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ORIGINAL ARTICLE

Comparison of door-to-balloon time and in-hospital outcomes in patients with ST-elevation myocardial infarction between before versus after COVID-19 pandemic

Satomi Kobayashi[1] · Kenichi Sakakura[1] · Hiroyuki Jinnouchi[1] · Yousuke Taniguchi[1] · Takunori Tsukui[1] · Yusuke Watanabe[1] · Kei Yamamoto[1] · Masaru Seguchi[1] · Hiroshi Wada[1] · Hideo Fujita[1]

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Abstract

The situation around primary percutaneous coronary intervention (PCI) has dramatically changed since coronavirus disease 2019 (COVID-19) pandemic. The impact of COVID-19 pandemic on clinical outcomes as well as door-to-balloon time (DTBT), which is known as one of the indicators of early reperfusion, has not been fully investigated in patients with ST-elevation acute myocardial infarction (STEMI). The purpose of this study was to compare DTBT and in-hospital outcomes in patients with STEMI between before versus after COVID-19 pandemic. The primary interest was DTBT and the incidence of in-hospital outcomes including in-hospital death. We included 330 patients with STEMI who underwent primary PCI, and divided them into the pre COVID-19 group ($n=209$) and the post COVID-19 group ($n=121$). DTBT was significantly longer in the post COVID-19 group than in the pre COVID-19 group ($p<0.001$), whereas the incidence of in-hospital death was comparable between the 2 groups ($p=0.238$). In the multivariate logistic regression analysis, chest CT before primary PCI (OR 4.64, 95% CI 2.58–8.34, $p<0.001$) was significantly associated with long DTBT, whereas chest CT before primary PCI (OR 0.76, 95% CI 0.29–1.97, $p=0.570$) was not associated with in-hospital death after controlling confounding factors. In conclusion, although DTBT was significantly longer after COVID-19 pandemic than before COVID-19 pandemic, in-hospital outcomes were comparable between before versus after COVID-19 pandemic. This study suggests the validity of the screening tests including chest CT for COVID-19 in patients with STEMI who undergo primary PCI.

Keywords Acute myocardial infarction · ST-elevation myocardial infarction · COVID-19 · Door-to-balloon time

Introduction

Primary percutaneous coronary intervention (PCI) has significantly improved the outcomes of ST-elevation acute myocardial infarction (STEMI) [1]. In primary PCI, early reperfusion is critically important, and door-to-balloon time (DTBT) is one of the indicators of early reperfusion [2]. Since DTBT was related to the long-term prognosis in patients with STEMI [3, 4], clinical guidelines recommended short DTBT for patients with STEMI [1, 5]. However, DTBT is influenced by various factors such as atypical clinical presentation, unstable medical condition, and patient's mis-triage [6, 7].

On the other hand, the situation around primary PCI has dramatically changed since coronavirus disease 2019 (COVID-19) pandemic. First, it was reported that the number of primary PCI cases decreased during January–March 2020 in the USA [8]. In addition, even if primary PCI was performed, delayed DTBT has been reported from Singapore and China [9, 10]. Although there were a few reports regarding DTBT in COVID-19 pandemic from Japan [11], the impact of COVID-19 pandemic on clinical outcomes as well as DTBT has not been fully investigated in patients with STEMI. The purpose of this study was to compare DTBT and in-hospital outcomes in patients with STEMI between before versus after COVID-19 pandemic.

✉ Kenichi Sakakura
ksakakura@jichi.ac.jp

[1] Division of Cardiovascular Medicine, Saitama Medical Center, Jichi Medical University, 1-847 Amanuma, Omiya, Saitama City 330-8503, Japan

Methods

Study design

We reviewed all acute myocardial infarction (AMI) patients treated at our institution (Saitama Medical Center, Jichi Medical University) between March 2018 and June 2021. The inclusion criteria were (1) patients with AMI and (2) STEMI. The exclusion criteria were (1) non-ST-elevation myocardial infarction, (2) delayed admission (> 24 h from the onset of AMI to hospital arrival) (3) patient with undetermined onset time, (4) nosocomial case, (5) patients who visited outpatient clinic or emergency room on foot, and (6) patient without primary PCI.

In Japan, community-acquired COVID-19 cases began to be reported around February 2020, and the total number of patients had exceeded 200 at the end of February 2020. Then, the Japanese government requested to reduce or cancel large-scale events, and to close schools temporarily. The WHO declared a pandemic of COVID-19 on March 11. Based on these circumstances, we divided our study population into pre COVID-19 group (before the outbreak of COVID-19: from March 2018 to February 2020) and post COVID-19 group (after the outbreak of COVID-19: from March 2020 to June 2021). The primary interest was DTBT and the incidence of in-hospital outcomes including in-hospital death. Our institution was the university hospital which accommodate both secondary and tertiary emergency patients in Saitama city (more than 1.3 million residents), Japan [12], and physicians in other divisions (the division of general medicine, the division of anesthesiology and critical care medicine, and the division of emergency and critical care medicine) have treated many COVID-19 patients including patients required veno-venous extracorporeal membrane oxygenation since the beginning of the pandemic [13]. This study was approved by the institutional review board of the Saitama Medical Center, Jichi Medical University (S21-076), and written informed consent was waived because of the retrospective study design. The data collection and storage were performed anonymously, according to the Japan Ministry of Health, Labour and Welfare guidelines.

Definitions

AMI was defined according to the universal definition [14, 15]. Diagnostic ST elevation was defined as new ST elevation at the J point in at least two contiguous leads of 2 mm (0.2 mV), and the AMI patients with ST elevation were diagnosed as STEMI [16]. The definitions of hypertension, diabetes mellitus, and dyslipidemia are described elsewhere [17, 18]. We used the laboratory data at admission. Since we could not measure some laboratory data such as hemoglobin A1c level or LDL cholesterol levels at off-hours (night or holidays), we substituted the earliest data since admission for the laboratory data at admission [19]. Left ventricular ejection fraction (LVEF) was measured by transthoracic echocardiography during the index hospitalization. LVEF was calculated through either modified Simpson's method, Teichholz method, or eyeball estimation. A Teichholz method was adopted only when a modified Simpson's method was not available. An eyeball estimation was adopted only when both modified Simpson's method and Teichholz method were not available [19]. We also calculated estimated glomerular filtration rate (eGFR) using serum creatinine (Cr), age, weight, and gender according to the following formula: $eGFR = 194 \times Cr^{-1.094} \times age^{-0.287}$ (male), or $eGFR = 194 \times Cr^{-1.094} \times age^{-0.287} \times 0.739$ (female) [20]. The initial thrombolysis in myocardial infarction (TIMI) flow grade and final TIMI flow grade were recorded from coronary angiography [21]. We investigated an onset time from our hospital records. In cases when the time of onset was described in ambiguous terms as just getting up, morning, noon, evening, bedtime, or mid-night in clinical records, those expressions were converted to specific times to calculate onset-to-balloon time as follows: Getting up as 6:00 am, morning as 9:00 am, noon as 12:00 pm, evening as 18:00 pm, bedtime as 21:00 pm, mid-night as 0:00 am [22]. We calculated onset-to-balloon time by 2 ways: (1) using all data as mentioned above and (2) using only the exact onset time, which excluded cases without the exact onset time. We defined a DTBT as the time from hospital arrival to the time of balloon dilation or thrombus aspiration [22].

Screening tests for COVID-19 before moving to catheter rooms

We performed some screening tests for COVID-19 as follows (Fig. 1). In the beginning (March 2020 to April 2020), only medical interview regarding COVID-19 and chest X-ray were must as screening tests for COVID-19 before moving to catheter rooms. Since May 2020, chest computed tomography (CT) has been added as a must screening test for COVID-19 before moving to catheter rooms, and chest X-ray has downgraded from must test to optional test. Our emergency department had 2 CT rooms dedicated for emergent patients. Since January 2021, nicking endonuclease amplification reaction (NEAR) test has been added as a must screening test for COVID-19 before moving to catheter rooms, because the result of NEAR test was available within 15–20 min. Although we could perform other COVID-19

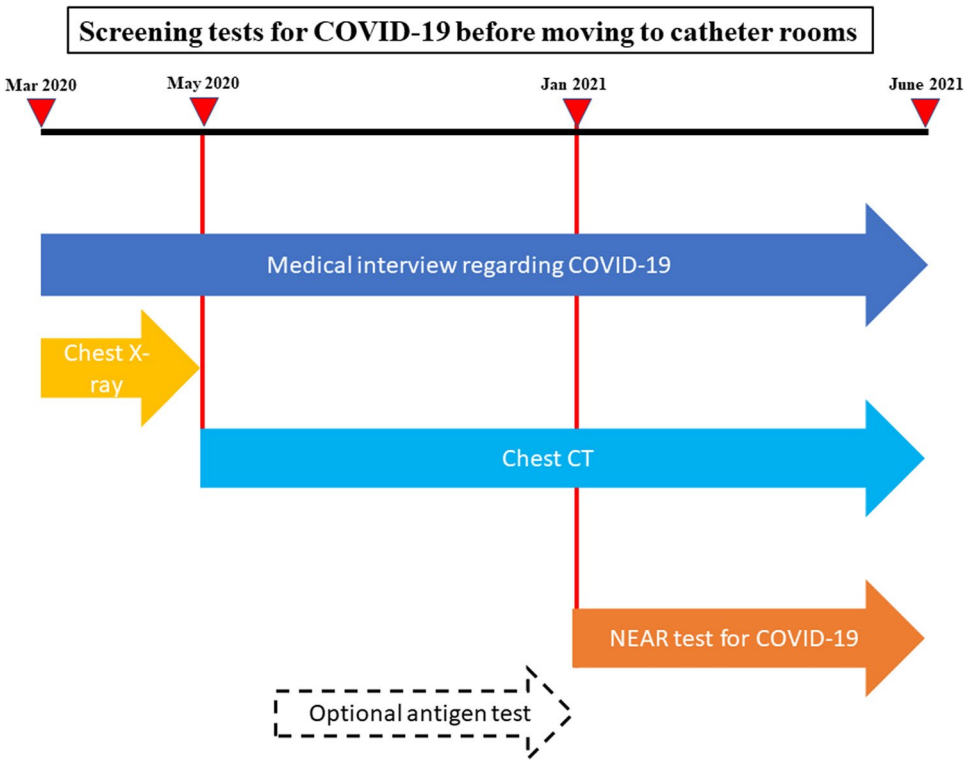

Fig. 1 Screening tests for COVID-19 before moving to catheter rooms. *COVID-19* coronavirus disease 2019, *CT* computed tomography, *NEAR* nicking endonuclease amplification reaction

screening tests such as antigen test during the study period, those tests were not must, but optional before moving to catheter rooms, because the results of those tests were not available in a short time.

Primary PCI

Our hospital has two catheter rooms dedicated for the cardiology department, where most of primary PCI were performed during the study period. Our hospital also has one catheter room dedicated for the radiology department, which could be used for primary PCI when two catheter rooms were not available, typically when two catheter rooms were occupied by elective procedures. Patients with STEMI received 162 mg of aspirin at emergency room (before transferring to catheter rooms) and received 300 mg of clopidogrel or 20 mg of prasugrel at catheter laboratories before coronary stenting (typically after coronary angiography). After the outbreak of COVID-19, staffs inside catheter room such as interventional cardiologists, nurses, medical engineers, and radiological technologists wore personal protective equipment including N95 mask in all emergent cases. Primary PCI was performed using standard techniques via radial artery, femoral artery, or rarely brachial artery. First, we advanced a conventional guidewire across the lesion, and used a small balloon or thrombus aspiration catheter (balloon time). Activated coagulation time (ACT) was maintained > 250 s during PCI.

Statistical analysis

Data are presented as a percentage for categorical variables, a mean ± standard deviation (SD) for normally distributed continuous variables, and median (quartile 1–quartile 3) for nonparametric variables. Categorical variables were presented as numbers (percentage) and were compared using Chi-square test. For continuous variables, the Shapiro–Wilk test was performed to determine whether the continuous variables were normally distributed or not. Normally distributed continuous variables were compared using a student's *t* test. Otherwise, continuous variables were compared using a Mann–Whitney *U* test. We performed a multivariate logistic regression analysis to find factors associated with long door-to-balloon time (DTBT), which was defined as > 90 min. We created two models in this analysis. In both models, we entered age [2], chronic renal failure on hemodialysis [2], Killip class 4 [2], left main-left anterior descending artery as the culprit lesion [22], triple vessel disease [6], and the use of mechanical support [16] as independent variables. In model 1, we also adopted chest CT before primary PCI as an independent variable, because chest CT before primary PCI was a must screening test in most patients in the post COVID-19 group. In model 2, we adopted post COVID-19 instead of chest CT before primary PCI as an independent variable to investigate whether the pandemic of COVID-19 itself was an independent factor of long DTBT or not. We also performed another multivariate logistic regression

analysis to find factors associated with in-hospital death. In this analysis, we entered age [23, 24], Killip class 4 [24], final TIMI flow ≤ 2 [25, 26], and chest CT before PCI as independent variables. Odds ratios and the 95% confidence intervals (CI) were calculated. p value < 0.05 was considered statistically significant. All analyses were performed using statistical software, SPSS 25/Windows (SPSS, Chicago, Illinois).

Results

From March 2018 to June 2021, a total of 963 AMI patients were admitted to our medical center. After excluding 633 patients who were compatible with the exclusion criteria, the final study population consisted of 330 STEMI patients, which were divided into the pre COVID-19 group ($n = 209$) and the post COVID-19 group ($n = 121$) (Fig. 2). There were no STEMI patients who were diagnosed as COVID-19 during the study period.

The comparison of patient's characteristics between the 2 groups is shown in Table 1. All variables were comparable between the 2 groups. Table 2 shows the comparison of lesion and procedural findings between the 2 groups. DTBT was significantly longer in the post COVID-19 group than in the pre COVID-19 group. Rapid inspection of COVID-19 before PCI was only performed in the post COVID-19 group. There were no cases that underwent both antigen test and NEAR test. Chest CT before primary PCI was more frequently performed in the post COVID-19 group than in the pre COVID-19 group.

Table 3 shows the comparison of clinical outcomes between the 2 groups. The incidence of in-hospital death was not significantly different between the 2 groups. Of 330 all study patients, 256 patients (77.6%) achieved DTBT within 90 min. Of 209 pre COVID-19 patients, 171 patients (81.8%) achieved DTBT within 90 min, whereas, of 121 post COVID-19 patients, 85 patients (70.2%) achieved DTBT within 90 min. When we divided the study population into a short DTBT (< 60 min) group ($n = 123$), an intermediate DTBT (60—< 120 min) group ($n = 168$), and a long DTBT (≥ 120 min) group ($n = 39$), the incidence of in-hospital death was least (4.1%) in the short DTBT group, followed by the intermediate group (13.1%), and highest (15.4%) in the long DTBT group ($p = 0.020$).

The multivariate logistic regression analysis regarding long DTBT was performed in Table 4. In model 1, age (10-year increase: OR 1.33, 95% CI 1.07–1.64, $p = 0.009$) and chest CT before primary PCI (OR 4.64, 95% CI 2.58–8.34, $p < 0.001$) was significantly associated with long DTBT after controlling multiple confounding factors. In model 2, age (10-year increase: OR 1.42, 95% CI 1.13–1.79, $p = 0.003$), Killip class 4 (OR 2.20, 95% CI 1.04–4.67, $p = 0.040$) and post COVID-19 (OR 2.10, 95% CI 1.21–3.64, $p = 0.008$) was significantly associated with long DTBT after controlling multiple confounding factors.

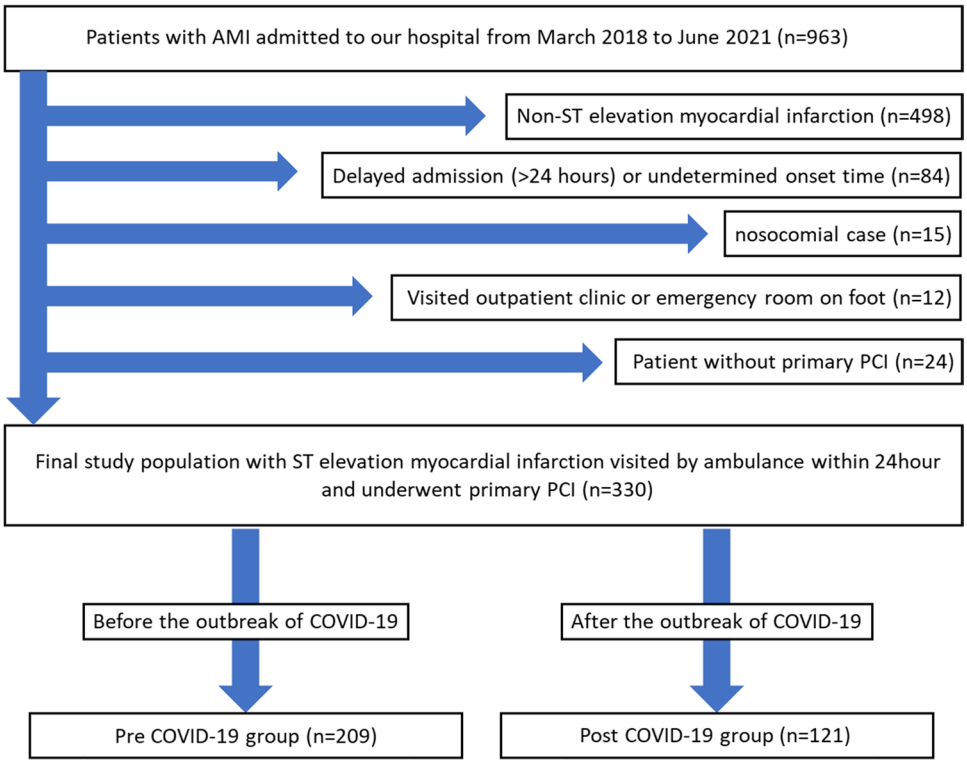

Fig. 2 Study flowchart. *AMI* acute myocardial infarction, *PCI* percutaneous coronary intervention, *COVID-19* coronavirus disease 2019

Table 1 The comparison of patient clinical characteristic between the pre COVID-19 and post COVID-19 groups

	All ($n=330$)	Pre COVID-19 ($n=209$)	Post COVID-19 ($n=121$)	p value
Age, years	69.2 (60.0–79.0)	68.9 (59.5–80.0)	69.6 (61.5–79.0)	0.750
Male, *n* (%)	266 (80.6)	164 (78.5)	102 (84.3)	0.197
Body mass index (kg/m^2)	23.8 (21.4–25.9) ($n=328$)	24.0 (21.7–25.9) ($n=207$)	23.4 (20.8–25.8) ($n=121$)	0.207
Comorbidities				
Hypertension, *n* (%)	246 (74.8) ($n=329$)	154 (74.0) ($n=208$)	92 (76.0) ($n=121$)	0.688
Hyperlipidemia, *n* (%)	175 (53.5) ($n=327$)	118 (57.0) ($n=207$)	57 (47.5) ($n=120$)	0.097
Diabetes mellitus, *n* (%)	129 (39.6) ($n=326$)	80 (38.8) ($n=206$)	49 (40.8) ($n=120$)	0.722
Current smoker, *n* (%)	122 (38.2) ($n=319$)	75 (37.5) ($n=200$)	47 (39.5) ($n=119$)	0.723
Chronic renal failure on hemodialysis, *n* (%)	13 (3.9)	7 (3.3)	6 (5.0)	0.469
History of previous PCI, *n* (%)	44 (13.4) ($n=329$)	28 (13.5) ($n=208$)	16 (13.2) ($n=121$)	0.951
History of previous CABG, *n* (%)	5 (1.5)	2 (0.6)	3 (0.9)	0.275
History of previous myocardial infarction, *n* (%)	35 (10.6)	22 (10.5)	13 (10.7)	0.951
Cardiopulmonary arrest out of hospital, *n* (%)	35 (10.6)	22 (10.5)	13 (10.7)	0.951
Shock at admission, *n* (%)	62 (18.8)	39 (18.7)	23 (19.0)	0.938
Killip class				0.299
Killip class 1 or 2, *n* (%)	250 (75.8)	155 (74.2)	95 (78.5)	
Killip class 3, *n* (%)	16 (4.8)	13 (6.2)	3 (2.5)	
Killip class 4, *n* (%)	64 (19.4)	41 (19.6)	23 (19.0)	
Region of infarction				0.590
Anterior, *n* (%)	173 (52.4)	112 (53.6)	61 (50.4)	
Inferior, *n* (%)	131 (39.7)	79 (37.8)	52 (43.0)	
Posterior, *n* (%)	26 (7.9)	18 (8.6)	8 (6.6)	
Vital signs				
Systolic blood pressure at admission, mmHg	133.8 ± 33.4	133.1 ± 34.4	135.1 ± 31.8	0.547
Diastolic blood pressure at admission, mmHg	82.4 (70.0–95.0)	81.3 (70.0–94.0)	84.2 (69.0–97.0)	0.444
Heart rate at admission, bpm	80.7 (62.0–96.3)	80.6 (62.0–96.0)	80.9 (64.0–97.0)	0.741
Body temperature, ℃	36.15 (35.80–36.60) ($n=329$)	36.10 (35.70–36.60) ($n=208$)	36.23 (35.95–36.60) ($n=121$)	0.544
Saturation of percutaneous oxygen, %	96.7 (96.0–100.0)	96.5 (96.0–99.0)	97.1 (97.0–100.0)	0.260
Laboratory data				
Hemoglobin levels, g/dL	14.02 (12.38–15.30)	14.01 (12.30–15.20)	14.02 (12.55–15.50)	0.070
Platelets, × 10^4/uL	23.77 (19.08–27.13)	24.17 (18.50–27.65)	23.06 (19.15–26.40)	0.779
Serum creatinine, mg/dL	1.15 (0.70–1.10)	1.11 (0.68–1.09)	1.21 (0.73–1.15)	0.146
eGFR, mL/min/1.73 m^2	65.05 (48.88–79.95)	66.78 (49.90–81.65)	62.08 (48.05–77.10)	0.274
Hemoglobin A1c, %	6.66 (5.70–7.00) ($n=314$)	6.71 (5.70–7.00) ($n=196$)	6.59 (5.80–6.83) ($n=118$)	0.482
C-reactive protein, mg/dL	0.94 (0.08–0.48)	1.10 (0.09–0.56)	0.65 (0.06–0.36)	0.063
Brain natriuretic peptide, pg/ml	268.5 (23.2–237.0) (n = 319)	272.6 (23.1–258.7) (n = 198)	261.7 (23.5–233.6) (n = 121)	0.983
Peak creatine kinase, U/L	3440.3 (935.8–4486.8)	3206.0 (878.8–4494.5)	3845.1(986.5–4492.0)	0.375
Peak creatine kinase-myocardial band, U/L	298.7 (78.8–427.5)	277.5 (71.5–392.0)	335.4 (92.5–492.5)	0.143
Left ventricular ejection fraction, %	48.0 (38.7–59.8) ($n=325$)	47.7 (38.2–59.7) ($n=205$)	48.4 (41.2–60.0) ($n=120$)	0.576
Medication at admission				
Aspirin, *n* (%)	50 (16.0) ($n=313$)	31 (15.7) ($n=197$)	19 (16.4) ($n=116$)	0.881
Thienopyridine, *n* (%)	24 (7.7) ($n=313$)	14 (7.1) ($n=197$)	10 (8.6) ($n=116$)	0.627
Statin, *n* (%)	82 (26.3) ($n=312$)	49 (25.0) ($n=196$)	33 (28.4) ($n=116$)	0.504
ACE inhibitors or ARBs, *n* (%)	81 (26.0) ($n=312$)	49 (25.0) ($n=196$)	32 (27.6) ($n=116$)	0.615
Beta-blocker, *n* (%)	37 (11.9) ($n=312$)	18 (9.2) ($n=196$)	19 (16.4) ($n=116$)	0.057

Table 1 (continued)

	All ($n=330$)	Pre COVID-19 ($n=209$)	Post COVID-19 ($n=121$)	p value
Calcium channel blocker, n (%)	100 (32.1) ($n=312$)	62 (31.6) ($n=196$)	38 (32.8) ($n=116$)	0.837
Diuretics, n (%)	21 (6.7) ($n=312$)	17 (8.7) ($n=196$)	4 (3.4) ($n=116$)	0.075
Oral antidiabetic, n (%)	72 (23.1) ($n=312$)	42 (21.4) ($n=196$)	30 (25.9) ($n=116$)	0.369
Insulin, n (%)	11 (3.5) ($n=313$)	8 (4.1) ($n=197$)	3 (2.6) ($n=116$)	0.494
Direct oral anticoagulants, n (%)	7 (2.2) ($n=312$)	3 (1.5) ($n=196$)	4 (3.4) ($n=116$)	0.269
Warfarin, n (%)	2 (0.6) ($n=312$)	2 (1.0) ($n=196$)	0 (0.0) ($n=116$)	0.275

Data were expressed as mean ± SD, median (Q1–Q3) or numbers (percentages). A Student's t test was used for normally distributed continuous variables and Mann–Whitney U test was used for abnormally distributed continuous variables. A Chi-square test was used for categorical variables

COVID-19 coronavirus disease 2019, *PCI* percutaneous coronary intervention, *CABG* coronary artery-bypass grafting, *eGFR* estimated glomerular filtration rate, *ACE inhibitors* angiotensin-converting enzyme inhibitors, *ARBs* angiotensin receptor blockers

The multivariate logistic regression analysis regarding in-hospital death was performed in Table 5. Killip class 4 (OR 75.01, 95% CI 21.38–263.2, $p<0.001$) was significantly associated with in-hospital death after controlling multiple confounding factors, whereas chest CT before PCI (OR 0.76, 95% CI 0.29–1.97, $p=0.570$) was not associated with in-hospital death after controlling multiple confounding factors.

Discussion

We included 330 STEMI patients who underwent primary PCI and divided those into the pre COVID-19 group ($n=209$) and the post COVID-19 group ($n=121$). DTBT was significantly longer in the post COVID-19 group than in the pre COVID-19 group. However, in-hospital outcomes were not significantly different between the 2 groups. In multivariate analysis, we focused on chest CT before primary PCI, which has been a must screening test in our hospital since May 2020. Chest CT before primary PCI was significantly associated with long DTBT (OR 4.64, 95% CI 2.58–8.34, $p<0.001$), whereas chest CT before PCI was not associated with in-hospital death (OR 0.76, 95% CI 0.29–1.97, $p=0.570$) after controlling multiple confounding factors.

We should discuss the reason why DTBT was longer in the post COVID-19 group than in the pre COVID-19 group. Although the antigen test might require additional time, we did not consider that the antigen test was the main cause of delayed DTBT, because we did not wait for the results of antigen test before moving to the catheter rooms. Furthermore, although we had to wait for 15–20 min before moving to catheter rooms when we ordered a NEAR test in the emergency department, we could perform other works such as echocardiography in waiting time. Our results showed that chest CT before primary PCI would be the most significant cause for delayed DTBT. Chest CT required additional 10–15 min including moving time, and we could not perform other works when a patient underwent chest CT. Therefore, those additional 10–15 min should directly affect DTBT. The reasons why we decided to perform chest CT for all emergent PCI cases were (1) the rapid screening test was not available in the beginning of COVID-19 pandemic, (2) the sensitivity and specificity of screening tests have not been calculated from a large sample size, (3) chest CT has the greater sensitivity for pneumonia as compared to chest X-ray, (4) plain chest CT was useful to detect pericardial effusion and to rule out other diseases such as aortic dissection, and (5) our emergency department had 2 CT rooms dedicated for emergent patients.

Although there was a significant difference in DTBT, in-hospital death and other in-hospital outcomes were not significantly different between the pre COVID-19 group and the post COVID-19 group. These results were inconsistent with earlier literatures that DTBT was associated with clinical outcomes [3, 4]. A possible explanation is the small sample size in the present study, which poses a risk of beta-error. In fact, Nallamothu, et al. included 150,116 procedures to show the association between short DTBT and lower mortality [3]. Another explanation is that onset-to-balloon time was not significantly different between the 2 groups. Shiomi et al. reported that not DTBT, but onset-to-balloon time was related to the long-term prognosis of patients with STEMI [27]. Although the difference in DTBT was statistically significant in the present study, such difference might not be so large to bear the difference in clinical outcomes.

Clinical implications of the present study should be noted. Screening tests for COVID-19 would be important to prevent secondary infection to medical staffs, followed by the hospital cluster infections. Although DTBT was extended when we performed several tests for COVID-19, clinical outcomes of patients with STEMI remained unchanged. Our results may support that our screening strategy for COVID-19 was acceptable in terms of preventing excess mortality of patients with STEMI. In addition, plain chest CT may be useful to detect aortic dissection as well as COVID-19

Table 2 The comparison of lesion and procedural characteristic between the pre COVID-19 and post COVID-19 groups

	All ($n=330$)	Pre COVID-19 ($n=209$)	Post COVID-19 ($n=121$)	p value
Angiographic lesion characteristics				
Number of narrowed coronary arteries				0.340
Single, *n* (%)	158 (47.9)	102 (48.8)	56 (46.3)	
Double, *n* (%)	105 (31.8)	61 (29.2)	44 (36.4)	
Triple, *n* (%)	67 (20.3)	46 (22.0)	21 (17.4)	
Infarct-related artery				0.695
Left main-left anterior descending artery, *n* (%)	171 (52.3)	110 (53.4)	61 (50.4)	
Right coronary artery, *n* (%)	127 (38.8)	76 (36.9)	51 (42.1)	
Left circumflex artery, *n* (%)	27 (8.3)	19 (9.2)	8 (6.6)	
Bypass graft, *n* (%)	2 (0.6)	1 (0.5)	1 (0.8)	
50% ≥ stenosis at left main, *n* (%)	30 (9.1)	25 (12.0)	5 (4.1)	0.017
First TIMI flow grade				0.350
0, *n* (%)	202 (61.2)	125 (59.8)	77 (63.6)	
1, *n* (%)	22 (6.7)	12 (5.7)	10 (8.3)	
2, *n* (%)	47 (14.2)	29 (13.9)	18 (14.9)	
3, *n* (%)	59 (17.9)	43 (20.6)	16 (13.2)	
Final TIMI flow grade				0.387
0, *n* (%)	2 (0.6)	2 (1.0)	0 (0.0)	
1, *n* (%)	7 (2.1)	6 (2.9)	1 (0.8)	
2, *n* (%)	21 (6.4)	12 (5.7)	9 (7.4)	
3, *n* (%)	300 (90.9)	189 (90.4)	111 (91.7)	
CTO in non-culprit arteries, *n* (%)	33 (10.0)	19 (9.1)	14 (11.6)	0.469
Procedure characteristics				
Door-to-balloon time, min	79.7 (53.0–86.3)	75.0 (49.0–84.0)	88.0 (59.0–95.5)	< 0.001
Onset-to-balloon time, min	313.7 (129.0–380.5) (n = 324)	298.5 (125.0–348.3) (n = 206)	340.3 (131.0–415.3) (n = 118)	0.147
Onset-to-balloon time, min*	319.6 (129.8–387.0)	307.0 (125.5–353.0)	341.4 (132.0–419.5)	0.153
Rapid inspection of COVID-19 before PCI				< 0.001
None, *n* (%)	246 (74.5)	209 (100)	37 (30.6)	
Antigen test only, *n* (%)	36 (10.9)	0 (0.0)	36 (29.8)	
NEAR only, *n* (%)	48 (14.5)	0 (0.0)	48 (39.7)	
Both antigen test and NEAR, *n* (%)	0 (0.0)	0 (0.0)	0 (0.0)	
Image inspection before PCI				< 0.001
None, *n* (%)	13 (3.9)	8 (3.8)	5 (4.1)	
Chest X-ray only, *n* (%)	175 (53.0)	165 (78.9)	10 (8.3)	
Chest CT only, *n* (%)	12 (3.6)	3 (1.4)	9 (7.4)	
Both chest X-ray and chest CT, *n* (%)	130 (39.4)	33 (15.8)	97 (80.2)	
Mechanical support before primary PCI				0.385
None, *n* (%)	279 (84.5)	173 (82.8)	106 (87.6)	
IABP, *n* (%)	16 (4.8)	12 (5.7)	4 (3.3)	
V-A ECMO, *n* (%)	19 (5.8)	11 (5.3)	8 (6.6)	
Temporary pacemaker, *n* (%)	13 (3.9)	10 (4.8)	3 (2.5)	
Both IABP and V-A ECMO	3 (0.9)	3 (1.4)	0 (0.0)	
Use of aspiration catheter, *n* (%)	67 (20.3)	43 (20.6)	24 (19.8)	0.872
Final PCI procedure				0.475
POBA only, *n* (%)	15 (4.5)	9 (4.3)	6 (5.0)	
Aspiration only, *n* (%)	2 (0.6)	2 (1.0)	0 (0.0)	
Drug coated balloon, *n* (%)	13 (3.9)	6 (2.9)	7 (5.8)	
Bare metal stent, *n* (%)	1 (0.3)	1 (0.5)	0 (0.0)	

Table 2 (continued)

	All ($n=330$)	Pre COVID-19 ($n=209$)	Post COVID-19 ($n=121$)	p value
Drug eluting stent, *n* (%)	291 (88.2)	184 (88.0)	107 (88.4)	
POBA and aspiration, *n* (%)	7 (2.1)	6 (2.9)	1 (0.8)	
Other, *n* (%)	1 (0.3)	1 (0.5)	0 (0.0)	
Approach site				0.098
Radial artery, *n* (%)	257 (77.9)	167 (79.9)	90 (74.4)	
Brachial artery, *n* (%)	4 (1.2)	4 (1.9)	0 (0.0)	
Femoral artery, *n* (%)	69 (20.9)	38 (18.2)	31 (25.6)	
Guide-Catheter size (Fr)				0.253
6Fr, *n* (%)	253 (76.7)	157 (75.1)	96 (79.3)	
7Fr, *n* (%)	76 (23.0)	52 (24.9)	24 (19.8)	
8Fr, *n* (%)	1 (0.3)	0 (0.0)	1 (0.8)	

Data were expressed as mean ± SD or numbers (percentages). Mann–Whitney *U* test was used for abnormally distributed continuous variables. A Chi-square test was used for categorical variables. In cases when the time of onset was described in ambiguous terms as just getting up, morning, noon, evening, bedtime, or mid-night in clinical records, those expressions were converted to specific times to calculate onset-to-balloon time as follows: Getting up as 6:00 am, morning as 9:00 am, noon as 12:00 pm, evening as 18:00 pm, bedtime as 21:00 pm, mid-night as 0:00 am. We calculated onset-to-balloon time both using all data as mentioned (*) and using only the exact onset time, which excluded cases without the exact onset time

COVID-19 coronavirus disease 2019, *TIMI* thrombolysis in myocardial infarction, *CTO* chronic total occlusion, *PCI* percutaneous coronary intervention, *NEAR* nicking endonuclease amplification reaction, *CT* computed tomography, *IABP* intra-aortic balloon pumping, *V-A ECMO* veno-arterial extracorporeal membrane oxygenation, *POBA* plain old balloon angioplasty

Table 3 Comparison of clinical outcomes between the pre COVID-19 and post COVID-19 groups

	All ($n=330$)	Pre COVID-19 ($n=209$)	Post COVID-19 ($n=121$)	p value
In-hospital death, *n* (%)	33 (10.0)	24 (11.5)	9 (7.4)	0.238
Total length of CCU stays, days	3.9 (2.0–3.0)	3.9 (2.0–3.0)	4.0 (2.0–3.0)	0.944
Total length of hospital stays, days	9.2 (5.0–10.0)	8.6 (5.0–10.0)	10.2 (5.5–10.0)	0.108
Presence of mechanical complications				0.693
Free wall rupture, *n* (%)	1 (0.3)	1 (0.5)	0 (0.0)	
Ventricular septal perforation, *n* (%)	0 (0.0)	0 (0.0)	0 (0.0)	
Papillary muscle rupture, *n* (%)	2 (0.6)	1 (0.5)	1 (0.8)	
Tracheal intubation during hospitalization, *n* (%)	61 (18.5)	37 (17.7)	24 (19.8)	0.631
NPPV during hospitalization, *n* (%)	30 (9.1)	22 (10.5)	8 (6.6)	0.233

Data were expressed as mean ± SD, median (Q1–Q3) or numbers (percentages). Mann–Whitney *U* test was used for abnormally distributed continuous variables. A Chi-square test was used for categorical variables.

CCU coronary care unit, *NPPV* noninvasive positive pressure ventilation

pneumonia. In clinical practice, STEMI can be a primary presentation of acute aortic dissection, and those patients may undergo emergent coronary angiography without awareness of aortic dissection [28, 29]. The Japanese Association of Cardiovascular Intervention and Therapeutics (CVIT) reported the results of national survey of PCI during the COVID-19 pandemic in Japan, and showed that approximately 10% of PCI-capable facilities performed chest CT as screening for COVID-19 in STEMI [30]. If chest CT is easily accessible for patients with STEMI in each hospital, chest CT before moving to catheter rooms may be an option as screening test for COVID-19 pneumonia without sacrificing patient's cardiovascular outcomes. However, we should remember that chest CT cannot detect COVID-19 without organic damage in the lung field.

Study limitations

As the current study was a single-center, retrospective study, there was a potential selection bias. Our study results would not directly translate to other facilities in different settings. Since the sample size was small, the results of statistical comparisons poses a possibility of beta (type II) error. Therefore, our study might be under-powered to

Table 4 Determinants of long door-to-balloon time: multivariate logistic regression analysis

Dependent variable: long door-to-balloon time			
	Odds ratio	95% confidence interval	*p* value
Model 1			
Independent variables			
Age (10-year increase)	1.33	1.07–1.64	0.009
Chronic renal failure on hemodialysis, n (%)	1.35	0.36–5.06	0.655
Killip class 4 (vs others)	1.90	0.87–4.16	0.107
Left main-left anterior descending artery (vs others)	1.13	0.64–2.00	0.671
Triple vessel disease (vs others)	1.59	0.79–3.19	0.192
Mechanical support	1.24	0.51–3.05	0.637
Chest CT before primary PCI	4.64	2.58–8.34	< 0.001
Model 2			
Independent variables			
Age (10-year increase)	1.42	1.13–1.79	0.003
Chronic renal failure on hemodialysis, n (%)	1.51	0.43–5.36	0.523
Killip class 4 (vs others)	2.20	1.04–4.67	0.040
Left main-left anterior descending artery (vs others)	1.08	0.62–1.87	0.784
Triple vessel disease (vs others)	1.54	0.80–2.96	0.197
Mechanical support	1.20	0.51–2.83	0.685
Post COVID-19 (vs pre COVID-19)	2.10	1.21–3.64	0.008

We defined long door-to-balloon time as cases that door-to-balloon time are more than 90 min. Mechanical support includes IABP, V-A ECMO and temporary pacemaker

CT computed tomography, *PCI* percutaneous coronary intervention, *COVID-19* coronavirus disease 2019

Table 5 Determinants of in-hospital death: multivariate logistic regression analysis

Dependent variable: in-hospital death			
	Odds ratio	95% confidence interval	*p* value
Independent variables			
Age (10-year increase)	1.21	0.87–1.69	0.256
Killip class 4 (vs others)	75.01	21.38–263.2	< 0.001
Final TIMI flow≦2 (vs TIMI flow 3)	2.35	0.61–9.05	0.214
Chest CT before primary PCI	0.76	0.29–1.97	0.570

CT computed tomography, *PCI* percutaneous coronary intervention, *TIMI* thrombolysis in myocardial infarction

detect differences of clinical outcomes such as in-hospital death. In the post COVID-19 group, the screening method for COVID-19 was not consistent during the study period.

Conclusions

Door-to-balloon time was significantly longer in the post COVID-19 group than in the pre COVID-19 group. However, in-hospital outcomes including in-hospital death were comparable between before versus after COVID-19 pandemic. This study suggests the validity of the screening tests including chest CT for COVID-19 in patients with STEMI who undergo primary PCI.

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Declarations

Conflict of interest Dr. Sakakura has received speaking honoraria from Abbott Vascular, AstraZeneca, Astellas, AMGEN, Boehringer Ingelheim, Boston Scientific, Daiichi-sankyo, Japan Lifeline, Kaneka, Kowa, Medtronic Cardiovascular, NIPRO, OrbusNeich, Otsuka, Sanofi, Shimadzu, Takeda, and Terumo. Dr. Jinnouchi has received speaking honoraria from Abbott Vascular. Prof. Fujita has served as a consultant for Mehergen Group Holdings, Inc.

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