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Comparison of Clinical Outcomes in Patients with ST Elevation Myocardial Infarction with Percutaneous Coronary Intervention and the Use of a Telemedicine App Before and After the COVID-19 Pandemic at a Center in Beijing, China, from August 2019 to March 2020

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Background:

The efficacy of telemedicine in reducing delay times and short-term adverse clinical outcomes in patients with ST segment elevation myocardial infarction (STEMI) during the coronavirus disease 2019 (COVID-19) pandemic is unclear. This study compared outcomes in patients with STEMI who had percutaneous coronary intervention (PCI) and the use of a telemedicine app from August 2019 to March 2020 at a single center in Beijing, China.

Material/Methods:

A total of 243 patients with STEMI who underwent PCI were consecutively enrolled and divided into 2 groups according to the date, before or after the pandemic. The 2 groups were further divided into patients who used the app for consulting and those who did not.

Results:

The time from symptom onset to calling an ambulance (SCT), door to balloon time (DTB), and total ischemia time (TIT) were significantly prolonged in patients after the pandemic. Patients who used the app had shorter SCT, DTB, and TIT before and after the pandemic compared to those who did not. Adverse clinical outcomes were significantly higher after compared with before the pandemic, despite the incidence rate of stroke, any revascularization, and stent thrombosis. However, there was no significant difference in short-term adverse clinical outcomes between patients who used the app and those who did not before and after the pandemic.

Conclusions:


Telemedicine reduced the delay time of STEMI patients during the COVID-19 pandemic. The difference in short-term adverse clinical outcomes was not statistically significant between patients who used the app and those who did not.

MeSH Keywords:

Acute Coronary Syndrome • COVID-19 • Telemedicine

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Background

Coronavirus disease 2019 (COVID-19), which is caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is presently a global pandemic [1]. The normal performance of medical services and the willingness of patients to seek treatment are compromised [2]. Acute ST segment elevation myocardial infarction (STEMI), a type of cardiovascular emergence, causes a large number of deaths in modern society. The prevalence of STEMI may increase under the social and psychosocial pressure caused by COVID-19 [3]. The importance of reducing the total ischemia time (TIT) to as short as possible is well recognized because opportune reperfusion therapy is related with marked improvement in clinical outcomes of STEMI patients [4–7]. The potential impact of COVID-19 on pre- and post-hospital delay times and short-term adverse clinical outcomes in patients with STEMI is unclear.

Telemedicine is a useful tool to improve health care performance and has been proven to be effective for the management of STEMI patients [8–10]. The crucial role of telemedicine in medical services during the COVID-19 pandemic has been discussed in several review articles [11–13]. However, the efficacy of telemedicine in reducing delay times and short-term adverse clinical outcomes in STEMI patients undergoing primary percutaneous coronary intervention (PCI) during the COVID-19 pandemic is ill-defined. In August 2019, our center developed a free-of-charge application (the Tiantanzhixin app) that enabled online communication between patients and doctors to improve the management quality of patients with chronic diseases. As of March 31, 2020, 4 866 patients had downloaded

this app. Some app users developed STEMI and consulted online via the app before and after the COVID-19 pandemic.

This study aimed to compare the clinical outcomes in patients with STEMI and PCI who used the telemedicine app with those patients who did not use the app before and after the COVID-19 pandemic from August 2019 to March 2020 at a single center in Beijing, China.

Material and Methods

Study design and participants

This was a single-center observational study conducted at the Beijing Tiantan Hospital, Capital Medical University, a large tertiary hospital in Beijing, China. Patients diagnosed with acute STEMI who underwent primary PCI within 24 h after symptom onset at our center from August 1, 2019, to March 31, 2020, were consecutively enrolled. STEMI was diagnosed according to the universal definition: myocardial ischemia symptoms with ST segment elevation >2 mm in V_2 – V_3 or >1 mm in other contiguous leads, or a new left bundle branch block. Patients were excluded from the study for the following reasons: patient refused or did not undergo primary PCI; patients with STEMI due to stent thrombosis; and patients with mechanical complications. The study flowchart is shown in the Figure 1.

Demographic characteristics, comorbidities, and risk factors including hypertension, dyslipidemia, diabetes mellitus, and smoking were collected and analyzed. Clinical manifestation (Killip

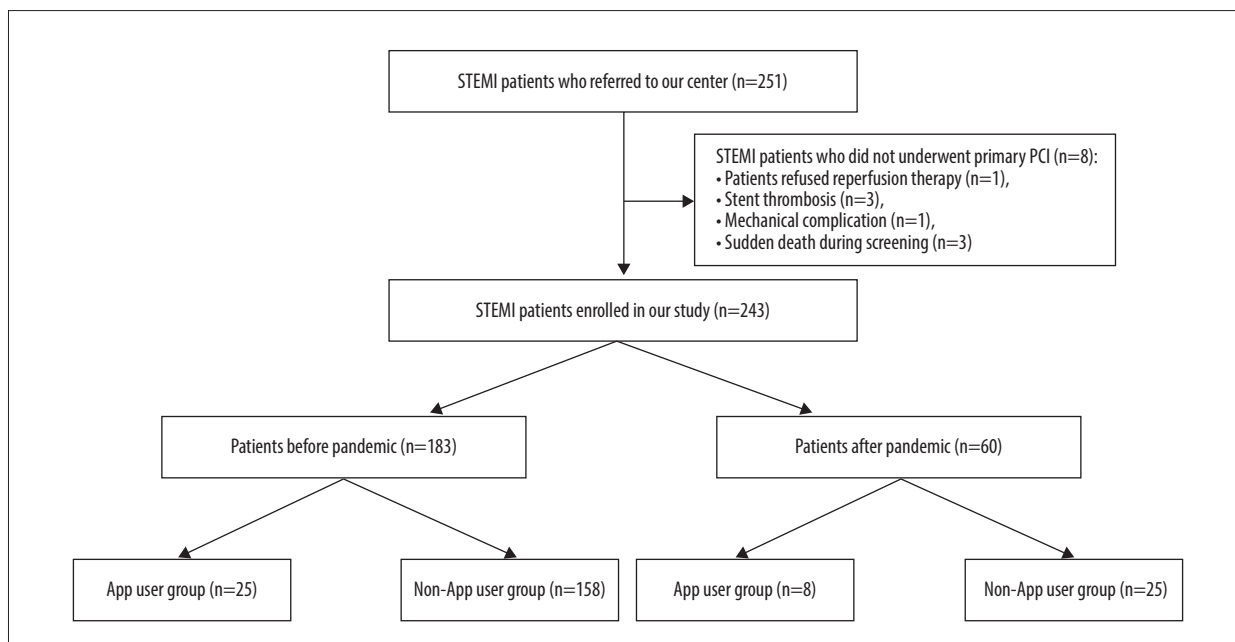


Figure 1. Study flowchart.

classification, hypotension, or cardiac shock) and risk stratification of the enrolled patients were documented and analyzed. Cardiogenic shock was diagnosed when the systolic blood pressure of STEMI patients was <90 mmHg or ≥ 90 mmHg with the need of therapeutically or mechanical support combined with hypoperfusion signs and a heart rate of ≥ 60 beats/min. Risk stratification was scored by the Global Registry of Acute Coronary Events (GRACE) scoring system which has 8 clinical variables ranging from 2 to 372 and the Thrombolysis in Myocardial Infarction (TIMI) scoring system which has 7 clinical variables ranging from 0 to 7 [14,15]. The coronary anatomy severity was scored using the Synergy Between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery (Syntax) score [16]. Upon admission, laboratory test results, including peak cardiac troponin I during hospitalization, B-type natriuretic peptide (BNP), and left ventricular ejection fraction, were also collected.

Study endpoints

The critical time intervals, namely, the time from symptom onset to calling ambulance (SCT), calling ambulance to first medical contact (FMC) arrival time, FMC to hospital arrival time, door to balloon (DTB) time, and TIT were retrieved. Short-term adverse clinical outcomes were also documented and compared. The adverse clinical outcomes included major adverse cardiac event (MACE), all-causes of death, cardiac death, non-fatal myocardial infarction, stroke, any revascularization, definite or probable stent thrombosis, and new renal replacement therapy. MACE was defined as the composite of death, myocardial infarction, and any revascularization. Cardiac death was diagnosed as any death due to cardiac or procedure-related causes. All of the deaths were considered cardiac related unless an unequivocal non-cardiac cause could be established. Myocardial infarction was defined by the following parameters: presence of clinical symptoms, electrocardiogram (ECG) changes or abnormal imaging findings indicative of myocardial infarction, and an increase in creatine kinase myocardial band fraction above the upper normal limits or an increase in troponin I above the 99th percentile. Stroke was diagnosed with the presence of a new focal neurological deficit with signs or symptoms persisting for 24 h and in the presence of cerebral lesions, which were detected by imaging procedures. Any revascularization was defined as a second PCI or coronary bypass surgery in the target vessel. Stent thrombosis was classified using the Academic Research Consortium definition [17]. In-hospital adverse events were recorded from patient electronic medical records, and 30-day adverse events were evaluated by telephone interviews, outpatient visits, or through the Tiantanzhixin app.

Screening protocol of STEMI patients at beijing tiantan hospital during the COVID-19 pandemic

During the pandemic, there was no restriction on the normal movements of patients; however, there were strict screening

protocols to reduce the risk of cross infection. In our hospital, all of the STEMI patients who intended to undergo primary PCI received COVID-19 screening before starting the primary PCI procedure after January 31, 2020, the day Wuhan was locked down. The screening protocol was as follows at our center: If a patient had fever or suspicious medical contact history in Hubei province, thrombolytic therapy was recommended instead of primary PCI. If a patient had no signs of infection and no suspicious medical contact history, he or she underwent primary PCI if the screening examination, including the complete blood count and chest computed tomography (CT), was normal. If a patient had no signs of infection and no suspicious medical history but the complete blood count or chest CT were suspicious for COVID-19 infection, he or she did not undergo primary PCI until a throat swab nucleic acid test was negative. The nucleic acid test was examined by reverse transcription polymerase chain reaction (RT-PCR) assays. RT-PCR was conducted with primers and probes targeting the ORF1ab and N genes and a positive reference gene according to the manufacturer's specifications (Beijing Yocan Biology Co Ltd., China). The diagnosis and management of patients with COVID-19 was conducted according to the current clinical guideline [18]. None of the patients enrolled in our study were diagnosed with COVID-19.

Detailed information on the tiantanzhixin application

The Tiantanzhixin app is a free-of-charge application designated for smart phones. All of the patients who visited the outpatient clinic or chest pain center, or were hospitalized in our department for any reason were recommended to install this app by scanning a quick response code. This novel application has bilateral communication functions that support real-time home-to-hospital interactions and online consulting. All of the patients who successfully installed the app can communicate with doctors online anytime using voice messages, text messages, or pictures. Trained professionals answer the patients' questions.

Primary PCI procedure and optimal medical therapy

Primary PCI was performed by trained clinicians using the standard technique via radial or femoral access routes, according to the recommendations from current guidelines. The employ of thrombus aspiration catheter, intra-aortic balloon counterpulsation (IABP), temporary pacemaker, lesion preparation, stent implantation, post-dilation, and the use of glycoprotein IIb/IIIa inhibitor (GPI) and anticoagulation regimens were left to the discretion of the clinician. All of the patients were prescribed aspirin (600 mg for loading dose, 100 mg per day for maintenance) in combination with clopidogrel (600 mg for loading dose, 75 mg per day for maintenance) or ticagrelor (180 mg for loading dose, 90 mg twice per day for maintenance).

Angiotensin-converting enzyme (ACE) inhibitors, angiotensin receptor blockers (ARB), β blockers, statins, and other medical therapies were prescribed as the guidelines recommended.

All of the patients provided written informed consent. Ethical approval was granted by the Beijing Tiantan Hospital, Capital Medical University.

Statistical analysis

Categorical variables were expressed as total numbers and percentages and were compared between groups by the chi-squared test and Yate's continuity correction when the total counts per category <5 . Continuous variables were expressed as mean \pm SD or median (quartiles 1 and 3) and compared using the independent sample *t* test or Mann-Whitney test based on the normality assumptions. A *P* value of <0.05 was considered statistically significant. The statistical analysis was performed by SPSS version 22.0 (SPSS Inc, Chicago, IL, USA).

Results

During the study period, 243 STEMI patients were enrolled in our study. A total of 183 patients underwent primary PCI between August 1, 2019, and January 22, 2020 (before the pandemic), and 60 patients underwent primary PCI between January 23, 2020, and March 31, 2020 (after the pandemic). Twenty-five patients used the app for consultation before the pandemic, and 8 patients used the app after the pandemic. All of the patients completed a 30-day follow-up.

Comparison of baseline clinical characteristics

The comparison of baseline clinical characteristics between the app user group and non-app user group before and after the pandemic are presented in Table 1. The differences between the patients before or after the pandemic regarding age, sex, and common comorbidities were not statistically significant, except that the incidence rate of hypertension and previous cerebrovascular events were lower in the patients after the pandemic compared with the patients before the pandemic (40.00% vs. 63.39%, $P=0.002$; 10.00% vs. 25.68%, $P=0.011$, respectively). The baseline medication therapy, BNP on admission, and left ventricular ejection fraction were comparable between the 2 groups. The peak cardiac troponin I level was higher in the patients after the pandemic compared with those before the pandemic, but the difference was not statistically significant (100.98 \pm 35.16 vs. 91.51 \pm 26.98, $P=0.06$, respectively). The patients after the pandemic had a higher possibility of having Killip classification ≥ 2 than did patients before the pandemic (60.00% vs. 40.40%, $P=0.011$). Before the pandemic, the patients who used the app had lower rates

of hypertension than the patients who did not use the app (32.00% vs. 68.40%, $P=0.001$), while the rate of prior percutaneous coronary intervention was higher in the patients who used the app, although the difference was not statistically significant (28.00% vs. 12.00%, $P=0.058$).

Comparison of angiographic and primary PCI procedural characteristics

The comparison of coronary angiographic and primary PCI procedural characteristics between the app user group and non-app user group before and after the pandemic are presented in Table 2. There were no significant differences in the pre-procedure TIMI flow grade, severity of coronary artery disease, location of infarct-related artery, and usage of temporary pacemakers between the patients before and after the pandemic. However, the patients after the pandemic had lower levels of post-procedure TIMI flow compared to those before the pandemic (3 [2–3] vs. 3 [3–3], $P=0.000$), higher rates of anterior wall infarction (68.33% vs. 54.64%, $P=0.045$), higher rates of IABP usage (35.00% vs. 16.40%, $P=0.003$) and vasopressor usage (58.30% vs. 40.40%, $P=0.017$), and higher GRACE scores (172.25 \pm 20.38 vs. 165.92 \pm 19.75, $P=0.034$). The angiographic and primary PCI procedural characteristics were comparable between the patients who used the app and the patients who did not.

Comparison of the critical time interval

The critical time intervals between the app user group and non-app user group before and after the pandemic are presented in Table 3. The SCT, DTB, and TIT were significantly prolonged in the patients after the pandemic compared with those before the pandemic (68 [56.5–90] min vs. 60 [47–78] min, $P=0.023$; 76.5 [65.25–85] min vs. 50 [40–60] min, $P=0.000$; and 185 [165.25–210.25] min vs. 150 [131–174] min, $P=0.000$, respectively). However, the SCT to the FMC arrival and the time from FMC to hospital arrival time were comparable between patients before and patients after the pandemic (20 [16–23.75] min vs. 20 [16–24], $P=0.900$; 17 [14–21] min vs. 18 [15–22] min, $P=0.06$, respectively). Compared with the patients who did not use the app, those who used the app had shorter SCT, DTB, and TIT before (61 [9.75–80] min vs. 45 [40–60] min, $P=0.000$; 45 [33–50] min vs. 50 [42.75–64.25] min, $P=0.002$; and 128 [116–142.5] min vs. 157 [135.5–177] min, $P=0.000$, respectively) and after the pandemic (47.5 [45–60] min vs. 70 [60–90] min, $P=0.007$; 65 [56.25–73.5] min vs. 77 [70–86.5] min, $P=0.010$; and 144.5 [132.75–162.5] min vs. 188 [171–213] min, $P=0.001$, respectively).

Comparison of in-hospital and 30-day adverse clinical outcome

The incidence rate of both in-hospital and 30-day adverse clinical outcomes between the app user group and non-app user

Table 1. Baseline clinical characteristics of the app user group and non-app user group before and after the COVID-19 pandemic.

	Patients before the pandemic (n=183)		*p value	Patients after the pandemic (n=60)		**p value	***p value
	App user group (n=25)	Non App user group (n=158)		App user group (n=8)	Non App user group (n=52)		
Age (years)	68 (51–73.5)	66.5 (57–76)	0.656	67.5 (53.25–81.25)	71.5 (56.75–77.75)	0.939	0.193
Male	13 (52%)	100 (63.3%)	0.376	5 (62.5%)	32 (61.5%)	1.000	1.000
Hypertension	8 (32%)	108 (68.4%)	0.001	4 (50%)	20 (38.5%)	0.702	0.002
Diabetes	7 (28%)	76 (48.1%)	0.083	2 (25%)	25 (48.1%)	0.276	1.000
Dyslipidemia	7 (28%)	61 (38.6%)	0.377	3 (37.5%)	13 (25%)	0.429	0.160
Current smoker	13 (52%)	58 (36.7%)	0.185	2 (25%)	16 (30.8%)	1.000	0.280
Prior myocardial infarction	5 (20%)	18 (11.4%)	0.325	2 (25%)	6 (11.5%)	0.288	0.827
Prior percutaneous coronary intervention	7 (28%)	19 (12.0%)	0.058	1 (12.5%)	5 (9.6%)	1.000	0.512
Previous coronary artery bypass surgery	0 (0%)	1 (0.6%)	1.000	1 (13.3%)	0 (0%)	0.133	0.434
Previous cerebrovascular event	5 (20%)	42 (26.6%)	0.625	2 (25%)	4 (7.7%)	0.178	0.011
Chronic renal failure (estimated glomerular filtration rate <60 mL/min)	1 (4%)	11 (6.3%)	1.000	0 (0%)	7 (13.5%)	0.578	0.265
Premature CAD history	1 (4%)	23 (14.6%)	0.207	0 (0%)	5 (9.6%)	1.000	0.369
Killip classification ≥2	10 (40%)	64 (40.5%)	1.000	4 (50%)	32 (61.5%)	0.702	0.011
Lab test							
Peak cTn-I	162.6±16.87	166.4±20.17	0.120	81.78±32.04	103.93±34.96	0.097	0.060
BNP on admission	303 (202.8–408)	301.5 (197.88–410.5)	0.969	328 (197.75–416)	303 (210–408.25)	0.913	0.626
Left ventricular ejection fraction (%)	47 (42–53)	47 (40.5–52.5)	0.541	46 (39.5–51.75)	45.5 (41.25–55)	0.711	0.677
Baseline medication							
Aspirin	12 (48%)	46 (29.1%)	0.068	2 (25%)	13 (25%)	1.000	0.417
ADP receptor antagonist	1 (4%)	9 (5.7%)	1.000	1 (12.5%)	5 (9.6%)	1.000	0.235
Oral anticoagulant	4 (16%)	30 (19%)	1.000	1 (12.5%)	16 (30.8%)	0.420	0.143
Statin	7 (28%)	59 (37.3%)	0.502	3 (37.5%)	14 (26.9%)	0.676	0.347
ACEI or ARB	4 (16%)	37 (23.4%)	0.606	1 (12.5%)	7 (13.5%)	1.000	0.142
β blocker	2 (8%)	23 (14.6%)	0.537	1 (12.5%)	2 (3.8%)	0.354	0.100

Frequencies are reported as n/total (%), unless otherwise specified. CAD – cardiovascular disease; BNP – B-type natriuretic peptide; ADP – adenosine diphosphate; ACEI – angiotensin-converting enzyme inhibitor; ARB – angiotensin receptor blocker. * Comparison between App user and non-App user group after the pandemic; ** comparison between App user and non-App user group after the pandemic; *** comparison between patients before and after the pandemic.

Table 2. Baseline angiographic and primary percutaneous coronary intervention (primary PCI) of the app user group and non-app user group before and after the COVID-19 pandemic.

	Patients before the pandemic (n=183)		*p value	Patients after the pandemic (n=60)		**p value	***p value
	App user group (n=25)	Non App user group (n=158)		App user group (n=8)	Non App user group (n=52)		
Location of infarct-related artery							
Left main coronary artery	0 (0%)	0 (0%)		0(0%)	1 (1.9%)		
Left anterior descending artery	12 (48%)	88 (55.7%)		4(50%)	35 (67.3%)		
Left circumflex artery	3 (12%)	31 (19.6%)		0(0%)	5 (9.6%)		
Right coronary artery	10 (40%)	39 (24.7%)		4(50%)	11 (21.2%)		
Saphenous vein graft	0 (0%)	0 (0%)	0.262	0 (%)	0 (%)	0.179	0.169
Location of infraction							
Anterior	12 (48%)	88 (55.7%)		4(50%)	37 (71.2%)		
inferial	12 (48%)	59 (37.3%)		4(50%)	14 (26.9%)		
lateral	1 (4%)	11 (7%)	0.595	0(0%)	1 (1.9%)	0.259	0.045
Preprocedural TIMI grade							
0	18 (72%)	135 (85.4%)		7(87.5%)	49 (94.2%)		
1	4 (16%)	19 (12%)		1(12.5%)	3 (5.8%)		
2	1 (4%)	3 (1.9%)		0(0%)	0 (0%)		
3	2 (8%)	1 (0.6%)	0.068	0(0%)	0 (0%)	0.481	0.054
Postprocedural TIMI grade							
0	1 (4%)	0 (0%)		1(12.5%)	0 (0%)		
1	1 (4%)	1 (0.6%)		1(12.5%)	1 (1.9%)		
2	1 (4%)	8 (5.1%)		2(25%)	10 (19.2%)		
3	22 (88%)	149 (94.3%)	0.209	4(50%)	41 (78.8%)	0.180	0.000
Lesion vessel number							
1	2 (8%)	13 (8.2%)		0(0%)	2 (3.8%)		
2	16 (64%)	112 (70.9%)		6(75%)	37 (71.2%)		
3	7 (28%)	33 (20.9%)	0.584	2(25%)	13 (25%)	0.868	0.417
Risk stratification							
TIMI risk score	5 (5–6)	5 (5–6)	0.076	5 (3.25–6.5)	6 (5–7)	0.403	0.781
GRACE risk score	162.6± 87	164.44±201.7	0.367	174.00 ± 20.87	171.98±20.50	0.797	0.034
Syntax score	26 (19.5–33)	29 (24–33)	0.407	23 (18–32.75)	28.5 (22.25–33)	0.210	0.824
Type of intervention							
PCI	25 (100%)	158(100%)	1.000	8 (100%)	52 (100%)	1.000	1.000
Type of stent							
Bare metal stent	0 (0%)	0(0%)		0 (0%)	0 (0%)		
drug-eluting stent	25 (100%)	158(100%)	1.000	8 (100%)	52 (100%)	1.000	1.000

Table 2 continued. Baseline angiographic and primary percutaneous coronary intervention (primary PCI) of the app user group and non-app user group before and after the COVID-19 pandemic.

	Patients before the pandemic (n=183)		*p value	Patients after the pandemic (n=60)		**p value	***p value
	App user group (n=25)	Non App user group (n=158)		App user group (n=8)	Non App user group (n=52)		
Intra-operation procedure							
Thrombus aspiration	6 (24.0%)	35(22.2%)	0.800	3 (37.5%)	12 (23.1%)	0.400	0.725
Intra-aortic balloon counter-pulsation	5 (20%)	25(15.8%)	0.569	3 (37.5%)	18 (34.6%)	1.000	0.003
Temporary pacemaker	2 (8%)	5(3.2%)	0.245	1 (12.5%)	2 (3.8%)	0.354	0.712
Vasopressors	10 (40%)	64(40.5%)	1.000	4 (50%)	31 (59.6%)	0.708	0.017
Cardiogenic shock	3 (12.0%)	8(5.1%)	0.176	2 (25%)	9 (17.3%)	0.631	0.008
GPI	24 (96%)	153(96.8%)	0.591	8 (100%)	50 (96.2%)	1.000	1.000
predialation	23 (92%)	135(85.4%)	0.537	6 (75%)	46 (88.5%)	0.288	1.000
Total number of stents implanted	1 (1-2)	1 (1-2)	0.237	1 (1-1.75)	1 (1-2)	0.384	0.343
Total stent length (mm)	24 (18-47.5)	29 (20-41.75)	0.349	24 (21-32)	26.5 (23-33)	0.638	0.869
Post dialation	23 (92.0%)	118(75.6%)	0.074	8 (100%)	41 (83.7%)	0.330	0.589
Non-culprit lesion intervention	0 (0%)	0 (0%)	1.000	0 (0%)	0 (0%)	1.000	1.000

Frequencies are reported as n/total (%), unless otherwise specified. TIMI – thrombolysis in myocardial infarction; GRACE – global registry of acute coronary events; GPI – glycoprotein IIb/IIIa inhibitor. * Comparison between App user and non-App user group after the pandemic; ** comparison between App user and non-App user group after the pandemic; *** comparison between patients before and after the pandemic.

Table 3. Comparison of the critical time intervals between the app user group and non-app user group before and after the COVID-19 pandemic.

	Patients before the pandemic (n=183)		*p value	Patients after the pandemic(n=60)		**p value	***p value
	App user group (n=25)	Non App user group (n=158)		App user group (n=8)	Non App user group (n=52)		
Symptom onset to call ambulance time (min)	45 (40-60)	61 (49.75-80)	0.000	47.5 (45-60)	70 (60-90)	0.007	0.023
Call ambulance time to first medical contact time (min)	18 (15-21)	20 (16-24)	0.157	17.5 (15-22.5)	20 (17-24)	0.315	0.900
First medical contact to door time (min)	17 (15-20)	18 (15-23)	0.158	17.5 (12.5-21)	17 (14.25-21)	0.948	0.060
Door to balloon time (min)	45 (33-50)	50 (42.75-64.25)	0.002	65 (56.25-73.5)	77 (70-86.5)	0.010	0.000
Total ischaemia time (min)	128 (116-142.5)	157 (135.5-177)	0.000	144.5 (132.75-162.5)	188 (171-213)	0.001	0.000

* Comparison between App user and non-App user group after the pandemic; ** comparison between App user and non-App user group after the pandemic; *** comparison between patients before and after the pandemic.

Table 4. Comparison of the incidence of adverse events between the app user group and non-app user group before and after the COVID-19 pandemic.

	Patients before the pandemic(n=183)		*p value	Patients after the pandemic(n=60)		**p value	***p value
	App user group (n=25)	Non-App user group (n=158)		App user group (n=8)	Non-App user group (n=52)		
In-hospital adverse event							
All-cause of death	0 (0%)	4 (2.5%)	1.000	1 (12.5%)	8 (15.4%)	1.000	0.001
Cardiac death	0 (0%)	4 (2.5%)	1.000	1 (12.5%)	8 (15.4%)	1.000	0.001
MACE	0 (0%)	5 (3.2%)	1.000	1 (12.5%)	10 (19.2%)	1.000	0.000
Non-fatal myocardial infarction	0 (0%)	1 (0.6%)	1.000	0 (0%)	4 (7.7%)	1.000	0.014
Stroke	0 (0%)	0 (0%)	1.000	0 (0%)	1 (1.9%)	1.000	0.247
Any revascularization	0 (0%)	1 (0.6%)	1.000	0 (0%)	0 (0%)	1.000	1.000
Definite or probable stent thrombosis	0 (0%)	1 (0.6%)	1.000	0 (0%)	0 (0%)	1.000	1.000
New renal replacement therapy	0 (0%)	9 (5.7%)	0.613	0 (0%)	11 (21.2%)	0.330	0.002
30-day adverse event							
All-cause of death	0 (0%)	5 (3.2%)	1.000	1 (12.5%)	8 (15.4%)	1.000	0.001
Cardiac death	0 (0%)	5 (3.2%)	1.000	1 (12.5%)	8 (15.4%)	1.000	0.001
MACE	0 (0%)	10 (6.3%)	0.362	2 (25%)	15 (28.8%)	1.000	0.000
Non-fatal myocardial infarction	0 (0%)	3 (1.9%)	1.000	0 (0%)	8 (15.4%)	0.582	0.001
Stroke	0 (0%)	2 (1.3%)	1.000	0 (0%)	3 (5.8%)	1.000	0.098
Any revascularization	0 (0%)	1 (0.6%)	1.000	0 (0%)	2 (3.8%)	1.000	0.152
Definite or probable stent thrombosis	0 (0%)	1 (0.6%)	1.000	0 (0%)	1 (1.9%)	1.000	0.434
New renal replacement therapy	0 (0%)	9 (5.7%)	0.613	2 (25%)	13 (25%)	1.000	0.000

Frequencies are reported as n/total (%), unless otherwise specified. MACE – major cardiovascular event. * Comparison between App user and non-App user group after the pandemic; ** comparison between App user and non-App user group after the pandemic; *** comparison between patients before and after the pandemic.

group are presented in Table 4. The in-hospital and 30-day follow-up adverse clinical outcomes, including all-cause mortality, cardiac death, MACE, non-fatal myocardial infarction, and new renal replacement therapy, were significantly higher in patients after the pandemic than in those before the pandemic, while stroke, any revascularization, and stent thrombosis were comparable between the 2 groups. However, the incidence rates of in-hospital and 30-day follow-up adverse clinical outcomes were comparable between the app user group and non-app user group before and after the pandemic.

Discussion

In this single-center retrospective observational study, the delay times in the STEMI patients after the pandemic were significantly prolonged compared to those before the pandemic. The prolonged pre- and post-hospital delay times further translated into higher rates of short-term adverse clinical outcomes. Telemedicine (via the Tiantanzhixin app) was effective for reducing delay times before and after the pandemic, but there was no significant difference in the incidence rates of short-term adverse clinical outcomes between the app user

group and non-app user group before and after the pandemic in our study.

Primary PCI is recommended as the first-line therapy for treating acute STEMI patients [5–7]. But this recommendation is based on the normal performance of health care services. Thrombolytic therapy is considered the first-line therapy during the COVID-19 pandemic, according to the expert consensus of the Chinese Society of Cardiology, to decrease the risk of cross infection [19]. Based on experiences in China and other countries, the use of proper personal protective equipment (PPE) should be considered for persons performing primary PCI [20–24]. However, a reduction in patients who underwent primary PCI was observed, which was associated with a concern of cross infection from both doctors and patients [25–27]. The number of STEMI patients who underwent primary PCI in this center did not decrease during the pandemic, which could be explained by the following: First and foremost, Beijing Tiantan Hospital was one of the few hospitals in Beijing where primary PCI was still available when other hospitals decided to shut down primary PCI during the COVID-19 pandemic, so additional patients might have been transferred to our center. Second, the risk of cross infection was relatively low in Beijing during the pandemic as compared with other countries.

The critical role of telemedicine during the COVID-19 pandemic was discussed in several articles that mentioned the potential benefit and inherent issues in telemedicine [11–13,28–31]. However, unlike our study, all of these articles proposed the importance of telemedicine during the pandemic but lacked specific clinical information to support their ideas.

This study produced some important findings. The first is that the delay times (both pre- and post-hospital) of STEMI patients were prolonged after the COVID-19 pandemic compared with the delay times before the pandemic. The increased pre-hospital delays were mostly related to the SCT, while the SCT to FMC arrival time and the FMC to hospital arrival time did not increase. Traditional pre-hospital delays include patient delays and emergency services delays [32,33]. In the present study, pre-hospital delays, including the SCT to the FMC and the FMC to hospital arrival time, were not influenced by COVID-19. The patient delays, judging from our results, were mostly related to increased pre-hospital delays during the pandemic. The reasons for the prolonged patient delays were associated not only with public awareness of how to recognize common acute myocardial infarction symptoms and call emergency services, but also with the fear of cross infection during the pandemic [2,3,5]. The prolonged post-hospital delay times were largely related to the screening protocol when medical quarantine was needed. In order to reduce the risk of cross infection, health care facilities established strict screening protocols to identify COVID-19 patients, which led to the deterioration of

patients with STEMI by prolonging the delay times, even after the patients arrived at the hospital. This is consistent with the latest findings from Hong Kong in which increased delay times, especially prolonged waiting times after arrival for patients with STEMI, were observed [34].

The second finding of the present study is the usefulness of telemedicine at reducing pre- and post-hospital delay times during the pandemic. Telemedicine has been demonstrated to be effective at reducing delay times in patients with STEMI [35–38], but all of the conclusions made by these studies were based on the normal functioning of health care facilities, when there were no screening protocols in place. To our knowledge, the present study is the first to explore the efficacy of telemedicine for reducing delay times in patients with STEMI during the COVID-19 pandemic. After comparing the critical time intervals of the app user group and non-app user group before and after the pandemic, we found that the patients in the app user group had shorter pre- and post-hospital delay times. The significant reduction in the pre- and post-hospital delay times in the app user group was related to the diminished fear of cross infection among the STEMI patients and better preparation after their arrival to reduce waiting and screening protocol times.

This study's third finding is the significantly increased rates of both in-hospital and 30-day adverse clinical outcomes after the pandemic. There are many reasons which could explain this. First, the prolonged delay times increased the total ischemia times, which may have further compromised hemodynamic stability and influenced clinical outcomes [39]. Several patients died during the screening protocols before they could undergo primary PCI at our center. Second, the proportion of patients with anterior wall myocardial infarction increased after the pandemic with an elevated proportion of cardiogenic shock, no-flow phenomena, and IABP usage. Lastly, a higher risk of STEMI patients with higher GRACE scores was another potential reason.

This study's final finding was that the rates of short-term adverse clinical outcomes were comparable between the patients who used the app for telemedicine support and those who did not. Although studies have demonstrated the efficacy of telemedicine for reducing short-term adverse clinical outcomes in patients with STEMI [40,41], there was no significant change in the incidence rate of in-hospital and 30-day follow-up adverse clinical outcomes in the present study. The reduction in TIT did not translate into clinical benefits for the app user group because of the limited number of patients who participated and the shorter follow-up periods with relatively low incidence rates of adverse clinical outcomes.

COVID-19 has had an obviously negative impact on the management of STEMI patient care, including prolonged delay times,

which may further influence these patients' clinical outcomes. Timely reperfusion therapy with reduced TIT is the key principle for the management of patients with STEMI, which is more complicated than ever before in the context of the COVID-19 pandemic. The results of our study demonstrate the efficacy of telemedicine at reducing delay times in STEMI patients, similar to other studies. However, our study is the first to prove the efficacy of telemedicine use in patients with STEMI during the COVID-19 pandemic. Properly managing the care of patients with STEMI by reducing delay times as much as possible and lessening the adverse impact of COVID-19 is critical and challenging during the pandemic while the number of new COVID-19 cases increases globally and social distancing and quarantines are deemed necessary [42].

Conclusions

This study demonstrated the efficacy of telemedicine for the management of patients with STEMI during the COVID-19 pandemic. In conclusion, COVID-19 prolonged pre- and post-hospital delay times in STEMI patients. Telemedicine appears to be useful by reducing delay times during the COVID-19 pandemic, although there was no statistical difference in short-term adverse clinical outcomes between the patients who used telemedicine and those who did not.

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Conflicts of interest

None.

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