Original paper

High in-hospital mortality and prevalence of cardiogenic shock in patients with ST-segment elevation myocardial infarction and concomitant COVID-19

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Abstract

Introduction: Published data suggest worse outcomes in acute coronary syndrome (ACS) patients with concomitant coronavirus disease (COVID-19) due to delays in standard management caused by burdened healthcare.

Aim: To report the demographics, angiographic findings, and in-hospital outcomes of COVID-19 ST-elevation myocardial infarction (STEMI) patients and to compare these with the non-COVID-19 cohort hospitalized during the same period with the same access to medical care.

Material and methods: From October 23rd, 2020 to April 23rd, 2021 (exactly 6 months) data were collected into a prospective ACS Registry. STEMI patients underwent invasive coronary angiography and were tested for COVID-19. Outcomes were in-hospital mortality and prevalence of cardiogenic shock.

Results: 125 patients, of whom 25 were COVID-19 positive, were admitted to the cardiology ward, and completed their hospital stay (i.e. discharge or death). There were no differences with regard to the time from symptom onset to reperfusion (median (Q1–Q3); 165 (130–202) vs. 170 (123–210), $p = 0.86$) and door-to-balloon time between the compared groups (25 (21–35) vs. 29 (21–59), $p = 0.26$). There was a higher GRACE risk score and mortality in the COVID-19 positive patients (180 (154–226) vs. 155 (132–181) and 48% vs. 10%, respectively, both $p < 0.0001$). Cardiogenic shock occurred more often in this group (32% vs. 13%; $p = 0.035$). COVID-19 positive patients had elevated high-sensitivity C-reactive protein (hsCRP) ($p < 0.0001$) and D-dimer ($p = 0.003$) and reduced left ventricular ejection fraction ($p = 0.037$). Postprocedural TIMI 3 flow grade was observed less frequently in this group ($p = 0.044$).

Conclusions: High in-hospital mortality in patients with STEMI and COVID-19 did not result from delays in standard management, and could be related to increased thrombogenicity.

Key words: COVID-19, myocardial infarction, in-hospital mortality, ST-elevation myocardial infarction.

Summary

Our study demonstrates high in-hospital mortality and prevalence of cardiogenic shock in subjects with ST-elevation myocardial infarction (STEMI) and concomitant COVID-19 compared to non-COVID-19 STEMI patients hospitalized at the same time, which eliminates differences resulting from reduced resources of burdened healthcare when compared to the pre-COVID era. 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. Infected patients had elevated GRACE risk score, high-sensitivity C-reactive protein, and D-dimer, and postprocedural TIMI 3 flow grade was less frequently observed in this group. They required prolonged hospitalization and often mechanical ventilation.

Introduction

Almost 3 years from the beginning of the pandemic much remains to be discovered about coronavirus disease (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Broadening of knowledge was accompanied by different evolving conceptions

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from atypical pneumonia, endothelial damage, and micro- and macrovascular thrombotic angiopathy leading to multiorgan dysfunction with a wide variety of clinical manifestations [1, 2]. There is also a large diversity of concepts concerning commonly observed myocardial injury in the course of SARS-CoV-2 infection including myocarditis, stress cardiomyopathy, and ischemic injury [3, 4]. Systemic viral infections may generate plaque rupture, thrombosis or mismatch between coronary oxygen supply and demand, leading to three different types of myocardial infarction (MI): type 1, type 2 and type 4b [5, 6]. Symptomatic arterial thrombosis occurs in approximately 4% of critically ill COVID-19 patients [7]. COVID-19 is associated with similar risk of arterial thrombosis as with influenza [8]. There is a commonly known connection between influenza vaccination and a lower risk of MI or stent thrombosis [9, 10]. Kaziród-Wolski *et al.* found no significant association between periprocedural death during acute coronary syndromes (ACS) and vaccinations against COVID-19 in 6 weeks of observations; however, their protective role observed in a long-term perspective as in the case of vaccinations against influenza remains unknown [11]. Despite the existence of various tools for primary prevention and treatment, COVID-19 still represent a major worldwide problem and its long-term impact on health remains unclear [12].

ACS are one of the most life-threatening cardiovascular emergencies and represent a major cause of mortality and morbidity all over the world [13, 14]. A variety of angiographic findings are observed during catheterization in patients with acute coronary syndrome and concomitant COVID-19 including obstructive coronary artery, angiographically normal epicardial arteries, and high thrombus burden [15, 16].

The reduction in hospital admissions due to ACS during the COVID-19 pandemic has been widely described [17–19]. Bryndza *et al.* reported a significant increase in the rate of mechanical complications following myocardial infarction during the first 2 months of the COVID-19 pandemic [18]. Based on the Polish National PCI Registry (ORPKI) both Tokarek *et al.* and Kaziród-Wolski *et al.* conducted multi-center studies evaluating factors influencing perioperative mortality in the catheterization laboratory in COVID-19 positive patients [20, 21]. However, in-hospital outcomes, laboratory parameters and GRACE risk scores were not available.

Aim

As there are limited reports regarding the abovementioned factors and cardiogenic shock (CS) occurrence in the Polish population comparing STEMI patients with and without concomitant COVID-19 treated with percutaneous coronary intervention (PCI), we aimed to present real-world data from all consecutive patients with STEMI admitted to a single center.

Material and methods

This was a single-center study of 125 consecutive patients admitted to a multi-specialist hospital during a period of 6 months when two cardiology departments operated simultaneously: for patients with COVID-19 and COVID-19 negative [22]. The ward functioned from October 23, 2020 to April 23, 2021 (exactly 6 months). Data were collected prospectively in an anonymized fashion without any sensitive data, therefore not requiring institutional review board approval. We designed the study to assess the in-hospital mortality and prevalence of CS in individuals with STEMI in the subgroups with and without concomitant SARS-CoV-2 infection. Our goal was to compare baseline characteristics, angiographic view, procedural characteristics alongside clinical outcomes. In-hospital death from any cause was the analyzed endpoint. Patients were confirmed as having SARS-CoV-2 infection through positive result on polymerase chain reaction testing of a nasopharyngeal sample in the post-catheterization period, in accordance with the recommendations of the World Health Organization [23]. None of the patients had been fully vaccinated against SARS-CoV-2. STEMI was defined based on the presence of typical symptoms associated with ST-segment elevation in a 12-lead electrocardiogram in accordance with the fourth universal definition of myocardial infarction [6].

CS was defined as systolic blood pressure (SBP) < 90 mm Hg for > 30 min or inotropes/vasopressors need to maintain SBP > 90 mm Hg with signs of hypoperfusion (cool extremities, oliguria or anuria, or elevated lactate levels).

Both risk factors and cardiovascular disease were identified based on a medical history or prior diagnosis or treatment and defined according to the current European Society of Cardiology guidelines [24].

On-hours admissions were defined as admissions from Monday to Friday between 7 am and 3 pm and off-hours as admissions between 3 pm and 7 am, during the weekend and nonworking holidays.

Laboratory investigations

Blood samples were drawn on admission before cardiac catheterization using a minimal stasis and atraumatic venipuncture from an antecubital vein. EDTA tubes were used for automatic blood count. Blood cell count, glucose, creatinine, high-sensitivity troponin I (hs-TnI), procalcitonin (PCT), N-terminal prohormone of brain natriuretic peptide (NT-pro-BNP) and lipid profile were measured using routine laboratory techniques. The blood count was measured using a Siemens high volume hematology analyzer (ADVIA 2120i). A sodium citrate tube and ACL TOP 500 analyzer were used for quantitative D-dimer measurement. High-sensitivity C-reactive protein (hsCRP) was measured by immunoturbidimetry (Roche Diagnostics GmbH, Mannheim, Germany).

Statistical analysis

Categorical variables are presented as numbers and percentages. To identify the normal distribution the Shapiro-Wilk test was applied. Student's *t*-test was used for variables with normal distribution and the values were presented as mean ± standard deviation (SD). Continuous variables without normal distribution were analyzed using the Mann-Whitney *U* test and the obtained values were presented as median (50^{th}) values and interquartile ranges (25^{th} and 75^{th}). Qualitative data were compared by the χ^2 test and Fisher's exact test. A two tailed *p*-value < 0.05 was considered statistically significant and confidence intervals (CI) were 95%. Data were analyzed using PQStat v.1.8.2.232 Software (Poznan, Poland).

Interventional procedures

According to the Polish National PCI Registry (ORPKI) all invasive cardiologists in this study performed at least 1000 trans-radial procedures in the last 5 years on their own. All of them had valid qualifications from the Association of Cardiovascular Interventions of the Polish Cardiac Society.

During the study period all health-care workers in cases of confirmed or suspected COVID-19 positive patients wore full personal protective equipment using FFP 2/N95 masks, eye protection, gowns and gloves during cardiac interventions.

Obstructive coronary artery disease was defined based on the angiographic evidence of stenosis > 50% on visual estimation. All patients underwent urgent coronary angiography and no one was treated with fibrinolysis.

The interventional strategy including the use of direct stenting, pro-/post-dilatation, aspiration thrombectomy, the use of glycoprotein (GP) IIb/IIIa inhibitors and type of stent was at the discretion of the operator and according to guidelines. All patients received a loading dose of aspirin 300 mg and either clopidogrel (600 mg), ticagrelor (180 mg) or prasugrel (60 mg). Maintenance therapy consisted of a daily dose of 75 mg aspirin and either clopidogrel (75 mg), ticagrelor (90 mg twice a day) or prasugrel (10 mg). During primary PCI unfractionated heparin was administered intravenously in a loading dose of 70 to 100 U/kg or 50 to 70 U/kg in the case of use of GP IIb/IIIa inhibitors.

Left ventricular ejection fraction was assessed using transthoracic echocardiography and the modified biplane Simpson's method with a Philips Affiniti CVx (Philips Healthcare, Amsterdam, The Netherlands). Measurements were performed by two independent cardiologists on the first day of hospitalization and their means were used. To detect and treat potential mechanical complications, control echocardiography was carried out before discharge and in case of deterioration of the general condition.

Calculation of the GRACE risk score

To predict in-hospital mortality the GRACE risk score was use [25]. The calculation was performed by identifying the score for each individual predictive factor (age, heart rate, systolic blood pressure, initial serum creatinine level, Killip class, cardiac arrest at hospital admission, elevated cardiac markers, and ST-segment deviation) and summing the individual factor scores to obtain a total score.

Results

Patients' characteristics

Demographic and clinical characteristics of the studied groups are presented in Table I. From October 23^{rd} to April 23^{rd} 2021, 125 patients were admitted to the cardiology ward and completed their hospital stay (i.e. discharge or death). SARS-CoV-2 infections were community-acquired as a positive result was obtained on the first day of stay. All patients were Caucasian. The overall median age was 68 ±12 and there were no intergroup differences with regard to the age and body mass index (BMI). Most of the patients were male, with a slight advantage in the COVID-19 group (92% vs. 71%, $p = 0.03$). Infected patients stayed longer in the hospital (median (Q1–Q3); 13 (6–20) vs. 5 (4–7), $p < 0.0001$), more frequently required mechanical ventilation (56% vs. 4%; $p < 0.0001$) and CS occurred more often in this group (32% vs. 13%; $p = 0.035$). 13 out of 21 patients with CS died (61.9%) and the mortality was higher in the COVID 19(+) group (75% vs. 53%); however, the difference did not reach statistical significance ($p > 0.05$). We analyzed the occurrence of mechanical complications (rupture of the free wall, rupture of the ventricular septum and acute mitral regurgitation due to rupture of the papillary muscles) in both groups. Only 1 case of acute mitral regurgitation was found in every group. Apart from the use of an intra-aortic balloon pump in those 2 cases, no other mechanical circulatory support such as Impella, left ventricle assist device or veno-arterial extracorporeal membrane oxygenation was used. We found no differences with regard to the time of mechanical ventilation between the groups (median (Q1–Q3); COVID-19 positive: 1.5 days (1–7) vs. COVID-19 negative: 3.5 (2.5–4.25); $p = 0.87$). Left ventricle ejection fraction was significantly lower in the COVID-19 patients (median (Q1–Q3); 35 (33–43) vs. 45 (33–50), $p < 0.0001$). The number of pre-hospital cardiac arrests were similar in both groups. There was a higher GRACE score and mortality in the COVID-19 positive patients (median (Q1–Q3); 180 (154–226) vs. 155 (132–181) and 48% vs. 10%, respectively, both $p < 0.0001$).

There was no significant difference between the COVID-19 positive and non-COVID-19 groups when comparing the number of admissions during on-hours with off-hours (63% vs. 52%; $p = 0.31$). The difference in mortality in these groups did not reach statistical significance (15.8% vs. 25.6%; $p = 0.51$).

Table I. Characteristics of the studied groups

Variable	All patients *n* = 125	Non-COVID-19 *n* = 100	COVID-19 positive *n* =25	*P*-value
Age [years]	67.78 ±12.23	67.3 ±12.92	69.64 ±8.91	0.39
Male sex, *n* (%)	94 (75)	71 (71)	23 (92)	0.03
Body mass index [kg/m^2]	27.33 ±4.67	26.87 ±4.20	29.50 ±6.34	0.09
Length of hospital stay [days]	5 (4–7)	5 (4–7)	13 (6–20)	< 0.0001
Mechanical ventilation, *n* (%)	18 (14)	4 (4)	14 (56)	< 0.0001
Ejection fraction (%)	40 (33–50)	45 (33–50)	35 (33–43)	0.037
Cardiogenic shock, *n* (%)	21 (17)	13 (13)	8 (32)	0.035
Cardiac arrest, *n* (%)	9 (7)	7 (7)	2 (8)	1
GRACE score	158 (133–188)	155 (132–181)	180 (154–226)	0.004
Off-hours admission, *n* (%)	76 (61)	63 (63)	13 (52)	0.31
Deaths, *n* (%)	22 (18)	10 (10)	12 (48)	< 0.0001
ECG presentation, *n* (%):				
Anterior	71 (56)	58 (58)	13 (52)	0.59
Inferior	42 (34)	35(35)	7 (28)	0.51
Lateral	7 (6)	4 (4)	3 (12)	0.14
Posterior	5 (4)	3 (3)	2 (8)	0.26
Risk factors and comorbidities, *n* (%):				
Diabetes mellitus	61 (49)	49 (49)	12 (48)	0.93
Arterial hypertension	80 (64)	63 (63)	17 (68)	0.64
Obesity	32 (26)	22 (22)	10 (40)	0.065
Coronary artery disease	23 (18)	17 (17)	6 (24)	0.40
Smoking	40 (32)	33 (33)	7 (28)	0.63
Previous stroke	11 (9)	7 (7)	4 (16)	0.23
Dyslipidemia	72 (58)	65 (65)	7 (28)	0.0008
Rheumatic disorder	7 (6)	6 (6)	1 (4)	1
Atrial fibrillation	21 (17)	14 (14)	7 (28)	0.13
Pulmonary disease	9 (7)	8 (8)	1 (4)	0.69
Laboratory parameters on admission:				
Hemoglobin [g/l]	13.75 (12.6–14.73)	13.8 (12.6–14.9)	13.4 (12.7–14.1)	0.15
Platelets [× 10^9/l]	237 (199–284)	240 (207–276)	207 (172–352)	0.31
White blood cells [× 10^9/l]	11.68 (8.8–15.04)	12 (9.30–15.16)	10.37 (7.68–14.18)	0.18
Creatinine [µmol/l]	70.29 (59.24–85.59)	68.08 (59.24–82.67)	74.27 (60.13–103.45)	0.40
hsCRP [mg/l]	12.1 (4–58)	6.2 (4–31.4)	84.7 (12.8–179.8)	< 0.0001
Procalcitonin [ng/ml]	0.24 (0.04–0.97)	0.19 (0.04–1.00)	0.24 (0.07–0.089)	0.81
NT-pro-BNP [pg/ml]	3234 (788–6544)	1375 (454–5647)	3644 (2568–6939)	0.15
hsTnI [ng/ml]	14528 (1579–25000)	20988 (1487–25000)	8259 (2501–23527)	0.24
Maximum hsTnI [ng/ml]	25000 (8259–25000)	25000 (7268–25000)	14632 (8849–25000)	0.23
D-dimer [ng/ml]	1339 (555–11080)	722 (412–1356)	11573 (1383–52785)	0.003
Fibrinogen [g/l]	3.13(2.5–4.2)	3.37 (3–4.4)	2.9 (2.3–4.0)	0.19
LDL [mg/dl]	106.54 ±38.3	111.33 ±36.81	80.88 ±36.94	0.002

Data are given as mean ± standard deviation, median (interquartile range) or number (percentage).

No differences were observed in the ECG presentation. The most common was an infarction of an anterior wall (56%), followed by an inferior wall (34%).

The most prevalent cardiovascular risk factor was arterial hypertension (64%). Dyslipidemia was significantly more common in the non-COVID-19 patients (65% vs. 28%, $p = 0.0008$).

Laboratory parameters are presented in Table I. COVID-19 patients had elevated levels of hsCRP (median (Q1–Q3); 84.7 (12.8–179.8) vs. 6.2 (4–31.4), $p < 0.0001$) and D-dimer (11573 (1383–52785) vs. 722 (412–1356), $p = 0.003$) and a lower level of LDL (mean ± SD; 80.88 ±36.94 vs. 111.33 ±36.81, $p = 0.002$).

Procedural characteristics and treatment

Coronary angiography and percutaneous coronary intervention were performed in all patients (Table II). There were no differences with regard to the time from symptom

onset to reperfusion (median (Q1–Q3); 165 (130–202) vs. 170 (123–210), p = 0.86) and door-to-balloon time between the compared groups (25 (21–35) vs. 29 (21–59), p = 0.26). The radial approach was by far the most common in both of them (94%). We found that patients with a femoral access had higher in-hospital mortality (p = 0.032). However, according to Table II, there were no differences in the type of vascular access between the compared groups (p = 0.66).

We found no differences with regard to the culprit artery. The left anterior descending artery was the most often responsible for myocardial infarction (53%) followed by the right coronary artery (30%) and circumflex artery (13%). Similar levels of baseline TIMI flow grade, the rate of aspiration thrombectomy use and successful stent implantation were observed in both groups. Postprocedural TIMI 3 was observed slightly less frequently in the COVID-19 positive patients (72% vs. 90%, p = 0.044). Only second-generation drug-eluting stents were inserted, from which sirolimus was the most common anti-proliferative agent (52%). Median radiation exposure was greater in the COVID-19 positive group in comparison to non-COVID-19 (median (Q1–Q3); 465 (232–732) vs. 283 (169–446), p = 0.026).

Table II. Procedural characteristics and treatment

Variable	All patients n = 125	Non-COVID-19 n = 100	COVID-19 positive n = 25	P-value
Symptom onset to reperfusion [min]	170 (128–206)	165 (130–202)	170 (123–210)	0.86
Door-to-balloon time [min]	26 (21–36)	25 (21–35)	29 (21–59)	0.26
Access, *n* (%):				
Radial	117 (94)	94 (94)	23 (92)	0.66
Femoral	8 (6)	6 (6)	2 (8)	0.66
Culprit vessel, *n* (%):				
LMS	5 (4)	4 (4)	1 (4)	1
LAD	66 (53)	55 (55)	11(44)	0.32
Cx	16 (13)	12 (12)	4 (16)	0.74
RCA	38 (30)	29 (29)	9 (36)	0.50
Three-vessel disease (3VD), *n* (%)	33 (26)	25 (25)	8 (32)	0.48
Baseline TIMI flow grade, *n* (%):				
0–1	71 (57)	60 (60)	11 (44)	0.15
2	47 (38)	35 (35)	12 (48)	0.23
3	7 (6)	5 (5)	2 (8)	0.63
Postprocedural TIMI 3 flow grade, *n* (%)	108 (86)	90 (90)	18 (72)	0.044
GP IIb/IIIa inhibitor use, *n* (%)	43 (34)	32 (32)	11 (44)	0.34
Aspiration thrombectomy use, *n* (%)	20 (16)	15 (15)	5 (20)	0.55
Stent implantation, *n* (%)	120 (96)	98 (98)	22 (88)	0.054
Second generation DES, *n* (%):				
Sirolimus	65 (52)	53 (53)	12 (48)	0.65
Zotarolimus	29 (23)	25 (25)	4 (16)	0.34
Everolimus	26 (21)	20 (20)	6 (24)	0.66
Radiation exposure [mGy]	299 (186–479)	283 (169–446)	465 (232–732)	0.026
Therapy, *n* (%):				
ASA + clopidogrel	40 (32)	23 (23)	17 (68)	< 0.0001
ASA + ticagrelor	82 (66)	75 (75)	7 (28)	< 0.0001
ASA + prasugrel	3 (2)	2 (2)	1 (4)	0.49
Anticoagulants	33 (26)	15 (15)	18 (72)	< 0.0001
B-blockers	103 (82)	85 (85)	18 (72)	0.15
ACEIs/ARBs	95 (76)	80 (80)	15 (60)	0.036
Statins	122 (98)	99 (99)	23 (92)	0.1
Steroids	22 (18)	6 (6)	16 (64)	< 0.0001
Convalescent plasma	1 (1)	0 (0)	1 (4)	0.2
Remdesivir	9 (7)	0 (0)	9 (36)	< 0.0001
Catecholamines	27 (22)	16 (16)	11 (44)	0.002

Data are given as mean ± standard deviation, median (interquartile range) or number (percentage).

In the COVID-19 positive group a therapeutic dose (with eGFR dose adjustment) of low molecular weight heparin was used subcutaneously in all patients treated with anticoagulants. In the COVID-19 negative group 5 (33%) patients received LMWH, 8 (53%) of them non vitamin-K antagonists oral anticoagulants (4 rivaroxaban, 3 apixaban, 1 dabigatran), and 2 (13%) of them received unfractionated heparin infusion.

The most commonly used P2Y12 inhibitor in the COVID-19 group was clopidogrel (68%) (often accompanied by anticoagulants), whereas ticagrelor was the main choice in others (75%). Angiotensin-converting enzyme inhibitors (ACEIs)/angiotensin II receptor blockers (ARBs) were used less often by COVID-19 patients (p = 0.036), whereas the use of catecholamines and steroids was the opposite (p = 0.002 and p < 0.0001; respectively). Regarding vasoactive medications, patients with CS were treated with norepinephrine, dopamine, and dobutamine. None of the patients received milrinone, levosimendan, vasopressin or isoproterenol.

Discussion

Treatment delay and clinical outcomes

In our study, we investigated and compared demographic, angiographic, and periprocedural characteristics along with in-hospital mortality in patients with STEMI and with or without concomitant COVID-19 in the Polish population. Hawranek *et al.* in the early stage of the pandemic described the treatment logistics and baseline characteristics of the abovementioned patients [26]. Kite *et al.* in "International Prospective Registry of Acute Coronary Syndromes in Patients with COVID-19" compared these patients with historical pre-COVID-19 cohorts [27]. To eliminate the differences resulting from reduced resources of burdened healthcare in the COVID-19 era and their impact on patient mortality, we compared patients hospitalized at the same time, which makes this publication unique in this area. The best example is a similar time from symptom onset to reperfusion in our study between the non-COVID-19 and COVID-19 positive group (median (Q1–Q3); 165 (130–202) vs. 170 (123–210), p = 0.86), in contrast to the abovementioned study by Kite *et al.* [27]. Significantly prolonged delays in patients seeking medical care may directly translate into excessive mortality in myocardial infarction and influence other measured parameters [28]. Despite a comparable delay, COVID-19 patients had significantly higher mortality rates in our study, 48% vs. 10%, which is in the wide range observed around the world when compared to the pre-COVID-19 era. (15.4–79.9%) [12]. This allowed us to exclude delay as a cause of increased mortality in this group.

Time of admission

Sorita *et al.* observed that patients with acute coronary syndromes admitted to hospital during off-hours have higher mortality and patients with STEMI have longer door-to-balloon times [29]. In our study there was no difference between the COVID-19 positive and non-COVID-19 groups with regard to the number of off-hours admissions. Therefore, the differences we observed between the groups did not arise from the time of hospital admission. The non-significantly higher off-hours mortality might reach statistical significance in a larger sample size.

Cardiogenic shock

Prediction of in-hospital mortality based on the Global Registry of Acute Coronary Events (GRACE) risk score in COVID-19-positive patients has already been assessed positively by Wójcik *et al.* [30]. This is most likely related to the more frequent occurrence of CS (13% vs. 32%; p = 0.035), i.e. lower systolic blood pressure and lower left ventricular ejection fraction (median (Q1–Q3); 35 (33–43) vs. 45 (33–50); p = 0.037), which may affect the class on the Killip scale [31]. These parameters are used in the calculation of the GRACE risk score [25]. Higher CS incidence could be related to lower rates of post-procedural Thrombolysis in Myocardial Infarction 3 (TIMI) flow grade (90% vs. 72%; p = 0.044). Several reports noted a higher thrombus burden in COVID-19 positive STEMI patients [15, 32]. In the study performed by Choudry *et al.* myocardial blush grade was significantly lower and correlated with D-dimer level [15]. All of that can suggest that increased thrombogenicity is a direct effect of the SARS-CoV-2 infection. It not only appears as a venous thromboembolism disease but may trigger an arterial thrombosis and lead to a lower observed postprocedural TIMI-3 flow grade and higher incidence of CS [33].

We noted high in-hospital mortality in patients with CS (61.9%) and it was higher in the COVID-19(+) group (75% vs. 53%); however, the difference did not reach statistical significance (p > 0.05). Advances in reperfusion therapy have been associated with improvements in survival, but in-hospital mortality remains high in this state (27–51%) [34]. The first attempts to use veno-arterial extracorporeal membrane oxygenation in COVID-19 positive patients with cardiogenic shock as a treatment of the last possible choice showed high 30-day mortality, but availability and rapid initiation of other methods of mechanical cardiac support or widespread use of levosimendan could improve outcomes in this group of patients [35–38].

Despite common knowledge about milder infection courses in patients using ACEIs or ARBs, they were used less frequently by non-COVID-19 patients (60% vs. 80%; p = 0.036) [39]. Hypotension observed in CS, which is a contraindication to the use of this group of drugs, could directly contribute to such observations [40]. As regards antiplatelet therapy, clopidogrel was the most frequently chosen P2Y12 (68%) in COVID-19 positive patients, which coincides with the frequency of the use of anticoagulants (68% and 72%).

Radiation exposure

Radiation exposure was higher in the COVID-19 positive group. It could be related to technical difficulties that may emerge while wearing personal protective equipment in contact with COVID-19 suspected patients. On the other hand, during the epidemic wave, infection status was often unknown on admission and it was widely used in all cases. Therefore, higher radiation exposure could be related to a diverse level of PCI complexity and lesion morphology [41]. Our study however did not provide these detailed data. Tokarek *et al.* suggested that invasive cardiologist experience might be related to the

Table III. Baseline characteristics, laboratory parameters and percutaneous coronary intervention details after propensity score matching

Variable	Non-COVID-19 *n* = 25	COVID-19 positive *n* = 25	*P*-value
Length of hospital stay [days]	5 (4–7)	13 (6–20)	0.002
Mechanical ventilation, *n* (%)	1 (4)	14 (56)	< 0.0001
Ejection fraction (%)	45 (40–50)	35 (33–43)	0.018
Cardiogenic shock, *n* (%)	2 (8)	8 (32)	0.033
Cardiac arrest, *n* (%)	2 (8)	2 (8)	1
GRACE score	155 (131–189)	180 (154–226)	0.04
Off-hours admission, *n* (%)	11 (44)	13 (52)	0.57
Deaths, *n* (%)	2 (8)	12 (48)	0.002
Laboratory parameters on admission:			
Hemoglobin [g/l]	14.2 (13.4–15.2)	13.4 (12.7–14.1)	0.08
Platelets [× 10^9/l]	245 (216–273)	207 (172–352)	0.36
White blood cells [× 10^9/l]	12.09 (9.38–13.46)	10.37 (7.68–14.18)	0.46
Creatinine [µmol/l]	75.16 (62.78–81.35)	74.27 (60.13–103.45)	0.85
hsCRP [mg/l]	11.5 (4–35.5)	84.7 (12.8–179.8)	0.016
Procalcitonin [ng/ml]	0.16 (0.05–0.3)	0.24 (0.07–0.089)	0.40
NT-pro-BNP [pg/ml]	1764 (777–4123)	3644 (2568–6939)	0.069
hsTnI [ng/ml]	20988 (2351–25000)	8259 (2501–23527)	0.30
Maximum hsTnI [ng/ml]	25000 (8389– 25000)	14632 (8849–25000)	0.41
D-dimer [ng/ml]	822 (572–2722)	11573 (1383–52785)	0.01
Fibrinogen [g/l]	3 (2.7–3.4)	2.9 (2.3–4.0)	0.75
LDL [mg/dl]	98.32 ±27.85	80.88 ±36.94	0.06
Procedural characteristics and treatment:			
Symptom onset to reperfusion [min]	144 (130–193)	170 (123–210)	0.64
Door-to-balloon time [min]	26 (22–33)	29 (21–59)	0.34
Access, *n* (%):			
Radial	24 (96)	23 (92)	1
Femoral	1 (4)	2 (8)	1
Culprit vessel, *n* (%):			
LMS	1 (4)	1 (4)	1
LAD	13 (52)	11(44)	0.32
Cx	4 (16)	4 (16)	1
RCA	7 (28)	9 (36)	0.54
Three-vessel disease (3VD), *n* (%)	6 (24)	8 (32)	0.52
Baseline TIMI flow grade, *n* (%):			
0–1	23 (92)	11 (44)	0.16
2	8 (32)	12 (48)	0.25
3	1 (4)	2 (8)	0.63
Postprocedural TIMI 3 flow grade, *n* (%)	24 (96)	18 (72)	0.048
GP IIb/IIIa inhibitor use, *n* (%)	8 (32)	11 (44)	0.38
Aspiration thrombectomy use, *n* (%)	3 (12)	5 (20)	0.7
Stent implantation, *n* (%)	24 (96)	22 (88)	0.6

Data are given as mean ± standard deviation, median (interquartile range) or number (percentage).

mortality in patients with CS and STEMI [41]. All of the invasive cardiologists in our study were highly experienced in PCI; however, we cannot rule out that higher radiation exposure might also be related to some differences in proficiency among them.

Conclusions

Our study demonstrates high in-hospital mortality and prevalence of CS in subjects with STEMI and concomitant COVID-19 compared to non-COVID-19 STEMI patients hospitalized at the same time, which eliminates differences resulting from reduced resources of burdened healthcare when compared to the pre-COVID era. 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. Infected patients had elevated GRACE risk score, hsCRP, and D-dimer, and postprocedural TIMI 3 flow grade was less frequently observed in this group. They required prolonged hospitalization and often mechanical ventilation.

Limitations of the study

It is a relatively small, monoethnic, observational study in a single center and therefore has several limitations of this kind of analysis. Nonrandomized design is crucial; however, we confirmed most of the differences and similarities between the groups in propensity score matching (Table III). Another major limitation is lack of long-term follow-up. All of the invasive cardiologists in our study were highly experienced in PCI, but we cannot rule out that the differences we found could be related to their individual predispositions. Moreover, we have not got any specific information about possible technical problems which could lead to no-reflow syndrome and increased periprocedural mortality. The clinical relevance of our findings needs to be further explored in a larger number of patients in a multicenter study.

Conflict of interest

The authors declare no conflict of interest.

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