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# Quality of healthcare and Admission Rates for Acute Cardiac Events during COVID-19 pandemic: a retrospective cohort study on ST-Segment-Elevation Myocardial Infarction in China

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Quality of healthcare and Admission Rates for Acute Cardiac Events during COVID-19 pandemic: a retrospective cohort study on ST-Segment-Elevation Myocardial Infarction in China

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\textbf{Short title:} Healthcare Quality for STEMI during COVID-19 pandemic

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Abstract

Objective: To evaluate changes in admission rates for and quality of healthcare of STEMI during the period of the COVID-19 outbreak and post outbreak.

Methods: We conducted a retrospective cohort study among patients with STEMI in the outbreak time and the post-outbreak time.

Design To examine the changes in the admission rates and in quality of healthcare, by comparison between periods of the post-outbreak and the outbreak, and between the post-outbreak and the corresponding periods.

Setting Data for this analysis were included from patients discharge diagnosed with STEMI from all the hospitals of Suzhou in each month of the year until the end of July 2020.

Participants 1,965 STEMI admissions.

Primary and secondary outcome measures The primary outcome was the number of monthly STEMI admissions, and the secondary outcomes was the quality metrics of STEMI healthcare.

Results: There were a 53% and 38% fall in daily admissions at the phase of outbreak and post-outbreak, compared with the 2019 corresponding. There remained a gap in actual number of admissions at 306 and the predicted number at 497. An estimated 26 deaths due to STEMI would have been caused by not seeking healthcare. The percentage of cases transferred by ambulance decreased from 9.3% to 4.2% (P=0.013), the door-to-balloon median time increased from 17.5 to 34.0 minutes (p=0.001) and the rate of PCI therapy declined from 71.3% to 60.1% (p=0.002).
Conclusions: The impact of public health restrictions may lead to unexpected out-of-hospital deaths and compromised quality of healthcare for acute cardiac events. Delay or absence in 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

COVID-19, Myocardial infarction, Quality in health care
Strengths and limitations of this study

- China has recovered from the initial outbreak and is experiencing the defense of the coronavirus bounce back, it’s suitable for research in the post-outbreak era.

- First study to examine the changes in the admission rates and in quality of healthcare between the post-outbreak and the corresponding periods in China, with the fading of the COVID-19 outbreak.

- Findings suggest that the impact of public health restrictions in the post-outbreak time is still significant, and may lead to unexpected out-of-hospital deaths and compromised quality of healthcare for acute cardiac events.

- This study was limited to Suzhou which limits the generalizability of the results, also it's a dynamic cohort study, there would be concerns related to confounding, bias, and temporal trends in quality of healthcare that might limit the validity of the findings.
Introduction

The coronavirus disease 2019 (COVID-19) pandemic is challenging healthcare delivery systems in unprecedented ways, and the effects will last for decades to come.\textsuperscript{1} 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 outbreak can compromise quality of healthcare for non-coronavirus diseases, especially for ST-Segment-Elevation Myocardial Infarction (STEMI), the deadliest and most time-sensitive acute cardiac event.\textsuperscript{2-4} A number of studies have reported substantial declines in the number of patients presenting with STEMI and the rate of percutaneous coronary intervention (PCI), the typically recommended treatment, during the outbreak.\textsuperscript{5-9} However, little is known regarding the impact of the post-outbreak on admission rate and healthcare quality for STEMI.

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 healthcare in the post-outbreak time: (i) delays in presentation, and (ii) delays in treatment.\textsuperscript{10-12} First, less is clear on whether there has 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.\textsuperscript{13} 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.\textsuperscript{14,15} Even yet in
the period of post-outbreak, the emphasis on social distancing might have inappropriately convinced patients to avoid in-person healthcare. 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 healthcare in a timely manner, which will lead to more unexpected out-of-hospital deaths and cause the secondary disaster of the outbreak.

Second, little is known regarding how the post-outbreak influenced the delivery of STEMI healthcare in terms of clinical services and processes based on the recommended guidelines. STEMI cases require rapid coordination of care beginning at the time once patients enter the healthcare delivery system. 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 healthcare delivery system to make a balance between identifying patients for PCI procedure, regardless of their coronavirus status, and maintaining the safety of healthcare 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 healthcare delivery 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 healthcare of STEMI in the post-outbreak time. The objectives of this study are two-
fold as follows: (1) to examine the changes in the admission rates, by comparing the numbers in the outbreak and post-outbreak with the predicted numbers based on the admissions in 2017-2019; (2) to investigate the changes in quality of healthcare, by comparison between periods of the post-outbreak and the outbreak, and between the post-outbreak and the corresponding periods in 2017-2019.

Materials and Methods

Data Statement

Data for this study were obtained from the China Chest Pain Center Database (http://data.chinacpc.org/), a nationwide clinical registry for collecting data of all consecutive patients diagnosed with STEMI enrolled by hospitals. 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 National Health Commission. 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 all the hospitals with capacity of PCI therapy in the city of 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 routine work and industry production.

Study Design

We conducted a retrospective cohort study of patients presenting with STEMI
between January of 2017 and July of 2020. The outbreak time was defined as period between January 23, 2020 and March 27, 2020, corresponding to the promulgation of the highest restrictions of movement and a public health drive to combat rising cases in Suzhou. The post-outbreak time was defined as period between March 28, 2020, and July 31, 2020 corresponding to the announcement of resumption of daily work and industry production by Suzhou Government. Data for this analysis were included from patients discharge diagnosed with STEMI from all the hospitals of Suzhou in each month of the year 2017-2019 until the end of July 2020.

**Measures**

The primary outcome was the number of monthly STEMI admissions, and the secondary outcomes was the quality metrics of STEMI healthcare 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 prehospital process indicators included percentage of onset-to-first medical contact (FMC) time ≤60 min, percentage of ambulance electrocardiogram (ECG) to door time ≤15 min, percentage of cases arriving at hospital by ambulance, percentage of ambulance ECG. The in-hospital process indicators included percentage of β-blocker usage, percentage of door-to-balloon time ≤60 min, percentage of FMC-to-device time ≤90 min, percentage of onset-to-device time ≤120 min, door-to-balloon time, FMC-to-device time, onset-to-device time, and PCI rate. The clinical outcome
indicator was 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**

A descriptive analysis presented the daily admission rates and median monthly onset-to-PCI time of STEMI patients over the periods of the post-outbreak time to the corresponding period in 2017-2019. To provide a more intuitive interpretation of unexpected out-of-hospital deaths, we predicted the number of admissions that should be in the post-outbreak time 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 common forecasting algorithm which weighted average of past observations with exponentially decaying weights to capture the trend in a time-series dataset\(^\text{19}\). The smoothing parameters were automatically generated prior modeling with Holt-Winters method. The \(\alpha\) (level), \(\beta\) (slope) and \(\gamma\) (seasonality) of trend 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. \(^{20}\) The predicated death number due to the lack of seeking healthcare was calculated by the forecast formula: \((\text{predicated numbers} - \text{actual numbers}) \times 8\%\) (average death rate in China) \(^{21,22}\).
To examine changes in quality metrics of STEMI healthcare, we compared the list of indicators in terms of prehospital process, in-hospital process, and clinical outcome, by a subsample of respective periods, including the outbreak period and the corresponding periods in 2019 and 2018, the post-outbreak 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 1,965 admissions for STEMI, of which 121 and 306 were in the outbreak and the post-outbreak time, respectively. Of those 306 patients in the post-outbreak time, 17.6% were women, with a mean age of 60.7 (SD 14.6) years. During the 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-outbreak time, respectively (Table 1).

Daily Admissions for STEMI

Figure 1 demonstrates daily admissions for STEMI over the periods of outbreak and post-outbreak to the corresponding time in 2018 and 2019. The percentage reduction in admissions were 57% and 55% between the 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-outbreak time, 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 during the outbreak and the post-outbreak. 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 outbreak and the post-outbreak time was 259 and 497. There were a 53% and 38% decline in admissions, with the actual numbers of 121 and 306. Predicted numbers of monthly admissions for STEMI are shown in Supplement Table 2. Based on the forecast formula, the predicted death number due to STEMI caused by the lack of seeking healthcare was 26.

Quality Metrics of STEMI Healthcare

Figure 3 presents the median monthly treatment delay for STEMI healthcare, 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 healthcare, by comparison between periods of the post-outbreak and the outbreak, and between the post-outbreak
and the corresponding periods in 2018-2019. The percentage of STEMI cases transferred by ambulance was both 4.2% in the outbreak and post-outbreak time, respectively, lower than those in the corresponding period of 2019 (16.9%, P=0.005; 9.3%, P=0.013). During the post-outbreak to the corresponding period of 2019, the 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 therapy 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 healthcare between the outbreak and post-outbreak time showed insignificant, with the percentage of cases transferred by ambulance, the percentage of onset-to-FMC time ≤60 min, the percentage of onset-to-device time ≤120 min, and the PCI rate decreasing, and the door-to-balloon time increasing.

Discussion

Principal Findings

This is, to our knowledge, the first study to investigate the changes in admissions for and quality of healthcare among acute cardiac events in the post-outbreak time, 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-outbreak time 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 healthcare, while no one died from COVID-19 in the post-outbreak time in
the city of Suzhou. 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 healthcare,
which could lead to over 20,000 death during the post-outbreak of study. Quality of
STEMI healthcare remained suboptimal in the post-outbreak time, comparing with
those in the corresponding periods in 2018-2019, especially for the percentage of
cases transferred by EMS, and the in-hospital process indicators. Although the in-
hospital mortality declined during the outbreak to the post-outbreak, the change was
not significant. These findings suggest that the impact of public health restrictions in
the post-outbreak time is still significant, and may lead to unexpected out-of-hospital
deaths and compromised quality of healthcare for acute cardiac events.

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 therapy during the outbreak. Previous studies using the self-controlled case
series method provided evidence that the outbreak may increase the risk of STEMI
during the acute phase of infection. However, the reduced number of admissions
during the outbreak is likely to have resulted in increases in out-of-hospital deaths and
long-term complications. Our current study focuses on the post-outbreak time, 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 outbreak and the corresponding period of 2019, and the post-outbreak 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-outbreak time in comparison with the corresponding period of 2019. Causes for less presentation for healthcare are likely multifactorial and most researches emphasize that patients may be reluctant to present to hospitals because of the fear of contracting the coronavirus 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 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, hospitals are encouraged to establish a medical consortium of STEMI healthcare. Hospitals are partnered with community healthcare centers to form an information-sharing and resource-management model. Community healthcare workers conduct management of STEMI healthcare 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 hospitals remain fully operational and have stringent infection-control protocols in place even in the post-outbreak time.

Obviously national lockdowns and altered healthcare priorities in response to COVID-19 outbreak are affecting the diagnosis and treatment of STEMI. According to Consensus 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. In fact, most hospitals 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 intervals of the
treatment delay including patient delay and system delay (including prehospital delay and in-hospital delay). Notably, the extension in patient delay showed no significant during the post-outbreak and the corresponding periods of 2018-2019. We observed a significant prolongation of the door-to-balloon time and the FMC-to-device time, mainly due to the requirement of testing negativity for coronavirus infection.

Meanwhile, a 12-point percentage of decline in rate of PCI therapy was observed over the period of the post-outbreak and the corresponding periods in 2019. Thus, even in the post COVID-19 era, delays in the 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 the in-hospital mortality increased from 2.1% to 6.0% between the outbreak and the corresponding period of 2019, and the in-hospital mortality declined from the outbreak to the post-outbreak time, but 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-outbreak time were about 5 years younger and had a 13-point lower percentage of female, comparing those in the outbreak time. 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.28,29 Nevertheless, data of our study provides additional information that neither the risk profile of patients
hospitalized with STEMI has significantly changed in the post-outbreak time and nor
have the clinical outcomes. Second is the treatment approaches for patients
hospitalized with STEMI. The rates of PCI therapy persisted about 60% during the
outbreak and the post-outbreak, 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 the PCI therapy as a result of the COVID-19 pandemic. These results
were coupled with delays in the PCI therapy, pointing to the persistently high in-
hospital mortality during the outbreak and the post-outbreak. Clinical outcome in
patients with STEMI in the post-outbreak time might be influenced by the delay to
treatment and less use of PCI therapy. Therefore, it is imperative to improve the
healthcare delivery system’s ability to maintain healthcare coordination for timely
PCI with respect to STEMI cases. Prior studies have shown that a dedicated
coordinator from a medical consortium of STEMI healthcare could play a critical role
in maintaining coordination of healthcare, in charge of coordination of community
healthcare centers, hospitals and EMS agencies, and collaboration of multidisciplinary
teams including the cardiology department, emergency department, infections
department, pneumology department, and the medical laboratory department.

Limitations

This study has several limitations. First, in a dynamic cohort study, there would
be concerns related to confounding, bias, and temporal trends in quality of healthcare
that might limit the validity of the findings. However, we compared the changes in the
quality metrics of healthcare 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 merely underestimate the impact of the COVID-19 outbreak and the post COVID-19 era on quality of healthcare. 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 lead to develop chest pain centers accredited by National Health Commission to guide standardized prehospital and in-hospital STEMI healthcare 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 healthcare 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.
Author Contributions

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, Mailikezhati Maimaitiming, Dahai Yue.

Contributorship statement

We thank the Suzhou Emergency Center for providing the data and sharing comments for the study’s findings.

Competing interests

None.

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Data sharing statement

Data for this study were obtained from the China Chest Pain Center Database.

(http://data.chinacpc.org/)
Ethics Statement

Ethics approvals of the study have been obtained from the Peking University Health Science Center Institutional Review Board (IRB00001052-21020). Informed consent was obtained from hospitals for research approval to collect data in the study.

Abbreviations

STEMI: ST-segment-elevation myocardial infarction; COVID-19: coronavirus disease 2019; PCI: percutaneous coronary intervention; FMC: first medical contact; EMS: emergency medical service; ACC/AHA: American College of Cardiology/American Heart Association

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**Figures Legends**

Figure 1. Daily admissions to hospitals among patients diagnosed with STEMI in Suzhou of China

Figure 2. Predicated monthly admissions for STEMI in Suzhou of China

Figure 3. Monthly mean delay time for healthcare of STEMI, by patient delay, transfer delay and in-hospital delay in Suzhou of China

**Supplement**

Supplement Table 1. Definition and measures of quality metrics of STEMI healthcare
Supplement Table 2. Predicated number of admissions for STEMI by each month in Suzhou of China
Table 1. Characteristic of STEMI patients during the outbreak and the post-outbreak, compared with corresponding periods in 2018 and 2019

|                          | Outbreak period of 2020 compared with | Post-outbreak period of 2020 compared with | Outbreak period compared with post-outbreak period of 2020 |
|--------------------------|----------------------------------------|---------------------------------------------|----------------------------------------------------------|
|                          | corresponding period of 2018 and 2019   | corresponding period of 2018 and 2019        | 2020.0 vs 2020.0                                         |
| Admissions for STEMI     | 280 (1.23-03.27)                       | 528 (3.28-07.31)                            | 121 (1.23-03.27)                                         |
| Age (years)*             | 61.5 (14.7)                            | 60.1 (14.6)                                | 65.2 (12.3)                                              |
| Female, n (%)            | 53 (18.9)                              | 94 (16.2)                                  | 7 (5.8)                                                  |
| Transfer mode, n (%)     | 22 (7.9)                               | 48 (9.1)                                   | 7 (5.8)                                                  |
| Directly via EMS         | 168 (58.8)                             | 168 (61.4)                                 | 168 (61.4)                                               |
| In-hospital              | 168 (58.8)                             | 168 (61.4)                                 | 168 (61.4)                                               |
| Transfer-in              | 168 (58.8)                             | 168 (61.4)                                 | 168 (61.4)                                               |
| Clinical characteristics  |                                        |                                            |                                                         |
| Sustainable chest pain,  | 211 (75.4)                             | 406 (76.9)                                 | 93 (76.9)                                                |
| n (%)                    | (75.4)                                 | (76.9)                                     | (76.9)                                                   |
| Intermittent chest pain, | 55 (17.8)                              | 79 (16.2)                                  | 17 (17.6)                                                |
|                          | (n) | (%)   | (n) | (%)   | (n) | (%)   | (n) | (%)   |
|--------------------------|-----|-------|-----|-------|-----|-------|-----|-------|
| Chest pain relief, n (%) |     |       |     |       |     |       |     |       |
|                          | 7   | 4     | 4   |       | 8   | 2     | 8   |       |
|                          | (2.5)| (1.5) | (3.3)|       | (1.5)| (0.4) | (2.6)|       |
|                          | 0.596| 0.438 |     |       | 0.166| 0.022 |     |       |
|                          | 0.288| 0.188 |     |       | 0.002| 0.052 |     |       |
|                          | 0.948| 0.658 |     |       | 0.350| 0.271 |     |       |
| Respiratory rate         |     |       |     |       |     |       |     |       |
| (breaths/min)*           | 18.1| 18.3  | 18.3|       | 18.1| 18.2  | 18.2|       |
|                          | 0.485| 0.961 |     |       | 0.666| 0.887 |     |       |
|                          | 0.002| 0.052 |     |       | 0.004| 0.091 |     |       |
|                          | 0.462| 0.462 |     |       | 0.367| 0.367 |     |       |
| Pulse frequency          |     |       |     |       |     |       |     |       |
| (pulse/min)*             | 79.1| 78.0  | 78.0|       | 77.2| 73.4  | 76.3|       |
|                          | 0.513| 0.986 |     |       | 0.002| 0.052 |     |       |
|                          | 0.002| 0.052 |     |       | 0.004| 0.091 |     |       |
|                          | 0.462| 0.462 |     |       | 0.367| 0.367 |     |       |
| Heart rate (beats/min)*  |     |       |     |       |     |       |     |       |
|                          | 79.2| 77.8  | 78.2|       | 77.1| 73.6  | 76.1|       |
|                          | 0.380| 0.838 |     |       | 0.004| 0.091 |     |       |
|                          | 0.002| 0.052 |     |       | 0.004| 0.091 |     |       |
|                          | 0.367| 0.367 |     |       | 0.350| 0.271 |     |       |
| Systolic blood pressure  |     |       |     |       |     |       |     |       |
| (mm Hg)*                 | 130.3| 133.0 | 128.3|       | 132.2| 133.3 | 131.3|       |
|                          | 0.274| 0.122 |     |       | 0.568| 0.360 |     |       |
|                          | 0.479| 0.255 |     |       | 0.479| 0.255 |     |       |
|                          | 0.155| 0.155 |     |       | 0.155| 0.155 |     |       |
| Diastolic blood pressure |     |       |     |       |     |       |     |       |
| (mm Hg)*                 | 81.1 | 82.6  | 79.1|       | 82.8 | 83.7  | 82.0|       |
|                          | 0.354| 0.083 |     |       | 0.479| 0.255 |     |       |
|                          | 0.479| 0.255 |     |       | 0.479| 0.255 |     |       |
|                          | 0.155| 0.155 |     |       | 0.155| 0.155 |     |       |
| Killip Class (%)         |     |       |     |       |     |       |     |       |
| I                        | 195 | 173   | 89  |       | 395 | 344   | 251 |       |
|                          | (79.9)| (84.4)| (74.2)|       | (84.9)| (88.0)| (82.6)|       |
|                          | 0.632| 0.120 |     |       | 0.485| 0.129 |     |       |
|                          | 0.144| 0.144 |     |       | 0.144| 0.144 |     |       |
| II                       | 22  | 15    | 12  |       | 31  | 17    | 14  |       |
|                          | (9.0)| (7.3) | (10.0)|       | (6.7)| (4.3) | (4.6)|       |
|                          | 0.332| 0.123 |     |       | 0.222| 0.091 |     |       |
|                          | 0.144| 0.144 |     |       | 0.144| 0.144 |     |       |
| III                      | 8   | 4     | 6   |       | 10  | 7     | 12  |       |
|                          | (3.3)| (2.0) | (5.0)|       | (2.2)| (1.8) | (3.9)|       |
|                          | 0.293| 0.100 |     |       | 0.222| 0.091 |     |       |
|                          | 0.144| 0.144 |     |       | 0.144| 0.144 |     |       |
| IV                       | 19  | 13    | 13  |       | 29  | 23    | 27  |       |
|                          | (7.8)| (6.3) | (10.8)|       | (6.2)| (5.9) | (8.9)|       |
|                          | 0.108| 0.089 |     |       | 0.108| 0.089 |     |       |

* Mean (SD)
Table 2. Quality metrics of STEMI healthcare during the outbreak and the post-outbreak, 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 vs 2019)  | 2018.0 2019.0 2020.0  | P (2018 vs 2019)  | 2020.0 2020.0  | P |
| Admissions for STEMI        | 280 267 121  |  0.002 0.005 | 528 463 306  |  1.000 0.013 | 121 306  |  0.672 |

**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 (%) | 5 (7.2) 18 (22.5) 3 (8.6)  | 0.019 0.129 | 5 (4.2) 16 (11.8) 6 (6.4)  | 0.052 0.256 | 3 (8.6) 6 (6.4)  | 0.964 |

**In-hospital process indicators**

| β-blocker usage, n (%) | 124 (54.1) 100 (46.5) 33 (31.1)  | 0.130 0.012 | 207 (54.0) 188 (50.4) 46 (18.0)  | 0.352 <0.001 | 33 (31.1) 46 (18.0)  | 0.009 |
| Door-to-balloon time ≤60 | 76 (76) 82 (82) 38 (38)  | - - | 127 (76) 188 (82) 93 (38)  | - - | 38 (76) 93 (82)  | - |
|                         | FMC-to-device time ≤90 | Onset-to-device time ≤120 | Door-to-balloon time, median (q₁, q₃) | PCI rate, n (%) | Outcome indicators |
|-------------------------|------------------------|---------------------------|--------------------------------------|-----------------|-------------------|
|                         | min, n (%)             | min, n (%)                 | Door-to-balloon time, median (q₁, q₃) |                 |       |
|                         | (100.0) (100.0) (100.0) | (100.0) (100.0) (100.0) | (100.0) (100.0) (100.0) | (100.0) (100.0) |       |
| FMC-to-device time      | 47 (68.1) 66 (89.2) 32 (84.2) | 21 (27.6) 35 (46.1) 9 (23.7) | 32.0 [12.0, 51.5] [116.5, 222.5] | 193 (68.9) 164 (61.4) 82 (67.8) |       |
| (min, n (%))            | 0.004 0.029 0.002 | 0.029 0.035 0.004 | 0.104 0.012 0.012 | 0.080 0.080 0.080 |       |
|                         | 0.651 0.035 0.004 | 0.035 0.048 0.004 | 0.396 0.052 0.052 | 0.276 0.276 0.276 |       |
|                         | (10.0) (100.0) (100.0) | (100.0) (100.0) (100.0) | (100.0) (100.0) (100.0) | (100.0) (100.0) |       |
|                         | 93 (75.6) 132 (80.0) 68 (71.6) | 52 (30.0) 70 (17.5) 34 (34.0) | 145.5 [14.0, 51.0] [145.5, 354] | 339 (64.2) 330 (71.3) 184 (60.1) |       |
|                         | 0.455 0.650 0.650 | 0.839 0.650 0.650 | 0.002 0.012 0.012 | 0.021 0.021 0.021 |       |
|                         | (100.0) (100.0) (100.0) | (100.0) (100.0) (100.0) | (100.0) (100.0) (100.0) | (100.0) (100.0) |       |
|                         | 32 (23.7) 68 (35.4) | 9 (23.7) 34 (35.4) | 49.8 [13.0, 52.5] [192.5, 392.5] | 63.0 [15.0, 63.0] [143.0, 354] |       |
|                         | 0.001 0.269 0.193 | 0.455 0.984 0.062 | 0.001 0.001 0.001 | 0.180 0.062 0.062 |       |

**Outcome indicators**

|                         | In-hospital mortality, n (%) |
|-------------------------|------------------------------|
|                         | (100.0) (100.0) (100.0)     | (100.0) (100.0) (100.0) |
|                         | 9 (3.2) 5 (2.1) 7 (6.0) | 11 (3.2) 13 (2.8) 12 (4.1) |
|                         | 0.585 0.080 0.080 | 0.100 0.276 0.276 | 0.590 0.021 0.021 | 0.442 0.021 0.021 | 0.572 0.021 0.021 |
|                         | (100.0) (100.0) (100.0) | (100.0) (100.0) (100.0) |
|                         | 7 (2.1) 12 (4.1) | 7 (2.1) 12 (4.1) | 7 (2.1) 12 (4.1) | 7 (2.1) 12 (4.1) | 0.572 0.021 0.021 |
Figure 1. Daily admissions to hospitals among patients diagnosed with STEMI in Suzhou of China
Figure 2. Predicated monthly admissions for STEMI in Suzhou of China
Figure 3. Monthly mean delay time for healthcare of STEMI, by patient delay, transfer delay and in-hospital delay in Suzhou of China
**Supplement Table 1. Definition and measures of quality metrics of STEMI healthcare**

| Pre-hospital process indicators | Definition                                                                 | Measures                                                                 |
|---------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Onset-to-FMC (EMS arrival or walk-in to ED) time $\leq 60$ min, n (%) | Percentage of patient onset time to first medical contact (FMC) time less than or equal 60 minutes | $(\text{Cases Onset-to-FMC} \leq 60 \text{ min})/(\text{Cases with onset time and FMC time})$ |
| Ambulance ECG to door time for ambulance transported cases $\leq 15$ min, n (%) | Percentage of ambulance transported patient pre-hospital ECG time to door time less than or equal 15 minutes | $(\text{Cases Ambulance ECG to door time} \leq 15 \text{ min})/(\text{Cases with pre-hospital ECG time and door time})$ |
| Percent of cases arriving at the first hospital by ambulance, n (%) | Percentage of cases arriving at the first hospital by ambulance among all transfer mode | $(\text{Cases arriving at the first hospital by ambulance})/(\text{All cases})$ |
| Pre-hospital ECGs, n (%) | Percentage of cases use pre-hospital ECGs among all ambulance transported cases | $(\text{Cases with pre-hospital ECG})/(\text{Cases arriving at the first hospital by ambulance})$ |

| Hospital process indicators | Definition                                                                 | Measures                                                                 |
|-----------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------|
| $\beta$-blocker usage, n (%) | Percentage of patient use $\beta$-blocker                                 | $(\text{Cases use } \beta\text{-blocker})/(\text{All cases})$ |
| Door-to-balloon time $\leq 60$ min, n (%) | Percentage of PCI patient door time to balloon time less than or equal 60 minutes | $(\text{PCI cases door-to-balloon time} \leq 60 \text{ min})/(\text{PCI Cases with door time and balloon time})$ |
| FMC-to-device time $\leq 90$ min, n (%) | Percentage of PCI and thrombolysis patient first medical contact time to device time less than or equal 90 minutes | $(\text{PCI and thrombolysis cases FMC-to-device time} \leq 90 \text{ min})/(\text{PCI and thrombolysis Cases with FMC time and device time})$ |
| Onset-to-device time $\leq 120$ min, n (%) | Percentage of PCI and thrombolysis patient onset time to device time less than or equal 90 minutes | $(\text{PCI and thrombolysis cases onset-to-device time} \leq 120 \text{ min})/(\text{PCI and thrombolysis Cases with onset time and device time})$ |
| Door-to-balloon time, median ($q_1$, $q_3$) | Median of door to balloon time for PCI patient                            | Balloon time – door time (min)                                          |
| FMC-to-device time, median ($q_1$, $q_3$) | Median of FMC to device time for PCI patient                              | device time – FMC time(min)                                             |
| Outcome indicators           | Description                                                                 | Formula                                      |
|-----------------------------|-----------------------------------------------------------------------------|----------------------------------------------|
| Onset-to-device time, median (q₁, q₃) | Median of onset to device time for PCI patient = device time – onset time(min) | = device time – onset time(min)              |
| PCI rate, n (%)             | Percentage of patients take PCI among all patients                           | = (Cases of PCI)/(All cases)                 |
| In-hospital mortality, n (%)| Percentage of patient died in hospital                                      | = (Cases of died patient)/(All cases)        |
Supplement Table 2. Predicated number of admissions for STEMI by each month in Suzhou of China

| Time period                        | Mean | Lower 80% | Lower 95% | Upper 80% | Upper 95% |
|------------------------------------|------|-----------|-----------|-----------|-----------|
| 1st January, 2020-31st January, 2020 | 136  | 107       | 94        | 173       | 197       |
| 1st February, 2020-28th February, 2020 | 107  | 85        | 75        | 135       | 153       |
| 1st March, 2020-31st March, 2020   | 129  | 101       | 88        | 166       | 189       |
| 1st April, 2020-30th April, 2020   | 107  | 84        | 73        | 137       | 156       |
| 1st May, 2020-31st May, 2020       | 122  | 94        | 82        | 158       | 181       |
| 1st June, 2020-30th June, 2020     | 135  | 103       | 89        | 177       | 204       |
| 1st July, 2020-31st July, 2020     | 116  | 89        | 77        | 151       | 174       |
# Reporting checklist for cohort study.

Based on the STROBE cohort guidelines.

## Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

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In your methods section, say that you used the STROBE cohort reporting guidelines, and cite them as:

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| Reporting Item | Page Number |
|----------------|-------------|
| **Title and abstract** | |
| Title | #1a | Indicate the study's design with a commonly used term in the title or the abstract | 1 |
| Abstract | #1b | Provide in the abstract an informative and balanced summary of what was done and what was found | 2-3 |
| **Introduction** | |
| Background / rationale | #2 | Explain the scientific background and rationale for the investigation being reported | 5-7 |
| Objectives | #3 | State specific objectives, including any prespecified hypotheses | 7-8 |
| **Methods** | |
| Study design | #4 | Present key elements of study design early in the paper | 8 |
| Setting | #5 | Describe the setting, locations, and relevant dates, including periods | 8-9 |
Eligibility criteria #6a Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up.

Eligibility criteria #6b For matched studies, give matching criteria and number of exposed and unexposed participants.

Variables #7 Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.

Data sources / measurement #8 For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for exposed and unexposed groups if applicable.

Bias #9 Describe any efforts to address potential sources of bias.

Study size #10 Explain how the study size was arrived at.

Quantitative variables #11 Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why.

Statistical methods #12a Describe all statistical methods, including those used to control for confounding.

Statistical methods #12b Describe any methods used to examine subgroups and interactions.

Statistical methods #12c Explain how missing data were addressed.

Statistical methods #12d If applicable, explain how loss to follow-up was addressed.

Statistical methods #12e Describe any sensitivity analyses.

Results

Participants #13a Report numbers of individuals at each stage of study—e.g., numbers potentially eligible, examined for eligibility, confirmed eligible,
included in the study, completing follow-up, and analysed. Give information separately for exposed and unexposed groups if applicable.

Participants #13b Give reasons for non-participation at each stage 10

Participants #13c Consider use of a flow diagram

10

Descriptive data #14a Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable. 10

Descriptive data #14b Indicate number of participants with missing data for each variable of interest 11

Descriptive data #14c Summarise follow-up time (eg, average and total amount) 11

11

Outcome data #15 Report numbers of outcome events or summary measures over time. Give information separately for exposed and unexposed groups if applicable. 10-12

Main results #16a Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included 10-12

Main results #16b Report category boundaries when continuous variables were categorized 10-12

Main results #16c If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period 10-12

10-12

Other analyses #17 Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses 10-12

Discussion
Key results #18 Summarise key results with reference to study objectives 12-17

Limitations #19 Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias. 17-18

Interpretation #20 Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence. 17-18

Generalisability #21 Discuss the generalisability (external validity) of the study results 17-18

Other Information

Funding #22 Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based 19

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### Quality of healthcare and Admission Rates for Acute Cardiac Events during COVID-19 pandemic: a retrospective cohort study on ST-Segment-Elevation Myocardial Infarction in China

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Quality of healthcare and Admission Rates for Acute Cardiac Events during COVID-19 pandemic: a retrospective cohort study on ST-Segment-Elevation Myocardial Infarction in China

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Short title: Healthcare Quality for STEMI during COVID-19 pandemic

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Abstract

Objective: To evaluate changes in admission rates for and quality of healthcare of STEMI during the period of the COVID-19 outbreak and post outbreak.

Methods: We conducted a retrospective study among patients with STEMI in the outbreak time and the post-outbreak time.

Design To examine the changes in the admission rates and in quality of healthcare, by comparison between periods of the post-outbreak and the outbreak, and between the post-outbreak and the corresponding periods.

Setting Data for this analysis were included from patients discharge diagnosed with STEMI from all the hospitals of Suzhou in each month of the year until the end of July 2020.

Participants 1,965 STEMI admissions.

Primary and secondary outcome measures The primary outcome was the number of monthly STEMI admissions, and the secondary outcomes was the quality metrics of STEMI healthcare.

Results: There were a 53% and 38% fall in daily admissions at the phase of outbreak and post-outbreak, compared with the 2019 corresponding. There remained a gap in actual number of post-outbreak admissions at 306 and the predicted number at 497, an estimated 26 deaths due to STEMI would have been caused by not seeking healthcare.

Post-outbreak period of 2020 compared with corresponding period of 2019, the percentage of cases transferred by ambulance decreased from 9.3% to 4.2% (P=0.013), the door-to-balloon median time increased from 17.5 to 34.0 minutes
(p=0.001) and the rate of PCI therapy declined from 71.3% to 60.1% (p=0.002).

Conclusions: The impact of public health restrictions may lead to unexpected out-of-hospital deaths and compromised quality of healthcare for acute cardiac events. Delay or absence in 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

COVID-19, Myocardial infarction, Quality in health care
Strengths and limitations of this study

- China has recovered from the initial outbreak and is experiencing the defense of the coronavirus bounce back, it’s suitable for research in the post-outbreak era.

- First study to examine the changes in the admission rates and in quality of healthcare between the post-outbreak and the corresponding periods in China, with the fading of the COVID-19 outbreak.

- Findings suggest that the impact of public health restrictions in the post-outbreak time is still significant, and may lead to unexpected out-of-hospital deaths and compromised quality of healthcare for acute cardiac events.

- This study was limited to Suzhou which limits the generalizability of the results, also it’s a dynamic retrospective study, there would be concerns related to confounding, bias, and temporal trends in quality of healthcare that might limit the validity of the findings.
Introduction

The coronavirus disease 2019 (COVID-19) pandemic is challenging healthcare delivery systems in unprecedented ways, and the effects will last for decades to come.\textsuperscript{1} 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 outbreak can compromise quality of healthcare for non-coronavirus diseases, especially for ST-Segment-Elevation Myocardial Infarction (STEMI), the deadliest and most time-sensitive acute cardiac event.\textsuperscript{2-4} A number of studies have reported substantial declines in the number of patients presenting with STEMI and the rate of percutaneous coronary intervention (PCI), the typically recommended treatment, during the outbreak.\textsuperscript{5-9} However, little is known regarding the impact of the post-outbreak on admission rate and healthcare quality for STEMI.

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 healthcare in the post-outbreak time: (i) delays in presentation, and (ii) delays in treatment.\textsuperscript{10-12} First, less is clear on whether there has 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.\textsuperscript{13} 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.\textsuperscript{14,15} Even yet in
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94    the period of post-outbreak, the emphasis on social distancing might have
95    inappropriately convinced patients to avoid in-person healthcare. The lack of
96    knowledge on personal protection measures compounded by fear of contracting an
97    infection may make patients much less likely to seek help. Thus, an increasing
98    number of patients presenting with STEMI at high coronary risk do not seek
99    healthcare in a timely manner, which will lead to more unexpected out-of-hospital
100   deaths and cause the secondary disaster of the outbreak.
101   Second, little is known regarding how the post-outbreak influenced the delivery
102   of STEMI healthcare in terms of clinical services and processes based on the
103   recommended guidelines. STEMI cases require rapid coordination of care beginning
104   at the time once patients enter the healthcare delivery system. However, the
105   emergency infection protocols (e.g., coronavirus screening upon hospital arrival) still
106   persistent, which could result in a considerable delay in timely treatment, and may
107   impact optimal treatment delivery for patients presenting with STEMI.\textsuperscript{16,17} It is a great
108   challenge for healthcare delivery system to make a balance between identifying
109   patients for PCI procedure, regardless of their coronavirus status, and maintaining the
110   safety of healthcare workers who may be exposed to the virus as well as minimizing
111   contamination of cardiac catheterization rooms. Thus, it is warranted to evaluate how
112   is the healthcare delivery system’s resilience to recover from the coronavirus
113   outbreak, for operational integrity with respect to STEMI cases.
114   To fill this gap, this study aims to investigate the admissions for and quality of
115   healthcare of STEMI in the post-outbreak time. The objectives of this study are two-
fold as follows: (1) to examine the changes in the admission rates, by comparing the
numbers in the outbreak and post-outbreak with the predicted numbers based on the
admissions in 2017-2019; (2) to investigate the changes in quality of healthcare, by
comparison between periods of the post-outbreak and the outbreak, and between the
post-outbreak and the corresponding periods in 2017-2019.

Materials and Methods

Data Statement

Data for this study were obtained from the China Chest Pain Center Database
(http://data.chinacpc.org/), a nationwide clinical registry for collecting data of all
consecutive patients diagnosed with STEMI enrolled by hospitals. The Data
Management Committee, one of the committees of the Management Board was
responsible for evaluating and monitoring the Date. All the accredited CPCs in
Suzhou were instructed to submit consecutive eligible patients to the Database. 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 National Health Commission.
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
all the hospitals with capacity of PCI therapy in the city of 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 routine work and industry production.

**Study Design**

We conducted a retrospective study of patients presenting with STEMI between January of 2017 and July of 2020. The outbreak time was defined as period between January 23, 2020 and March 27, 2020, corresponding to the promulgation of the highest restrictions of movement and a public health drive to combat rising cases in Suzhou. The post-outbreak time was defined as period between March 28, 2020, and July 31, 2020 corresponding to the announcement of resumption of daily work and industry production by Suzhou Government. The corresponding periods are defined as the same time quantum in 2017, 2018 and 2019. Data for this analysis were included from patients discharge diagnosed with STEMI from all the hospitals of Suzhou in each month of the year 2017-2019 until the end of July 2020.

**Measures**

The primary outcome was the number of monthly STEMI admissions, and the secondary outcomes was the quality metrics of STEMI healthcare 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 prehospital process indicators included percentage of onset-to-first medical contact (FMC) time ≤60 min, percentage of ambulance electrocardiogram (ECG) to
door time ≤15 min, percentage of cases arriving at hospital by ambulance, percentage of ambulance ECG. The in-hospital process indicators included percentage of β-blocker usage, percentage of door-to-balloon time ≤60 min, percentage of FMC-to-device time ≤90 min, percentage of onset-to-device time ≤120 min, door-to-balloon time, FMC-to-device time, onset-to-device time, and PCI rate. The clinical outcome indicator was 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**

A descriptive analysis presented the daily admission rates and median monthly onset-to-PCI time of STEMI patients over the periods of the post-outbreak time to the corresponding period in 2017-2019. To provide a more intuitive interpretation of unexpected out-of-hospital deaths, we predicted the number of admissions that should be in the post-outbreak time 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 common forecasting algorithm which weighted average of past observations with exponentially decaying weights to capture the trend in a time-series dataset\(^20\). The component form of the addition model is:

\[
y_{t+h|t} = \ell_t + hb_t + s_{t-m} + h_m +
\]
\[ \ell_t = \alpha(y_t - s_{t-m}) + (1 - \alpha)(\ell_{t-1} + b_{t-1}) \]

\[ b_t = \beta \cdot (\ell_t - \ell_{t-1}) + (1 - \beta) b_{t-1} \]

\[ s_t = \gamma(y_t - \ell_{t-1} - b_{t-1}) + (1 - \gamma)s_{t-m} \]

Where \( k \) is the integral part of \((h-1)/m\), which ensures that the estimates of the seasonal index used for the prediction are from the last year of the sample. Level equations of the "t", means the weighted average of seasonal adjustment of observations \((y_t - s_{t-m})\) and Non-seasonally adjusted observations \((\ell_{t-1} + b_{t-1})\).

The trend equation is the same as Holt linear method. The weighted mean seasonality equation represents the current seasonality index, \((y_t - \ell_{t-1} - b_{t-1})\), A weighted average of the seasonal index from the same season last year (\(m\) time periods ago).

The smoothing parameters were automatically generated prior modeling with Holt-Winters method. The \(\alpha\) (level), \(\beta\) (slope) and \(\gamma\) (s\text{t}) of trend 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.\(^{21}\) The predicated death number due to the lack of seeking healthcare was calculated by the forecast formula: \((\text{predicated numbers} - \text{actual numbers}) \times 8\%\) (average death rate in China).\(^{22,23}\)

To examine changes in quality metrics of STEMI healthcare, we compared the list of indicators in terms of prehospital process, in-hospital process, and clinical outcome, by a subsample of respective periods, including the outbreak period and the corresponding periods in 2019 and 2018, the post-outbreak 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).

Patient and Public Involvement

Patients and the public were not directly involved in the study.

Results

Patient Characteristics

The study comprised 1,965 admissions for STEMI, of which 121 and 306 were in the outbreak and the post-outbreak time, respectively. Of those 306 patients in the post-outbreak time, 17.6% were women, with a mean age of 60.7 (SD 14.6) years.

During the 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-outbreak time, respectively (Table 1).

Daily Admissions for STEMI

Figure 1 demonstrates daily admissions for STEMI over the periods of outbreak and post-outbreak to the corresponding time in 2018 and 2019. The percentage reduction in admissions were 57% and 55% between the 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-outbreak time, 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 during the outbreak and the post-outbreak. 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 outbreak and the post-outbreak time was 259 and 497. There were a 53% and 38% decline in admissions, with the actual numbers of 121 and 306. Predicated numbers of monthly admissions for STEMI are shown in Supplement Table 2. Based on the forecast formula, the predicted death number due to STEMI caused by the lack of seeking healthcare was 26.

Quality Metrics of STEMI Healthcare

Figure 3 presents the median monthly treatment delay for STEMI healthcare, 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 healthcare, by comparison between periods of the post-outbreak and the outbreak, and between the post-outbreak and the corresponding periods in 2018-2019. The percentage of STEMI cases transferred by ambulance was both 4.2% in the outbreak and post-outbreak time, respectively, lower than those in the corresponding period of 2019 (16.9%, $P=0.005$; 9.3%, $P=0.013$). During the post-outbreak to the corresponding period of 2019, the
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 therapy 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 healthcare between the outbreak and post-outbreak time showed insignificant, with the percentage of cases transferred by ambulance, the percentage of onset-to-FMC time ≤60 min, the percentage of onset-to-device time ≤120 min, and the PCI rate decreasing, and the door-to-balloon time increasing.

Discussion

Principal Findings

This is, to our knowledge, the first study to investigate the changes in admissions for and quality of healthcare among acute cardiac events in the post-outbreak time, 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-outbreak time 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 healthcare, while no one died from COVID-19 in the post-outbreak time in the city of Suzhou. 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 healthcare, which could lead to over 20,000 death during the post-outbreak of study.23 Quality of
STEMI healthcare remained suboptimal in the post-outbreak time, comparing with those in the corresponding periods in 2018-2019, especially for the percentage of cases transferred by EMS, and the in-hospital process indicators. Although the in-hospital mortality declined during the outbreak to the post-outbreak, the change was not significant. These findings suggest that the impact of public health restrictions in the post-outbreak time is still significant, and may lead to unexpected out-of-hospital deaths and compromised quality of healthcare for acute cardiac events.

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 therapy during the outbreak. Previous studies using the self-controlled case series method provided evidence that the outbreak may increase the risk of STEMI during the acute phase of infection. However, the reduced number of admissions during the outbreak is likely to have resulted in increases in out-of-hospital deaths and long-term complications. Our current study focuses on the post-outbreak time, 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 outbreak and the
corresponding period of 2019, and the post-outbreak 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-outbreak time in comparison with the 
corresponding period of 2019. Causes for less presentation for healthcare are likely 
multifactorial and most researches emphasize that patients may be reluctant to present 
to hospitals because of the fear of contracting the coronavirus infection.\textsuperscript{6,25} 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 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, hospitals are 
encouraged to establish a medical consortium of STEMI healthcare. Hospitals are 
partnered with community healthcare centers to form an information-sharing and 
resource-management model. Community healthcare workers conduct management of 
STEMI healthcare 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 hospitals remain fully operational and have stringent infection-
control protocols in place even in the post-outbreak time. 

Obviously national lockdowns and altered healthcare priorities in response to 
COVID-19 outbreak are affecting the diagnosis and treatment of STEMI. According
to Consensus 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 very few patients with suspected COVID-19, emergency intravenous thrombolysis is the first choice for cases with no contraindication to thrombolysis, which will not impact the proportion of PCI rate and affect the quality of medical care; 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. In fact, most hospitals 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 intervals of the treatment delay including patient delay and system delay (including prehospital delay and in-hospital delay). Notably, the extension in patient delay showed no significant during the post-outbreak and the corresponding periods of 2018-2019. We observed a
significant prolongation of the door-to-balloon time and the FMC-to-device time,
mainly due to the requirement of testing negativity for coronavirus infection.

Meanwhile, a 12-point percentage of decline in rate of PCI therapy was observed over
the period of the post-outbreak and the corresponding periods in 2019. Thus, even in
the post COVID-19 era, delays in the 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 the in-hospital mortality increased from 2.1% to
6.0% between the outbreak and the corresponding period of 2019, and the in-hospital
mortality declined from the outbreak to the post-outbreak time, but 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-outbreak time
were about 5 years younger and had a 13-point lower percentage of female,
comparing those in the outbreak time. 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-outbreak time and nor
have the clinical outcomes. Second is the treatment approaches for patients
hospitalized with STEMI. The rates of PCI therapy persisted about 60% during the
outbreak and the post-outbreak, 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 the PCI therapy as a result of the COVID-19 pandemic.\(^1\)\(^{31,32}\) These results were coupled with delays in the PCI therapy, pointing to the persistently high in-hospital mortality during the outbreak and the post-outbreak. Clinical outcome in patients with STEMI in the post-outbreak time might be influenced by the delay to treatment and less use of PCI therapy. Therefore, it is imperative to improve the healthcare delivery system’s ability to maintain healthcare coordination for timely PCI with respect to STEMI cases. Prior studies have shown that a dedicated coordinator from a medical consortium of STEMI healthcare could play a critical role in maintaining coordination of healthcare, in charge of coordination of community healthcare centers, hospitals and EMS agencies, and collaboration of multidisciplinary teams including the cardiology department, emergency department, infections department, pneumology department, and the medical laboratory department.\(^{16,33}\)

**Limitations**

This study has several limitations. First, in a dynamic retrospective study, there would be concerns related to confounding, bias, and temporal trends in quality of healthcare that might limit the validity of the findings. However, we compared the changes in the quality metrics of healthcare 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 merely underestimate the impact of the COVID-19 outbreak and the post COVID-19 era on quality of healthcare. 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 lead to develop chest pain centers accredited by National Health Commission to guide standardized prehospital and in-hospital STEMI healthcare in a regional level in China. Third, for PCI procedure, team co-working problem and a number of extra shifts in catheterization lab which may affect treatment time and quality of care were not considered in this study, due to the data availability. Future researches need to focus on the coordination of care and task shifts for STEMI patients in responses to the pandemic from the perspectives of quality of care. 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 healthcare 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.

Author Contributions

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,

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Contributorship statement

We thank the Suzhou Emergency Center for providing the data and sharing comments for the study’s findings.

Competing interests

None.

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Data sharing statement
Data for this study were obtained from the China Chest Pain Center Database.

(http://data.chinacpc.org/)

**Ethics Statement**

Ethics approvals of the study have been obtained from the Peking University Health Science Center Institutional Review Board (IRB00001052-21020). Informed consent was obtained from hospitals for research approval to collect data in the study.

**Abbreviations**

STEMI: ST-segment-elevation myocardial infarction; COVID-19: coronavirus disease 2019; PCI: percutaneous coronary intervention; FMC: first medical contact; EMS: emergency medical service; ACC/AHA: American College of Cardiology/American Heart Association

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**Figures Legends**

Figure 1. Daily admissions to hospitals among patients diagnosed with STEMI in Suzhou of China

Figure 2. Predicated monthly admissions for STEMI in Suzhou of China

Figure 3. Monthly mean delay time for healthcare of STEMI, by patient delay,
transfer delay and in-hospital delay in Suzhou of China

Supplement

Supplement Table 1. Definition and measures of quality metrics of STEMI healthcare

Supplement Table 2. Predicated number of admissions for STEMI by each month in Suzhou of China
Table 1. Characteristic of STEMI patients during the outbreak and the post-outbreak, 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 |
| Admissions for STEMI | 280    | 267    | 121    | 528           | 2018.0 | 2019.0 | 2020.0 | (2018 vs 2019) | 121    | 306    |
|                      | 61.5   | 62.0   | 65.2   | 60.1          | 2019.0 | 2019.0 | 2020.0 | (2019 vs 2019) | 65.2   | 60.7   |
| Age (years)*         | (14.7) | (14.4) | (12.3) | 0.685         | 2020.0 | 2020.0 | 2020.0 | (2020 vs 2020) | 0.003  |        |
|                      | 53     | 42     | 32     | 94            | 3018.0 | 2019.0 | 2019.0 | (2018 vs 2019) | 32     | 54     |
| Female, n (%)        | (18.9) | (15.7) | (26.4) | 0.382         | 2018.0 | 2019.0 | 2020.0 | (2018 vs 2019) | 0.056  |        |
| Transfer mode, n (%) | 22     | 45     | 7      | 48            | 2018.0 | 2019.0 | 2020.0 | 0.007 0.012 | 7      | 13     |
|                      | 48     | 43     | 13     | 0.082         | 2019.0 | 2019.0 | 2019.0 | 0.482 0.010 | 0.666  |
| Directly via EMS     | (7.9)  | (16.9) | (5.8)  | (9.1)         | 2020.0 | 2020.0 | 2020.0 | (2020 vs 2020) | (5.8)  | (4.2)  |
|                      | 8      | 6      | 6      | 11            | 2018.0 | 2019.0 | 2019.0 | (2018 vs 2019) | 6      | 9      |
| In-hospital          | (2.9)  | (2.2)  | (5.0)  | (2.1)         | 2018.0 | 2019.0 | 2019.0 | (2018 vs 2019) | 5.0    | (2.9)  |
|                      | 82     | 59     | 34     | 145           | 2019.0 | 2019.0 | 2019.0 | (2019 vs 2019) | 34     | 88     |
| Transfer-in          | (29.3) | (22.1) | (28.1) | (27.5)        | 2020.0 | 2020.0 | 2020.0 | (2020 vs 2020) | (28.1) | (28.8) |
|                      | 168    | 157    | 74     | 324           | 2018.0 | 2019.0 | 2019.0 | (2018 vs 2019) | 74     | 196    |
| Directly by self     | (60.0) | (58.8) | (61.2) | (61.4)        | 2019.0 | 2019.0 | 2019.0 | (2019 vs 2019) | (61.2) | (64.1) |
| Clinical characteristics |       |       |       |               | 2020.0 | 2020.0 | 2020.0 | (2020 vs 2020) |       |       |
| Sustainable chest pain, n (%) | 211    | 188    | 93     | 406           | 2018.0 | 2019.0 | 2019.0 | (2018 vs 2019) | 93    | 240    |
|                        | (75.4) | (70.4) | (76.9) | (76.9)        | 2019.0 | 2019.0 | 2019.0 | (2019 vs 2019) | 76.9  | (78.4) |
| Intermittent chest pain, n (%) | 55     | 45     | 17     | 79            | 2018.0 | 2019.0 | 2019.0 | (2018 vs 2019) | 17    | 41     |
|                        | 0.464  | 0.583  | 0.583  | 0.583         | 2019.0 | 2019.0 | 2019.0 | (2019 vs 2019) | 0.583 | 0.583  |

*Age in years (mean ± SD)
|                          | n (%)   | (%)       | (%)       | (%)       | (%)       | (%)       | (%)       | (%)       | (%)       | (%)       |
|--------------------------|---------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|                          | (19.6)  | (16.9)    | (14.0)    | (15.0)    | (17.7)    | (13.4)    | (14.0)    | (13.4)    | (19.6)    | (16.9)    |
| Chest pain relief, n     | 7       | 4         | 4         | 8         | 2         | 8         | 4         | 8         | 0.166     | 0.022     |
|                          | (2.5)   | (1.5)     | (3.3)     | (1.5)     | (0.4)     | (2.6)     | (3.3)     | (2.6)     | (3.2)     | (3.7)     |
| Respiratory rate (breaths/min)* | 18.1    | 18.3      | 18.3      | 18.1      | 18.2      | 18.2      | 18.3      | 18.2      | 0.666     | 0.887     |
|                          | (3.6)   | (3.9)     | (3.2)     | (2.9)     | (3.4)     | (3.7)     | (3.2)     | (3.7)     | (3.2)     | (3.7)     |
| Pulse frequency (pulse/min)* | 79.1    | 78.0      | 78.0      | 77.2      | 73.4      | 76.3      | 78.0      | 76.3      | 0.002     | 0.052     |
|                          | (19.8)  | (18.9)    | (23.7)    | (18.0)    | (18.8)    | (21.2)    | (23.7)    | (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      | 0.004     | 0.091     |
|                          | (19.7)  | (19.7)    | (23.5)    | (17.9)    | (18.9)    | (21.2)    | (23.5)    | (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     | 0.568     | 0.360     |
| (mm Hg)*                 | (30.5)  | (28.3)    | (27.8)    | (28.0)    | (29.4)    | (29.1)    | (27.8)    | (29.1)    | (3.0)     | (2.9)     |
| Diastolic blood pressure | 81.1    | 82.6      | 79.1      | 82.8      | 83.7      | 82.0      | 79.1      | 82.0      | 0.479     | 0.255     |
| (mm Hg)*                 | (20.3)  | (17.9)    | (19.5)    | (18.8)    | (20.0)    | (19.0)    | (19.5)    | (19.0)    | (3.0)     | (2.3)     |
| Killip Class (%)         | 195     | 173       | 89        | 632       | 120       | 251       | 89        | 251       | 0.485     | 0.129     |
| I                        | (79.9)  | (84.4)    | (74.2)    | (84.9)    | (88.0)    | (82.6)    | (74.2)    | (82.6)    | (79.9)    | (84.4)    |
|                          | 22      | 15        | 12        | 31        | 17        | 14        | 12        | 14        | 12        | 12        |
| II                       | (9.0)   | (7.3)     | (10.0)    | (6.7)     | (4.3)     | (4.6)     | (10.0)    | (4.6)     | 6         | 12        |
|                          | 8       | 4         | 6         | 10        | 7         | 12        | 6         | 12        | 6         | 12        |
| III                      | (3.3)   | (2.0)     | (5.0)     | (2.2)     | (1.8)     | (3.9)     | (5.0)     | (3.9)     | 5         | 12        |
|                          | 19      | 13        | 13        | 29        | 23        | 27        | 13        | 27        | 5         | 12        |
| IV                       | (7.8)   | (6.3)     | (10.8)    | (6.2)     | (5.9)     | (8.9)     | (10.8)    | (8.9)     | 7         | 14        |

* Mean (SD)
Table 2. Quality metrics of STEMI healthcare during the outbreak and the post-outbreak, 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 vs 2019) | 2018.0 | 2019.0 | 2020.0 | P (2018 vs 2019) | 2020.0 | 2020.0 | P |
| 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     | 45     | 7      | 0.002          | 48     | 43     | 13      | 1.000          | 7      | 13     | 0.672 |
| Pre-hospital ECGs, n (%) | 70     | 85     | 35     | 0.093          | 121    | 138    | 94      | 0.017          | 35     | 94     | 0.805 |
| Onset-to-FMC (EMS arrival or walk-in to ED) time ≤60 min, n (%) | 90     | 94     | 35     | 0.383          | 182    | 144    | 102     | 0.439          | 35     | 102    | 0.445 |
| Ambulance ECG-to-door time for ambulance transported cases ≤15 min, n (%) | 5      | 18     | 3      | 0.019          | 5      | 16     | 6       | 0.052          | 3      | 6      | 0.964 |
| In-hospital process indicators |       |        |        |                |        |        |        |                |        |        |    |
| β-blocker usage, n (%)   | 124    | 100    | 33     | 0.130          | 207    | 188    | 46      | 0.352          | 33     | 46     | 0.009 |
| Door-to-balloon time ≤60 | 76     | 82     | 38     |                | 127    | 188    | 93      |                | 38     | 93     |    |
| Description                                      | n (%)    | n (%)    | n (%)    | n (%)    | n (%)    | n (%)    |
|-------------------------------------------------|----------|----------|----------|----------|----------|----------|
| FMC-to-device time ≤90 min                        | 47 (68.1)| 66 (89.2)| 32 (84.2)| 93 (75.6)| 132 (80.0)| 68 (71.6)|
| Onset-to-device time ≤120 min                     | 21 (27.6)| 35 (46.1)| 9 (23.7) | 32.0     | 15.5     | 39.5     |
| Door-to-balloon time, median (q_1, q_3)          | [12.0, 50.2] | [0.0, 38.5] | [13.0, 49.8] | 30.0 [12.0, 45.5] | 17.5 [37.4, 48.0] | 34.0 [15.4, 48.0] |
| FMC-to-device time, median (q_1, q_3)            | [12.0, 52.0] | [11.0, 51.5] | [11.2, 52.5] | 14.0 [11.0, 51.0] | 12.0 [46.0, 63.0] | 15.0 [48.0, 63.0] |
| Onset-to-device time, median (q_1, q_3)          | [116.5, 388.8] | [74.5, 250.5] | [126.5, 395.8] | 93.8 [126.5, 339.8] | 94.5 [261.5, 330] | 107.0 [236.2, 184] |
| PCI rate, n (%)                                   | 193 (68.9) | 164 (61.4) | 82 (67.8) | 111 (64.2) | 13 (71.3) | 12 (60.1) |
| In-hospital mortality, n (%)                      | 9 (3.2)   | 5 (2.1)   | 7 (6.0)   | 11 (2.1) | 13 (2.8) | 12 (4.1) |

Outcome indicators

| Description                        | n (%)    | n (%)    | n (%)    | n (%)    |
|-----------------------------------|----------|----------|----------|----------|
| In-hospital mortality, n (%)      | 0.585    | 0.100    | 0.590    | 0.442    |
| [3.2, 6.0] [2.1, 4.1]             | [0.100, 0.100] | [0.442, 0.442] | [0.590, 0.590] | [0.442, 0.442] |
Figure 1. Daily admissions to hospitals among patients diagnosed with STEMI in Suzhou of China
Figure 2. Predicted monthly admissions for STEMI in Suzhou of China
Figure 3. Monthly median delay time for healthcare of STEMI, by patient delay, transfer delay and in-hospital delay in Suzhou of China
Supplement Table 1. Definition and measures of quality metrics of STEMI healthcare

| Pre-hospital process indicators | Definition | Measures |
|--------------------------------|------------|----------|
| Onset-to-FMC (EMS arrival or walk-in to ED) time ≤ 60 min, n (%) | Percentage of patient onset time to first medical contact (FMC) time less than or equal 60 minutes | (Cases Onset-to-FMC ≤ 60 min)/(Cases with onset time and FMC time) |
| Ambulance ECG to door time for ambulance transported cases ≤ 15 min, n (%) | Percentage of ambulance transported patient pre-hospital ECG time to door time less than or equal 15 minutes | (Cases Ambulance ECG to door time ≤ 15 min)/(Cases with pre-hospital ECG time and door time) |
| Percent of cases arriving at the first hospital by ambulance, n (%) | Percentage of cases arriving at the first hospital by ambulance among all transfer mode | (Cases arriving at the first hospital by ambulance)/(All cases) |
| Pre-hospital ECGs, n (%) | Percentage of cases use pre-hospital ECGs among all ambulance transported cases | (Cases with pre-hospital ECG)/(Cases arriving at the first hospital by ambulance) |

| Hospital process indicators | Definition | Measures |
|-----------------------------|------------|----------|
| β-blocker usage, n (%) | Percentage of patient use β-blocker | (Cases use β-blocker)/(All cases) |
| Door-to-balloon time ≤ 60 min, n (%) | Percentage of PCI patient door time to balloon time less than or equal 60 minutes | (PCI cases door-to-balloon time ≤ 60 min)/(PCI Cases with door time and balloon time) |
| FMC-to-device time ≤ 90 min, n (%) | Percentage of PCI and thrombolysis patient first medical contact time to device time less than or equal 90 minutes | (PCI and thrombolysis cases FMC-to-device time ≤ 90 min)/(PCI and thrombolysis Cases with FMC time and device time) |
| Onset-to-device time ≤ 120 min, n (%) | Percentage of PCI and thrombolysis patient onset time to device time less than or equal 90 minutes | (PCI and thrombolysis cases onset-to-device time ≤ 120 min)/(PCI and thrombolysis Cases with onset time and device time) |
| Door-to-balloon time, median (q₁, q₃) | Median of door to balloon time for PCI patient | Balloon time – door time (min) |
| FMC-to-device time, median (q₁, q₃) | Median of FMC to device time for PCI patient | device time – FMC time(min) |
| Indicator                              | Formula                                                                 |
|---------------------------------------|-------------------------------------------------------------------------|
| Onset-to-device time, median (q₁, q₃) | Median of onset to device time for PCI patient = device time – onset time (min) |
| PCI rate, n (%)                       | Percentage of patients take PCI among all patients = (Cases of PCI)/(All cases) |
| In-hospital mortality, n (%)          | Percentage of patient died in hospital = (Cases of died patient)/(All cases) |
| Time period                            | Mean | Lower 80% | Lower 95% | Upper 80% | Upper 95% |
|----------------------------------------|------|-----------|-----------|-----------|-----------|
| 1st January, 2020-31st January, 2020  | 136  | 107       | 94        | 173       | 197       |
| 1st February, 2020-28th February, 2020| 107  | 85        | 75        | 135       | 153       |
| 1st March, 2020-31st March, 2020      | 129  | 101       | 88        | 166       | 189       |
| 1st April, 2020-30th April, 2020      | 107  | 84        | 73        | 137       | 156       |
| 1st May, 2020-31st May, 2020          | 122  | 94        | 82        | 158       | 181       |
| 1st June, 2020-30th June, 2020        | 135  | 103       | 89        | 177       | 204       |
| 1st July, 2020-31st July, 2020        | 116  | 89        | 77        | 151       | 174       |
Quality of healthcare and Admission Rates for Acute Cardiac Events during COVID-19 pandemic: a retrospective cohort study on ST-Segment-Elevation Myocardial Infarction in China

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Quality of healthcare and Admission Rates for Acute Cardiac Events during COVID-19 pandemic: a retrospective cohort study on ST-Segment-Elevation Myocardial Infarction in China

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Short title: Healthcare Quality for STEMI during COVID-19 pandemic

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Abstract

Objective: To evaluate changes in admission rates for and quality of healthcare of STEMI during the period of the COVID-19 outbreak and post outbreak.

Methods: We conducted a retrospective study among patients with STEMI in the outbreak time and the post-outbreak time.

Design To examine the changes in the admission rates and in quality of healthcare, by comparison between periods of the post-outbreak and the outbreak, and between the post-outbreak and the corresponding periods.

Setting Data for this analysis were included from patients discharge diagnosed with STEMI from all the hospitals of Suzhou in each month of the year until the end of July 2020.

Participants 1,965 STEMI admissions.

Primary and secondary outcome measures The primary outcome was the number of monthly STEMI admissions, and the secondary outcomes was the quality metrics of STEMI healthcare.

Results: There were a 53% and 38% fall in daily admissions at the phase of outbreak and post-outbreak, compared with the 2019 corresponding. There remained a gap in actual number of post-outbreak admissions at 306 and the predicted number at 497, an estimated 26 deaths due to STEMI would have been caused by not seeking healthcare.

Post-outbreak period of 2020 compared with corresponding period of 2019, the percentage of cases transferred by ambulance decreased from 9.3% to 4.2% (P=0.013), the door-to-balloon median time increased from 17.5 to 34.0 minutes
and the rate of PCI therapy declined from 71.3% to 60.1% (p=0.002).

**Conclusions:** The impact of public health restrictions may lead to unexpected out-of-hospital deaths and compromised quality of healthcare for acute cardiac events. Delay or absence in 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**

COVID-19, Myocardial infarction, Quality in health care
Strengths and limitations of this study

- China has recovered from the initial outbreak and is experiencing the defense of the coronavirus bounce back, it’s suitable for research in the post-outbreak era.

- First study to examine the changes in the admission rates and in quality of healthcare between the post-outbreak and the corresponding periods in China, with the fading of the COVID-19 outbreak.

- Findings suggest that the impact of public health restrictions in the post-outbreak time is still significant, and may lead to unexpected out-of-hospital deaths and compromised quality of healthcare for acute cardiac events.

- This study was limited to Suzhou which limits the generalizability of the results, also it’s a dynamic retrospective study, there would be concerns related to confounding, bias, and temporal trends in quality of healthcare that might limit the validity of the findings.
Introduction

The coronavirus disease 2019 (COVID-19) pandemic is challenging healthcare delivery systems in unprecedented ways, and the effects will last for decades to come.¹ Most countries have implemented stringent infection-control measures, including but not limited to social distancing measures, emergency infection protocols instituted in hospitals to contain COVID-19, and adjustment of clinical services. The response to outbreak can compromise quality of healthcare for non-coronavirus diseases, especially for ST-Segment-Elevation Myocardial Infarction (STEMI), the deadliest and most time-sensitive acute cardiac event.²⁻⁴ A number of studies have reported substantial declines in the number of patients presenting with STEMI and the rate of percutaneous coronary intervention (PCI), the typically recommended treatment, during the outbreak.⁵⁻⁹ However, little is known regarding the impact of the post-outbreak on admission rate and healthcare quality for STEMI.

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 healthcare in the post-outbreak time: (i) delays in presentation, and (ii) delays in treatment.¹⁰⁻¹² First, less is clear on whether there has 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.¹³ 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.¹⁴,¹⁵ Even yet in
the period of post-outbreak, the emphasis on social distancing might have inappropriately convinced patients to avoid in-person healthcare. 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 healthcare in a timely manner, which will lead to more unexpected out-of-hospital deaths and cause the secondary disaster of the outbreak.

Second, little is known regarding how the post-outbreak influenced the delivery of STEMI healthcare in terms of clinical services and processes based on the recommended guidelines. STEMI cases require rapid coordination of care beginning at the time once patients enter the healthcare delivery system. 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 healthcare delivery system to make a balance between identifying patients for PCI procedure, regardless of their coronavirus status, and maintaining the safety of healthcare 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 healthcare delivery 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 healthcare of STEMI in the post-outbreak time. The objectives of this study are two-
fold as follows: (1) to examine the changes in the admission rates, by comparing the
numbers in the outbreak and post-outbreak with the predicted numbers based on the
admissions in 2017-2019; (2) to investigate the changes in quality of healthcare, by
comparison between periods of the post-outbreak and the outbreak, and between the
post-outbreak and the corresponding periods in 2017-2019.

Materials and Methods

Data Statement

Data for this study were obtained from the China Chest Pain Center Database
(http://data.chinacpc.org/), a nationwide clinical registry for collecting data of all
consecutive patients diagnosed with STEMI enrolled by hospitals. The Data
Management Committee, one of the committees of the Management Board was
responsible for evaluating and monitoring the Data. All the accredited CPCs in
Suzhou were instructed to submit consecutive eligible patients to the Database. 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 National Health Commission.

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
all the hospitals with capacity of PCI therapy in the city of Suzhou (Represents
China's second-tier cities, mainly urban areas), 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 routine work and industry production.

**Study Design**

We conducted a retrospective study of patients presenting with STEMI between
January of 2017 and July of 2020. The outbreak time was defined as period between
January 23, 2020 and March 27, 2020, corresponding to the promulgation of the
highest restrictions of movement and a public health drive to combat rising cases in
Suzhou. The post-outbreak time was defined as period between March 28, 2020, and
July 31, 2020 corresponding to the announcement of resumption of daily work and
industry production by Suzhou Government. The corresponding periods are defined
as the same time quantum in 2017, 2018 and 2019. Data for this analysis were
included from patients discharge diagnosed with STEMI from all the hospitals of
Suzhou in each month of the year 2017-2019 until the end of July 2020.

**Measures**

The primary outcome was the number of monthly STEMI admissions, and the
secondary outcomes was the quality metrics of STEMI healthcare 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 prehospital process indicators included percentage of onset-to-first medical
contact (FMC) time $\leq 60$ min, percentage of ambulance electrocardiogram (ECG) to
door time $\leq 15$ min, percentage of cases arriving at hospital by ambulance, percentage of ambulance ECG. The in-hospital process indicators included percentage of $\beta$-blocker usage, percentage of door-to-balloon time $\leq 60$ min, percentage of FMC-to-device time $\leq 90$ min, percentage of onset-to-device time $\leq 120$ min, door-to-balloon time, FMC-to-device time, onset-to-device time, and PCI rate. The clinical outcome indicator was 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**

A descriptive analysis presented the daily admission rates and median monthly onset-to-PCI time of STEMI patients over the periods of the post-outbreak time to the corresponding period in 2017-2019. To provide a more intuitive interpretation of unexpected out-of-hospital deaths, we predicted the number of admissions that should be in the post-outbreak time 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 common forecasting algorithm which weighted average of past observations with exponentially decaying weights to capture the trend in a time-series dataset$^{20}$. The component form of the addition model is:

$$y_{t+h|t} = \ell_t + h b_t + s_{t-m} + h_m +$$
\[ \ell_t = \alpha(y_t - s_{t-m}) + (1 - \alpha)(\ell_{t-1} + b_{t-1}) \]
\[ b_t = \beta^*(\ell_t - \ell_{t-1}) + (1 - \beta^*)b_{t-1} \]
\[ s_t = \gamma(y_t - \ell_{t-1} - b_{t-1}) + (1 - \gamma)s_{t-m} \]

Where \( k \) is the integral part of \((h-1)/m\), which ensures that the estimates of the seasonal index used for the prediction are from the last year of the sample. Level equations of the “t”, means the weighted average of seasonal adjustment of observations \((y_t - s_{t-m})\) and Non-seasonally adjusted observations \((\ell_{t-1} + b_{t-1})\).

The trend equation is the same as Holt linear method. The weighted mean seasonality equation represents the current seasonality index, \((y_t - \ell_{t-1} - b_{t-1})\), A weighted average of the seasonal index from the same season last year (\(m\) time periods ago).

The smoothing parameters were automatically generated prior modeling with Holt-Winters method. The \(\alpha\) (level), \(\beta\) (slope) and \(\gamma\) (st) of trend 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. \(^{21}\) The predicated death number due to the lack of seeking healthcare was calculated by the forecast formula: (predicated numbers - actual numbers) \(\times\) 8% (average death rate in China)\(^{22,23}\).

To examine changes in quality metrics of STEMI healthcare, we compared the list of indicators in terms of prehospital process, in-hospital process, and clinical outcome, by a subsample of respective periods, including the outbreak period and the corresponding periods in 2019 and 2018, the post-outbreak period and the corresponding periods in 2019 and 2018. To test the robustness of our findings, we conducted two step of sensitivity analyses. First, we found the estimated trend of the...
time series was drawn by the function to determine the seasonality of the model (Supplement Figure 1). Then, repeated Holt-Winters exponential smoothing was employed after time series analysis by monthly data to verify the stability of data and consistency of results (Supplement Figure 2). 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).

**Patient and Public Involvement**

Patients and the public were not directly involved in the study.

**Results**

**Patient Characteristics**

The study comprised 1,965 admissions for STEMI, of which 121 and 306 were in the outbreak and the post-outbreak time, respectively. Of those 306 patients in the post-outbreak time, 17.6% were women, with a mean age of 60.7 (SD 14.6) years.

During the 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-outbreak time, respectively (Table 1).

**Daily Admissions for STEMI**

**Figure 1** demonstrates daily admissions for STEMI over the periods of outbreak and post-outbreak to the corresponding time in 2018 and 2019. The percentage
reduction in admissions were 57% and 55% between the 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-outbreak time, 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 during the outbreak and the post-outbreak. 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 outbreak and the post-outbreak time was 259 and 497. There were a 53% and 38% decline in admissions, with the actual numbers of 121 and 306. Predicated numbers of monthly admissions for STEMI are shown in Supplement Table 2. Based on the forecast formula, the predicted death number due to STEMI caused by the lack of seeking healthcare was 26.

Quality Metrics of STEMI Healthcare

Figure 3 presents the median monthly treatment delay for STEMI healthcare, 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 healthcare, by comparison
between periods of the post-outbreak and the outbreak, and between the post-outbreak and the corresponding periods in 2018-2019. The percentage of STEMI cases transferred by ambulance was both 4.2% in the outbreak and post-outbreak time, respectively, lower than those in the corresponding period of 2019 (16.9%, P=0.005; 9.3%, P=0.013). During the post-outbreak to the corresponding period of 2019, the 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 therapy 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 healthcare between the outbreak and post-outbreak time showed insignificant, with the percentage of cases transferred by ambulance, the percentage of onset-to-FMC time ≤60 min, the percentage of onset-to-device time ≤120 min, and the PCI rate decreasing, and the door-to-balloon time increasing.

Discussion

Principal Findings

This is, to our knowledge, the first study to investigate the changes in admissions for and quality of healthcare among acute cardiac events in the post-outbreak time, 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-outbreak time 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 healthcare, while no one died from COVID-19 in the post-outbreak time in the city of Suzhou. 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 healthcare, which could lead to over 20,000 death during the post-outbreak of study. Quality of STEMI healthcare remained suboptimal in the post-outbreak time, comparing with those in the corresponding periods in 2018-2019, especially for the percentage of cases transferred by EMS, and the in-hospital process indicators. Although the in-hospital mortality declined during the outbreak to the post-outbreak, the change was not significant. These findings suggest that the impact of public health restrictions in the post-outbreak time is still significant, and may lead to unexpected out-of-hospital deaths and compromised quality of healthcare for acute cardiac events.

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 therapy during the outbreak. Previous studies using the self-controlled case series method provided evidence that the outbreak may increase the risk of STEMI during the acute phase of infection. However, the reduced number of admissions during the outbreak is likely to have resulted in increases in out-of-hospital deaths and long-term complications. Our current study focuses on the post-outbreak time, 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 outbreak and the corresponding period of 2019, and the post-outbreak 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-outbreak time in comparison with the corresponding period of 2019. Causes for less presentation for healthcare are likely multifactorial and most researches emphasize that patients may be reluctant to present to hospitals because of the fear of contracting the coronavirus 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 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, hospitals are encouraged to establish a medical consortium of STEMI healthcare. Hospitals are partnered with community healthcare centers to form an information-sharing and resource-management model. Community healthcare workers conduct management of STEMI healthcare 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 hospitals remain fully operational and have stringent infection-
control protocols in place even in the post-outbreak time.

Obviously national lockdowns and altered healthcare priorities in response to
COVID-19 outbreak are affecting the diagnosis and treatment of STEMI. According
to Consensus 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
very few patients with suspected COVID-19, emergency intravenous thrombolysis is
the first choice for cases with no contraindication to thrombolysis, which will not
impact the proportion of PCI rate and affect the quality of medical care; 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.

In fact, most hospitals 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.\textsuperscript{28} In our study, all the patients enrolled were negative for COVID-19. We have analyzed all the intervals of the treatment delay including patient delay and system delay (including prehospital delay and in-hospital delay). Notably, the extension in patient delay showed no significant during the post-outbreak and the corresponding periods of 2018-2019. We observed a significant prolongation of the door-to-balloon time and the FMC-to-device time, mainly due to the requirement of testing negativity for coronavirus infection. Meanwhile, a 12-point percentage of decline in rate of PCI therapy was observed over the period of the post-outbreak and the corresponding periods in 2019. Thus, even in the post COVID-19 era, delays in the 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 the in-hospital mortality increased from 2.1\% to 6.0\% between the outbreak and the corresponding period of 2019, and the in-hospital mortality declined from the outbreak to the post-outbreak time, but 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-outbreak time were about 5 years younger and had a 13-point lower percentage of female, comparing those in the outbreak time. 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.\textsuperscript{29,30} Nevertheless, data of our study provides additional information that neither the risk profile of patients hospitalized with STEMI has significantly changed in the post-outbreak time and nor have the clinical outcomes. Second is the treatment approaches for patients hospitalized with STEMI. The rates of PCI therapy persisted about 60\% during the outbreak and the post-outbreak, 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 the PCI therapy as a result of the COVID-19 pandemic.\textsuperscript{1,31,32} These results were coupled with delays in the PCI therapy, pointing to the persistently high in-hospital mortality during the outbreak and the post-outbreak. Clinical outcome in patients with STEMI in the post-outbreak time might be influenced by the delay to treatment and less use of PCI therapy. Therefore, it is imperative to improve the healthcare delivery system’s ability to maintain healthcare coordination for timely PCI with respect to STEMI cases. Prior studies have shown that a dedicated coordinator from a medical consortium of STEMI healthcare could play a critical role in maintaining coordination of healthcare, in charge of coordination of community healthcare centers, hospitals and EMS agencies, and collaboration of multidisciplinary teams including the cardiology department, emergency department, infections department, pneumology department, and the medical laboratory department.\textsuperscript{16,33} COVID-19 has influenced the treatment of STEMI patients from the organizational and management structure, such as reduced public willing, stricter community control, complicated medical referral process, occupation of ambulance
infectious disease services, and crowding of hospital medical resources. It is urgent for the medical Alliance to provide relevant treatment referral strategies to promote the implementation of local government. Advocacy is also needed to raise public awareness and further improve treatment.

Limitations

This study has several limitations. First, in a dynamic retrospective study, there would be concerns related to confounding, bias, and temporal trends in quality of healthcare that might limit the validity of the findings. However, we compared the changes in the quality metrics of healthcare 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 merely underestimate the impact of the COVID-19 outbreak and the post COVID-19 era on quality of healthcare. 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 lead to develop chest pain centers accredited by National Health Commission to guide standardized prehospital and in-hospital STEMI healthcare in a regional level in China. Third, for PCI procedure, team co-working problem and a number of extra shifts in catheterization lab which may affect treatment time and quality of care were not considered in this study, due to the data availability. Future researches need to
focus on the coordination of care and task shifts for STEMI patients in responses to
the pandemic from the perspectives of quality of care. 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 healthcare 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.

Author Contributions

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, Mailikezhati Maimaitiming, Dahai
Yue.
Contributorship statement

We thank the Suzhou Emergency Center for providing the data and sharing comments for the study’s findings.

Competing interests

None.

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Data sharing statement

Data for this study were obtained from the China Chest Pain Center Database. (http://data.chinacpc.org/)

Ethics Statement

Ethics approvals of the study have been obtained from the Peking University Health Science Center Institutional Review Board (IRB00001052-21020). Informed consent was obtained from hospitals for research approval to collect data in the study.

Abbreviations

STEMI: ST-segment-elevation myocardial infarction; COVID-19: coronavirus disease 2019; PCI: percutaneous coronary intervention; FMC: first medical contact; EMS: emergency medical service; ACC/AHA: American College of
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### Figures Legends

Figure 1. Daily admissions to hospitals among patients diagnosed with STEMI in Suzhou of China

Figure 2. Predicated monthly admissions for STEMI in Suzhou of China

Figure 3. Monthly mean delay time for healthcare of STEMI, by patient delay, transfer delay and in-hospital delay in Suzhou of China

### Supplement

Supplement Table 1. Definition and measures of quality metrics of STEMI healthcare

Supplement Table 2. Predicated number of admissions for STEMI by each month in Suzhou of China

Supplement Figure 1. Predicated number of admissions for STEMI by each month in Suzhou of China

Supplement Figure 2. Time series Estimated trend model to determine the seasonality
Table 1. Characteristic of STEMI patients during the outbreak and the post-outbreak, compared with corresponding periods in 2018 and 2019

|                                | 2018.0 | 2019.0 | 2020.0 | P (2018 vs 2019) | 2019.0 | 2020.0 | P (2019 vs 2020) | P (2018 vs 2020) |
|--------------------------------|--------|--------|--------|------------------|--------|--------|------------------|------------------|
| Admissions for STEMI           | 280    | 267    | 121    |                  | 528    | 463    | 306              |                  |
| Age (years)*                   | (14.7) | (14.4) | (12.3) | 0.685            | (14.8) | (13.5) | (14.6)          | 0.310            |
| Female, n (%)                  | (18.9) | (15.7) | (26.4) | 0.382            | (17.8) | (16.2) | (17.6)          | 0.558            |
| Transfer mode, n (%)           |        |        |        |                  |        |        |                  |                  |
| Directly via EMS               | (7.9)  | (16.9) | (5.8)  | 0.007            | (9.1)  | (9.3)  | (4.2)           | 0.482            |
| In-hospital                    | 8      | 6      | 6      |                  | 11     | 4      | 9                |                  |
| Transfer-in                    | (29.3) | (22.1) | (28.1) |                  | (27.5) | (27.9) | (28.8)          |                  |
| Directly by self               | (60.0) | (58.8) | (61.2) |                  | (61.4) | (62.0) | (64.1)          |                  |
| Clinical characteristics       |        |        |        |                  |        |        |                  |                  |
| Sustainable chest pain, n (%)  | (75.4) | (70.4) | (76.9) | 0.228            | (76.9) | (74.1) | (78.4)          | 0.340            |
| Intermittent chest pain, n (%) | 55     | 45     | 17     | 0.464            | 79     | 82     | 41              | 0.278            |
|                         | (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 (breaths/min)* | 18.1  | 18.3   | 18.3   | 18.1   | 18.2   | 18.2   | 18.3   | 18.2   |
| (%)                     | 3.6    | 3.9    | 3.2    | 2.9    | 3.4    | 3.7    | 3.2    | 3.7    |
| Pulse frequency (pulse/min)* | 79.1  | 78.0   | 78.0   | 77.2   | 73.4   | 76.3   | 78.0   | 76.3   |
| (%)                     | 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 (mm Hg)* | 130.3 | 133.0  | 128.3  | 132.2  | 133.3  | 131.3  | 128.3  | 131.3  |
| (%)                     | 30.5   | 28.3   | 27.8   | 28.0   | 29.4   | 29.1   | 27.8   | 29.1   |
| Diastolic blood pressure (mm Hg)* | 81.1  | 82.6   | 79.1   | 82.8   | 83.7   | 82.0   | 79.1   | 82.0   |
| (%)                     | 20.3   | 17.9   | 19.5   | 18.8   | 20.0   | 19.0   | 19.5   | 19.0   |
| Killip Class (%)        | 195    | 173    | 89     | 0.632  | 0.120  | 0.485  | 0.129  | 0.485  |
|                         | (79.9) | (84.4) | (74.2) | (84.9) | (88.0) | (82.6) | (74.2) | (82.6) |
| I                       | 22     | 15     | 12     | 31     | 17     | 14     | 12     | 14     |
|                         | (9.0)  | (7.3)  | (10.0) | (6.7)  | (4.3)  | (4.6)  | (10.0) | (4.6)  |
| II                      | 8      | 4      | 6      | 10     | 7      | 12     | 6      | 12      |
|                         | (3.3)  | (2.0)  | (5.0)  | (2.2)  | (1.8)  | (3.9)  | (5.0)  | (3.9)  |
| III                     | 19     | 13     | 13     | 29     | 23     | 27     | 13     | 27     |
|                         | (7.8)  | (6.3)  | (10.8) | (6.2)  | (5.9)  | (8.9)  | (10.8) | (8.9)  |

* Mean (SD)
Table 2. Quality metrics of STEMI healthcare during the outbreak and the post-outbreak, 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  | 2018.0  | 2019.0  | 2020.0  | 2020.0  | 2020.0  | P       | P       | P       | P       |
|                              | 1.23-   | 1.23-   | 1.23-   | (2018)  | (2019)  | (2019)  | (2019)  | (2020)  |         |         |         |         |
|                              | 03.27   | 03.27   | 03.27   |         |         |         |         |         |         |         |         |         |
| Percent of cases arriving at | 22      | 45      | 7       | 0.002   | 0.005   | 48      | 43      | 13      | 1.000   | 0.013   | 7       | 13      | 0.672   |
| the first hospital by        | (7.9)   | (16.9)  | (5.8)   |         |         | (9.1)   | (9.3)   | (4.2)   |         |         | (5.8)   | (4.2)   |         |
| ambulance, n (%)             |         |         |         |         |         |         |         |         |         |         |         |         |         |
| Pre-hospital ECGs, n (%)     | 70      | 85      | 35      | 0.093   | 0.648   | 121     | 138     | 94      | 0.017   | 0.849   | 35      | 94      | 0.805   |
| (25.0)                       | (31.8)  | (28.9)  |         |         |         | (22.9)  | (29.8)  | (30.7)  |         |         | (28.9)  | (30.7)  |         |
| Onset-to-FMC (EMS arrival    | 90      | 94      | 35      | 0.383   | 0.108   | 182     | 144     | 102     | 0.439   | 0.959   | 35      | 102     | 0.445   |
| or walk-in to ED) time ≤60   | (34.0)  | (38.1)  | (28.9)  |         |         | (35.5)  | (32.9)  | (33.3)  |         |         | (28.9)  | (33.3)  |         |
| min, n (%)                   |         |         |         |         |         |         |         |         |         |         |         |         |         |
| Ambulance ECG-to-door time  | 5       | 18      | 3       | 0.019   | 0.129   | 5       | 16      | 6       | 0.052   | 0.256   | 3       | 6       | 0.964   |
| for ambulance transported    | (7.2)   | (22.5)  | (8.6)   |         |         | (4.2)   | (11.8)  | (6.4)   |         |         | (8.6)   | (6.4)   |         |
| cases ≤15 min, n (%)         |         |         |         |         |         |         |         |         |         |         |         |         |         |
| In-hospital process indicators| 124     | 100     | 33      | 0.130   | 0.012   | 207     | 188     | 46      | 0.352   | <0.001  | 33      | 46      | 0.009   |
| β-blocker usage, n (%)       | (54.1)  | (46.5)  | (31.1)  |         |         | (54.0)  | (50.4)  | (18.0)  |         |         | (31.1)  | (18.0)  |         |
| Door-to-balloon time ≤60     | 76      | 82      | 38      | -       | -       | 127     | 188     | 93      | -       | -       | 38      | 93      | -       |
|                                      | min, n (%) | (100.0) | (100.0) | (100.0) | (100.0) | (100.0) | (100.0) | (100.0) | (100.0) |
|--------------------------------------|------------|---------|---------|---------|---------|---------|---------|---------|---------|
| **FMC-to-device time ≤90**           |            |         |         |         |         |         |         |         |         |
| min, n (%)                           |            |         |         |         |         |         |         |         |         |
|                                       |            | 47      | 66      | 32      | 0.004   | 0.651   | 93      | 132     | 68      |
|                                       |            | 68      | 60      | 62      | 0.455   | 0.162   | 32      | 68      | 0.193   |
| **Onset-to-device time ≤120**        |            |         |         |         |         |         |         |         |         |
| min, n (%)                           |            |         |         |         |         |         |         |         |         |
|                                       |            | 21      | 35      | 9       | 0.029   | 0.035   | 52      | 70      | 34      |
|                                       |            | 66      | 60      | 62      | 0.650   | 0.839   | 23      | 34      | 0.269   |
| **Door-to-balloon time, median (q₁, q₃)** |            |         |         |         |         |         |         |         |         |
| FMC-to-device time, median (q₁, q₃)  |            |         |         |         |         |         |         |         |         |
|                                       |            | 12.0    | 11.0    | 12.0    | 0.104   | 0.396   | 14.0    | 12.0    | 15.0    |
|                                       |            | 50.2    | 38.5    | 49.8    | 45.5    | 46.0    | 48.0    | 49.8    | 48.0    |
|                                       |            | 52.0    | 51.5    | 52.5    | 51.0    | 52.0    | 63.0    | 52.5    | 63.0    |
| **Onset-to-device time, median (q₁, q₃)** |            |         |         |         |         |         |         |         |         |
|                                       |            | 116.5   | 74.5    | 126.5   | 0.012   | 0.052   | 93.8    | 94.5    | 107.0   |
|                                       |            | 388.8   | 250.5   | 395.8   | 254.2   | 261.5   | 236.2   | 395.8   | 236.2   |
|                                       |            | 193     | 164     | 82      | 339     | 330     | 184     | 82      | 184     |
| **PCI rate, n (%)**                  |            |         |         |         |         |         |         |         |         |
|                                       |            | 68.9    | 61.4    | 67.8    | 64.2    | 71.3    | 60.1    | 67.8    | 60.1    |
| **Outcome indicators**               |            |         |         |         |         |         |         |         |         |
| In-hospital mortality, n (%)         |            |         |         |         |         |         |         |         |         |
|                                       |            | 9       | 5       | 7       | 0.585   | 0.100   | 11      | 13      | 12      |
|                                       |            | (3.2)   | (2.1)   | (6.0)   | (2.1)   | (2.8)   | (4.1)   | (6.0)   | (4.1)   |
Supplement Figure 1. Time series Estimated trend model to determine the seasonality
Supplement Figure 2. Predicated number of admissions for STEMI by each month in Suzhou of China
Figure 1. Daily admissions to hospitals among patients diagnosed with STEMI in Suzhou of China
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Figure 3. Monthly median delay time for healthcare of STEMI, by patient delay, transfer delay and in-hospital delay in Suzhou of China.
Supplement Table 1. Definition and measures of quality metrics of STEMI healthcare

|                                                                                      | Definition                                                                 | Measures                                                                 |
|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------|
| **Pre-hospital process indicators**                                                 |                                                                           |                                                                          |
| Onset-to-FMC (EMS arrival or walk-in to ED) time ≤ 60 min, n (%)                     | Percentage of patient onset time to first medical contact (FMC) time less than or equal 60 minutes | = (Cases Onset-to-FMC ≤ 60 min)/(Cases with onset time and FMC time) |
| Ambulance ECG to door time for ambulance transported cases ≤ 15 min, n (%)          | Percentage of ambulance transported patient pre-hospital ECG time to door time less than or equal 15 minutes | = (Cases Ambulance ECG to door time ≤ 15 min)/(Cases with pre-hospital ECG time and door time) |
| Percent of cases arriving at the first hospital by ambulance, n (%)                 | Percentage of cases arriving at the first hospital by ambulance among all transfer mode | = (Cases arriving at the first hospital by ambulance)/(All cases)          |
| Pre-hospital ECGs, n (%)                                                            | Percentage of cases use pre-hospital ECGs among all ambulance transported cases | = (Cases with pre-hospital ECG)/(Cases arriving at the first hospital by ambulance) |
| **Hospital process indicators**                                                     |                                                                           |                                                                          |
| β-blocker usage, n (%)                                                              | Percentage of patient use β-blocker                                        | = (Cases use β-blocker)/(All cases)                                       |
| Door-to-balloon time ≤ 60 min, n (%)                                                | Percentage of PCI patient door time to balloon time less than or equal 60 minutes | = (PCI cases door-to-balloon time ≤ 60 min)/(PCI Cases with door time and balloon time) |
| FMC-to-device time ≤ 90 min, n (%)                                                  | Percentage of PCI and thrombolysis patient first medical contact to device time less than or equal 90 minutes | = (PCI and thrombolysis cases FMC-to-device time ≤ 90 min)/(PCI and thrombolysis Cases with FMC time and device time) |
| Onset-to-device time ≤ 120 min, n (%)                                               | Percentage of PCI and thrombolysis patient onset time to device time less than or equal 90 minutes | = (PCI and thrombolysis cases onset-to-device time ≤ 120 min)/(PCI and thrombolysis Cases with onset time and device time) |
| Door-to-balloon time, median (q₁, q₃)                                               | Median of door to balloon time for PCI patient                            | Balloon time – door time (min)                                            |
| FMC-to-device time, median (q₁, q₃)                                                 | Median of FMC to device time for PCI patient                              | = device time – FMC time(min)                                             |
| Onset-to-device time, median (q₁, q₃) | Median of onset to device time for PCI patient = device time – onset time (min) |
| PCI rate, n (%) | Percentage of patients take PCI among all patients = (Cases of PCI)/(All cases) |

**Outcome indicators**

| In-hospital mortality, n (%) | Percentage of patient died in hospital = (Cases of died patient)/(All cases) |
Supplement Table 2. Predicated number of admissions for STEMI by each month in Suzhou of China

| Time period                  | Mean | Lower 80% | Lower 95% | Upper 80% | Upper 95% |
|------------------------------|------|-----------|-----------|-----------|-----------|
| 1st January, 2020-31st January, 2020 | 136  | 107       | 94        | 173       | 197       |
| 1st February, 2020-28th February, 2020 | 107  | 85        | 75        | 135       | 153       |
| 1st March, 2020-31st March, 2020   | 129  | 101       | 88        | 166       | 189       |
| 1st April, 2020-30th April, 2020   | 107  | 84        | 73        | 137       | 156       |
| 1st May, 2020-31st May, 2020      | 122  | 94        | 82        | 158       | 181       |
| 1st June, 2020-30th June, 2020    | 135  | 103       | 89        | 177       | 204       |
| 1st July, 2020-31st July, 2020    | 116  | 89        | 77        | 151       | 174       |
Supplement Figure 1. Predicated number of admissions for STEMI by each month in Suzhou of China
Supplement Figure 2. Time series Estimated trend model to determine the seasonality
# Quality of healthcare and Admission Rates for Acute Cardiac Events during COVID-19 pandemic: a retrospective cohort study on ST-Segment-Elevation Myocardial Infarction in China

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Quality of healthcare and Admission Rates for Acute Cardiac Events during COVID-19 pandemic: a retrospective cohort study on ST-Segment-Elevation Myocardial Infarction in China

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Abstract

Objective: To evaluate changes in admission rates for and quality of healthcare of STEMI during the period of the COVID-19 outbreak and post outbreak.

Methods: We conducted a retrospective study among patients with STEMI in the outbreak time and the post-outbreak time.

Design: To examine the changes in the admission rates and in quality of healthcare, by comparison between periods of the post-outbreak and the outbreak, and between the post-outbreak and the corresponding periods.

Setting: Data for this analysis were included from patients discharge diagnosed with STEMI from all the hospitals of Suzhou in each month of the year until the end of July 2020.

Participants: 1,965 STEMI admissions.

Primary and secondary outcome measures: The primary outcome was the number of monthly STEMI admissions, and the secondary outcomes was the quality metrics of STEMI healthcare.

Results: There were a 53% and 38% fall in daily admissions at the phase of outbreak and post-outbreak, compared with the 2019 corresponding. There remained a gap in actual number of post-outbreak admissions at 306 and the predicted number at 497, an estimated 26 deaths due to STEMI would have been caused by not seeking healthcare.

Post-outbreak period of 2020 compared with corresponding period of 2019, the percentage of cases transferred by ambulance decreased from 9.3% to 4.2% (P=0.013), the door-to-balloon median time increased from 17.5 to 34.0 minutes.
(p=0.001) and the rate of PCI therapy declined from 71.3% to 60.1% (p=0.002).

**Conclusions:** The impact of public health restrictions may lead to unexpected out-of-hospital deaths and compromised quality of healthcare for acute cardiac events. Delay or absence in 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**

COVID-19, Myocardial infarction, Quality in health care
Strengths and limitations of this study

- This study is the first study to examine the changes in the admission rates and in quality of healthcare between the post-outbreak and the corresponding periods in China, with the fading of the COVID-19 outbreak.

- Our confidence in the findings is further increased by Holt-Winters Exponential smoothing analysis, stable sensitivity analyses.

- This study was limited to Suzhou which limits the generalizability of the results.

- It's a dynamic retrospective study, there would be concerns related to confounding, bias, and temporal trends in quality of healthcare that might limit the validity of the findings.
**Introduction**

The coronavirus disease 2019 (COVID-19) pandemic is challenging healthcare delivery 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 measures, emergency infection protocols instituted in hospitals to contain COVID-19, and adjustment of clinical services. The response to outbreak can compromise quality of healthcare for non-coronavirus diseases, especially for ST-Segment-Elevation Myocardial Infarction (STEMI), the deadliest 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 rate of percutaneous coronary intervention (PCI), the typically recommended treatment, during the outbreak. However, little is known regarding the impact of the post-outbreak on admission rate and healthcare quality for STEMI.

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 healthcare in the post-outbreak time: (i) delays in presentation, and (ii) delays in treatment. First, less is clear on whether there has 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 in
the period of post-outbreak, the emphasis on social distancing might have
inappropriately convinced patients to avoid in-person healthcare. 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
healthcare in a timely manner, which will lead to more unexpected out-of-hospital
deaths and cause the secondary disaster of the outbreak.

Second, little is known regarding how the post-outbreak influenced the delivery
of STEMI healthcare in terms of clinical services and processes based on the
recommended guidelines. STEMI cases require rapid coordination of care beginning
at the time once patients enter the healthcare delivery system. 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 healthcare delivery system to make a balance between identifying
patients for PCI procedure, regardless of their coronavirus status, and maintaining the
safety of healthcare 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 healthcare delivery 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
healthcare of STEMI in the post-outbreak time. The objectives of this study are two-
fold as follows: (1) to examine the changes in the admission rates, by comparing the
numbers in the outbreak and post-outbreak with the predicted numbers based on the
admissions in 2017-2019; (2) to investigate the changes in quality of healthcare, by
comparison between periods of the post-outbreak and the outbreak, and between the
post-outbreak and the corresponding periods in 2017-2019.

**Materials and Methods**

**Data Statement**

Data for this study were obtained from the China Chest Pain Center Database (http://data.chinacpc.org/), a nationwide clinical registry for collecting data of all consecutive patients diagnosed with STEMI enrolled by hospitals. The Data Management Committee, one of the committees of the Management Board was responsible for evaluating and monitoring the data. All the accredited CPCs in Suzhou were instructed to submit consecutive eligible patients to the Database. 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 National Health Commission. 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 all the hospitals with capacity of PCI therapy in the city of Suzhou (Represents China's second-tier cities, mainly urban areas), 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 routine work and industry production.

Study Design

We conducted a retrospective study of patients presenting with STEMI between January of 2017 and July of 2020. The outbreak time was defined as period between January 23, 2020 and March 27, 2020, corresponding to the promulgation of the highest restrictions of movement and a public health drive to combat rising cases in Suzhou. The post-outbreak time was defined as period between March 28, 2020, and July 31, 2020 corresponding to the announcement of resumption of daily work and industry production by Suzhou Government. The corresponding periods are defined as the same time quantum in 2017, 2018 and 2019. Data for this analysis were included from patients discharge diagnosed with STEMI from all the hospitals of Suzhou in each month of the year 2017-2019 until the end of July 2020.

Measures

The primary outcome was the number of monthly STEMI admissions, and the secondary outcomes was the quality metrics of STEMI healthcare 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 prehospital process indicators included percentage of onset-to-first medical contact (FMC) time ≤60 min, percentage of ambulance electrocardiogram (ECG) to
door time ≤15 min, percentage of cases arriving at hospital by ambulance, percentage of ambulance ECG. The in-hospital process indicators included percentage of β-blocker usage, percentage of door-to-balloon time ≤60 min, percentage of FMC-to-device time ≤90 min, percentage of onset-to-device time ≤120 min, door-to-balloon time, FMC-to-device time, onset-to-device time, and PCI rate. The clinical outcome indicator was 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

A descriptive analysis presented the daily admission rates and median monthly onset-to-PCI time of STEMI patients over the periods of the post-outbreak time to the corresponding period in 2017-2019. To provide a more intuitive interpretation of unexpected out-of-hospital deaths, we predicted the number of admissions that should be in the post-outbreak time 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 common forecasting algorithm which weighted average of past observations with exponentially decaying weights to capture the trend in a time-series dataset. The component form of the addition model is:

\[ y_{t+h|t} = l_t + h b_t + s_{t-m} + h_m + \]
\[ \ell_t = \alpha(y_t - s_{t-m}) + (1-\alpha)(\ell_{t-1} + b_{t-1}) \]
\[ b_t = \beta^*(\ell_t - \ell_{t-1}) + (1-\beta^*)b_{t-1} \]
\[ s_t = \gamma(y_t - \ell_{t-1} - b_{t-1}) + (1-\gamma)s_{t-m} \]

Where \( k \) is the integral part of \( (h-1)/m \), which ensures that the estimates of the seasonal index used for the prediction are from the last year of the sample. Level equations of the "\( t \)", means the weighted average of seasonal adjustment of observations \( (y_t - s_{t-m}) \) and Non-seasonally adjusted observations \( (\ell_{t-1} + b_{t-1}) \).

The trend equation is the same as Holt linear method. The weighted mean seasonality equation represents the current seasonality index, \( (y_t - \ell_{t-1} - b_{t-1}) \), A weighted average of the seasonal index from the same season last year (\( m \) time periods ago).

The smoothing parameters were automatically generated prior modeling with Holt-Winters method. The \( \alpha \) (level), \( \beta \) (slope) and \( \gamma \) (\( s_t \)) of trend 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. The predicated death number due to the lack of seeking healthcare was calculated by the forecast formula: (predicated numbers - actual numbers) \( \times \) 8% (average death rate in China).

To examine changes in quality metrics of STEMI healthcare, we compared the list of indicators in terms of prehospital process, in-hospital process, and clinical outcome, by a subsample of respective periods, including the outbreak period and the corresponding periods in 2019 and 2018, the post-outbreak period and the corresponding periods in 2019 and 2018. To test the robustness of our findings, we conducted two step of sensitivity analyses. First, we found the estimated trend of the
time series was drawn by the function to determine the seasonality of the model (Supplement Figure 1). Then, repeated Holt-Winters exponential smoothing was employed after time series analysis by monthly data to verify the stability of data and consistency of results (Supplement Figure 2). 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).

Patient and Public Involvement

Patients and the public were not directly involved in the study.

Results

Patient Characteristics

The study comprised 1,965 admissions for STEMI, of which 121 and 306 were in the outbreak and the post-outbreak time, respectively. Of those 306 patients in the post-outbreak time, 17.6% were women, with a mean age of 60.7 (SD 14.6) years. During the 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-outbreak time, respectively (Table 1).

Daily Admissions for STEMI

Figure 1 demonstrates daily admissions for STEMI over the periods of outbreak and post-outbreak to the corresponding time in 2018 and 2019. The percentage
reduction in admissions were 57% and 55% between the 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-outbreak time, such that there were 306 admissions, representing
a 42% and 34% reduction from 2018 and 2019 baseline.

Figure 2 shows predicated number of daily admissions for STEMI during the
outbreak and the post-outbreak. After Holt-Winters exponential smoothing, the
smoothing parameters are $\alpha = 0.27$, $\beta = 3 \times 10^{-4}$, $\gamma = 0.23$. Prediction based on level
(\(\alpha\)), trend (\(\beta\)) and seasonal (\(\gamma\)) parameters , all of them are relatively between 0-1 and
closer to 0, which reflects that the model is relatively stable and the predictions are
more reliable. The predicted numbers of admissions for STEMI that might be in the
outbreak and the post-outbreak time was 259 and 497. There were a 53% and 38%
decline in admissions, with the actual numbers of 121 and 306. Predicated numbers of
monthly admissions for STEMI are shown in Supplement Table 2. Based on the
forecast formula, the predicted death number due to STEMI caused by the lack of
seeking healthcare was 26.

Quality Metrics of STEMI Healthcare

Figure 3 presents the median monthly treatment delay for STEMI healthcare, 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 healthcare, by comparison between periods of the post-outbreak and the outbreak, and between the post-outbreak and the corresponding periods in 2018-2019. The percentage of STEMI cases transferred by ambulance was both 4.2% in the outbreak and post-outbreak time, respectively, lower than those in the corresponding period of 2019 (16.9%, P=0.005; 9.3%, P=0.013). During the post-outbreak to the corresponding period of 2019, the 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 therapy 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 healthcare between the outbreak and post-outbreak time showed insignificant, with the percentage of cases transferred by ambulance, the percentage of onset-to-FMC time ≤60 min, the percentage of onset-to-device time ≤120 min, and the PCI rate decreasing, and the door-to-balloon time increasing.

Discussion

Principal Findings

This is, to our knowledge, the first study to investigate the changes in admissions for and quality of healthcare among acute cardiac events in the post-outbreak time,
with the fading of the COVID-19 outbreak. In this study, the Holt-Winters exponential smoothing analysis was used to effectively predict the number of admissions in 2019-2020 and estimate the gap by adding seasonal parameters. Although we observed the reversed increase in STEMI admissions, there remained a gap in the number of the post-outbreak time 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 healthcare, while no one died from COVID-19 in the post-outbreak time in the city of Suzhou. According to the incidence of STEMI about 55/100,000 in China, it can be preddated that there will be nearly 300,000 STEMI not seeking healthcare, which could lead to over 20,000 death during the post-outbreak of study. Quality of STEMI healthcare remained suboptimal in the post-outbreak time, comparing with those in the corresponding periods in 2018-2019, especially for the percentage of cases transferred by EMS, and the in-hospital process indicators. Although the in-hospital mortality declined during the outbreak to the post-outbreak, the change was not significant. These findings suggest that the impact of public health restrictions in the post-outbreak time is still significant, and may lead to unexpected out-of-hospital deaths and compromised quality of healthcare for acute cardiac events.

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 therapy during the outbreak. Previous studies using the self-controlled case series method provided evidence that the outbreak may increase the risk of STEMI during the acute phase of infection. However, the reduced number of admissions...
during the outbreak is likely to have resulted in increases in out-of-hospital deaths and long-term complications. Our current study focuses on the post-outbreak time, 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 outbreak and the corresponding period of 2019, and the post-outbreak 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-outbreak time in comparison with the corresponding period of 2019. Causes for less presentation for healthcare are likely multifactorial and most researches emphasize that patients may be reluctant to present to hospitals because of the fear of contracting the coronavirus 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 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, hospitals are
encouraged to establish a medical consortium of STEMI healthcare. Hospitals are partnered with community healthcare centers to form an information-sharing and resource-management model. Community healthcare workers conduct management of STEMI healthcare 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 hospitals remain fully operational and have stringent infection-control protocols in place even in the post-outbreak time.

Obviously national lockdowns and altered healthcare priorities in response to COVID-19 outbreak are affecting the diagnosis and treatment of STEMI. According to Consensus 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 very few patients with suspected COVID-19, emergency intravenous thrombolysis is the first choice for cases with no contraindication to thrombolysis, which will not impact the proportion of PCI rate and affect the quality of medical care; 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.

In fact, most hospitals 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 intervals of the treatment delay including patient delay and system delay (including prehospital delay and in-hospital delay). Notably, the extension in patient delay showed no significant during the post-outbreak and the corresponding periods of 2018-2019. We observed a significant prolongation of the door-to-balloon time and the FMC-to-device time, mainly due to the requirement of testing negativity for coronavirus infection.

Meanwhile, a 12-point percentage of decline in rate of PCI therapy was observed over the period of the post-outbreak and the corresponding periods in 2019. Thus, even in the post COVID-19 era, delays in the 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 the in-hospital mortality increased from 2.1% to 6.0% between the outbreak and the corresponding period of 2019, and the in-hospital mortality declined from the outbreak to the post-outbreak time, but 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-outbreak time were about 5 years younger and had a 13-point lower percentage of female, comparing those in the outbreak time. 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.\textsuperscript{29,30} Nevertheless, data of our study provides additional information that neither the risk profile of patients hospitalized with STEMI has significantly changed in the post-outbreak time and nor have the clinical outcomes. Second is the treatment approaches for patients hospitalized with STEMI. The rates of PCI therapy persisted about 60% during the outbreak and the post-outbreak, 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 the PCI therapy as a result of the COVID-19 pandemic.\textsuperscript{1,31,32} These results were coupled with delays in the PCI therapy, pointing to the persistently high in-hospital mortality during the outbreak and the post-outbreak. Clinical outcome in patients with STEMI in the post-outbreak time might be influenced by the delay to treatment and less use of PCI therapy. Therefore, it is imperative to improve the healthcare delivery system’s ability to maintain healthcare coordination for timely PCI with respect to STEMI cases. Prior studies have shown that a dedicated coordinator from a medical consortium of STEMI healthcare could play a critical role in maintaining coordination of healthcare, in charge of coordination of community healthcare centers, hospitals and EMS agencies, and collaboration of multidisciplinary
teams including the cardiology department, emergency department, infections

COVID-19 has influenced the treatment of STEMI patients from the organizational and management structure, such as reduced public willing, stricter community control, complicated medical referral process, occupation of ambulance infectious disease services, and crowding of hospital medical resources. It is urgent for the medical Alliance to provide relevant treatment referral strategies to promote the implementation of local government. Advocacy is also needed to raise public awareness and further improve treatment.

Limitations

This study has several limitations. First, in a dynamic retrospective study, there would be concerns related to confounding, bias, and temporal trends in quality of healthcare that might limit the validity of the findings. However, we compared the changes in the quality metrics of healthcare 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 merely underestimate the impact of the COVID-19 outbreak and the post COVID-19 era on quality of healthcare. 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 lead to
develop chest pain centers accredited by National Health Commission to guide standardized prehospital and in-hospital STEMI healthcare in a regional level in China. Third, for PCI procedure, team co-working problem and a number of extra shifts in catheterization lab which may affect treatment time and quality of care were not considered in this study, due to the data availability. Future researches need to focus on the coordination of care and task shifts for STEMI patients in responses to the pandemic from the perspectives of quality of care. 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 healthcare 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.

Contributions
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, Mailikezhati Maimaitiming, Dahai Yue.

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Competing interests

None.

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Data sharing statement

Data for this study were obtained from the China Chest Pain Center Database. (http://data.chinacpc.org/)

Ethics Statement

Ethics approvals of the study have been obtained from the Peking University Health Science Center Institutional Review Board (IRB00001052-21020). Informed consent was obtained from hospitals for research approval to collect data in the study.
**Abbreviations**

STEMI: ST-segment-elevation myocardial infarction; COVID-19: coronavirus disease 2019; PCI: percutaneous coronary intervention; FMC: first medical contact; EMS: emergency medical service; ACC/AHA: American College of Cardiology/American Heart Association

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**Figures Legends**

Figure 1. Daily admissions to hospitals among patients diagnosed with STEMI in Suzhou of China

Figure 2. Predicated monthly admissions for STEMI in Suzhou of China

Figure 3. Monthly mean delay time for healthcare of STEMI, by patient delay, transfer delay and in-hospital delay in Suzhou of China

**Supplement**

Supplement Table 1. Definition and measures of quality metrics of STEMI healthcare

Supplement Table 2. Predicated number of admissions for STEMI by each month in Suzhou of China
Supplement Figure 1. Predicated number of admissions for STEMI by each month in Suzhou of China

Supplement Figure 2. Time series Estimated trend model to determine the seasonality
Table 1. Characteristic of STEMI patients during the outbreak and the post-outbreak, 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 vs 2019) 2020.0  2020.0  \( P \) (2019 vs 2020) | 2018.0  2019.0  2020.0  \( P \) (2018 vs 2019) 2019.0  2020.0  \( P \) (2019 vs 2020) | 2020.0  2020.0  \( P \) (2019 vs 2020) |
| Admissions for STEMI     | 280 267 121                                                                                   | 528 463 306                                                                   | 121 306                                                   |
| Age (years)*             | 61.5 62.0 65.2 0.685 0.036                                                                 | 60.1 59.1 60.7 0.310 0.127                                                   | 65.2 60.7 0.003                                           |
| Female, n (%)            | 53 42 32 0.382 0.019                                                                          | 94 75 54 0.558 0.669                                                        | 32 54 0.056                                               |
| Transfer mode, n (%)     | 22 45 7 0.007 0.012                                                                          | 48 43 13 0.482 0.010                                                        | 7 13 0.666                                                |
| Directly via EMS         | (7.9) (16.9) (5.8) \( P \) (2018 vs 2019) (9.1) (9.3) (4.2) \( P \) (2019 vs 2020)          | (5.8) (4.2)                                                                  | (5.8) (4.2)                                               |
| In-hospital              | 8 6 6                                                                                        | 11 4 9                                                                       | 6 9                                                      |
| Transfer-in              | (2.9) (2.2) (5.0) \( P \) (2018 vs 2019) (2.1) (0.9) (2.9) \( P \) (2019 vs 2020)          | (5.0) (2.9)                                                                  | (5.0) (2.9)                                               |
| Directly by self         | 168 157 74                                                                                   | 324 287 196                                                                  | 74 196                                                   |
| Clinical characteristics  |                                                                                  |                                                                                  |                                                          |
| Sustainable chest pain,  | 211 188 93 0.228 0.233                                                                        | 406 343 240 0.340 0.196                                                       | 93 240 0.823                                             |
| n (%)                    | (75.4) (70.4) (76.9) \( P \) (2018 vs 2019) (76.9) (74.1) (78.4) \( P \) (2019 vs 2020) | (76.9) (78.4)                                                                | (76.9) (78.4)                                             |
| Intermittent chest pain, | 55 45 17 0.464 0.583                                                                         | 79 82 41 0.278 0.135                                                         | 17 41 0.984                                              |
|                              | (19.6) | (16.9) | (14.0) | (15.0) | (17.7) | (13.4) | (14.0) | (13.4) |
|------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Chest pain relief, n (%)     | 7      | 4      | 4      | 0.596  | 0.438  | 0.166  | 0.022  | 0.948  |
| Respiratory rate (breaths/min)* | 18.1   | 18.3   | 18.3   | 18.1   | 18.2   | 18.2   | 18.3   | 18.2   | 0.658  |
| Pulse frequency (pulse/min)* | 79.1   | 78.0   | 78.0   | 77.2   | 73.4   | 76.3   | 78.0   | 76.3   | 0.462  |
| Heart rate (beats/min)*      | 19.8   | 18.9   | 23.7   | 18.0   | 18.8   | 21.2   | 23.7   | 21.2   | 0.325  |
| Systolic blood pressure (mm Hg)* | 103.0 | 133.0  | 128.3  | 132.2  | 133.3  | 131.3  | 128.3  | 131.3  | 0.155  |
| Diastolic blood pressure (mm Hg)* | 30.5  | 28.3   | 27.8   | 28.0   | 29.4   | 29.1   | 27.8   | 29.1   | 0.144  |
| Killip Class (%)             | 195    | 173    | 89     | 0.632  | 0.120  | 0.485  | 0.129  | 0.89   | 0.251  |
| I                            | 79.9   | 84.4   | 74.2   | 84.9   | 88.0   | 82.6   | 74.2   | 82.6   | 0.144  |
| II                           | 22     | 15     | 12     | 31     | 17     | 14     | 12     | 14     | 0.354  |
| III                          | 8      | 4      | 6      | 10     | 7      | 12     | 6      | 12     | 0.460  |
| IV                           | 19     | 13     | 13     | 29     | 23     | 27     | 13     | 27     | 0.155  |

* Mean (SD)
Table 2. Quality metrics of STEMI healthcare during the outbreak and the post-outbreak, 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 2018.0 2019.0 2020.0 (P vs P)                        | 2018.0 2019.0 2020.0 2018.0 2019.0 2020.0 (P vs P)                           | 2020.0 2020.0 (P vs P)                                   |
| Admissions for STEMI | 220 267 121 48 43 13 1.000 0.013 7 13 0.672                            | 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 9 (1.1) (9.3) (4.2) 1.000 0.013 7 (5.8) (4.2) 0.672 | 48 43 13 1.000 0.013 7 13 0.672 | 528 463 306 121 306 |
| Pre-hospital ECGs, n (%) | 70 (25.0) 50 (18.9) 35 (28.9) 0.93 0.648 121 (22.9) (29.8) (30.7) 0.017 0.849 35 94 0.805 | 121 138 94 0.017 0.849 35 94 0.805 | 528 463 306 121 306 |
| Onset-to-FMC (EMS arrival or walk-in to ED) time ≤60 min, n (%) | 90 (34.0) 94 (38.1) 35 (28.9) 0.38 0.108 182 (35.5) (32.9) (33.3) 0.43 0.959 35 102 0.445 | 182 144 102 0.3 0.959 35 102 0.445 | 528 463 306 121 306 |
| Ambulance ECG-to-door time for ambulance transported cases ≤15 min, n (%) | 5 (7.2) 18 (22.5) 3 (8.6) 0.01 0.129 5 (4.2) (11.8) (6.4) 0.05 0.256 3 (8.6) (6.4) 0.964 | 5 16 6 0.05 0.256 3 6 0.964 | 528 463 306 121 306 |
| In-hospital process indicators |                                                                  |                                                                                |                                                          |
| β-blocker usage, n (%) | 124 (54.1) 100 (46.5) 33 (31.1) 0.13 0.012 207 (54.0) (50.4) (18.0) 0.35 <0.001 33 (31.1) (18.0) 0.009 | 207 188 46 0.35 <0.001 33 46 0.009 | 528 463 306 121 306 |
| Door-to-balloon time ≤60 | 76 (46.5) 82 (31.1) 38 - - 127 (54.0) (50.4) (18.0) - - | 127 188 93 - - | 528 463 306 121 306 |
| Outcome indicators |   |   |   |   |   |
|--------------------|---|---|---|---|---|
| **In-hospital mortality, n (%)** | 9 | 5 | 7 | 11 | 13 |
|                     | (3.2) | (2.1) | (6.0) | (2.1) | (2.8) |
|                     | 0.585 | 0.100 | 0.590 | 0.442 | 0.442 |
|                     | (4.1) | (6.0) | (6.0) | (4.1) | (4.1) |
|                     | 0.572 | 0.175 | 0.124 | 0.062 | 0.005 |

**Outcome indicators**

- **FMC-to-device time ≤90 min, n (%)**
  - 47 (68.1), 66 (89.2), 32 (84.2) vs 93 (75.6), 132 (80.0), 68 (71.6)
  - 93 (100.0), 132 (100.0), 68 (100.0)
  - 0.004 vs 0.651
  - 0.455 (84.2), 0.162 (71.6)

- **Onset-to-device time ≤120 min, n (%)**
  - 21 (27.6), 35 (46.1), 9 (23.7) vs 52 (40.6), 70 (37.4), 34 (35.4)
  - 52 (100.0), 70 (100.0), 34 (100.0)
  - 0.029 vs 0.035
  - 0.650 (23.7), 0.839 (35.4)

- **Door-to-balloon time, median (q1, q3)**
  - 32.0 [12.0, 50.2] vs 30.0 [11.0, 17.5]
  - 39.5 [11.2, 34.0] vs 39.5 [11.2, 34.0]
  - 0.002 vs 0.104
  - 0.004 vs 0.396

- **FMC-to-device time, median (q1, q3)**
  - 120, 192.5 [12.0, 132.0] vs 14.0 [11.0, 222.5]
  - 112, 192.5 [11.0, 192.5] vs 14.0 [11.2, 122.5]
  - 0.002 vs 0.104
  - 0.004 vs 0.396

- **Onset-to-device time, median (q1, q3)**
  - 222.5 [116.5, 388.8] vs 93.8 [94.5, 261.5]
  - 236.2 [107.0, 395.8] vs 236.2 [107.0, 395.8]
  - 0.012 vs 0.010
  - 0.052 vs 0.052

- **PCI rate, n (%)**
  - 193 (68.9), 164 (61.4), 82 (67.8) vs 339 (64.2), 330 (71.3), 184 (60.1)
  - 339 (100.0), 330 (100.0), 184 (100.0)
  - 0.080 vs 0.021
  - 0.276 vs 0.002

- **Outcome indicators**
  - **In-hospital mortality, n (%)**
    - 9 (3.2), 5 (2.1), 7 (6.0) vs 11 (2.1), 13 (2.8), 12 (4.1)
    - 11 (100.0), 13 (100.0), 12 (100.0)
    - 0.585 vs 0.100
    - 0.590 (4.1), 0.442 (4.1)
Figure 1. Daily admissions to hospitals among patients diagnosed with STEMIs in Suzhou of China.
Figure 2. Predicted monthly admissions for STEMI in Suzhou of China
Figure 3. Monthly median delay time for healthcare of STEMI, by patient delay, transfer delay and in-hospital delay in Suzhou of China
Supplement Table 1. Definition and measures of quality metrics of STEMI healthcare

| Indicator | Definition | Measure |
|-----------|------------|---------|
| **Pre-hospital process indicators** | | |
| Onset-to-FMC (EMS arrival or walk-in to ED) time ≤ 60 min, n (%) | Percentage of patient onset time to first medical contact (FMC) time less than or equal 60 minutes | = (Cases Onset-to-FMC ≤ 60 min)/(Cases with onset time and FMC time) |
| Ambulance ECG to door time for ambulance transported cases ≤ 15 min, n (%) | Percentage of ambulance transported patient pre-hospital ECG time to door time less than or equal 15 minutes | = (Cases Ambulance ECG to door time ≤ 15 min)/(Cases with pre-hospital ECG time and door time) |
| Percent of cases arriving at the first hospital by ambulance, n (%) | Percentage of cases arriving at the first hospital by ambulance among all transfer mode | = (Cases arriving at the first hospital by ambulance)/(All cases) |
| Pre-hospital ECGs, n (%) | Percentage of cases use pre-hospital ECGs among all ambulance transported cases | = (Cases with pre-hospital ECG)/(Cases arriving at the first hospital by ambulance) |
| **Hospital process indicators** | | |
| β-blocker usage, n (%) | Percentage of patient use β-blocker | = (Cases use β-blocker)/(All cases) |
| Door-to-balloon time ≤ 60 min, n (%) | Percentage of PCI patient door time to balloon time less than or equal 60 minutes | = (PCI cases door-to-balloon time ≤ 60 min)/(PCI Cases with door time and balloon time) |
| FMC-to-device time ≤ 90 min, n (%) | Percentage of PCI and thrombolysis patient first medical contact time to device time less than or equal 90 minutes | = (PCI and thrombolysis cases FMC-to-device time ≤ 90 min)/(PCI and thrombolysis Cases with FMC time and device time) |
| Onset-to-device time ≤ 120 min, n (%) | Percentage of PCI and thrombolysis patient onset time to device time less than or equal 90 minutes | = (PCI and thrombolysis cases onset-to-device time ≤ 120 min)/(PCI and thrombolysis Cases with onset time and device time) |
| Door-to-balloon time, median (q1, q3) | Median of door to balloon time for PCI patient | = Balloon time – door time (min) |
| FMC-to-device time, median (q1, q3) | Median of FMC to device time for PCI patient | = device time – FMC time(min) |
| Metric                          | Description                                                                 |
|--------------------------------|-----------------------------------------------------------------------------|
| Onset-to-device time, median (q₁, q₃) | Median of onset to device time for PCI patient = device time – onset time(min) |
| PCI rate, n (%)                  | Percentage of patients take PCI among all patients = (Cases of PCI)/(All cases) |

**Outcome indicators**

| Metric                          | Description                                                                 |
|--------------------------------|-----------------------------------------------------------------------------|
| In-hospital mortality, n (%)    | Percentage of patient died in hospital = (Cases of died patient)/(All cases) |
Supplement Table 2. Predicated number of admissions for STEMI by each month in Suzhou of China

| Time period                        | Mean | Lower 80% | Lower 95% | Upper 80% | Upper 95% |
|------------------------------------|------|-----------|-----------|-----------|-----------|
| 1st January, 2020-31st January, 2020 | 136  | 107       | 94        | 173       | 197       |
| 1st February, 2020-28th February, 2020 | 107  | 85        | 75        | 135       | 153       |
| 1st March, 2020-31st March, 2020   | 129  | 101       | 88        | 166       | 189       |
| 1st April, 2020-30th April, 2020   | 107  | 84        | 73        | 137       | 156       |
| 1st May, 2020-31st May, 2020       | 122  | 94        | 82        | 158       | 181       |
| 1st June, 2020-30th June, 2020     | 135  | 103       | 89        | 177       | 204       |
| 1st July, 2020-31st July, 2020     | 116  | 89        | 77        | 151       | 174       |
Supplement Figure 1. Time series Estimated trend model to determine the seasonality.
Supplement Figure 2. Predicated number of admissions for STEMI by each month in Suzhou of China