Admissions for and Quality of Care of ST-Segment-Elevation Myocardial Infarction in the Post COVID-19 Era in China

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Short title: Quality of Care of STEMI in the Post COVID-19 Era

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Abstract

**Objective:** To evaluate changes in admission rates for and quality of care of ST-Segment-Elevation Myocardial Infarction (STEMI) during the period of the coronavirus disease 2019 (COVID-19) outbreak and post COVID-19 era.

**Methods:** We conducted a retrospective cohort study of patients with STEMI in the outbreak era (between January 23, 2020 and March 27, 2020), and the post era (between March 28, 2020, and July 31, 2020) in Suzhou Province, drawn from the China Chest Pain Center Database.

**Results:** 1965 STEMI admissions were enrolled. During the corresponding period of 2019 to the post COVID-19 era, there were a 53% and 38% fall in admissions in outbreak and the post era. There remained a gap in actual number of admissions at 306 and the predicted number that might be at 497. An estimated 26 deaths due to STEMI would have been caused by not seeking health care while no one died from COVID-19. The percentage of STEMI cases transferred by ambulance decreased from 9.3% to 4.2% (P=0.013). Door-to-balloon and the FMC-to-device median (q1, q3) time increased from 17.5 (10.0, 46.0) and 52.0 (12.0, 86.0) minutes to 34.0 (15.0, 48.0) and 63.0 (15.0, 94.0) minutes, respectively (p=0.001, p=0.005), and rate of PCI practice declined from 71.3% to 60.1% (p=0.002).

**Conclusions:** The impact of public health restrictions in the post COVID-19 era is significant, and may lead to unexpected out-of-hospital deaths and compromised quality of STEMI care. Delay or absence in presentation in STEMI patients should be continuously considered to avoid the secondary disaster of the pandemic. System delay should be modifiable for reversing the worse clinical outcomes from the COVID-19 outbreak, by coordination measures with focus on the balance between timely PCI procedure and minimizing contamination of cardiac catheterization rooms.
Keywords

Post COVID-19 era, STEMI, Quality of care
What is already known about this topic?

- The number of patients presenting with STEMI and the number of percutaneous coronary intervention (PCI) practice decreased during the coronavirus outbreak.
- Time Delay or absence in presentation in STEMI patients in COVID-19 outbreak era may impact optimal treatment delivery.

What does this article add?

- Admissions for and quality of care of STEMI got worse even in the post COVID-19 era, there were a 53% and 38% fall in admissions for STEMI in outbreak and post era.
- Restrictions in the post era may lead to unexpected deaths and poor care of STEMI, system delay should be modifiable for reversing the worse clinical outcomes.
Introduction

The coronavirus disease 2019 (COVID-19) pandemic is challenging health care systems in unprecedented ways, and the effects will last for decades to come. Most countries have implemented stringent infection-control measures, including but not limited to social distancing measure, emergency infection protocols instituted in hospitals to contain COVID-19, and adjustment of clinical services. The response to COVID-19 can compromise quality of care for non-COVID-19 diseases, especially for ST-Segment-Elevation Myocardial Infarction (STEMI), the deadlest and most time-sensitive acute cardiac event. A number of studies have reported substantial declines in the number of patients presenting with STEMI and the number of percutaneous coronary intervention (PCI) practice, the typically recommended treatment, during the coronavirus outbreak. However, little is known regarding the impact of the post COVID-19 era on admission rate and quality of STEMI care.

China has recovered from the initial outbreak and is experiencing the defense of the coronavirus bounce back. There are two major public health concerns with respect to STEMI care in the post COVID-19 era: (i) delays in presentation, and (ii) delays in treatment. First, less is clear on whether there have been a rebound in STEMI presentation. Several studies have reported a surge in STEMI admission rate correlating with the fading of the first wave of the COVID-19 outbreak. Changes in lifestyle pattern (e.g. physical inactivity and weight gain) during lockdown, has been suggested as a potential factor for exacerbating the population cardiovascular risk profile and creating a greater number of vulnerable coronary patients. Even yet after the wave of the COVID-19 outbreak, the emphasis on social distancing might have inappropriately convinced patients to avoid in-person health care. The lack of knowledge on personal protection measures compounded by fear of contracting an infection may make patients much less likely to seek help. Thus, an increasing number of patients presenting with STEMI at high coronary risk do not seek health care in a timely manner, which will lead to more unexpected out-of-hospital deaths and cause the secondary disaster of the pandemic.

Second, little is known regarding how the post COVID-19 era influenced the delivery of STEMI care in terms of care processes based on the recommended guidelines, once patients
entered the health care system. STEMI cases require rapid coordination of care beginning at the time of symptom onset. However, the emergency infection protocols (e.g., coronavirus screening upon hospital arrival) still persistent, which could result in a considerable delay in timely treatment, and may impact optimal treatment delivery for patients presenting with STEMI.\textsuperscript{16,17} It is a great challenge for health care system to make a balance between identifying patients for PCI procedure, regardless of their coronavirus status, and maintaining the safety of health care workers who may be exposed to the virus as well as minimizing contamination of cardiac catheterization rooms. Thus, it is warranted to evaluate how is the health care system’s resilience to recover from the coronavirus outbreak, for operational integrity with respect to STEMI cases.

To fill this gap, this study aims to investigate the admissions for and quality of care of STEMI in the post COVID-19 era. The objectives of this study are two-fold as follows: (1) to examine the changes in the admission rates during the COVID-19 outbreak and the post COVID-19 era, by comparing the number in the post COVID-19 era and predicted numbers based on the admissions in 2017-2019; (2) to investigate the changes in quality metrics of care, by comparison between periods of the post COVID-19 era and the COVID-19 outbreak, and between the post COVID-19 era and the corresponding periods in 2018 and 2019.

Methods

Data and Study Design

Data for this study were obtained from the China Chest Pain Center (CPC) Database (http://data.chinacpc.org/), a nationwide clinical registry for collecting data of all consecutive patients diagnosed with STEMI enrolled by the accredited hospital-based CPCs. The data elements include patient demographics, prehospital treatment, presenting features, in-hospital medication and reperfusion practice, clinical outcomes and discharge. This national audit is supervised by the China Cardiovascular Association (CCA), located in the city of Suzhou. Accredited hospitals are instructed to submit consecutive eligible patients to the database in real time. Improvement in adherence to data reporting is facilitated through monthly and quarterly hospital-specific performance feedback reports. We extracted the data from the
CPCs in Suzhou, which has been one of the pilot cities to implement the highest restrictions of lockdown. Suzhou has also taken the lead to announce the unlock and resumption of work and production.

We conducted a retrospective cohort study of patients presenting with STEMI between January, 2017 and July, 2020 in Suzhou. The COVID-19 outbreak era was defined as period between January 23, 2020 and March 27, 2020, corresponding to the introduction of the highest restrictions of movement and a public health drive to combat rising cases in Suzhou. The post COVID-19 era was defined as period between March 28, 2020, and July 31, 2020 corresponding to the announcement of resumption of work and production by the Suzhou Government. Data for this analysis were included from all the accredited CPCs in Suzhou in each month of the year 2017-2020 until the end of July 2020. Our study took the advantage that data was prospectively collected and data checks and validations took place.

Measures

The primary outcome was number of monthly STEMI admissions, and the secondary outcomes was quality metrics of STEMI care in terms of prehospital process, in-hospital process, and clinical outcome. The quality metrics were selected, based on the Class I Recommendations from the most updated American College of Cardiology/American Heart Association (ACC/AHA) clinical practice guidelines (Supplementary Table 1).  

The pre-hospital process indicators included percentage of onset-to-FMC (EMS arrival or walk-in to ED) time \( \leq 60 \text{ min} \), percentage of ambulance ECG to door time \( \leq 15 \text{ min} \), percentage of cases arriving at hospital by ambulance, percentage of ambulance ECG.  

In-hospital process indicators included percentage of \( \beta \)-blocker usage, percentage of door-to-balloon time \( \leq 60 \text{ min} \), percentage of FMC-to-device time \( \leq 90 \text{ min} \), percentage of onset-to-device time \( \leq 120 \text{ min} \), door-to-balloon time, FMC-to-device time, onset-to-device time, and PCI rate. Outcome indicator is in-hospital mortality.

Demographic and clinical characteristics for this study included age, sex, presenting chest pain status, vital signs (respiratory rate, pulse frequency, heart rate, blood pressure), and Killip class.

Statistical Analysis

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A descriptive analysis presented the daily STEMI admission rates and median monthly onset-to-PCI time of STEMI patients over the periods of the post COVID-19 era to the corresponding period in 2018. To provide a more intuitive interpretation of unexpected out-of-hospital deaths, we predicted the number of admissions that should be in the post COVID-19 era based on the numbers over the corresponding periods in 2017-2019 by the method of Holt-Winters exponential smoothing after time series analysis, and computed the gap between the actual number and predicted number of admissions.

Holt-Winters Exponential smoothing is a famous forecasting algorithm which weighted average of past observations with exponentially decaying weights to capture the trend in a time-series dataset\(^1\). The smoothing parameters were automatically generated with R3.6.3 prior modeling with Holt-Winters method. The \(\alpha\) (level), \(\beta\) (slope) and \(\gamma\) (seasonality) should lie between 0 and 1, with values closer to 0 implying that the estimates at the current/future time points are based on recent observations\(^2\). The predicated death number due to the lack of seeking medical resource was calculated by the formula (Predicated numbers-actual numbers)\(^*\) 8\(^%\)\(^2\)^{21,22} (the average death rate).

To examine changes in quality metrics of STEMI care, were compared the list of indicators in terms of prehospital process, in-hospital process, and clinical outcome, by a subsample of respective periods, including the COVID-19 outbreak period and the corresponding periods in 2019 and 2018, the post COVID-19 period and the corresponding periods in 2019 and 2018. Changes in quality metrics were assessed using univariate analyses, including the Kruskal-Wallis test, chi-square test, t-test and one-way analysis of variance. Fisher’s exact test was used to compute 95% confidence intervals for each quality metric. P-values <0.05 were considered statistically significant. All statistical analyses were conducted in R software (R Foundation for Statistical Computing, Vienna, Austria, and Version 3.6.3).

**Results**

**Patient Characteristics**

The study cohort comprised 1965 admissions for STEMI, of which 98 and 313 were in
the COVID-19 outbreak and the post COVID-19 era, respectively. Of those 306 patients with STEMI in the post COVID-19 era, 17.6% were women, with a mean age of 60.7 (SD 14.6) years. During the COVID-19 outbreak, 26.4% of patients were women and the mean age was 65.2 (SD 12.3), significantly higher (P=0.008, P=0.005) than those in the post COVID-19 era, respectively (Table 1).

**Daily admissions for STEMI**

*Figure 1* demonstrates daily admissions for STEMI over the periods of the post COVID-19 era to the corresponding period in 2018. In total, the percentage reduction in admissions were 57% and 55% between the COVID-19 outbreak and the corresponding periods in 2018 and 2019, respectively, with the 2018 and 2019 baseline number of 280 and 267 admissions falling to 121. This decline was partly reversed in the post COVID-19 era, such that there were 306 admissions, representing a 42% and 34% reduction from 2018 and 2019 baseline.

*Figure 2* shows predicted number of daily admissions for STEMI between March 28, 2020, and July 31, 2020. After Holt-Winters exponential smoothing, the smoothing parameters are \( \alpha = 0.27, \beta = 3 \times 10^{-4}, \gamma = 0.23 \). The predicted numbers of admissions for STEMI that might be in the COVID-19 outbreak and the post COVID-19 era was 259 and 497. 53% and 38% declines were evaluated in hospital admissions for STEMI, with the actual numbers of 259 and 497 admissions, falling to the actual numbers of 121 and 306. Predicted numbers of monthly admissions for STEMI are shown in supplement Table 2. Based on the formula that (Predicated numbers-actual numbers)*8% (the average death rate), the predicated death number due to the lack of seeking medical care was 26.

**Quality metrics of STEMI care**

*Figure 3* presents the median monthly treatment delay for STEMI care, by patient delay, transfer delay and in-hospital delay. The median (q1, q3) monthly time from onset to PCI were 179 (86, 622), 169 (89, 350), 159 (76, 622), and 152 (80, 296) minutes between April and July of 2020, significantly higher than those in the corresponding months of 2019 at 156 (88, 328), 144 (65, 287), 150 (80, 316), and 139 (60, 456) minutes, although those were lower than the number of 210 (78, 511), 230 (113, 662) and 293 (118, 521) minutes, between January and March of 2020.
Table 2 shows the changes in quality metrics of care, by comparison between periods of the post COVID-19 era and the COVID-19 outbreak, and between the post COVID-19 era and the corresponding periods in 2018-2019. The percentage of STEMI cases transferred by ambulance was both 4.2% in the COVID-19 outbreak and post COVID-19 era, respectively, lower than those in the corresponding period of 2019 (16.9%, P=0.005; 9.3%, P=0.013). During the corresponding period of 2019 to the post COVID-19 era, door-to-balloon and the FMC-to-device median (q1, q3) time increased from 17.5 (10.0, 46.0) and 52.0 (12.0, 886.0) minutes to 34.0 (15.0, 46.0) and 63.0 (15.0, 94.0) minutes, respectively (p<0.001, p=0.004), and rate of PCI practice declined from 71.3% to 60.1% (p=0.002), accompanied with the in-hospital mortality increasing from 2.8% to 4.1% although it was insignificant. Changes in all the quality metrics of STEMI care between the COVID-19 outbreak and post COVID-19 era showed insignificant, with the percentage of cases transferred by ambulance, percentage of onset-to-FMC time ≤60 min, percentage of onset-to-device time ≤120 min, and PCI rate decreasing, and door-to-balloon time increasing during the corresponding period of 2019 and the COVID-19 outbreak.

Discussion
Principal Findings
This is, to our knowledge, the first study to investigate the changes in STEMI admissions for and quality of care in the post COVID-19 era, with the fading of the COVID-19 outbreak. Although we observed the reversed increase in STEMI admissions, there remained a gap in the number of the post COVID-19 era and predicted numbers based on the admissions in 2018-2019. We explored to predict that 26 deaths due to STEMI would have been caused by not seeking health care, while no one died from COVID-19 with the total number of infections was 87, in the post COVID-19 era. According to the incidence of STEMI about 55/100,000 in China, it can be predicated that there will be nearly 300,000 STEMI not seeking health care because of COVID-19, which could lead to over 20,000 death in the post COVID-19 era. Quality of STEMI care remained suboptimal in the post COVID-19 era, comparing with that in the corresponding periods in 2018-2019, especially.
for percentage of cases transferred by EMS, and in-hospital process indicators. Although in-hospital mortality declined during the COVID-19 outbreak to the post COVID-19 era, the change was not significant. These findings suggest that the impact of public health restrictions in the post COVID-19 era is still significant, and may lead to unexpected out-of-hospital deaths and compromised quality of care among patients with STEMI.

Our findings on the impact of the COVID-19 outbreak are consistent with prior studies that have already reported on decline in admission rate and prolonged time to PCI practice during the COVID-19 outbreak. Previous studies using the self-controlled case series method provided evidence that COVID-19 may increase the risk of STEMI during the acute phase of infection. However, the reduced number of admissions during the COVID-19 outbreak is likely to have resulted in increases in out-of-hospital deaths and long-term complications. Our current study focuses on the post COVID-19 era, with the advantage that data is prospectively collected and data validation is facilitated through monthly and quarterly data audit and feedback. A nationwide study in UK reported a 23% decrease in admissions for STEMI from 2019 to the end of March, 2020, and admission rates for STEMI had partly recovered but remained about 16% below baseline levels by the end of May, 2020. While a few studies indicated that there might be a post COVID-19 rebound for STEMI admissions. Our current study adds the evidence from the low- and middle-income countries, showing a 53% and 38% decline in STEMI admissions, respectively, comparing the COVID-19 outbreak and the corresponding period of 2019, and the post COVID-19 era and the corresponding period of 2019. Moreover, we find that the percent of cases transferred by ambulance declined significantly from 9.3% to 4.2% in the post COVID-19 era in comparison with the corresponding period of 2019. Causes for less presentation for health care are likely multifactorial and most researches emphasize that patients may be reluctant to present to hospital because of the fear of contracting the SARS-CoV-2 infection. Thus, the risk for patients failing to attend hospitals with STEMI would be lasted even after the wave of the COVID-19 outbreak, leading to unnecessary deaths and disability. This is particularly true for China and other low- and middle-income countries, where patients’ knowledge on STEMI and awareness of protection are relatively limited with the information of prevention of COVID-19 explosion. Educational outreach to community including STEMI awareness and
COVID-19 knowledge is warranted. In China, hospital-based CPCs should follow the criteria of Chinese CPC development for establishing a medical consortium of STEMI care. Hospitals are partnered with community health centers to form an information-sharing and resource-management model. Health care workers at community health centers conduct management of STEMI care among community residents, which are part of the essential public health services in China. Thus, community-based education supervised by hospitals within a medical consortium should be established within routine services delivery, to inform the public that the CPCs remain fully operational and have stringent infection-control protocols in place even in the post COVID-19 era.

Obviously national lockdowns and altered health care priorities in response to COVID-19 outbreak are affecting the diagnosis and treatment of STEMI. According to Consensus of CCA on Diagnosis and Treatment Processes of STEMI in the Context of Prevention and Control of COVID-19, patients excluded from COVID-19 should be transferred immediately to the cardiac catheterization room for PCI therapy. For patients with suspected COVID-19, emergency intravenous thrombolysis is the first choice for cases with no contraindication to thrombolysis; If COVID-19 is excluded after intravenous thrombolysis, patients could be transferred to the cardiac care units. In the post COVID-19 era, it is still recommended to follow the Consensus by the CCA. In fact, most CPCs do not have professional protected cardiac catheterization rooms and cardiac care units for respiratory infectious diseases. Given the conflict between time required for coronavirus nucleic acid detection and early PCI for STEMI, thrombolysis is conducted in priority in the emergency room, and sample for the coronavirus nucleic acid detection is sent after the start of thrombolysis. Since the results of nucleic acid detection should be waited for several hours that must lead to delays in treatment, cardiologists can make the treatment decision after full consideration of the benefit to risk ratio; if the possibility of having COVID-19 based on the respiratory symptoms and epidemiological exposure history is clinically small, PCI can be conducted immediately in an isolation ward. In our study, all the patients enrolled were negative for COVID-19. We have analyzed all the components of the treatment time including patient delay and system delay. Notably, the extension in patient delay showed no significant during the post COVID-19 era and the corresponding periods of 2018-2019. We
observed a significant prolongation of the door-to-balloon time and FMC-to-device time, mainly due to the requirement of testing negativity for SARS-CoV-2 infection. Meanwhile, a 12-point percentage of decline in rate of PCI practice was observed over the period of the post COVID-19 era and the corresponding periods in 2019. Thus, even in the post COVID-19 era, delays in in-hospital treatment may be prolonged because the emergency infection protocols could result in a hinder for timely PCI therapy.

Our findings also show that in-hospital mortality increased from 2.1% to 6.0% between the COVID-19 outbreak and the corresponding period of 2019, and although in-hospital mortality declined from the COVID-19 outbreak to the post COVID-19 era, the change was not significant. There are several potential reasons for the persistent clinical outcome during the COVID-19 outbreak and the post COVID-19 era. First is the characteristics of patients hospitalized with STEMI. Although clinical characteristics, vital signs and Killip class were fairly consistent across periods, patients in the post COVID-19 era were about 5 years younger and had a 13-point lower percentage of female, comparing those in the COVID-19 outbreak. Although the explication of reasons for these changes is beyond the scope of our study, a number of prior studies pointed out the fact that elderly and female patients with STEMI have higher in-hospital mortality or worse clinical outcomes than the young and the male. Nevertheless, data of our study provides additional information that neither the risk profile of patients hospitalized with STEMI has significantly changed in the post COVID-19 era and nor have the clinical outcomes. Second is the treatment approaches for patients hospitalized with STEMI. The rates of PCI practice persisted about 60% during the COVID-19 outbreak and the post COVID-19 era, lower than those in the corresponding periods of 2018-2019 at about 70%. The result is in line with a series of studies reporting a reduction in PCI practice as a result of the COVID-19 pandemic. These results were coupled with delays in PCI practice, pointing to the persistently high in-hospital mortality during the COVID-19 outbreak and the post COVID-19. Clinical outcome in patients with STEMI in the post COVID-19 era might be influenced by time delay to treatment and less use of PCI therapy. Therefore, it is imperative to improve the health care system’s ability to maintain care coordination for timely PCI with respect to STEMI cases. Prior studies have shown that a dedicated coordinator from a CPC could play a critical role in maintaining
coordination of care, in charge of coordination of the hospital and EMS agencies, and collaboration of multidisciplinary teams including the cardiology department, emergency department, infections department, pneumology department, and the medical laboratory department.\textsuperscript{16,32}

Limitations

This study has several limitations. First, in a dynamic cohort study, there will be concerns related to confounding, bias, and temporal trends in quality of care that may limit the validity of the findings. However, we compared the changes in the quality metrics of care by comparison between the corresponding periods in 2020 and 2019, as well as those in 2019 and 2018. Our findings showed that most of indicators got better or remained stable over the periods of 2018 and 2019, while got worse during 2019 and 2020. These results indicated that our study may underestimate the impact of the COVID-19 outbreak and the post COVID-19 era on quality of care. Second, with one city selected in the sampling frame, the national representativeness of the study sample cannot be ascertained. However, the city of Suzhou is one of the first cities having responded to the national call for public health measures for combating the pandemic, and having developed accredited CPCs to guide standardized pre-hospital and in-hospital STEMI care in a regional level in China. We believe that the selected sample is generally representative of the health and economic development in the most developed urban China.

Conclusions

It is key to note that the impact of public health restrictions in the post COVID-19 era is significant, and may lead to unexpected out-of-hospital deaths and negatively influence quality of care among patients with STEMI. Delay or absence in presentation in STEMI patients should be continuously considered to avoid the secondary disaster of the pandemic. System delay should be modifiable for reversing the worse clinical outcomes from the COVID-19 outbreak, by coordination measures with focus on the balance between timely PCI procedure and minimizing contamination of cardiac catheterization rooms.

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Junxiong Ma had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Design of the study: Yinzi Jin, Zhi-Jie Zheng
Collection, analysis, and interpretation of the data: Yinzi Jin, Junxiong Ma
Preparation, review, or approval of the manuscript: Yinzi Jin, Zhi-Jie Zheng, Junxiong Ma, Na Li, Shuduo Zhou, Xuejie Dong

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Conflict of Interest
None.

Abbreviations
STEMI: ST-Segment-Elevation Myocardial Infarction
COVID-19: coronavirus disease 2019
PCI: percutaneous coronary intervention
CPC: Chest Pain Center
FMC: first medical contact
EMS: emergency medical service
CCA: China Cardiovascular Association
ACC/AHA: American College of Cardiology/American Heart Association

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**Figures Legends**

Figure 1. Daily admissions to hospital-based chest pain centers in Suzhou of China with ST-Segment-Elevation Myocardial Infarction

Figure 2. Predicated number of monthly admissions to hospital-based chest pain centers in Suzhou of China without COVID-19

Figure 3. Mean monthly onset-to-PCI time delay for care of ST-Segment-Elevation Myocardial Infarction, by patient delay, transfer delay and in-hospital delay

**Supplement**

Supplement Table 1. Definition and measures of quality metrics

Supplement Table 2. Predicated number of monthly admissions to hospital-based chest pain centers in Suzhou of China without COVID-19

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Table 1. Characteristic of STEMI during the COVID-19 outbreak and the post COVID-19 era, compared with corresponding periods in 2018 and 2019

|                        | Outbreak period of 2020 compared with corresponding period of 2018 and 2019 | Post-outbreak period of 2020 compared with corresponding period of 2018 and 2019 | Outbreak period compared with post-outbreak period of 2020 |
|------------------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------|----------------------------------------------------------|
|                        | 2018.0 | 2019.0 | 2020.0 | P       | 2018.0 | 2019.0 | 2020.0 | P       | 2020.0 | 2020.0 | P       |
| Admissions for STEMI   | 280    | 267    | 121    |         | 528    | 463    | 306    |         | 121    | 306    |         |
| Age (years)*           | (14.7) | (14.4) | (12.3) | 0.036   | (14.8) | (13.5) | (14.6) | 0.127   | (12.3) | (14.6) | 0.003   |
| Female, n (%)          | (18.9) | (15.7) | (26.4) | 0.019   | (17.8) | (16.2) | (17.6) | 0.669   | (26.4) | (17.6) | 0.056   |
| Transfer mode, n (%)   | 22     | 45     | 7      | 0.007   | 48     | 43     | 13     | 0.482   | 7      | 13     | 0.666   |
| Directly via EMS       | (7.9)  | (16.9) | (5.8)  |         | (9.1)  | (9.3)  | (4.2)  |         | (5.8)  | (4.2)  |         |
| In-hospital            | (2.9)  | (2.2)  | (5.0)  |         | (2.1)  | (0.9)  | (2.9)  |         | (5.0)  | (2.9)  |         |

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|                        | 82   | 59   | 34   | 145  | 129  | 88   | 34   | 88   |
|------------------------|------|------|------|------|------|------|------|------|
| Transfer-in            | (29.3) | (22.1) | (28.1) | (27.5) | (27.9) | (28.8) | (28.1) | (28.8) |
| Directly by self       | (60.0) | (58.8) | (61.2) | (61.4) | (62.0) | (64.1) | (61.2) | (64.1) |
| Clinical characteristics|      |      |      |      |      |      |      |      |
| Sustainable chest pain, | 211  | 188  | 93   | 406  | 343  | 240  | 93   | 240  |
| n (%)                  | (75.4) | (70.4) | (76.9) | (76.9) | (74.1) | (78.4) | (76.9) | (78.4) |
| Intermittent chest pain,| 55   | 45   | 17   | 79   | 82   | 41   | 17   | 41   |
| n (%)                  | (19.6) | (16.9) | (14.0) | (15.0) | (17.7) | (13.4) | (14.0) | (13.4) |
| Chest pain relief, n (%)| 7    | 4    | 4    | 8    | 2    | 8    | 4    | 8    |
| (2.5)                  | (1.5) | (3.3) | (1.5) | (0.4) | (2.6) | (3.3) | (2.6) |
| Respiratory rate       | 18.1 | 18.3 | 18.3 | 18.1 | 18.2 | 18.2 | 18.3 | 18.2 |
| (breaths/min)*         | (3.6) | (3.9) | (3.2) | (2.9) | (3.4) | (3.7) | (3.2) | (3.7) |
| Pulse frequency        | 79.1 | 78.0 | 78.0 | 77.2 | 73.4 | 76.3 | 78.0 | 76.3 |
| (pulse/min)*           | (19.8) | (18.9) | (23.7) | (18.0) | (18.8) | (21.2) | (23.7) | (21.2) |
| Heart rate (beats/min)*| 79.2 | 77.8 | 78.2 | 77.1 | 73.6 | 76.1 | 78.2 | 76.1 |
| (19.7)                 | (19.7) | (23.5) | (17.9) | (18.9) | (21.2) | (23.5) | (21.2) |
| Systolic blood pressure| 130.3 | 133.0 | 128.3 | 132.2 | 133.3 | 131.3 | 128.3 | 131.3 |
| (mm Hg)*               | (30.5) | (28.3) | (27.8) | (28.0) | (29.4) | (29.1) | (27.8) | (29.1) |

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|                      | Diastolic blood pressure (mm Hg)* | Killip Class (%) |
|----------------------|-----------------------------------|------------------|
|                      | 81.1 (20.3) 82.6 (17.9) 79.1 (19.5) | 195 (79.9) 173 (84.4) 89 (74.2) |
|                      | 0.354 0.083 0.354 0.083 0.354 0.083 | 0.632 0.120 0.632 0.120 0.632 0.120 |
|                      | 82.8 (18.8) 83.7 (20.0) 82.0 (19.0) | 395 (84.9) 344 (88.0) 251 (82.6) |
|                      | 0.479 0.255 0.479 0.255 0.479 0.255 | 0.485 0.129 0.485 0.129 0.485 0.129 |
|                      | 79.1 (19.5) 82.0 (19.0)            | 89 (74.2) 251 (82.6) |
|                      | 0.155                               | 0.144            |

* Mean (SD)
Table 2. Quality metrics of STEMI care during the COVID-19 outbreak and the post COVID-19 era, compared with corresponding periods in 2018 and 2019

|                      | Outbreak period of 2020 compared with corresponding period of 2018 and 2019 | Post-outbreak period of 2020 compared with corresponding period of 2018 and 2019 | Outbreak period compared with post-outbreak period of 2020 |
|----------------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------|-----------------------------------------------------------|
|                      | 2018.0 2019.0 2020.0 (2018 vs 2019)                                         | 2018.0 2019.0 2020.0 (2018 vs 2019)                                          | 2020.0 2020.0                                             |
|                      | 1.23-0 1.23-0 1.23-0                                                       | 3.28-0 3.28-0 3.28-0 vs vs                                                    | 1.23-0 3.28-0 P                                          |
|                      | 3.27 3.27 3.27 2019 (2019)                                                  | 7.31 7.31 7.31 2019 (2020)                                                   | 3.27 7.31                                               |
| Admissions for STEMI | 280 267 121                                                                  | 528 463 306                                                                    | 121 306                                                  |
| Pre-hospital process indicators |                              |                                                                              |                                                          |
| Percent of cases arriving at the first hospital by ambulance, n (%) | 22 (7.9) 45 (16.9) 7 (5.8) 0.002 0.005                                           | 48 (9.1) 43 (9.3) 13 (4.2) 1.000 0.013                          | 7 (5.8) 13 (4.2) 0.672                                   |
| Pre-hospital ECGs, n (%) | 70 (25.0) 85 (31.8) 35 (28.9) 0.093 0.648                                  | 121 (22.9) 138 (29.8) 94 (30.7) 0.017 0.849                                  | 35 (28.9) 94 (30.7) 0.805                                |
| Onset-to-FMC (EMS arrival or walk-in to ED) time ≤60 min, n (%) | 90 (34.0) 94 (38.1) 35 (28.9) 0.383 0.108                               | 182 (35.5) 144 (32.9) 102 (33.3) 0.439 0.959                        | 35 (28.9) 102 (33.3) 0.445                               |
### Ambulance ECG-to-door time for ambulance transported cases ≤15 min, n (%)

| Time Interval | ≤15 min | >15 min | p-value |
|---------------|---------|---------|---------|
| 5             | 0.019   | 0.052   | 0.019   |
| 18            | 0.129   | 0.256   | 0.019   |
| 3             | 0.964   | 0.964   | 0.964   |

### In-hospital process indicators

| Indicator                        | ≤60 min | >60 min | p-value |
|----------------------------------|---------|---------|---------|
| β-blocker usage, n (%)           | (54.1)  | (54.0)  | <0.001  |
| Door-to-balloon time ≤60 min, n (%) | (100.0) | (100.0) | 0.009   |
| FMC-to-device time ≤90 min, n (%) | (68.1)  | (75.6)  | 0.193   |
| Onset-to-device time ≤120 min, n (%) | (27.6)  | (40.6)  | 0.269   |

| Door-to-balloon time, median (q1, q3) | 12.0, 30.0 | 11.0, 37.6 | 0.033, 0.180 |
| FMC-to-device time, median (q1, q3) | 12.0, 52.0 | 11.0, 52.0 | 0.062, 0.180 |
| Outcome indicators | Onset-to-device time, median (q₁, q₃) | PCI rate, n (%) | In-hospital mortality, n (%) |
|--------------------|--------------------------------------|----------------|------------------------------|
| | 222.5 [116.5, 165.5], 132.0 [74.5, 126.5], 192.5 [126.5, 388.8] | 0.012 0.052 | 0.080 0.276 |
| | 145.5 [93.8, 107.0], 145.0 [94.5, 107.0], 143.0 [126.5, 0.939 0.583 | 0.021 0.002 | 0.021 0.002 |
| | 192.5 [126.5, 395.8], 143.0 [107.0, 236.2], 145.0 [94.5, 250.5] | 0.052 0.002 | 0.052 0.002 |
| | 193 [68.9], 164 [61.4], 82 [67.8] | 0.012 0.052 | 0.012 0.052 |
| | 339 [64.2], 330 [71.3], 184 [60.1] | 0.021 0.002 | 0.021 0.002 |
| | 82 [67.8], 184 [60.1] | 0.124 0.002 | 0.124 0.002 |
| | 9 (3.2), 5 (2.1), 7 (6.0) | 0.080 0.276 | 0.080 0.276 |
| | 5 (2.1), 13 (2.8), 7 (4.1) | 0.021 0.002 | 0.021 0.002 |
| | 11 (2.1), 13 (2.8), 12 (4.1) | 0.059 0.442 | 0.059 0.442 |
| | 7 (6.0), 12 (4.1) | 0.572 0.572 | 0.572 0.572 |
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