID-19** = Coronavirus disease-2019
- ECG** = electrocardiogram
- GP** = glycoprotein
- PCI** = percutaneous coronary intervention
- SARS-CoV-2** = severe acute respiratory syndrome-coronavirus-2
- STEMI** = ST-segment elevation myocardial infarction
- TIMI** = Thrombolysis In Myocardial Infarction

TABLE 1 Baseline Patient Characteristics

	Non-COVID-19 (n = 76)	COVID-19 (n = 39)	p Value
Age, yrs	61.7 ± 12.6	61.7 ± 11.0	0.633
Male	57 (75.0)	33 (84.6)	0.340
Black, Asian, minority ethnicity	34 (44.7)	22 (56.4)	0.246
Body mass index, kg/m ²	26.87 (22.6-29.4)	26.7 (24.8-30.7)	0.363
Past medical history			
Hypertension	32 (42.1)	28 (71.8)	0.003*
Hypercholesterolemia	28 (36.8)	24 (61.6)	0.017†
Diabetes mellitus	20 (26.3)	18 (46.2)	0.038†
Smoking history	35 (46.1)	24 (61.6)	0.167
Previous myocardial infarction	3 (3.9)	6 (15.4)	0.060
Previous PCI	5 (6.6)	9 (23.1)	0.016†
STEMI presentation			
Time chest pain to reperfusion, h	4 (2-7)	4 (2-6)	0.845
ECG presentation			
Anterior/LBBB	43 (56.7)	24 (61.6)	-
Inferior	27 (35.5)	11 (28.2)	-
Lateral	3 (3.9)	3 (7.7)	-
Posterior	3 (3.9)	1 (2.6)	-
Cardiac arrest	7 (9.2)	11 (28.2)	0.0133†
Cardiogenic shock	8 (10.5)	6 (15.4)	0.549
Intubated	5 (6.6)	5 (12.8)	0.303
Laboratory values			
Troponin T, ng/l	369 (78.5-1,109)	1,221 (179-4,143)	0.0028*
White cell count, 10 ⁹ /l	12.2 (9.7-14.9)	12.9 (10.6-16.4)	0.596
Lymphocyte count, 10 ⁹ /l	1.7 (1.3-2.2)	1.3 (0.7-2.0)	0.0002‡
Lactate dehydrogenase, unit/l	374.5 (268-707)	553 (340-935)	0.1489
D-dimer, mg/l	0.52 (0.40-1.0)	1.86 (0.98-6.6)	0.0012*
Fibrinogen, g/l	3.88 (3.2-4.6)	4.26 (3.2-7.3)	0.0842
Ferritin, µg/l	194 (121-308)	323 (174-859)	0.0976
Creatinine, µmol/l	81 (72-98)	80 (71-118)	0.827
Creatine kinase, µ/l	641.5 (163.5-1,376)	493 (165-1,613)	0.822
C-reactive protein, mg/l	12 (5-50)	50 (8-185)	0.010†

Values are mean ± SD, n (%), or median (interquartile range). *p < 0.01, †p < 0.05, ‡p < 0.001.
COVID = coronavirus disease; ECG = electrocardiogram; LBBB = left bundle branch block; PCI = percutaneous coronary intervention; STEMI = ST-segment elevation myocardial infarction.

inhibitor. Data regarding intraprocedural anticoagulant use and ACTs were collected from patient records with data collectors blinded to patients' COVID-19 status.

ENDPOINTS. The primary endpoint was all-cause in-hospital mortality. Secondary endpoints included thrombus burden, Thrombolysis In Myocardial Infarction (TIMI) flow, myocardial blush grade, length of hospitalization, and the need for intensive care unit admission. A panel of 3 interventional cardiologists, blinded to patient COVID-19 status, retrospectively reviewed cine-angiographic images of all patients and scored pre- and post-PCI TIMI flow in the infarct-related artery, thrombus burden pre- and post-PCI (modified thrombus grade for grade 5 thrombus post initial balloon inflation) (9), and myocardial blush grade (10).

All patient data were anonymized before analysis. The local ethics committee advised that formal ethical approval was not required.

STATISTICAL ANALYSIS

Descriptive statistical analyses were performed using SPSS Statistics version 25.0 (IBM, Armonk, New York). A 2-sided p value <0.05 defined statistical significance. Variables are expressed as counts (percentages), mean ± SD, and median (interquartile range) as appropriate. Chi-square analysis or Fisher exact test was used to compare categorical data between groups. The independent samples Student's t-test or analysis of variance test was used to compare normally distributed continuous data between groups, and the Mann-Whitney U test was used to compare the distribution of skewed continuous data between groups. Correlation was performed using Pearson's correlation analysis and Spearman's correlation analysis in the case of skewed variables.

RESULTS

The study population consisted of 115 consecutive patients with confirmed STEMI who were admitted during a 12-week period. The median age was 62 years, 78% were male, and 48.7% were from Black, Asian, or minority ethnic groups. Of the 115 patients, 39 (33.9%) were diagnosed with concurrent COVID-19 infection, and 76 (66.1%) patients showed no clinical evidence of COVID-19 infection (non-COVID-19 group).

PATIENT CHARACTERISTICS. There were no significant differences in age, sex, ethnic background, or body mass index between the 2 groups (Table 1). Patients presenting with concurrent COVID-19 infection were more likely than non-COVID-19 patients to be diabetic (46% vs. 26%, p = 0.038), hypertensive (72% vs. 42%, p = 0.003), hyperlipidemic (62% vs. 37%, p = 0.038) and were more likely to have a history of previous PCI (23% vs. 7%, p = 0.016). Time from symptoms to reperfusion, ECG presentations, rates of cardiogenic shock, and requirement for pre-hospital intubation were similar in both groups. However, there was a higher incidence of cardiac arrest in patients who were COVID-19 positive compared with the non-COVID-19 group (28% vs. 9%, p = 0.0013).

Patients with concurrent COVID-19 infection had higher levels of hs-troponin (1,221 ng/l vs. 369 ng/l, p = 0.0028), D-dimer (1.86 mg/l vs. 0.52 mg/l, p = 0.0012), and C-reactive protein (12 mg/l vs. 50 mg/l, p = 0.01) but lower lymphocyte counts (1.3 10⁹/l vs. 1.7 10⁹/l, p = 0.0002) than non-COVID-19 patients. Similar levels of lactate dehydrogenase,

fibrinogen, and ferritin were seen in the 2 groups, although trends to higher levels in the COVID-19 group were seen in all 3 measurements ($p = 0.14$, $p = 0.08$, and $p = 0.09$, respectively).

PROCEDURAL CHARACTERISTICS. All patients underwent a primary PCI procedure in both groups (Table 2). Median door-to-balloon times were within 60 min and similar for both groups. There was evidence of higher thrombogenicity in the COVID-19 group with significantly higher rates of multivessel thrombosis ($p = 0.0003$) and stent thrombosis ($p = 0.04$). Despite similar levels of baseline TIMI flow grade 0/1 and thrombus grade 4/5, the modified thrombus grade post first device for cases with thrombus grade 5 was significantly higher in the COVID-19 group (modified thrombus grade 4/5 in 75% vs. 31%, $p = 0.0006$). In keeping with this, there was significantly greater use of GP IIb/IIIa inhibitors ($p < 0.0001$) and aspiration thrombectomy ($p = 0.0021$) in patients with COVID-19. Although TIMI flow grade 3 was achieved at similar high levels in both groups, myocardial blush grade was significantly lower in the COVID-19 group (myocardial blush grade of 2 to 3 in 54% vs. 93%, $p < 0.0001$), median peak plasma hs-troponin concentration was greater and left ventricular ejection fraction was significantly lower in the COVID-19 group compared with the non-COVID-19 group (42.5% vs. 45%, $p = 0.019$).

Levels of blood D-dimer correlated with modified thrombus grade ($r = 0.299$, $p = 0.068$), myocardial blush grade ($r = 0.501$, $p = 0.0003$) (Figure 1) and level of heparinization required to maintain ACT >250 s during primary PCI ($r = 0.488$, $p = 0.0029$) (Figure 2).

There were no significant differences between groups in the total dose of heparin administered (COVID-19 11,125 U vs. non-COVID-19 10,066 U, $p = 0.15$), and similar average ACTs were achieved during the procedures ($p = 0.261$). Although first measured ACTs correlated with administered baseline heparin dose in the whole cohort ($r = 0.401$, $p = 0.0002$), and in the non-COVID group ($r = 0.461$, $p = 0.0004$), this correlation was not seen in the COVID group ($r = 0.279$, $p = 0.144$) suggesting that more heparin was required in the COVID group to achieve similar ACTs. A trend to higher heparin dose per kg ($p = 0.15$) was observed in the COVID group; however, this was not statistically significant and no difference was seen when adjusting for procedural time ($p = 0.14$).

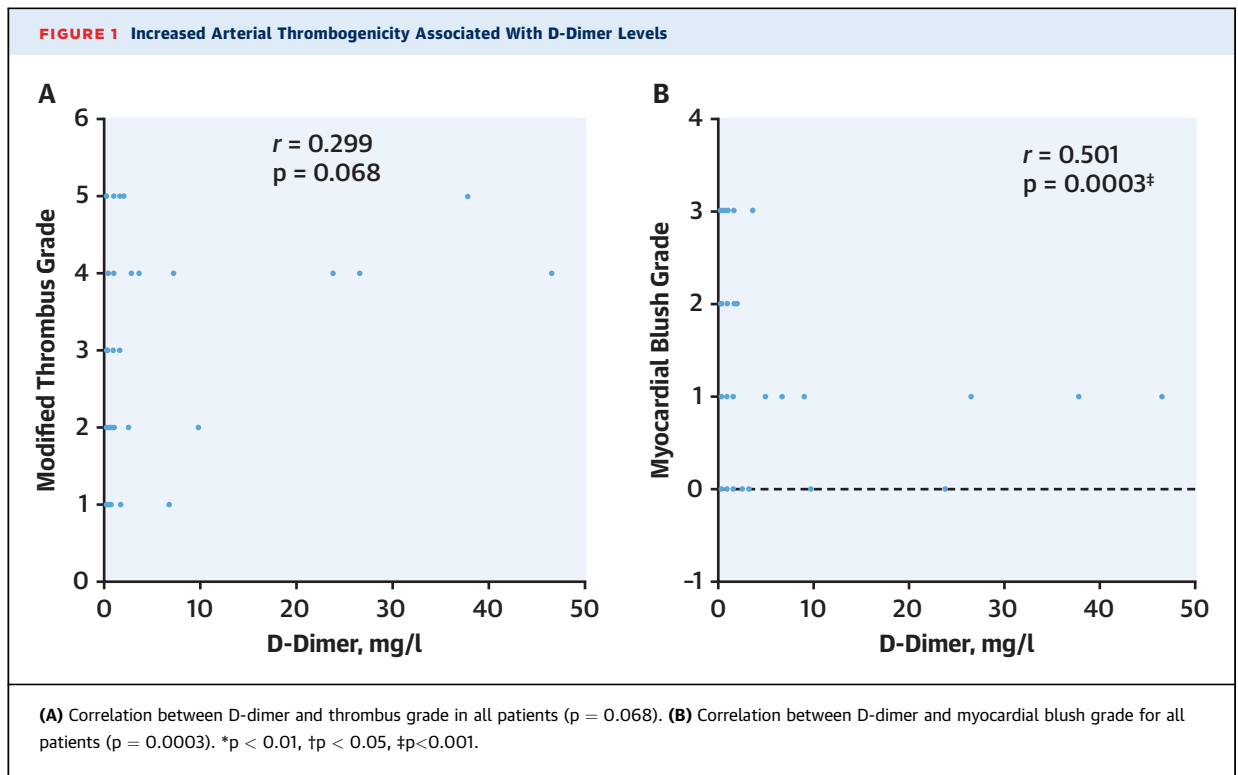
IN-HOSPITAL OUTCOMES. The COVID-19 group had significantly longer in-patient stays ($p = 0.0004$) and were more likely to require intensive care ($p = 0.003$), reflecting a greater level of morbidity in this STEMI cohort. However, despite numerically higher rates of

	Non-COVID-19 (n = 76)	COVID-19 (n = 39)	p Value
Coronary intervention	74 (97.3)	38 (97.4)	1.000
Door-to-balloon time, min	50 (34.8-57.5)	52 (39-70)	0.248
Duration of case, min	50 (39-70)	55 (44-90)	0.054
Culprit vessel			0.621
LMS	1 (1.4)	2 (5.1)	-
LAD	41 (55.4)	22 (56.4)	-
Cx	1 (1.4)	4 (10.3)	-
RCA	24 (32.4)	10 (25.6)	-
Multivessel thrombosis	0 (0.0)	7 (17.9)	0.0003‡
Stent thrombosis	1 (1.2)	4 (10.3)	0.0445†
Baseline TIMI flow grade 0-1	60 (80.0)	32 (82.1)	0.798
Baseline thrombus grade (4-5)	59 (77.3)	33 (84.6)	0.440
Modified thrombus grade post first device	51	28	0.005*
0	2 (3.9)	0 (0.0)	
1	9 (17.6)	0 (0.0)	
2	11 (21.6)	1 (3.6)	
3	13 (25.5)	7 (25.0)	
4	12 (23.5)	12 (42.9)	
5	4 (7.8)	8 (28.6)	
Modified thrombus grade (4-5)	16 (31.4)	21 (75)	0.0006‡
GP IIb/IIIa inhibitor use	7 (9.2)	23 (59.0)	<0.0001‡
Aspiration thrombectomy use	1 (1.3)	7 (17.9)	0.0021*
Total heparin dose, U	10,066 ± 3,176	11,125 ± 3,875	0.151
Average ACT	287.8 ± 66.9	270.6 ± 69.5	0.261
Total heparin dose per weight, U/kg	134.1 ± 35.9	146.2 ± 43.5	0.151
Total heparin dose per kg per min of case, units/kg/min	2.6 ± 0.9	2.3 ± 0.8	0.144
Multivessel PCI	5 (6.8)	8 (20.5)	0.033†
Procedural success			
Post-PCI TIMI flow grade 3	70 (93.3)	35 (89.7)	0.687
Myocardial blush grade (end) 2-3	70 (93.3)	21 (53.8)	<0.0001‡
LV ejection fraction, %	45 (40-55)	42.5 (30-50)	0.019†

Values are n (%), median (interquartile range), mean ± SD, or n. * $p < 0.01$, † $p < 0.05$, ‡ $p < 0.001$
 ACT = active clotting time; Cx = circumflex; GP = glycoprotein; LAD = left anterior descending; LMS = left main stem; LV = left ventricular; RCA = right coronary artery; TIMI = Thrombolysis in Myocardial Infarction. Other abbreviations as in Table 1.

in-hospital mortality among the COVID-19 STEMI patients, this did not reach significance (17.9% vs. 6.5%, $p = 0.10$) (Figure 3).

DISCUSSION. This observational study represents the first comparative data to describe the impact of COVID-19 infection on patients presenting with STEMI to a primary PCI center (Central Illustration). This analysis demonstrates a clear signal of increased thrombus burden in STEMI patients who are infected with COVID-19 compared with STEMI patients who are not infected. This is evidenced by a higher incidence of multiple thrombotic culprit lesions as well as stent thrombosis, higher thrombus grade, lower resultant myocardial blush grade, and associated increased use of GP IIb/IIIa inhibition and thrombus aspiration. Consistent with this, COVID-19 infection was associated with greater myocardial damage with lower left



ventricular systolic function and increased troponin levels, despite similar median ischemia times in the 2 groups. Higher rates of pre-hospital cardiac arrest, intensive care admission, longer in-patient stays, and a trend toward increased in-hospital mortality were also seen in this patient group.

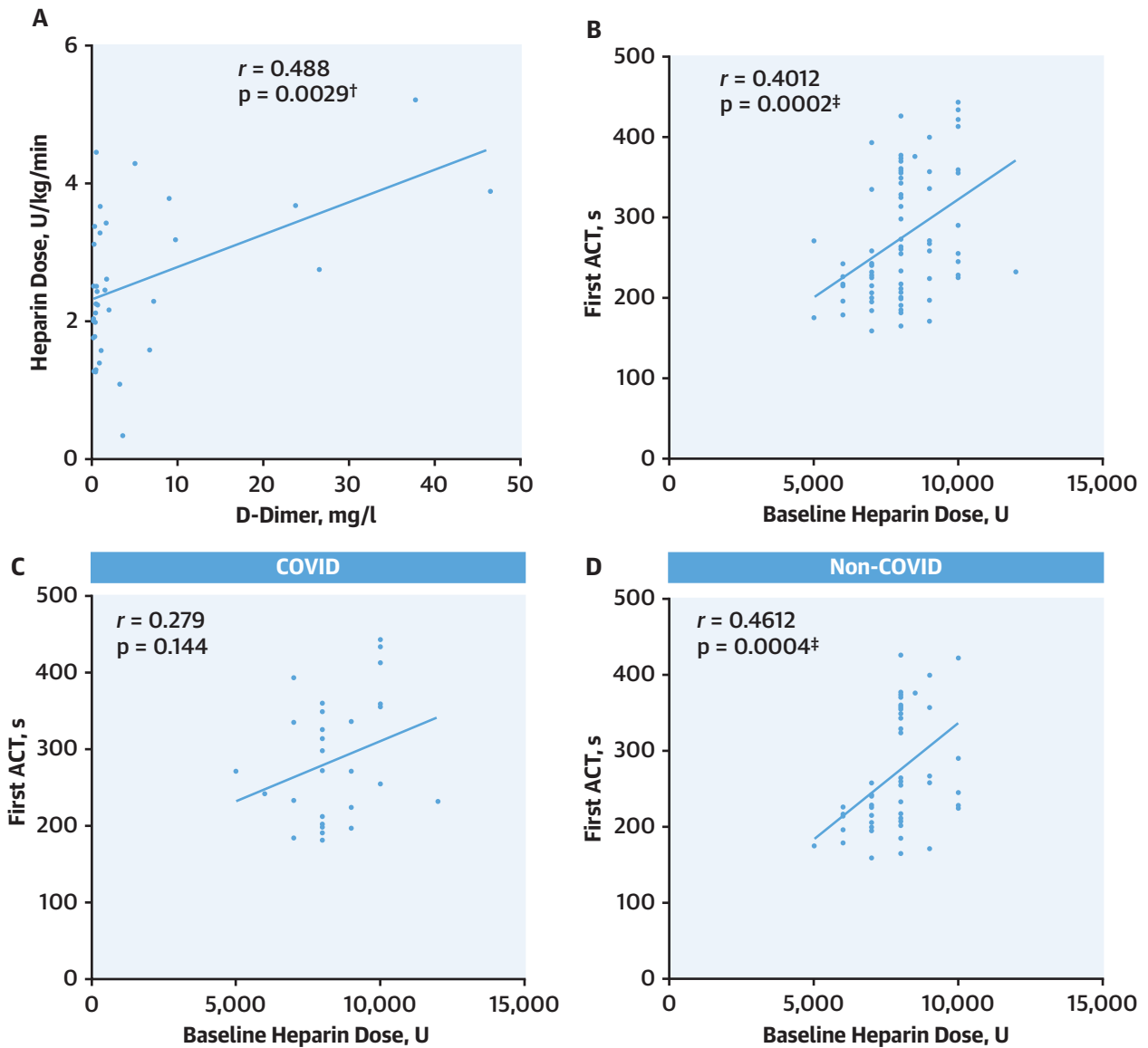
Patients with STEMI who were COVID positive more often had diabetes, hypertension, and blood abnormalities, reflecting a systemic inflammatory response (lymphopenia, elevated D-dimers, and C-reactive protein levels) compared with COVID-19-negative patients. These features are those previously reported to be associated with more aggressive infection and poorer outcomes in COVID cohorts without STEMI (11-14). Interestingly, levels of D-dimer were found to correlate with thrombus grade, myocardial blush grade, and levels of heparin requirement during the primary PCI procedure, with a suggestion of higher heparin doses required to achieve therapeutic ACTs in this cohort. Taken together, these data support the role of early assessment of COVID-19 status in all STEMI patients, as it may have major implications in patient management.

COVID-19 infection is associated with a pro-thrombotic state. The occurrence of venous thrombo-embolic complications, both clinically apparent and subclinical, appears to be an important manifestation of the disease and one that is

related to disease severity and outcome (1,15-17). Increased thrombogenicity in acute ischemic stroke also has been described (18). Moreover, emerging data from large COVID-19 cohorts without STEMI (19) suggest that the use of anticoagulation confers mortality benefit in this patient group. However, to date there have been no reports of increased coronary artery thrombus burden, rather the number of patients presenting with STEMI has reduced with an increased incidence of nonobstructed coronary arteries in the published small case series of patients with STEMI (3,4). Here we describe features apparent on angiographic assessment such as multivessel thrombosis, stent thrombosis, and high thrombus burden that should raise the suspicion of COVID-19 infection. STEMI was the first manifestation of the disease in this cohort, and our data suggest that presentation of STEMI might itself be considered a thrombotic complication of COVID-19 infection. Of note, the median duration of symptoms to reperfusion was 4 h in both COVID-19-positive and COVID-19-negative patients. Therefore, delayed presentation in COVID-positive patients could not account for the observed differences between groups.

Mechanisms that trigger presentation with STEMI and its associated higher arterial thrombus burden in patients with COVID-19 are as yet unknown. Relative

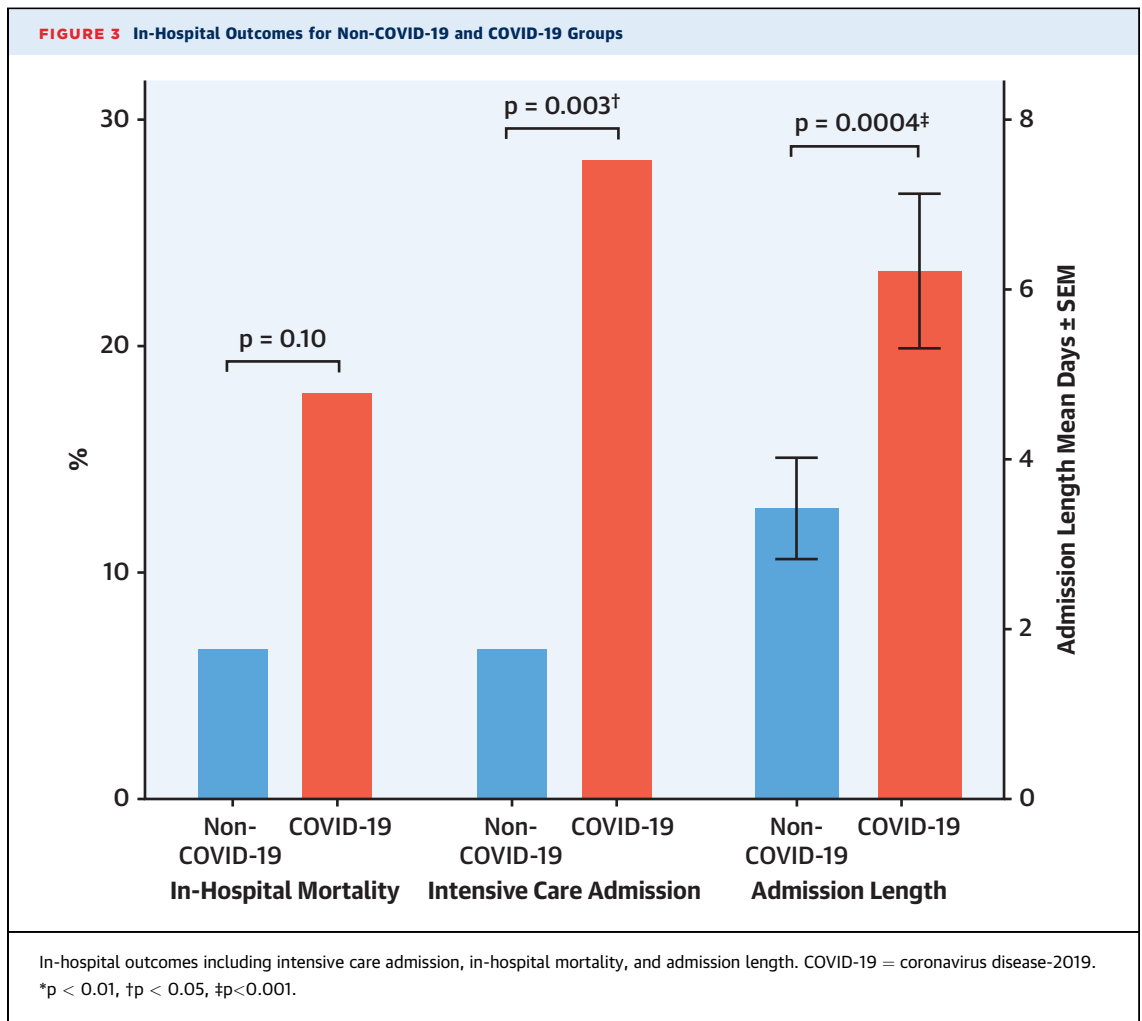
FIGURE 2 Requirement for Heparin During Primary PCI



(A) Correlation between D-dimer and total heparin dose U/kg/min required to maintain activated clotting time (ACT) >250 s during primary percutaneous coronary intervention (PCI) procedure for all patients ($p = 0.0029$). (B) Correlation between baseline heparin dose and first ACT measured after a 10- to 15-min interval in all patients ($p = 0.0002$). (C) Correlation between baseline heparin dose and first ACT measured after a 10- to 15-min interval in coronavirus disease-2019 (COVID-19) group ($p = 0.144$). (D) Correlation between baseline heparin dose and first ACT measured after a 10- to 15-min interval in non-COVID-19 group ($p = 0.0004$). * $p < 0.01$, $^\dagger p < 0.05$, $^\ddagger p < 0.001$.

to venous thromboembolism, arterial thrombus formation is more likely to be due to platelet activation and endothelial dysfunction. Pre-COVID-19 data regarding the influenza virus suggest that patients with acute respiratory infections are at significantly elevated risk for developing atherosclerotic plaque rupture leading to myocardial infarction as a result of the profound inflammatory response and

hemodynamic changes (20). SARS-CoV-2 infection causes a systemic inflammatory response that leads to endothelial and hemostatic activation, including activation of platelets and the coagulation cascade (21). Patients in the coronary risk groups of diabetes and hypertension have shown increased incidence of COVID-19 and subsequent case fatality (11). In keeping with this, the data presented here show



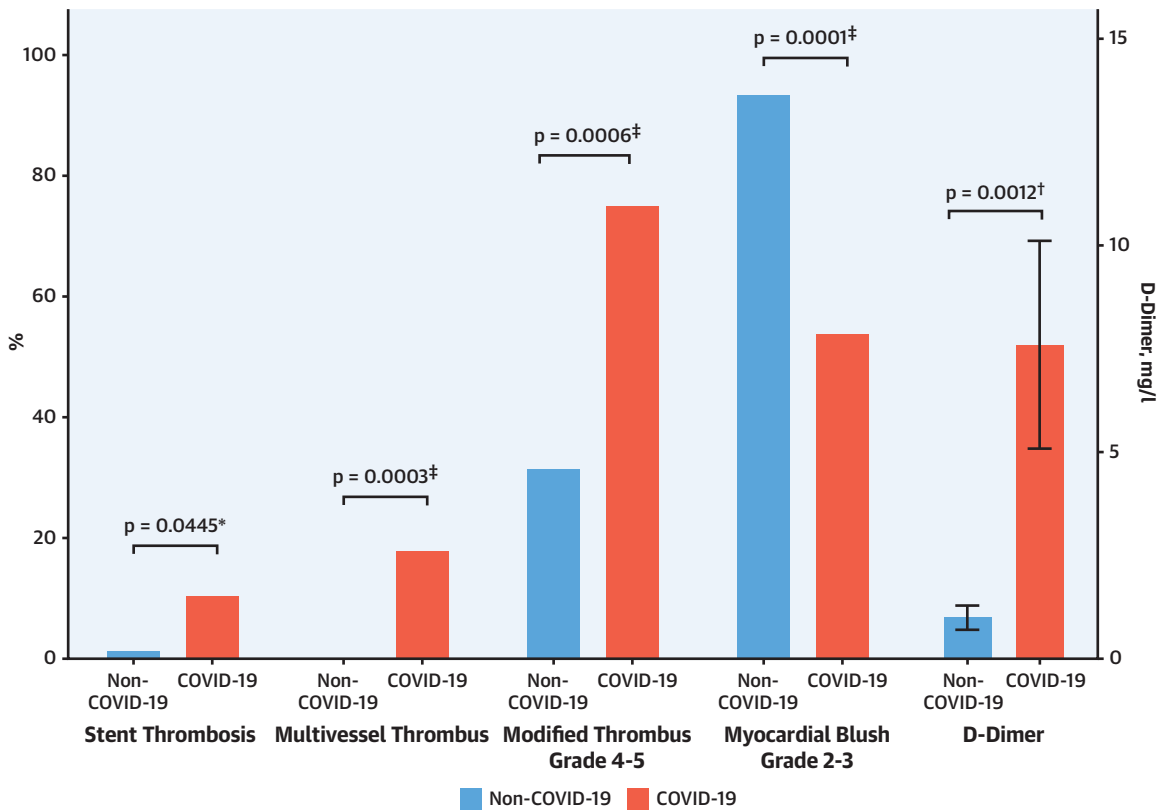
significantly higher rates of diabetes, hyperlipidemia, and hypertension in the COVID-19 group, suggesting that these conditions may also confer an increased risk of STEMI in COVID-19-infected patients. Mechanisms for this might include increased endothelial dysfunction or their effects on the immune system (21-25).

Although our data point toward a higher morbidity and mortality in the COVID-19 group compared with the non-COVID-19 group, the rate of in-hospital mortality was lower than that previously published in a smaller cohort of 18 COVID-19-positive patients with STEMI (4) (18% compared with 72% in-hospital mortality). This is likely to be related to the difference in the cohorts studied. Although our study focused on patients presenting through the primary PCI pathway, with STEMI as their first presentation of COVID-19, all receiving PCI, the previous case series is a more heterogeneous cohort, of which only 6 individuals presented through this pathway and

received emergent coronary assessment, with the remaining patients developing ECG changes while admitted with advanced COVID-19 infection. Therefore, it is likely that the severity of COVID-19 infection may have been less in our study cohort in which 12.8% of patients were ventilated compared with 70% in other series.

The COVID-19 era has presented numerous challenges for emergency intervention services, which have required restructuring to maintain health care delivery (26). COVID-19 status is invariably not known at the time of presentation. Most primary PCI units manage STEMI patients as if they are COVID-19 positive because of the risk of peri-procedure cardiac arrest and the potential for aerosol generation. Changes have been required in the management of access to the unit, the designation of COVID-19 catheter laboratories, the use of personal protective equipment, deep laboratory cleaning after cases, ward reorganization, and patient COVID-19 testing

CENTRAL ILLUSTRATION Characteristics of ST-Segment Elevation Myocardial Infarction in COVID-19 Infection



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ST-segment elevation myocardial infarction (STEMI) in coronavirus disease-2019 (COVID-19) infection is associated with significantly higher rates of stent thrombosis ($p = 0.0445$), multivessel thrombus ($p = 0.0003$), modified thrombus grade 4 to 5 ($p = 0.0006$), lower rates of myocardial blush grade 2 to 3 ($p = 0.0001$), and raised D-dimer levels ($p = 0.012$). * $p < 0.01$, † $p < 0.05$, ‡ $p < 0.001$.

protocols. Despite these challenges, primary PCI was delivered within existing guidelines (median door-to-balloon times 50 min).

The strength of this study is that it presents real-world consecutive data from all patients with STEMI admitted to a single center during the COVID-19 outbreak in the United Kingdom, both with and without the infection. The compared COVID-19 and non-COVID-19 group faced the same health care restrictions and were managed according to the same, modified, COVID-19 primary PCI pathway and protocol. Moreover, our center had an early adoption of COVID-19 testing for all patients with STEMI. All patients with STEMI received a nasal/pharyngeal swab as well as chest imaging and laboratory testing for markers of severe COVID-19 infection to assist in diagnosis in the event of a negative nasal/pharyngeal swab.

STUDY LIMITATIONS. Despite this being the largest series to date, it is a relatively small retrospective observational study in a single center and therefore

has all the limitations of this type of analysis including bias and the potential for confounding. Furthermore, as has been universally accepted, the sensitivity of diagnostic testing for SARS-CoV-2 is modest at approximately 60% to 70% with nasal/pharyngeal swab (27).

CONCLUSIONS

We present the largest comparative dataset of COVID-19 versus non-COVID-19 patients presenting with STEMI. Concurrent infection with COVID-19 presents new procedural challenges and is associated with poorer outcomes. The strong signal toward significantly higher thrombus burden is a novel finding that raises the question of more aggressive antithrombotic therapy in selected COVID-19 STEMI cases and provides a rationale for establishing COVID-19 status in all STEMI cases. Further work is

required to unravel the underlying mechanism of coronary thrombosis in patients with COVID-19 infection.

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PERSPECTIVES

COMPETENCY IN PATIENT CARE AND

PROCEDURAL SKILLS: Patients presenting with STEMI who test positive for COVID-19 have a higher thrombus burden than those without COVID-19.

TRANSLATIONAL OUTLOOK: Further work is necessary to understand the mechanisms responsible for increased thrombus burden in patients with concurrent STEMI and COVID-19 infection and establish optimum antithrombotic management.

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