【 ORIGINAL ARTICLE 】

Impact of the COVID-19 Pandemic on ST-elevation Myocardial Infarction from a Single-center Experience in Tokyo

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Abstract:

Objective The coronavirus disease 2019 (COVID-19) pandemic has had a significant impact on global healthcare systems. Some studies have reported the negative impact of COVID-19 on ST-elevation myocardial infarction (STEMI) patients; however, the impact in Japan remains unclear. This study investigated the impact of the COVID-19 pandemic on STEMI patients admitted to an academic tertiary-care center in Tokyo, Japan.

Methods In this retrospective, observational, cohort study, we included 398 consecutive patients who were admitted to our institute from January 1, 2018, to March 10, 2021, and compared the incidence of hospitalization, clinical characteristics, time course, management, and outcomes before and after March 11, 2020, the date when the World Health Organization declared COVID-19 a pandemic.

Results There was a 10.7% reduction in hospitalization of STEMI patients during the COVID-19 pandemic compared with that in the previous year (117 vs. 131 cases). During the COVID-19 pandemic, the incidence of late presentation was significantly higher (26.5% vs. 12.1%, p<0.001), and the onset-to-door [241 (IQR: 70-926) vs. 128 (IQR: 66-493) minutes, p=0.028] and door-to-balloon [72 (IQR: 61-128) vs. 60 (IQR: 43-90) min, p<0.001] times were significantly longer than in the previous year. Furthermore, the in-hospital mortality was higher, but the difference was not significant (9.4% vs. 5.0%, p=0.098).

Conclusion The COVID-19 pandemic significantly impacted STEMI patients in Tokyo and resulted in a slight decrease in hospitalization, a significant increase in late presentation and treatment delays, and a slight but nonsignificant increase in mortality. In the COVID-19 era, the acute management system for STEMI in Japan must be reviewed.

Key words: acute myocardial infarction, coronavirus disease, COVID-19, percutaneous coronary intervention, ST-elevation myocardial infarction, acute coronary syndrome

Introduction

Coronavirus disease (COVID-19) has significantly impacted healthcare worldwide, and the World Health Organization (WHO) declared it a pandemic on March 11, 2020 (1). COVID-19 is also prevalent across Japan. In response to the first wave of the COVID-19 pandemic, the Japanese government declared the first state of emergency in the Tokyo metropolitan area on April 7, 2020, which ended on May 14, 2020, as the situation improved (2). However, a second state of emergency was declared on January 7, 2021, to curb the second and third waves of COVID-19, as the incidence of COVID-19 drastically increased again (3). The

government called for social distancing and urged people to stay home and refrain from non-essential, non-urgent outings to prevent virus spread. As a result, patients hesitated to visit medical institutions due to fears of contracting COVID-19.

During this pandemic, a decrease in the number of hospitalizations, treatment delays, and worsened cardiac outcomes in cases of ST-elevation myocardial infarction (STEMI) have been observed (4-8). In Japan, few studies have reported the impact of the COVID-19 pandemic and state of emergency on STEMI patients. A previous study from Tokyo revealed that the time course of STEMI management and mortality was comparable before and after the pandemic (9). Another study from Osaka reported similar mortality rates before and after the pandemic, despite an increased incidence of mechanical complications of STEMI (10). However, these studies may have underestimated the impact of the pandemic, as data were limited to the early pandemic period, thereby excluding data from the third and largest wave in Japan; thus, the impact of the COVID-19 pandemic on STEMI patients in Japan remains unclear.

We examined the long-term impact of the COVID-19 pandemic on STEMI patients in Tokyo. We retrospectively compared the incidence, time course, and outcomes of patients with STEMI before and during the COVID-19 pandemic.

Materials and Methods

Study design, population, and data collection

This study was a retrospective, observational cohort study that included consecutive STEMI patients admitted to the Cardiovascular Intensive Care Unit (CICU) at Nippon Medical School Hospital between January 1, 2018, and March 10, 2021. We categorized the study population into two groups according to the COVID-19 pandemic time course: the pre-COVID-19 period (from January 1, 2018, to March 10, 2020), and the COVID-19 period (from March 11, 2020, when the WHO declared a pandemic, to March 10, 2021). We compared the clinical characteristics, time course, management, and outcomes of STEMI patients between the groups. All patients were followed up until hospital discharge or death. We analyzed the number of hospitalizations for STEMI during the COVID-19 period (from March 11, 2020, to March 10, 2021) and the equivalent period each year from March 11, 2016, to March 10, 2020.

The following data were collected from medical records: demographics, medical history, clinical presentation including vital signs, Killip classification, out-of-hospital cardiac arrest, peak creatine kinase level, left ventricular ejection fraction (LVEF), culprit vessel, time course from the onset of symptoms to coronary revascularization, management during hospitalization, length of stay, and outcomes (mechanical complication rate and in-hospital mortality). STEMI was defined based on the Japanese Circulation Society Guideline (11). The time course terms were defined as follows: onset-to-first medical contact (FMC), FMC-to-door, onset-to-door, and door-to-balloon times were defined as the time from symptom onset to FMC, from FMC to hospital arrival, from symptom onset to hospital arrival, and from hospital arrival to the first passage of an intracoronary device, respectively. Late presentation was defined as an onset-to-door time >24 hours; the LVEF was assessed using echocardiography on admission. Furthermore, to clarify the changes in time course to treatment during the COVID-19 pandemic period, we compared the time courses of two groups: the early pandemic period (from March 11 to September 10, 2020) group and the late pandemic period (from September 11, 2020, to March 10, 2021) group.

This study was approved by the Institutional Review Board of Nippon Medical School (Reference no. B-2020-338) and conducted as per the revised Declaration of Helsinki. The first and second authors take complete responsibility for the data integrity and accuracy of the data analysis.

Statistical analyses

Categorical variables were presented as numbers and percentages and compared using the chi-square or Fisher's exact test. Continuous variables were presented as medians with interquartile ranges (IQRs) and tested using Student's t-test or the Mann-Whitney U test. The 30-day mortality rate was estimated using the Kaplan-Meier method, and survival estimates were compared using the log-rank test. A two-sided $p<0.05$ was considered significant. Statistical analyses were conducted using the SPSS software program, version 26 (IBM, Armonk, USA).

Results

Incidence of hospitalization

From March 11, 2016, to March 10, 2021, the number of hospitalizations for STEMI each year were 96, 123, 123, 131, and 117, respectively (Fig. 1). There was a 10.7% reduction in hospitalization during the COVID-19 period (from March 11, 2020, to March 10, 2021) compared to the previous year (from March 11, 2019, to March 10, 2020).

Clinical characteristics

From January 1, 2018, to March 10, 2021, 398 consecutive STEMI patients were included: 281 before and 117 during the COVID-19 period. Table 1 shows the clinical characteristics, time course, management, and outcomes of patients in both groups. Although patients in the COVID-19 period had a higher prevalence of hypertension than those in the earlier period (73.6% vs. 84.5%, p=0.019), the incidence of other conditions was similar. There were no significant differences in clinical presentation, including Killip class distribution, between the groups.
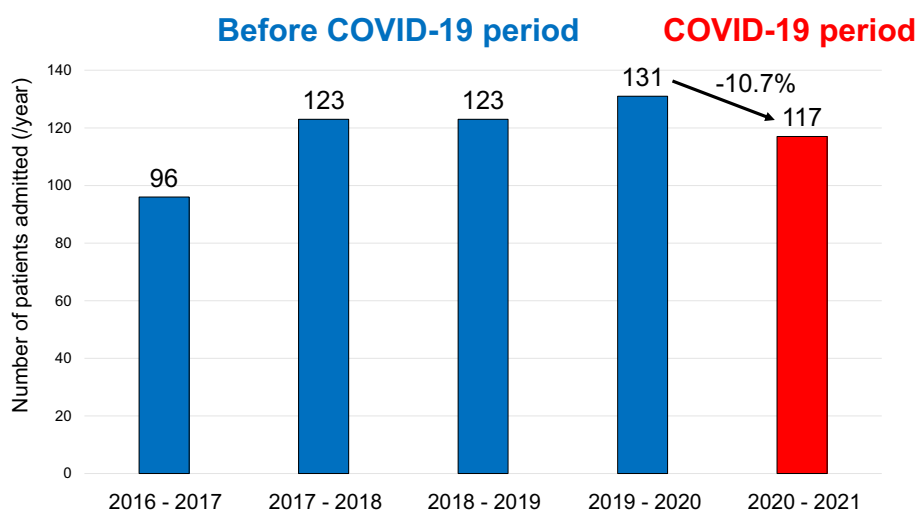
Figure 1. A comparison of the number of admissions for STEMI during the COVID-19 period (from March 11, 2020, to March 10, 2021) and the equivalent period each year from March 11, 2016, to March 10, 2020. There was a 10.7% reduction in STEMI patients during the COVID-19 period compared to the previous year (from March 11, 2019, to March 10, 2020). COVID-19: coronavirus disease 2019, STEMI: ST-elevation myocardial infarction

Time course

The incidence of late presentation was significantly higher during the COVID-19 period than before the COVID-19 period (12.1% vs. 26.5%, p<0.001). The onset-to-door time was significantly longer during the COVID-19 period than before the COVID-19 period [128 (66-493) vs. 241 (70-926) minutes, p=0.028]. When limiting the analysis to cases with an onset-to-door time ≤ 24hours, FMC-to-door [30 (26-37) vs. 35 (29-41) minutes, p=0.009] and door-to-balloon [60 (43-90) vs. 72 (61-128) minutes, p<0.001] times were significantly longer during the COVID-19 period than before the COVID-19 period; furthermore, the proportion of cases with a door-to-balloon time ≤90 minutes was lower during the COVID-19 period than before the COVID-19 period (74.8% vs. 63.6%, p=0.098), although this difference was not significant. Fig. 2 shows a comparison of the median time course between the groups.

Table 2 shows the comparison of the time course between the early and late pandemic. The onset-to-door time was significantly longer in the late pandemic period than in the early pandemic period [213 (52-491) vs. 489 (128-1,307) minutes, p=0.031]. When limiting the analysis to cases with an onset-to-door time ≤24 hours, the onset-to-FMC time was significantly longer in the late pandemic period than in the early pandemic period [69 (13-195) vs. 263 (29-743) minutes, p=0.014], with FMC-to-door [33 (29-39) vs. 36 (32-45) minutes, p=0.235] and door-to-balloon [69 (54-100) vs. 85 (63-135) minutes, p=0.179] times being longer as well but not to a significant degree.

Management

There were no marked differences in therapeutic interventions or in the overall mechanical circulatory use rate be-tween groups. Since the implementation of Impella (Abiomed, Danvers, USA) at our CICU in January 2018, the proportion of intra-aortic balloon pump usage decreased significantly (15.9% vs. 6.9%, p=0.016), and that of Impella usage increased (6.1% vs. 12.2%, p=0.043). Regarding medications during hospitalization, a higher rate of calcium channel blocker use was noted during the COVID-19 period than before the COVID-19 period (13.2% vs. 23.1%, p=0.014); however, the use of other medications remained similar.

Outcomes

The length of hospital stay was shorter during the COVID-19 period than before the COVID-19 period, although not significantly so [15 (11-26) vs. 13 (10-22) days, p=0.054]. Although the in-hospital mortality and the 30-day cumulative mortality rates were higher during the COVID-19 period than before the COVID-19 period (5.0% vs. 9.4%, p=0.098, chi-square test; 6.6% vs. 13.7%, p=0.074, log-rank test, Fig. 3; respectively), these differences were not significant. When we limited the analysis to cases with an onset-to-door time ≤24 hours, the in-hospital mortality was higher during the COVID-19 period than before the COVID-19 period (5.7% vs. 9.3%, p=0.243), although the difference was not significant.

Management of patients with suspected COVID-19

Regarding the infection control measures implemented during the study period at our institution, patients with a fever, a temperature over 37.5 °C, and either cough, dyspnea, smell disorder, or taste disorder were defined as suspected COVID-19 patients. Suspected COVID-19 patients underwent COVID-19 polymerase chain reaction (PCR) testing in the designated emergency room, and we treated them using personal protective equipment (PPE), including N95 respira-

Table 1.   Patient's Clinical Characteristics, Time Course, Management, and Outcomes.

	Pre-COVID-19 period (n=281)	COVID-19 period (n=117)	p value
Age (years)	70 [59-79]	69 [59-79]	0.369
Male sex	212 (75.4)	82 (70.1)	0.268
Medical history			
Hypertension	203 (73.6)	98 (84.5)	0.019
Diabetes mellitus	104 (37.5)	42 (36.2)	0.802
Dyslipidemia	175 (63.4)	79 (68.7)	0.318
Hyperuricemia	51 (18.5)	24 (20.9)	0.584
Smoking	167 (61.7)	78 (67.2)	0.305
Previous myocardial infarction	17 (6.7)	10 (8.6)	0.502
Previous PCI	22 (8.6)	8 (6.9)	0.584
Previous CABG	2 (0.8)	1 (0.9)	0.674
Clinical presentation			
Killip classification			0.506
Killip I	189 (67.3)	77 (65.8)	
Killip II	34 (12.1)	8 (6.8)	
Killip III	20 (7.1)	10 (8.5)	
Killip IV	38 (13.5)	22 (18.8)	
OHCA	18 (6.4)	5 (4.3)	0.406
Peak CK (IU/L)	1,787 [737-3,992]	1,898 [740-2,949]	0.352
LVEF (%)	50 [40-60]	50 [40-59]	0.828
LVEF ≤20%	13 (4.7)	9 (7.8)	0.221
Culprit vessel			0.887
Left main coronary artery	5 (1.9)	2 (1.8)	
Left anterior descending artery	116 (43.8)	64 (58.2)	
Left circumflex artery	36 (13.6)	6 (5.5)	
Right coronary artery	108 (40.8)	38 (34.5)	
Time course			
Emergency medical services	234 (83.3)	95 (81.2)	0.618
Late presentation	34 (12.1)	31 (26.5)	<0.001
Onset-to-door time (min)	128 [66-493]	241 [70-926]	0.028
Time course (onset-to-door time ≤24 h)			
Onset-to-FMC time	n=125	n=52	
Median time (min)	84 [31-221]	137 [23-313]	0.883
FMC-to-door time	n=129	n=55	
Median time (min)	30 [26-37]	35 [29-41]	0.009
Door-to-balloon time	n=139	n=66	
Median time (min)	60 [43-90]	72 [61-128]	<0.001
Door-to-balloon time ≤90 min	104 (74.8)	42 (63.6)	0.098
Therapeutic interventions			
Radial approach	186 (71.0)	81 (71.7)	0.892
Emergency PCI	246 (87.5)	102 (87.2)	0.920
Drug-eluting stent	233 (82.9)	95 (81.2)	0.681
Thrombus aspiration	175 (70.3)	68 (64.2)	0.255
CABG	14 (5.1)	5 (4.3)	0.736
Mechanical supports			
Mechanical circulatory supports	61 (21.9)	26 (22.2)	0.951
IABP	44 (15.9)	8 (6.9)	0.016
Impella	17 (6.1)	14 (12.2)	0.043
VA-ECMO	11 (4.0)	10 (8.6)	0.060
Ventilator	61 (21.7)	33 (28.2)	0.164
NPPV	28 (10.0)	15 (12.8)	0.403
Medications			
Anticoagulants	30 (10.7)	15 (12.8)	0.538
Antiplatelets	261 (94.6)	112 (95.7)	0.632
Aspirin	256 (92.8)	110 (94.0)	0.651
P2Y12 inhibitor	229 (83.0)	104 (88.9)	0.136
β blocker	228 (81.1)	93 (79.5)	0.704
ACEI/ARB	218 (77.6)	95 (81.2)	0.423
CCB	37 (13.2)	27 (23.1)	0.014
Statin	261 (92.9)	112 (95.7)	0.287
Nitrate	83 (29.5)	26 (22.2)	0.136
Nicorandil	24 (8.5)	17 (14.5)	0.073
Diuretic	97 (34.5)	48 (41.0)	0.219
Outcomes			
Length of CICU stay (days)	4 [2-7]	4 [3-7]	0.128
Length of hospital stay (days)	15 [11-26]	13 [10-22]	0.054
Mechanical complications	5 (1.8)	1 (0.9)	0.436
Cardiac rupture	3 (1.1)	1 (0.9)	0.666
Papillary muscle dysfunction	2 (0.7)	0 (0.0)	0.500
In-hospital mortality	14 (5.0)	11 (9.4)	0.098
In-hospital mortality (onset-to-door time ≤24 h)	n=247	n=86	
	14 (5.7)	8 (9.3)	0.243

Categorical data presented as n (%). Continuous data presented as median values [interquartile range].
ACEI: angiotensin-converting enzyme inhibitor, ARB: angiotensin II receptor blocker, CABG: coronary artery bypass grafting, CCB: calcium channel blocker, CICU: cardiovascular intensive care unit, CK: creatine kinase, FMC: first medical contact, IABP: intra-aortic balloon pump, LVEF: left ventricular ejection fraction, NPPV: noninvasive positive pressure ventilation, OHCA: out of hospital cardiac arrest, PCI: percutaneous coronary intervention, VA-ECMO: venoarterial extracorporeal membrane oxygenation
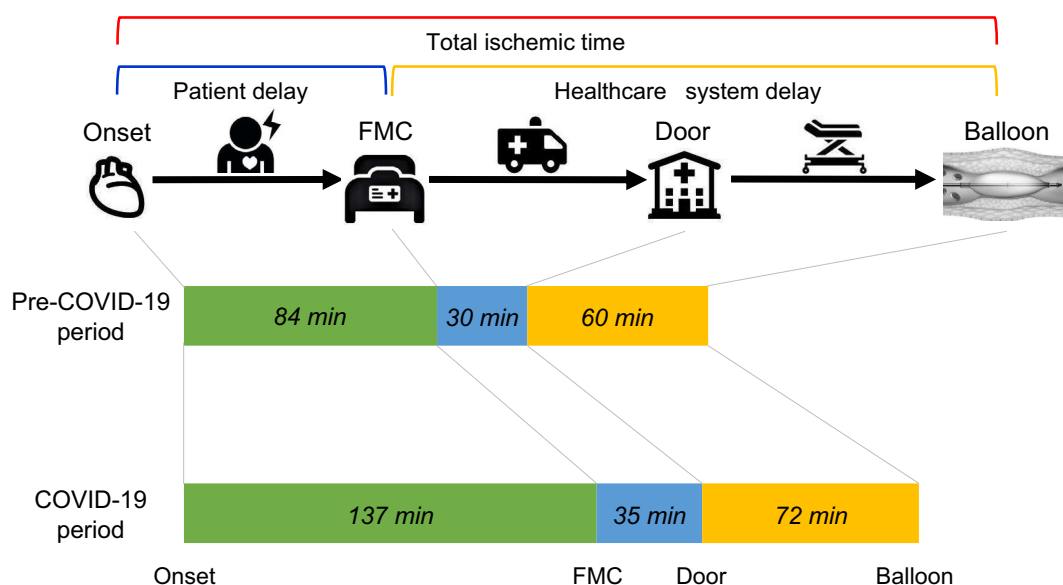
Figure 2. A comparison of the time course in patients whose onset-to-door time was ≤24 hours before and during the COVID-19 pandemic. The FMC-to-door [30 (26-37) vs. 35 (29-41) minutes, p=0.009] and door-to-balloon [60 (43-90) vs. 72 (61-128) minutes, p<0.001] times were significantly longer during the COVID-19 period than the pre-COVID-19 period. The onset-to-FMC time was longer during the COVID-19 period than in the pre-COVID-19 period, although not to a significant degree [84 (31-221) vs. 137 (23-313) minutes, p=0.883]. COVID-19: coronavirus disease 2019, FMC: first medical contact

Table 2. Comparison of the Time Course between Early and Late Pandemic.

	Early pandemic period (March 11, 2020-September 10, 2020)	Late pandemic period (September,11 2020-March,10 2021)	p value
Time course	n=65	n=52	
Emergency medical services	54 (83.1)	41 (78.8)	0.561
Late presentation	16 (24.6)	15 (28.8)	0.606
Onset-to-door time (min)	213 [52-491]	489 [128-1,307]	0.031
Time course (onset-to-door time ≤24 h)			
Onset-to-FMC time	n=32	n=20	
Median time (min)	69 [13-195]	263 [29-743]	0.014
FMC-to-door time	n=34	n=21	
Median time (min)	33 [29-39]	36 [32-45]	0.235
Door-to-balloon time	n=37	n=29	
Median time (min)	69 [54-100]	85 [63-135]	0.179
Door-to-balloon time ≤90 min	25 (67.6)	17 (58.6)	0.453

Categorical data presented as n (%). Continuous data presented as median values [interquartile range]. FMC: first medical contact

tors, goggles, gowns, gloves, and surgical caps. When performing emergency catheterization in patients with COVID-19 or suspected COVID-19 patients, healthcare workers were required to wear PPE. We treated patients with a low probability of COVID-19 infection with surgical masks, goggles, and gloves.

During the COVID-19 period, six patients suspected of having COVID-19 underwent a COVID-19 PCR test, with negative findings obtained. Two of these six patients underwent emergency coronary angiography (CAG), and healthcare workers wore PPE before the PCR test results were available. One patient underwent percutaneous coronary in-

tervention (PCI), and the other underwent coronary artery bypass grafting. The remaining four patients underwent CAG after confirmation of a negative PCR test to ensure the safety of health workers. Table 3 shows the clinical characteristics of suspected COVID-19 patients in our cohort.

Discussion

This retrospective observational cohort study explored the long-term impact of the COVID-19 pandemic on STEMI patients in Tokyo, Japan. The following major findings were observed during the pandemic: 1) a 10.7% reduction was
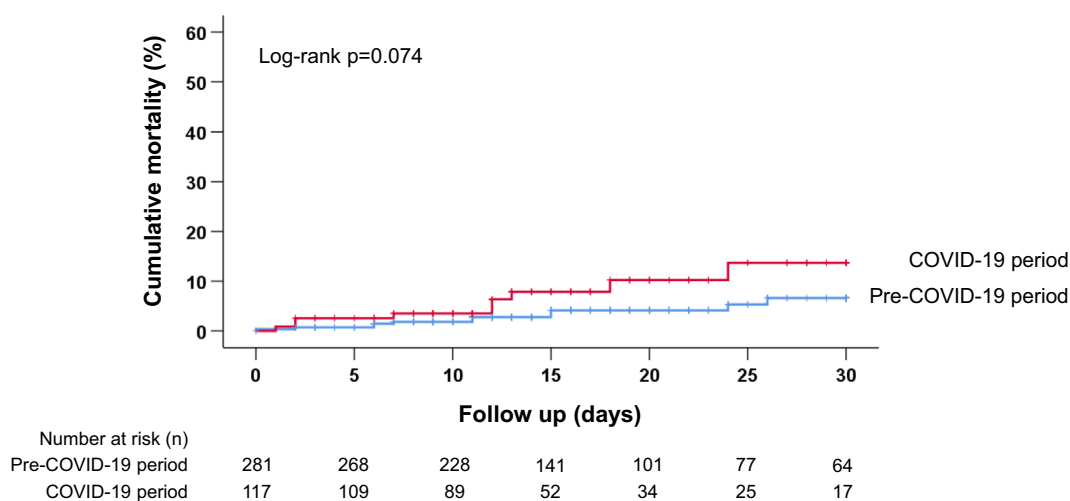
Figure 3. Kaplan-Meier curves of the 30-day cumulative mortality. The 30-day cumulative mortality increased more during the COVID-19 period than during the pre-COVID-19 period, although not to a significant degree (6.6% vs. 13.7%, p=0.074 by log-rank test). COVID-19: coronavirus disease 2019

Table 3. Clinical Characteristics of Suspected COVID-19 Patients.

No.	Age (years)	Male sex	Killip classification	Peak CK (IU/L)	Late presentation	Door-to-balloon time (min)	Primary PCI under PPE	The reason for suspicion of COVID-19	Outcome
1	55	(+)	I	180	(-)	475	(-)	Fever and cough	Alive
2	37	(+)	III	417	(+)	258	(+)	Fever and dyspnea	Alive
3	77	(+)	III	1,001	(-)	940	(-)	Fever and dyspnea	Alive
4	46	(+)	III	2,041	(+)	1,561	(-)	Fever and dyspnea	Alive
5*	79	(+)	IV	1,915	(+)	6,060	(+)	Fever and dyspnea	Alive
6	89	(+)	IV	1,941	(+)	1,576	(-)	Fever and dyspnea	Death

* This patient underwent emergency CAG under PPE. After confirming negative PCR test, the patient underwent CABG due to triple vessel disease. Door-to-CABG time was shown. CABG: coronary artery bypass grafting, CAG: coronary angiography, COVID-19: coronavirus disease 2019, PCI: percutaneous coronary intervention, PCR: polymerase chain reaction, PPE: personal protective equipment

seen in STEMI hospitalization rates; 2) a significantly higher incidence of late presentations and significantly longer onset-to-door, FMC-to-door, and door-to-balloon times were noted; 3) a higher in-hospital mortality was observed among STEMI patients, although this difference was not significant; and 4) the onset-to-door time was significantly longer during the late pandemic period than in the early pandemic period. To our knowledge, this is the first study to reveal the long-term impact of the COVID-19 pandemic, including the third and largest wave, on STEMI patients in Japan.

Our findings showed a 10.7% reduction within 1 year after the start of the COVID-19 pandemic. This reduction is consistent with the findings of previous studies, which report 10.1%, 40%, 38%, and 27% reductions in Tokyo (12), Spain (5), the United States (7), and Italy (8), respectively. The mechanism underlying the decline in STEMI hospitalizations is multifactorial, with the major cause being avoidance of medical care due to fear of not being able to maintain social distancing and contracting COVID-19 in medical

institutions (4, 6-8, 13). Other causes include a true reduction in the incidence of STEMI, possibly due to low physical stress under lockdown and stay-home orders (14) and fewer misdiagnoses of STEMI (7). The reduction rate of STEMI in our cohort is considerably smaller than that reported in other countries. In Japan, the pandemic has had a different impact from that seen in other regions, such as Europe and the United States, in that the number of patients affected by COVID-19 is markedly lower. Therefore, there are significant differences between Japan and other countries in governmental measures that have been implemented against the pandemic; for example, in contrast to the lockdowns and stay-home orders seen in other countries, the state of emergency in Japan had no restrictive powers under law. In Taiwan, which succeeded in controlling the virus during the early pandemic, no marked reduction in STEMI hospitalizations was observed (15). These observations suggest an association between the degree of severity of the COVID-19 pandemic and STEMI reduction.

In Japan, limited studies have reported the time course

and STEMI outcomes during the early COVID-19 pandemic. A single-center retrospective cohort study from Tokyo showed no significant differences in the time course or 30-day mortality in STEMI patients before and after the COVID-19 outbreak (9), while another study from Osaka reported that the in-hospital mortality was comparable, despite an increased incidence of late presentation and mechanical complications of STEMI (10). In contrast, we demonstrated treatment delays and a tendency toward increased STEMI mortality during this pandemic; however, the increment in mortality was not significant. Our findings are similar to those of previous studies from other countries (4, 8, 16). Treatment delays during the pandemic may have worsened cardiac outcomes, as time delays in primary PCI for STEMI affect mortality (17). The increase in late-presenting STEMI patients is associated with a worse long-term mortality (18). Thus, time delays in STEMI management during the COVID-19 pandemic may have negative impacts on the short- and long-term prognosis.

While the previous study did not suggest a significant difference in the onset-to-door time [median (control period vs. COVID-19 period): 205 vs. 266 minutes, p=0.20] (9), our study revealed a significantly longer time during the COVID-19 period (128 vs. 241 minutes, p=0.028). Regarding the prognosis, while the 30-day cumulative mortality rates were comparable in the previous study (8.3% vs. 9.4%, p=0.772, log-rank test), they were found to be higher during the COVID-19 pandemic in the present study (6.6% vs. 13.7%, p=0.074, log-rank test). The difference of results between our study and the previous study seemed to be mainly due to the observation period. Our study included data from the third wave of the COVID-19 pandemic, which has had the worst impact in Tokyo so far. The previous study suggested that the prognosis was comparable because the time course of STEMI management remained unchanged. This finding is consistent with our opinion that time delays in treatment may lead to a poor prognosis. Our findings might be more robust due to the larger sample size and long-term observation period compared with the previous study. Our findings also suggested that the FMC-to-door time was significantly longer after the COVID-19 outbreak than before it. The FMC-to-door time essentially depends on the emergency medical service (EMS). The EMS in Tokyo has developed a system that cooperates with the Tokyo CCU network (19). However, it should also be recognized that the emergency transportation time has increased recently because of the COVID-19 pandemic.

The Tokyo CCU network reported that while the number of hospitalizations for acute myocardial infarction (AMI) from October to December 2020 in Tokyo decreased by 10.1% compared to the previous year, the incidence of out-of-hospital cardiac arrest (OHCA) in December 2020 was significantly higher than that in the previous year (12). There were similar reports from Italy (20) and France (21) concerning increases in OHCA during the COVID-19 pandemic. This may suggest that patients' reluctance to seek medical attention during the COVID-19 pandemic was associated with an increase in cardiac arrest before arrival at a hospital. Therefore, since patients with OHCA are not included in the analysis, the prognosis of STEMI patients during the COVID-19 pandemic period may be underestimated.

In the COVID-19 era, delays in the timeline of STEMI management are a critical issue. Public health and social measures for COVID-19 may affect healthcare systems. We described increased late presentation as "patient delay" and prolonged FMC-to-door and door-to-balloon times as "healthcare system delay". The fear of not being able to maintain social distancing and contracting COVID-19 made patients reluctant to visit medical institutions. Therefore, information about the risk of refusing medical attention and symptoms of myocardial infarction should be shared in order to reduce patient delay. In England, a national campaign to encourage citizens experiencing symptoms of AMI to call an ambulance have produced an effect during the COVID-19 pandemic (22). Healthcare system delays are caused by infection control measures, such as recording a detailed contact history, performing regular temperature measurements and chest X-ray, and wearing PPE. Furthermore, of note, several patients in our cohort underwent CAG after a confirmed negative PCR test had been conducted to ensure the safety of medical professionals. Transportation systems have experienced strain during the COVID-19 pandemic. Many hospitals refused to accept STEMI patients because all beds are designated for COVID-19 management, thereby increasing delays in transportation to hospitals. Our study also revealed that the time course of STEMI patients was more markedly delayed during the late pandemic phase, including the third wave of COVID-19, than in the early phase. Of the 73 hospitals participating in the Tokyo CCU network, 11 had stopped accepting patients who were transported via the Tokyo CCU network. Furthermore, while the acceptance rate for ambulances in the Tokyo CCU network was usually about ≥70%, it dropped to <50% in January 2021 (23). Therefore, the transportation system during the third wave of COVID-19 in Tokyo almost completely collapsed in the wake of the pandemic.

The best way to achieve both rapid management of STEMI and the enaction of control measures for COVID-19 should be determined. Healthcare professionals should recognize the existence of treatment delays and poor STEMI outcomes during the COVID-19 pandemic, even in Japan, and an acute management system for STEMI must be reconsidered in case further waves of the pandemic should appear.

Study limitations

Several limitations associated with the present study warrant mention. First, this was a retrospective, observational, single-center study conducted in Tokyo. Our findings may not be applicable to other regions or countries. Second, our analysis did not include non-ST-elevation myocardial infarction (NSTEMI); NSTEMI patients are more strongly affected by the COVID-19 pandemic than STEMI pa-

tients (8, 22). Third, during this study period, COVID-19 PCR tests were performed markedly less frequently in Japan than in Europe or the United States because the resources, transportation, and qualified staff for COVID-19 tests remained low (24); therefore, these tests were performed only in suspected patients with a fever, respiratory symptoms, pneumonia, or close contact with confirmed COVID-19 patients. In this regard, we might have underestimated the incidence of COVID-19 in our cohort. Finally, the geographical distribution of the STEMI population might have changed before and after the COVID-19 outbreak as medical facilities in hotspots were overwhelmed with COVID-19 patients, which might have affected the management and outcomes. Further large-scale studies should evaluate the impact of the COVID-19 pandemic on STEMI patients in Japan.

Conclusion

A slight decrease in hospitalization, an increased late presentation, treatment delay, and mortality of STEMI patients were noted during the COVID-19 pandemic. The STEMI management system in Japan must be reconsidered in case further waves of the COVID-19 pandemic appear.

The authors state that they have no Conflict of Interest (COI).

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