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ORIGINAL ARTICLE

Delays in first medical contact to primary interventional therapy and left ventricular remodelling in ST-segment elevation myocardial infarction

Jiali Wang[1,2] · Yankai Meng[2] · Chao Zhang[2] · Yuan Lu[3] · Chunfeng Hu[2] · Kai Xu[1,2]

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Abstract

Background Early reperfusion and early evaluation of adverse cardiovascular events have become important aspects of treatment for ST-segment elevation myocardial infarction post–primary percutaneous coronary intervention (PPCI). However, emergency medical service (EMS) delays always occur, especially in developing countries.

Aims The aim of this study was to investigate the impact of EMS delays on short-term predictions of the severity of myocardial injury in STEMI patients after PPCI.

Methods A total of 151 STEMI patients who underwent successful PPCI and two postoperative cardiac magnetic resonance (CMR) imaging examinations (1 week and 4 months postoperatively) were retrospectively analysed. CMR cine and late gadolinium enhancement (LGE) images were analysed to evaluate left ventricular (LV) function, LV global longitudinal peak strain (GLS) and scar characteristics. The time from first medical contact to balloon (FMC2B) and door-to-balloon (D2B) time, expressed in minutes, were recorded and compared with the recommended timelines. Unadjusted and multivariable analyses were used to assess the impact of EMS delays on short-term left ventricular remodelling (ALVR).

Results EMS delays (FMC2B time > 90 min) led to larger infarct size (IS) and microcirculation obstruction (MVO) and poor recovery of the LV ejection fraction and GLS (all $p < 0.05$). Logistic regression analysis showed that an FMC2B time > 90 min ($p = 0.028$, OR = 2.661, 95% CI 1.112–6.367) and baseline IS ($p = 0.016$, OR = 1.079, 95% CI 1.015–1.148) were independent predictors of short-term ALVR.

Conclusion Delays in FMC2B time were strongly associated with short-term ALVR; shorter ischaemic times may improve the cardiac function and prognosis of patients.

Keywords Cardiac magnetic resonance · Myocardial infarction · Percutaneous coronary intervention

Introduction

Primary percutaneous coronary intervention (PPCI) is the preferred treatment strategy for ST-segment elevation myocardial infarction (STEMI), and the application of PPCI can quickly open the responsible vessels, protect left ventricular systolic function and improve the survival rate after acute myocardial infarction [1, 2]. However, a considerable proportion of STEMI patients suffer adverse left ventricular remodelling (ALVR) after PPCI, which leads to adverse cardiovascular events. Early evaluation of ALVR has become an important aspect of treatment for STEMI [3]. Modern STEMI regional systems of care emphasise the importance of simplifying access to care, including emergency medical services (EMS) and inpatient care [4]. The first medical contact to balloon (FMC2B) time and the hospital door to balloon (D2B) time are important time points that impact the care process of STEMI patients. There is a general consensus that a shorter ischaemic time always results in a smaller infarct size and less myocardial damage than prolonged occlusion. Previously published studies have shown that STEMI patients who experienced longer D2B delays (D2B time > 90 min) were at higher risk of reinfarction, major adverse cardiac events (MACEs) and death [5]. However, D2B time only focuses on the final component

✉ Kai Xu
xkxz0814@163.com

1 Department of Radiology, Nanjing Medical University, Nanjing 211166, China

2 Department of Radiology, The Affiliated Hospital of Xuzhou Medical University, Xuzhou, China

3 Department of Cardiac Care Unit, The Affiliated Hospital of Xuzhou Medical University, Xuzhou, China

of the regional systems of care, and more recently, FMC2B time has been considered a more relevant indicator because it includes all factors involved in the healthcare chain for STEMI patients [6]. Scholz et al. [7] demonstrated that timely revascularisation with an FMC2B time of < 90 min was a crucial component of improving the in-hospital mortality of STEMI patients, but there was no observation of what happened to the patients after they were discharged from the hospital.

Cardiac magnetic resonance (CMR) imaging can be used to evaluate the degree of myocardial injury early in the postreperfusion period in STEMI patients. CMR can be used to show the anatomy of the cardiac structure, myocardial function and infarction characteristics, myocardial infarct size (IS) and microvascular obstruction (MVO), and results obtained by CMR late gadolinium enhancement (LGE) are known to have added value as predictors of adverse outcomes after acute myocardial infarction [8–10]. CMR feature-tracking (FT) has been recently applied to routine CMR cine sequences without additional scanning time and has become a promising standard technique for quantifying myocardial strain in STEMI patients [11, 12]. Myocardial strain, including global radial, circumferential and longitudinal strains (GRS, GCS and GLS, respectively), can be used to assess both global systolic function and systolic and diastolic function.

Therefore, the primary purpose of this study was to investigate the relationship between EMS delays, especially FMC2B delays, and short-term ALVR in STEMI patients post-PPCI. The secondary purpose was to investigate the relationship between EMS delays and the recovery of cardiac function using CMR to provide clinicians with strategies for decision-making during the early evaluation of the condition of STEMI patients and for the prevention of serious adverse events.

Materials and methods

Study population

This was a retrospective analysis of STEMI patients who received emergency PPCI treatment in our hospital between September 2019 and November 2021. The inclusion criteria were as follows: (a) patients who met the diagnostic criteria of the 2013 guidelines for the diagnosis and treatment of acute STEMI [1]; (b) patients who agreed to receive PPCI within 12 h after the first onset of STEMI; (c) patients with clear records at the important time points; (d) patients who underwent two CMR examinations 7 days (acute phase) and 3–4 months (convalescent phase) after PPCI. The exclusion criteria were as follows: (a) treated patients with incomplete records obtained at the critical time points; (b) patients with a CMR image quality that did not meet the diagnostic requirements; (c) patients with multiple vessel diseases; (d) patients with a previous history of myocardial infarction. This retrospective study was approved by the Ethics Committee of our hospital (document number XYFY2021-KL086-01), and the requirement for informed consent was waived.

CMR protocol

CMR scans were performed on a 3.0 T all-digital MR scanner (Ingenia; Philips Healthcare, Amsterdam, Netherlands) using a surface body coil and posterior spinal coil. All images were collected by ECG gating and breath holding. The protocol included steady-state free precession (SSFP), T2-weighted sequences, rest perfusion scans (with an intravenous infusion of 0.15 mmol/kg gadolinium-based contrast agents at an injection rate of 3 mL/s, followed by a 30-mL saline flush) and an LGE sequence obtained 10–15 min after the administration of contrast agents. Both SSFP cine and LGE MR images were obtained, including two-chamber and four-chamber view images and a set of short-axis images covering the entire left ventricle from the atrioventricular ring to the apex. The SSFP sequence was obtained with 30 phases in the cardiac cycle; the parameters were as follows: field of view, 350 × 350 mm; repetition time/echo time (TR/TE), 2.6/1.3 ms; flip angle, 45°; slice thickness, 8 mm. The LGE-CMR parameters were as follows: TR/TE, 3.0/6.1 ms; flip angle, 25°; slice thickness, 8 mm.

CMR data analysis

CMR analyses were performed using a commercially available workstation (Circle Cardiovascular Imaging, cvi42, v5.12.4, Calgary, Alberta, Canada) by two cardiac radiologists who had 8 and 10 years of experience in double-blind studies. When there were differences, an agreement was reached through consultation. Left ventricular end-diastolic volume (LVEDV), left ventricular end-systolic volume (LVESV) and left ventricular ejection fraction (LVEF) were obtained from the short-axis cine-CMR sequence. CMR-FT strain analysis was performed on four cine views, namely the two-, three-, four-chamber, and short-axis cine CMR images, and the peak values of the radial strain, circumferential strain and longitudinal strain were set as the GRS, GCS and GLS, respectively, for statistical analysis.

IS and MVO were evaluated by the LGE images. The delayed enhancement region was defined as the region with a signal intensity greater than five standard deviations from the signal intensity of the distal normal myocardium at the same level on the LGE images, and the MVO region was defined as the low signal region within the high signal region on the LGE images. The IS and MVO are expressed as percent of the LV myocardium for statistical analysis [13].

Observation indicators and evaluation criteria

1. The basic clinical data of the selected patients, including sex, age, body mass index (BMI), Killip cardiac function classification, smoking history, and the presence or absence of hypertension, hyperlipidaemia and diabetes, were collected.
2. The peak values of the serological myocardial enzyme index were recorded within 48 h after admission; these included the high-sensitivity cardiac troponin-T (hs-cTnT), creatine kinase-myocardial band (CK-MB) and N-terminal pro-brain natriuretic peptide (NT-proBNP) levels.
3. The FMC2B and D2B times were recorded; an FMC2B time of no more than 120 min met the standard, and a D2B time of no more than 90 min met the standard.
4. The thrombolysis in myocardial infarction (TIMI) score of responsible coronary angiography was recorded during the PPCI operations.
5. The LVEDV and LVESV parameters obtained by two CMR examinations were used to divide the STEMI patients into three groups [14]: group 1: reverse LV remodelling: an LVESV decrease ≥ 12%; group 2: no LV remodelling: the changes in the LVEDV and LVESV were < 12%; Group 3: adverse LV remodelling: an LVEDV increase ≥ 12%. The clinical indexes, FMC2B time, D2B time and CMR parameters of the three groups were compared.

Statistical analysis

Statistical analysis was performed using the statistical software SPSS 22.0. The quantitative data are expressed as the mean ± standard deviation. The quantitative data components were compared by the independent sample *t* test or nonparametric Mann–Whitney *U* test. The measurement data are expressed as rates or constituent ratios, and the chi-square test was used for intergroup comparisons. After excluding confounding factors by univariate logistic regression analysis, the variables with $p < 0.1$ were included in the multivariate logistic regression model to analyse the risk factors for adverse LV remodelling 4 months after PPCI. Univariate and multivariate logistic regression analyses were performed to calculate the OR value and 95% confidence interval (CI). There was a statistically significant difference between the two groups ($p < 0.05$).

Results

Clinical characteristics

In total, 151 STEMI patients treated by PPCI after a mean FMC2B time of 110 ± 73 min were included. The patient flowchart is shown in Fig. 1, and the baseline patient characteristics are provided in detail in Table 1. The FMC2B standard (FMC2B time < 120 min) rate of this group of patients was 68.2%, and the D2B standard (D2B time < 90 min) rate was 88.1%. Reverse LV remodelling (group 1) accounted for 45.0% of the patients, no LV remodelling (group 2) accounted for 27.2% and adverse LV remodelling accounted for 26.5%. Two patients with LVESV reductions > 12% and LVESV reduction < 12% were excluded from the groups.

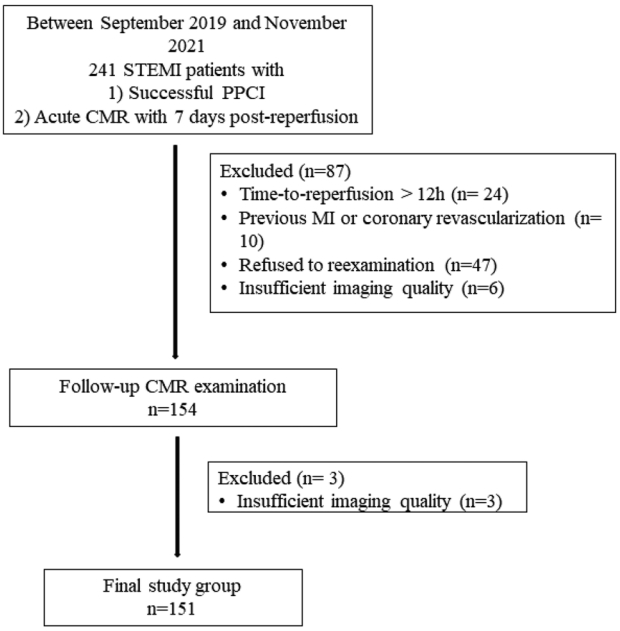

Fig. 1 Patient flowchart. CMR, cardiac magnetic resonance; MI, myocardial infarction; STEMI, ST-segment elevation myocardial infarction

There was no significant difference in age, sex, risk factors for cardiovascular disease, heart rate, vessels responsible for the myocardial infarction, Killip cardiac function grade or TIMI grade among the three groups. Compared with the other two groups, the patients in group 3 had higher levels of hs-cTnT and CK-MB, longer FMC2B times, a larger IS and MVO, and a lower LVEF in the acute phase.

Comparison of the different emergency treatment times and CMR parameters

According to the FMC2B and D2B times, the patients were divided into the FMC2B time ≤ 90 min and FMC2B time > 90 min groups and D2B time ≤ 60 min and D2B time > 60 min groups [11]. An FMC2B time > 90 min was regarded as an EMS delay. The MVO was larger in the FMC2B time > 90 min group and D2B time > 60 min group, the IS was larger and the recovery of LVEF and GLS were worse in the group of patients who experienced EMS delays (Table 2). Case examples of CMR are shown in Fig. 2.

Table 1 Baseline characteristics of study population

Characteristics	Total $n=151$	Group 1 $n=68$	Group 2 $n=41$	Group 3 $n=40$	p value
Age, years	54 ± 13	54 ± 12	53 ± 13	55 ± 12	0.951
Male, *n* (%))	129 (85.4%)	57 (83.8%)	36 (87.8)	34 (85.0%)	0.850
Cardiovascular risk factors					
Hypertension, *n* (%)	93 (61.6%)	36 (52.9%)	28 (68.3%)	27 (67.5%)	0.175
Cigarette smoking, *n* (%)	76 (50.3%)	34 (50%)	20 (48.8%)	21 (52.5%)	0.943
Hyperlipidaemia, *n* (%)	80 (53.0%)	35 (51.5%)	25 (61%)	20 (50.0%)	0.348
Diabetes mellitus, *n* (%)	101 (66.9%)	42 (61.8%)	32 (78%)	27 (67.5%)	0.211
Body mass index, kg/m^2	26.5 ± 4.1	26.8 ± 5.2	25.9 ± 2.8	26.2 ± 2.8	0.906
Heart rate, beats/min	71 ± 8	69 ± 10	71 ± 8	74 ± 7	0.006
Infarct-related artery					0.846
Right coronary artery (%)	57 (37.7%)	27 (39.7%)	17 (41.5%)	13 (32.5%)	
Left anterior descending (%)	79 (52.3%)	33 (48.5%)	21 (51.2%)	23 (57.5%)	
Left circumflex (%)	15 (9.9%)	8 (11.8%)	3 (7.3%)	4 (10%)	
Serologic tests					
Peak hs-cTnT concentration, ng/L	3617 ± 2994	2793 ± 2473	3778 ± 3040	4873 ± 3394	0.008
peak CK-MB concentration, U/L	154 ± 107	131 ± 93	154 ± 104	266 ± 459	0.014
peak NT-proBNP, pg/mL	920 ± 1109	883 ± 1256	861 ± 864	1000 ± 1080	0.523
Killip class on admission					0.466
Grade 1	145 (96%)	65 (95.6%)	40 (97.6%)	38 (95.0%)	
Grade 2	2 (1.3%)	2 (2.9%)	0 (0%)	0 (0%)	
Grade 3	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
Grade 4	4 (2.6%)	1 (1.5%)	1 (2.4%)	2 (5.0%)	
D2B, min	65 ± 21	64 ± 22	68 ± 13	65 ± 24	0.245
FMC2B, min	110 ± 73	95 ± 68	112 ± 68	135 ± 83	0.016
TIMI flow grade before PCI					0.431
0/1	135 (89.4%)	58 (85.3%)	37 (90.2%)	38 (95.0%)	
2/3	16 (10.6%)	10 (14.7%)	4 (9.8%)	2 (5.0%)	
TIMI flow grade post-PCI					–
0/1	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
2/3	151 (100%)	68 (100%)	41 (100%)	40(100%)	
Baseline CMR parameters					
IS, % of LV myocardial mass	22.9 ± 10.6	19.5 ± 11.1	21.4 ± 8.0	29.5 ± 9.0	< 0.001
MVO, % of LV myocardial mass	1.1 ± 1.6	0.6 ± 1.0	1.1 ± 1.5	2.0 ± 2.2	< 0.001
LVEDV, mL	148.6 ± 33.2	147.2 ± 30.8	151.6 ± 36.4	146.3 ± 32.5	0.707
LVESV, mL	75.9 ± 29.1	71.6 ± 22.5	75.3 ± 31.7	81.6 ± 33.7	0.394
LVEF, %	50.5 ± 11.0	52.2 ± 10.4	51.8 ± 9.8	46.9 ± 12.1	0.039
GLS, %	-8.4 ± 2.3	-8.9 ± 2.2	-8.1 ± 2.5	-8.0 ± 2.0	0.096

CK-MB creatine kinase-myocardial band, *CMR* cardiovascular magnetic resonance, *D2B* door-to-balloon, *FMC2B* First medical contact to balloon *hs-cTnT* high-sensitivity cardiac troponin T, *IS* infarct size, *LVEDV* left ventricular end-diastolic volume, *LVEF* left ventricular ejection fraction, *LVESV* left ventricular end-systolic volume, *MVO* microvascular obstruction, *NT-proBNP* N-terminal pro–brain natriuretic peptide, *PCI* percutaneous coronary intervention, *TIMI* thrombolysis in myocardial infarction

Combined emergency treatment time and CMR parameters to predict myocardial injury

To prevent the omission of important variables, indicators with p values of < 0.1 in the univariate logistic analysis were included in the multivariate logistic analysis. hs-cTnT levels, CK-MB levels, an FMC2B time > 90 min, acute LVEF, IS, MVO and GLS were included in the multivariate logistic regression analysis, and an FMC2B time > 90 min and IS were found to be independent influencing factors of short-term adverse LV remodelling after PCI. In the patients with an FMC2B time > 90 min, the incidence of short-term adverse LV remodelling after PCI was approximately 2.7 times higher than that of the patients with an FMC2B time ≤ 90 min ($p = 0.028$, OR = 2.661, 95%

Table 2 Comparison and change in the CMR parameters between the different treatment time groups

CMR parameters	FMC2B ≤ 90 min $n=93$	FMC2B > 90 min $n=58$	p value	D2B ≤ 60 min $n=75$	D2B > 60 min $n=76$	p value
Baseline IS, %	21.0 ± 10.7	25.9 ± 9.7	0.004	21.9 ± 9.6	23.9 ± 11.4	0.384
Baseline MVO, %	0.9 ± 1.6	1.4 ± 1.7	0.009	0.8 ± 1.4	1.4 ± 1.8	0.016
LVEF, %						
Baseline	50.3 ± 10.7	50.7 ± 11.6	0.903	52.1 ± 9.6	48.8 ± 12.1	0.063
Follow-up	55.4 ± 11.6	50.3 ± 12.5	0.011	54.8 ± 11.7	52.2 ± 12.6	0.117
Change	4.8 ± 8.6	–0.2 ± 9.9	< 0.001	2.6 ± 8.4	3.2 ± 10.4	0.714
GLS, %						
Baseline	–8.6 ± 2.2	–8.3 ± 2.4	0.184	–8.4 ± 2.2	–8.5 ± 2.4	0.831
Follow-up	–10.0 ± 2.4	–8.8 ± 2.5	0.012	–9.9 ± 2.4	–9.2 ± 2.5	0.104
Change	–1.3 ± 2.1	–0.8 ± 1.8	0.025	–1.5 ± 1.9	–0.8 ± 2.1	0.028

CI 1.112–6.367). For every 1% increase in acute IS, the probability of short-term adverse LV remodelling increased by 7.9% ($p=0.016$, OR = 1.079, 95% CI 1.015–1.148) (Table 3).

Discussion

This retrospective study found that (a) patients with ALVR had larger IS, larger MVO, and higher hs-cTnT and CK-MB levels in the acute phase; (b) the longer the FMC2B time was, the larger the IS and MVO and the worse the recovery of the LVEF and myocardial strain; and (c) FMC2B time > 90 min was an independent prognostic factor of short-term adverse LV remodelling after PPCI in STEMI patients. The results of this study are clinically valuable for improving the total ischaemic time of patients with STEMI, supporting the early evaluation of disease severity and understanding the short-term prognosis of STEMI patients after undergoing emergency PCI.

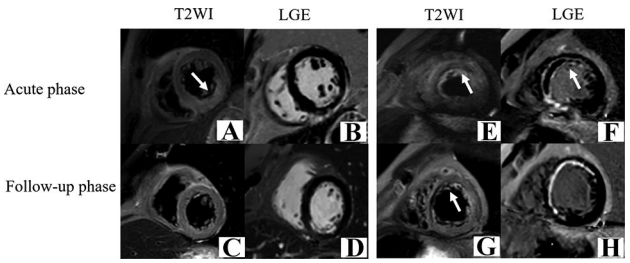

Fig. 2 Representative CMR images of two patients with STEMI. Patient 1 (**A**–**D**): A 70-year-old female patient presented to our emergency department after chest pain lasting 3 h and was diagnosed with STEMI after admission. FMC2B time = 53 min, D2B time = 52 min. Coronary angiography showed approximately 100% stenosis in the proximal segment of the right coronary artery, and a stent was inserted. Acute CMR demonstrated inferior myocardial oedema (**A**) and subendocardial myocardial infarction (**B**). Follow-up CMR showed that the myocardial oedema gradually subsided (**C**), and the subendocardial infarct size was slightly reduced (**D**). The LVEDV decreased by 4% and the LVESV decreased by 9% in the follow-up period. Patient 2 (**E**–**H**): A 42-year-old male patient presented to a local hospital with chest tightness for 6 h. An electrocardiogram showed ST-segment elevation in leads V1–V6 and the patient was then transferred by ambulance to our emergency centre. FMC2B time = 135 min, D2B time = 56 min. Coronary angiography showed a TIMI of 0 in the proximal segment of the left anterior descending branch, and a stent was inserted. Acute CMR demonstrated anterior wall and septum myocardial infarction, intramyocardial haemorrhage (**E**, arrow) and MVO (**F**, arrow). Follow-up CMR showed that cardiac scarring had formed (**G**, **H**). The LVEDV increased by 16% and the LVESV increased by 7% in the follow-up period. Abbreviations are shown in Table 1

LV remodelling after STEMI refers to the progressive changes in the size, shape and function of the LV chamber in patients with STEMI who are in the chronic phase of myocardial infarction, and adverse LV remodelling is strongly associated with increased mortality. Previous studies have shown that the IS provides important prognostic information for the development of adverse remodelling and MACEs after myocardial infarction [8–10]. Similar conclusions can also be drawn in our study since the IS was larger in the EMS delay group and was independently predictive of adverse LV remodelling. However, many of these studies focused only on the diagnostic value of CMR, and the time to myocardial ischaemia was not included in these studies. The D2B time and FMC2B time were included in this study as important time nodes in the STEMI treatment process and combined with CMR indicators to evaluate short-term left ventricular remodelling after PCI in STEMI patients.

The CHINA Patient-centred Evaluative Assessment of Cardiac Events (China PEACE) showed that delayed treatment of STEMI led to a prolonged total ischaemia time, and the proportion of patients with early reperfusion treatment was relatively low in China [15]. The quality of care provided by EMS has gradually improved, and this has reduced treatment delays, provided standard diagnoses and standard treatments, and improved the treatment efficiency and clinical prognoses in STEMI patients [4, 16, 17]. The current guidelines recommend that FMC2B must be performed in less than 120 min and further reduced it to 90 min in hospitals in which PPCI is initially performed [1, 2]. In the current study, the compliance

Table 3 Logistic regression analysis for the prediction of short-term adverse LV remodelling

	Univariate			Multivariate		
	OR	95% CI	*p* value	OR	95% CI	*p* value
Peak hs-cTnT	1.000	1.000–1.000	0.003			
Peak CK-MB	1.005	1.001–1.008	0.007			
FMC2B > 90 min	2.861	1.358–6.024	0.006	2.661	1.112–6.367	0.028
Baseline LVEF	0.950	0.916–0.986	0.007			
Baseline IS	1.098	1.053–1.146	< 0.001	1.079	1.015–1.148	0.016
Baseline MVO	1.547	1.225–1.953	< 0.001			
Baseline GLS	1.159	0.987–1.360	0.072			

CI confidence interval, *CK-MB* creatine kinase-myocardial band, *hs-cTnT* high-sensitivity cardiac troponin T, *IS* infarct size, *LVEDV* left ventricular end-diastolic volume, *LVEF* left ventricular ejection fraction, *LVESV* left ventricular end-systolic volume, *MVO* microvascular obstruction, *OR* odds ratio

rate of an FMC2B time < 90 min was 61.6%. Delays in EMS may be due to delays in medical decision-making procedures; a patient being admitted to the hospital on their own rather than through an ambulance; family members failing to give timely informed consent before PPCI; and waiting times for screening tests, such as nucleic acid tests, particularly between January 2020 and March 2020, which was the peak of the COVID-19 pandemic [18].

A clinical study showed that the delayed treatment of STEMI patients leads to a higher risk of reinfarction and MACEs after PPCI, with a 7.5% increase in the 1-year mortality rate for every 30 min of delay in treatment [9]. In the current study, an FMC2B time > 90 min was a predictor of short-term adverse LV remodelling in STEMI patients even after adjustment for IS, while D2B time was not. The results were similar to those of an international multicentre trial [10]. In the study, the FMC-reperfusion time was shown to be associated with mortality in 10,732 STEMI patients, while the results were different from those of a meta-analysis [5]. The analysis included 32 prospective studies and found that a D2B time delay increased the risk of a poor prognosis. The possible reason for the different results may be that both the D2B time and FMC2B time were included in our study, and the previous analysis focused on the D2B time or FMC2B time only. In addition, considerable efforts have been made to reduce the hospital-related D2B time, and the D2B time is now significantly shorter than it was in the past [1, 2]. Therefore, more attention should be given to reducing the FMC2B time and the total time of myocardial ischaemia. The following measures should be taken to decrease the FMC2B time: STEMI patients should receive treatment in a hospital with an optimised in-hospital process for PPCI; grassroots hospitals should be connected with PPCI-accredited hospitals by using modern network technology to shorten the time of prehospital first aid and improve the process of regional collaborative treatment for STEMI patients; the community and the media should publicise the health of the public, improve patients' awareness of acute myocardial infarction, increase the awareness and emphasise the importance of calling 120 in a timely manner to obtain appropriate medical treatment and prevent delayed medical care [19, 20].

Myocardial strain parameters provided by CMR-FT can provide additive value to current imaging diagnostics, especially for those with severe renal impairment. Myocardial fibres are composed of three layers: the subendocardium are longitudinal fibres, the middle layer are oblique fibres and the subepicardium are circumferential fibres [21]. When myocardial infarction occurs, subendocardial longitudinal myofibres are theoretically more vulnerable to early myocardial damage. In addition, previous studies have shown that GLS is a strong independent predictor of MACEs in STEMI patients [22–24]. Thus, GLS was selected as one of the indicators to measure cardiac function in our study. The GLS improved in all patients at the 4-month follow-up after reperfusion in our study, while the no-EMS delay group showed better recovery than the EMS delay group, which may suggest that EMS delays lead to more severe infarct-related myocardial injury. In the univariate logistic regression, the GLS was associated with the occurrence of adverse left ventricular remodelling; however, after adjusting for IS and clinical confounders in the multivariable analysis, the GLS could not significantly predict the development of adverse remodelling. The reason may be the collinearity between parameters, as previous studies have shown that there was good correlation between baseline IS and strain parameters [25, 26]. Larger studies will be required to determine whether CMR myocardial strain can be a promising parameter for early risk stratification after reperfusion in STEMI patients.

There are some limitations in this study. First, the total ischaemic time of patients with acute myocardial infarction can be divided into two parts: the time from symptom onset (symptom onset) to seeking medical assistance (S2FMC time) and the time of medical intervention (FMC2B time). The S2FMC time was not included in this study because the timing of symptom onset is subject to recall bias, and symptoms may be preceded by a period of instability and angina. Therefore, the exact timing of STEMI may be uncertain. Second, as a retrospective study, only haemodynamically stable patients, not critically ill patients, were

included in this study because critically ill patients were unable to undergo two CMR examinations, so the results may induce many biases. Finally, this study was a single-centre study, the sample size was relatively small, and the follow-up time was short and, therefore, may not be representative. Therefore, its conclusions need to be confirmed by large-scale clinical studies.

Conclusions

In conclusion, EMS delays (FMC2B time > 90 min) were associated with poor recovery of cardiac function and short-term adverse LV remodelling. The ischaemia time of patients should be shortened, the proportion of early reperfusion treatment should be increased, and the cardiac function and prognosis of patients should be improved.

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Declarations

Conflict of interest The authors declare no competing interests.

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