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ORIGINAL RESEARCH

Impact of COVID-19 outbreak on patients with ST-segment elevated myocardial infarction undergoing primary percutaneous coronary intervention in a regional emergency center in Seoul, Korea

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Abstract

The corona virus disease 2019 (COVID-19) outbreak may have delayed the treatment of patients with ST-segment elevated myocardial infarction (STEMI) in the emergency department (ED). This study aimed to determine the causes for treatment delay and evaluate the outcomes of such delays in STEMI patients undergoing primary percutaneous coronary intervention. This was a single-center retrospective observational study. Hospital records of STEMI patients who received primary percutaneous coronary intervention from 01 January 2019, to 31 December 2020, were assessed. The pre-COVID-19 period was set before 01 January 2020, and the COVID-19 period was set after 01 January 2020, following which the data between these two periods were compared. During the COVID-19 period, there was a decrease in the reported incidence of STEMI patients compared with during the pre-COVID-19 period (incidence rate ratio, 0.74; 95% confidence interval, 0.55–0.99; p = 0.04). After arrival at ED, the time from door to balloon significantly differed between the pre-COVID-19 and COVID-19 period (78.0 min *vs.* 102.0 min, $p < 0.001$). Also, the time to alert a cardiologist (16 min *vs.* 9 min), puncture time after cardiologist arrival (57 min *vs.* 42 min), and puncture to balloon time (19 min *vs.* 14 min) were significantly longer during the COVID period. However, the time from alert to cardiologist arrival was similar. Compared to the pre-COVID 19 period, more patients suffered from major adverse cardiac events during the COVID-19 period (n = 20 (25.3%) *vs.* n = 12 (11.2%), p = 0.012). In both periods, the number of patients admitted to the intensive care unit and died (106 *vs.* 79, 9 *vs.* 10, respectively) and the number of days spent in the ICU were similar. Early recognition of critically ill patients and appropriate response in the ED can lower misdiagnosis rates and increase prompt and correct treatments, thereby improving patient prognosis.

Keywords

COVID-19; ST-segment elevated myocardial infarction; Acute myocardial infarct; Percutaneous coronary intervention

1. Introduction

Since December 2019, the coronavirus disease (COVID-19) has spread globally and become a pandemic [1]. COVID-19 causes respiratory system infection, and its highly infectious nature has urged great alertness from healthcare personnel and the implementation of special infection control measures to limit its spread [2, 3]. Despite the use of vaccines and medicines, the COVID-19 pandemic has been difficult to be contained due to rapid mutation, and as of 13 July 2022, it has infected 554,290,112 people and led to 6,351,801 deaths worldwide, of whom 18,602,109 were confirmed COVID-19 cases from Korea, including 24,680 deaths [4, 5].

The outcomes of patients with acute myocardial infarct (AMI) prognosis depend on early diagnosis and timely treatment. Many reports have recommended an early intervention at door-to-balloon (D2B) time of <90 min. For such reasons, early and quick transportation and hospital admission with skilled and qualified cardiologists are critical to improve post-AMI prognosis [6–8]. In early COVID-19 pandemics, many studies reported on delays in the treatment of ST-segment elevated myocardial infarction (STEMI) patients worldwide [9, 10], but the studies were mixed in Asia, such as Hongkong, Singapore and Taiwan [11–14]. In addition, many studies have shown a decrease in the overall number of patients with AMI, including NSTEMI, as well as patients with STEMI

[9, 10, 14, 15].

During the early COVID-19 pandemic in 2020, a large number of COVID-19 patients occurred in Korea from February to March 2020. However, with strong quarantine measures and social distancing, public health responses in Korea have become a role model for flattening the infection curve of COVID-19. Despite some discrepant results, we presume that the COVID-19 outbreak has delayed the time for STEMI patients to undergo percutaneous coronary intervention (PCI) in the emergency department (ED). Under these strong quarantine measures and social distancing, this study was performed to identify the factors and assess the outcomes of STEMI patients with treatment delay.

2. Methods

2.1 Study Design and Setting

This was a single-center retrospective study. Data were collected from a hospital-based registry. Our regional emergency center covers the south-western region of Seoul and has an annual visit of 70,000 patients. Our center has a cardiology team on standby to provide 24/7 PCI. The cardiology team is alerted by an urgent treatment processing system (UTPS), an alert system that requires corresponding specialists to respond in priority.

We assessed the hospital records for STEMI patients who received primary PCI from 01 January 2019, to 31 December 2020. The cases that STEMI was diagnosed but transferred due to not possible immediate treatment, delayed PCI was performed, cardiac arrest occurred before PCI, and cases with insufficient records were excluded. The pre-COVID-19 period was set to be before 01 January 2020, and the COVID-19 period was set to be from 01 January 2020. The data collected included: general characteristics, time from door to UTPS activation time, time from UTPS to cardiologist arrival, time from cardiologist arrival to function, and time from puncture to balloon time. To determine the cause of delayed D2B time, it was collected separately the times from door to UTPS activation, UTPS to cardiologist arrival, cardiologist arrival to puncture, and puncture to balloon. The same parameters were also analyzed for the following subgroups: STEMI patients who were referred from the primary care clinic and those who were not. The patients' outcomes were measured using the in-hospital major adverse cardiac events (MACEs) such as cardiogenic shock, heart failure, and death.

2.2 Quarantine protocol in the emergency department

During the early COVID-19 pandemics, it is reported that COVID-19 was first diagnosed in Korea on 20 January 2020, because of the Chinese female tourist from Wuhan. After the super-spreading event around mid-February, the number of confirmed cases rose sharply and reached more than a thousand (Fig. 1). Quarantine protocol, which was based on the patient's travel and contact history, changed to become stricter based on symptoms and fever as well as the patient's history. In addition, to protect other patients in the ED, a portable chest X-ray was taken before entering the ED to confirm the presence of pneumonia. In the case of pneumonia, the patient had to wait until there was an isolation zone. If the patient needed hospitalization, hospitalization was delayed until the results of COVID-19 were released (Fig. 2). When there was a high-risk group or pneumonia and the patient needed surgery or procedure in an emergency setting, the medical staff had to wore level D protection.

2.3 Statistical Analyses

An imputation method was not used to handle missing data because we only used complete case data. Chi-squared test was used to compare categorical variables. In the case of continuous variables, the Mann-Whitney U test and the independent t-test were used after the Kolmogorov-Smirnov normality test was performed to test normality. The number of days and cases were corrected during the pre-COVID-19 and COVID-19 periods. The incidence rate ratio (IRR) per day was calculated to compare the incidence of STEMI during pre-COVID-19 and COVID-19 periods. The SPSS version 20.0 (IBM Corp., Armonk, NY, USA) and R version 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria) were used to perform all statistical analyses. A p-value < 0.05 was considered statistically significant.

3. Results

3.1 Baseline characteristics of STEMI patients between the pre- and during COVID-19 periods

There were 189 STEMI patients enrolled during the study period, of whom 107 were during the pre-COVID-19 period and 79 during the COVID-19 period (Fig. 3). During the COVID-19 period, we observed a decrease in the incidence of STEMI patients compared with during the pre-COVID-19 period (IRR, 0.74; 95% CI, 0.55–0.99; p = 0.04). No significant difference was observed in general demographic characteristics between the two groups (Table 1).

3.2 Comparison of elapsed time of STEMI patient from D2B between pre-COVID-19 and COVID-19 periods

After arrival at the ED, the D2B time was found to be delayed during the COVID-19 period (102.0 min *vs.* 78.0 min, $p < 0.001$). Also, the UTPS activation time was increased to 16.0 min during the COVID-19 period compared with the 9.0 min in the pre-COVID-19 period ($p < 0.001$). Puncture time after cardiologist arrival (57.0 min *vs.* 42.0 min, $p < 0.001$) and puncture to balloon time (19 min *vs.* 14 min, $p < 0.001$) were also significantly longer during the COVID period. However, the cardiologist's arrival time after UTPS activation was not statistically different between the two periods (Fig. 4, Table 2).

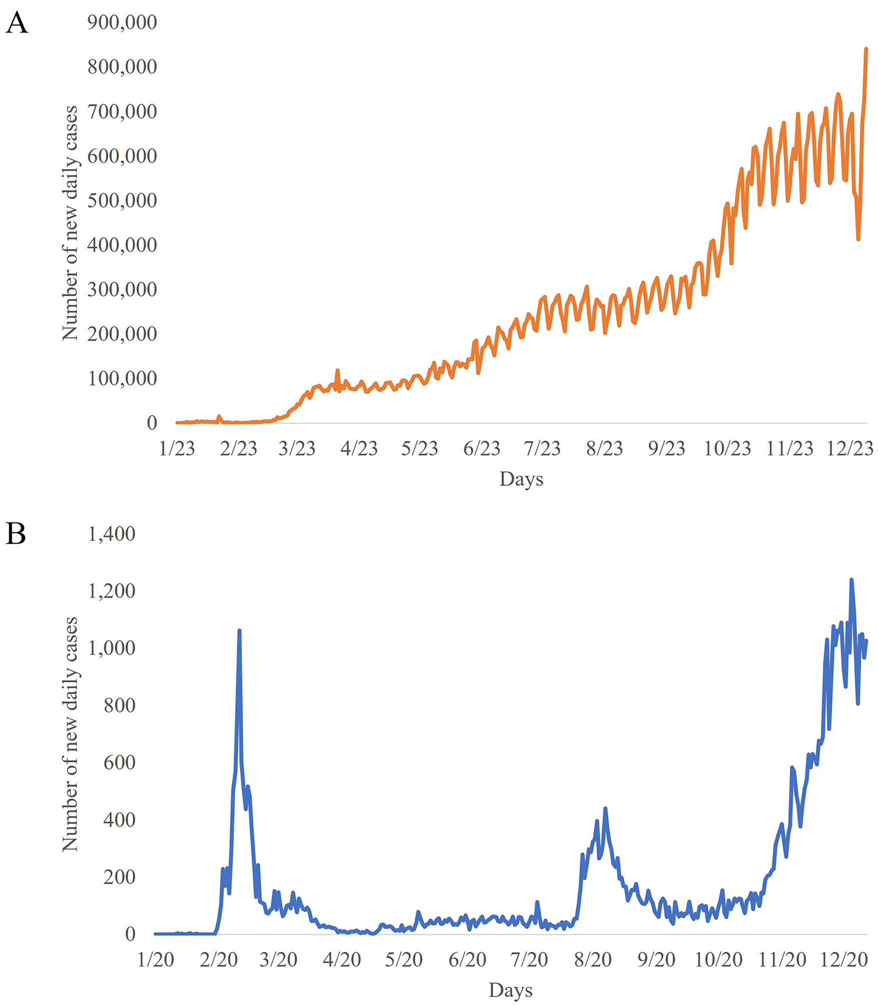

FIGURE 1. Number of new daily cases of COVID-19 worldwide (A) and in Korea (B).

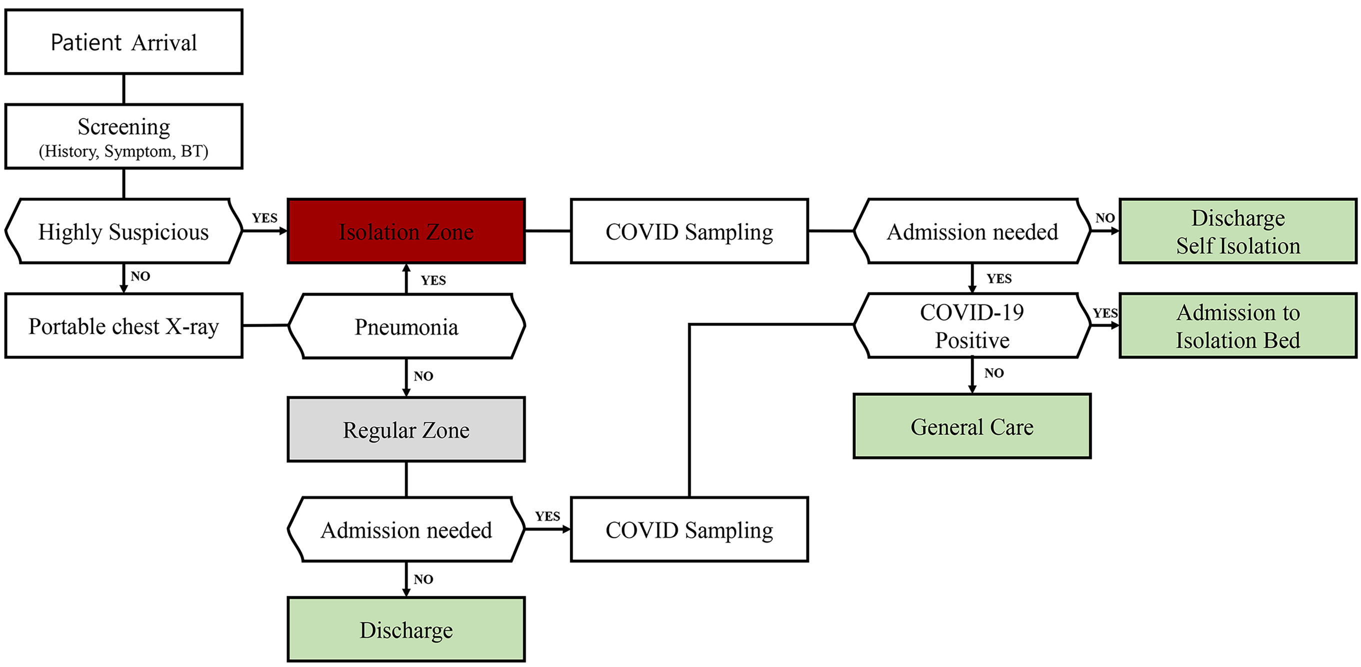

FIGURE 2. Diagram of the quarantine protocol in emergency department. COVID, the coronavirus disease. BT, body temperature.

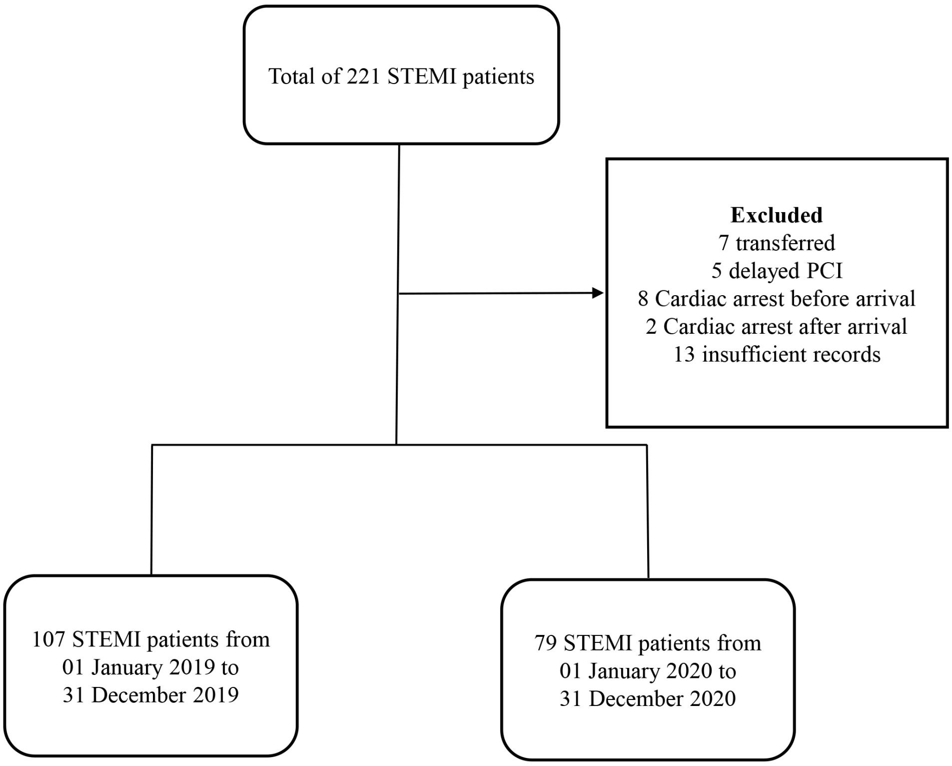

FIGURE 3. Flowchart of the study patient selection process and outcomes. STEMI, ST-segment elevation myocardial infarction; PCI, percutaneous coronary intervention.

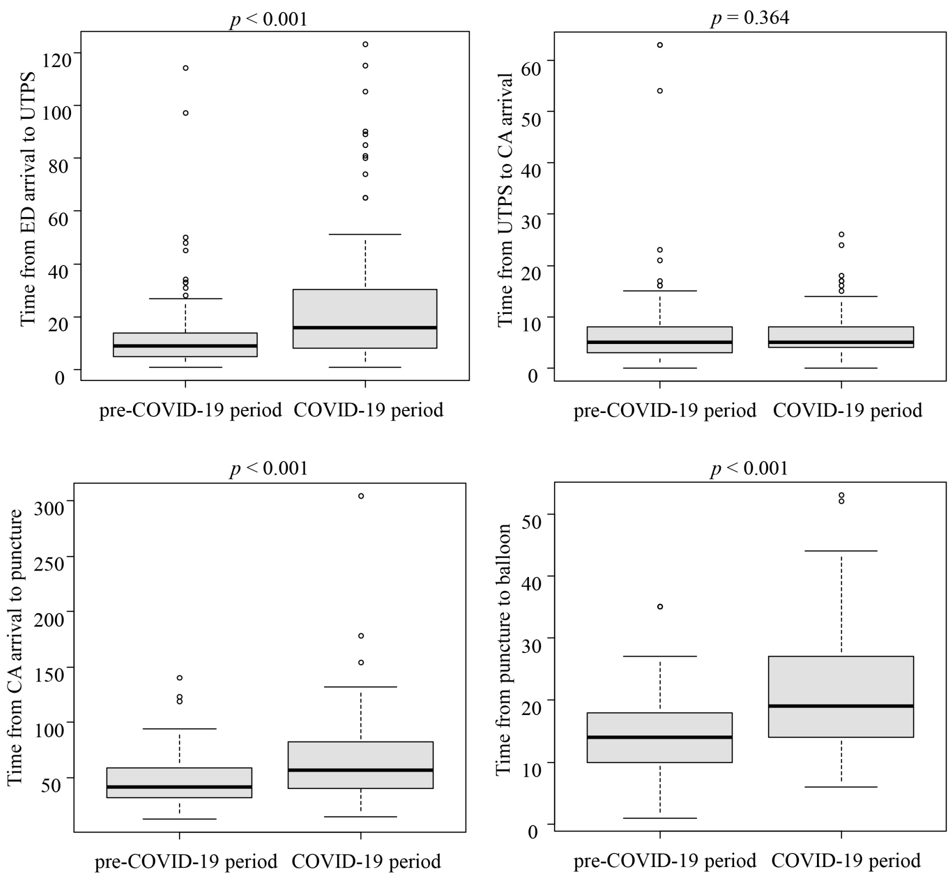

FIGURE 4. Comparison of elapsed time of STEMI patient from the arrival at the hospital to PCI between the pre-COVID-19 period and COVID-19 period. UTPS, urgent treatment processing system; COVID, the coronavirus disease; ED, emergency department; CA, cardiologist.

TABLE 1. Baseline characteristics of the whole study cohort of STEMI patients who visited regional emergency center between the pre-COVID-19 period and COVID-19 period.

Variables	Pre-COVID-19 (n = 107)	COVID-19 (n = 79)	*p*-value
Age	62.5 ± 12.0	62.6± 12.7	0.947
Male	90 (84.1%)	67 (84.8%)	0.897
Route			
Home	77 (72.0%)	57 (72.2%)	0.977
EMS	59 (55.1%)	49 (62.0%)	0.347
HTN	57 (53.3%)	40 (50.6%)	0.722
DM	34 (31.8%)	26 (32.9%)	0.870
Dyslipidemia	22 (20.6%)	10 (12.7%)	0.158
Smoking	20 (18.7%)	10 (12.7%)	0.269
CAG History	6 (5.6%)	9 (11.4%)	0.152
PCI History	5 (4.7%)	9 (11.4%)	0.086

STEMI, ST-segment elevated myocardial infarction; EMS, emergency medical service; HTN, hypertension; DM, diabetes mellitus; CAG, coronary angiography; PCI, percutaneous coronary intervention; COVID, the coronavirus disease.

TABLE 2. Comparison of elapsed time of STEMI patient from the arrival at the hospital to PCI between the pre-COVID-19 and COVID-19 periods.

Variables	Pre-COVID-19 (n = 107)	COVID-19 (n = 79)	*p*-value
Door to balloon, min	78.0 (64.0–89.0)	102.0 (82.0–159.0)	<0.001
Door to UTPS, min	9.0 (5.3–14.0)	16.0 (8.0–30.5)	<0.001
UTPS to cardiologist arrival, min	5.0 (3.0–8.0)	5.0 (4.0–8.0)	0.364
Cardiologist arrival to puncture, min	42.0 (32.0–59.0)	57.0 (40.5–82.0)	<0.001
Puncture to balloon, min	14.0 (10.0–18.0)	19.0 (14.0–27.0)	<0.001

STEMI, ST-segment elevation myocardial infarction; UTPS, urgent treatment processing system; COVID, the coronavirus disease.

TABLE 3. Comparison of elapsed time from the hospital arrival to PCI during the pre-COVID-19 and COVID-19 periods between STEMI patients who were referred from primary clinics (A) and those who were not referred (B).

TABLE 3A. Referral from primary clinic group.

Variables	Pre-COVID-19 (n = 30/107)	COVID-19 (n = 22/79)	*p*-value
Percentage of patients, %	28.04	27.85	0.977
Door to balloon, min	64.50 (57.75–11.75)	85.50 (74.00–139.50)	<0.001
Door to UTPS, min	8.00 (5.00–11.75)	10.50 (7.25–20.00)	0.086
UTPS to cardiologist arrival, min	3.00 (2.00–4.00)	5.50 (3.25–8.75)	0.007
Cardiologist arrival to puncture, min	36.50 (26.25–42.00)	50.00 (43.00–73.00)	0.001
Puncture to balloon, min	13.50 (11.00–18.00)	19.00 (15.00–27.00)	0.012

STEMI, ST-segment elevation myocardial infarction; UTPS, urgent treatment processing system; COVID, the coronavirus disease.

TABLE 3B. Non-referral group.

Variables	Pre-COVID-19 (n = 77/107)	COVID-19 (n = 57/79)	*p*-value
Percentage of patients, %	71.96	72.15	0.977
Door to balloon, min	82.00 (69.50–101.00)	122.00 (88.00–160.50)	<0.001
Door to UTPS, min	10.00 (6.00–16.25)	17.00 (11.00–39.00)	<0.001
UTPS to cardiologist arrival, min	6.00 (4.00–9.00)	5.00 (4.00–8.00)	0.464
Cardiologist arrival to puncture, min	48.00 (33.00–64.00)	60.00 (40.00–89.00)	0.008
Puncture to balloon, min	14.00 (10.00–18.00)	20.00 (14.00–26.00)	<0.001

UTPS, urgent treatment processing system; COVID, the coronavirus disease.

TABLE 4. Comparison of in-hospital MACE, ICU admission, ICU length of stay and death between the pre-COVID 19 and COVID 19 periods.

Variables	Pre-COVID-19 (n = 107)	COVID-19 (n = 79)	*p*-value
MACE, n (%)	12 (11.2)	20 (25.3)	0.012
ICU admission	106 (99.1)	79 (100)	0.344
ICU length of stay, days	1.00 (0.00–2.00)	0.00 (0.00–2.00)	0.143
Expire, n (%)	9 (8.4)	10 (12.7)	0.344

MACE, major adverse cardiac event; ICU, intensive care unit; COVID, the coronavirus disease.

3.3 Comparison of elapsed time of STEMI patients from D2B between the group referred from primary clinics and non-referred during pre-COVID-19 and COVID-19 periods

We found no significant difference in the percentage of patients visiting ED with a referral from the primary care clinic between the two periods. However, the UTPS activation time from the non-referral group was significantly higher during the COVID-19 period (17.0 min *vs.* 10.0 min, $p < 0.001$). Further, the puncture to balloon time for the non-referral group was also noticeably longer during the COVID-19 period (20.0 min *vs.* 14.0 min, $p < 0.001$) (Table 3).

3.4 Comparison of in-hospital MACEs, ICU admission, ICU length of stay, and death between pre-COVID-19 and during COVID-19 periods

Our results showed that more patients suffered from MACEs during the COVID-19 period than during the pre-COVID-19 period (n = 20 (25.3%) *vs.* n = 12 (11.2%), $p = 0.012$). However, the number of patients admitted to the ICU and died were similar during the two periods. In addition, we also found that the number of days spent in the ICU was also similar during the two periods (Table 4).

4. Discussion

This study analyzes how STEMI patients are affected in situations where COVID-19 prevalence is suppressed by implementing strong quarantine measures and social distancing in the early COVID-19 period. As far as we know, this is the first research to analyze how each step in D2B time was affected by COVID-19.

Similar to other previous studies [9–11, 14], our research showed an overall decrease in STEMI patients' incidence and delayed D2B time. Some studies reported a marked reduction of 40%–50% of STEMI patients during the early COVID-19 pandemics [9, 16–18]. A recent large meta-analysis [14] showed that this 40%–50% decrease was overestimated and about 20% were decreased in the first peak of COVID-19. Our study also showed a similar level of decrease in STEMI patients, but the cause of this reduction remains unclear. In fact, the number of STEMI patients may have decreased. However, several studies [13, 15] also reported an increase in the time from symptom onset to hospital visit. Through mass media and social media announcing that there are COVID-19 suspected patients or confirmed patients in the hospital, the fear of exposure to COVID-19 in the hospital environment may have served as a factor of reluctance to visit the hospital [12, 19, 20]. Actually, during the severe acute respiratory syndrome outbreak in 2009, the events that infection spread in hospital were reported [21]. Similarly, when the MERS outbreak occurred in Korea in 2015, one patient with confirmed MERS had infected 81 patients in the ED [22]. In addition, these results may have also resulted from unintentional "stay at home" by strong social distancing. Interestingly, a study in Taiwan, which is geographically close to Korea, showed the opposite results, whereby the researchers reported no decrease in STEMI patients during early COVID-19 period [13]. This difference in Taiwan may be related to the fact that there were only a few cases of wearing personal protective equipment in the process of treating STEMI patients because the spread of infection did not occur in hospitals.

Many studies reported an increase in D2B time during the COVID-19 period [9–11, 15], which was concordant with our present study, where we found an increase in D2B time during the COVID-19 period than in the pre-COVID-19 period. Moreover, our analysis showed an increase in door to UTPS time, cardiologist arrival to puncture time, and puncture to balloon time except for the time from UTPS activation to cardiologist arrival. It should be noted that this is not a problem on the manpower of medical personnel in hospitals, but as reported in several studies [11, 12, 15], it could be due to several factors following quarantine measures under COVID-19. The screening of patient's respiratory symptoms, close contact and travel history and chest radiography are used in ED for risk stratification and can increase the time to diagnosis of STEMI by electrocardiogram (EKG) after arrival in ED. In addition, catheterization laboratories had positive pressure systems allowing COVID-19 to spread widely, making it difficult for medical personnel to safely move patients with COVID-19 risk symptoms from ED to the catheterization laboratory. Further, even after the patients arrive at the catheterization laboratory, it may take a lot of time to wear protective gear and prepare the patients. In addition, if the cardiologist is not familiar with performing PCI under full protective gear, it might lead to a long time to perform PCI.

Regionally, there have been conflicting studies on the increase in D2B time in Hongkong [11] and Singapore [12], which belong to the Asian region. Similar to our study, a study conducted in Hong Kong [11] showed an increase in D2B time, an increase in the time from catheterization laboratory to balloon, in-hospital death and cardiogenic shock. On the other hand, in a study conducted in Singapore [12], the authors reported no increase in overall D2B time during the COVID-19 period. In addition, there was no significant increase in all components of primary PCI workflow, including time from ED to cardiologist action, cardiologist action to the catheterization laboratory, catheterization laboratory to the start of PCI, and PCI start to balloon. Since the study in Singapore was conducted during the narrow COVID-19 period of two months, such as in Taiwan [13], the quarantine guidelines and screening protocols may not have been stricter than in Korea. In a study performed in Singapore, since the onset-to-door (O2D) time and D2B time were similar to before the COVID-19 period, there was no significant difference during the COVID-19 period in the case of mortality and cardiogenic shock. The mortality rate was not increased in this present study, which might be related to the excluded cases in our study where the cardiac arrest occurred before PCI, which can increase D2B time.

We also observed no significant difference in the number of STEMI patients referred from primary clinics between the two periods and the non-referred group. In the door to UTPS time in referral from the primary clinic group, we found no apparent significant changes, which is thought to be because patients who went through primary clinics had already been diagnosed through EKG, and hospitals often know in advance that patients are coming. In Korea, pre-hospital EMS personnel are restricted from taking the 12-lead EKG. Therefore, it would be helpful to actively take 12-lead EKG at the pre-hospital level rather than simply looking for a hospital that can be transferred in a pandemic situation where hospital resources are limited.

During the COVID-19 pandemic, when no beds were available for AMI patients, including in general wards, ICU and ED, our hospital could not accommodate them, which forced these patients highly suspected of AMI to go to other hospitals where they could be treated at a pre-hospital level. Therefore, major factors needed for critical patients such as STEMI patients include the availability of ED beds and ICU units. Other studies showed that STEMI hospitalization plummeted in countries with lower hospital bed availability, while it remained near historical levels in countries with much higher bed availability, similar to COVID-19 mortality which showed a close effect on hospital bed availability [14, 23, 24]. In case of a shortage of spaces in hospitals, the flexibility of a regional emergency care system is critical, such as rearranging ED and ICU capacities to maximize treatment effects for STEMI patients while preserving the safety of medical service providers and patients.

5. Limitations

This study had several limitations. First, this was a single-center retrospective observational study with small sample size. Considering that each hospital has a different quarantine policy, the results of this present study cannot represent every hospital in Korea. However, our study was conducted in one of five regional emergency medical centers in Seoul, with a population of ten million; thus, we could expect a certain level of representation. Even though each hospital might have different quarantine protocols, the basic idea of separating high-risk patients, including patients with pneumonia, was almost similar. Second, this study did not include the O2D time, which is the time from symptoms onset to ED arrival. It is likely that the COVID-19 pandemic led to an increase in O2D time, which influenced patients' outcomes. Further evaluation is needed to evaluate the effect of O2D time on COVID-19 pandemic and STMEI patients.

6. Conclusions

The early recognition of critically ill patients and appropriate responses, such as EKG and rapid diagnostic studies, at ED are necessary during pandemic settings. These efforts could lower misdiagnosis rates and increase prompt and correct treatments, thereby improving patients' treatment outcomes.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

AUTHOR CONTRIBUTIONS

YDC and SHC—Conceptualization; HEB and YDC—Data curation; SJP—Formal analysis; JYK and YHY—Investigation; YJK and YHY—Methodology; SJP—Software; YDC—Validation; SHC and YHY—Supervision; JYK and YHY—Visualization; HEB—Writing—original draft; SJP—

Writing—review & editing.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was reviewed and approved by the Institutional Review Board of Korea University. The requirement for informed consent was waived (IRB no.: 2022GR0192).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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