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Assessment of Left Ventricular Systolic Function After Revascularization in Patients with ST Segment Elevation Myocardial Infarction by Stratified Strain Technique

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Abstract

Objective: Stratified strain was used to evaluate the local stratified strain and the overall longitudinal strain of the left ventricle of the affected myocardium after revascularization in patients with ST-segment elevation myocardial infarction (STEMI).

Methods: 120 patients diagnosed as STEMI in the Affiliated Hospital of Jiangsu University from July 2017 to August 2018 were selected. According to the time from symptom onset to balloon dilation (S-TO-B), 120 patients were divided into group A (S-TO-B≤6h) and group B (6h<S-TO-B <12h) .The changes of left ventricular global longitudinal strain (GLS), local partial layer strain (TLSendo, TLS-mid, TLSepi) and LVEF were compared between the two groups immediately after operation, 3 hours ,24 hours and 1 week after operation. The incidence of major adverse cardiovascular events (MACE) and LVEF were followed up during hospitalization and one month after operation.

Results: In group A, TLSendo, TLSmid, TLSepi and GLS increased gradually at each time after vascular opening; in group B, TLSendo, TLSmid, TLSepi and GLS decreased immediately after vascular opening 3 hours after surgery, with obvious TLSendo and gradually increased, but the increase was smaller than that in group A. TLSendo,TLSmid, TLSepi and GLS increased in all patients one week after operation, but TLSendo and TLSepi increased more significantly than TLSmid, and GLS changed less. TlSendo increase of 4.50% is the most accurate parameter to predict the significant improvement of left ventricular systolic function in patients with STEMI one month after operation, with an AUC area of 0.87, sensitivity and specificity of 80.0% and 86.0%, respectively.

Conclusions: Layered strain technique can be used to evaluate the myocardial strain in patients with STEMI, and recognize the effect of S-TO-B on the prognosis of STEMI, which has important clinical application value.

Introduction

STEMI is generally considered to be caused by plaque rupture, secondary thrombosis, and acute vascular occlusion. After vascular occlusion, myocardial necrosis progresses from the epicardium to the endocardium, and it usually takes more than 6 hours for full-thickness transmural necrosis to occur. International guidelines recommend that all patients with symptomatic onset < 12 h and sustained ST segment elevation or newly developed left bundle branch block receive reperfusion therapy, with a significant increase in cardiac function and long-term survival after surgery [1][2]. For STEMI patients, the status of cardiac function within 24 hours after PCI is particularly important for the prognosis of STEMI patients. However, there is no effective and reliable method to judge and detect the continuous changes of cardiac function in this period. The purpose of this study was to use two-dimensional speckle tracking imaging (2D-STI) to accurately evaluate the changes in left ventricular function after PCI in STEMI patients, and to further explore its prognostic value for long-term treatment effect of patients.

Methods

1. Study population

181 patients with PCI were selected prospectively from July 20, 2017 to July 16, 2018. Inclusion criteria: (1) patients with acute STEMI less than 12 hours, with symptoms lasting less than 24 hours and lasting more than 30 minutes of chest pain;(2) The electrocardiogram showed an upward elevation of the ST-segment dorsal arch, with or without pathological Q wave and R wave decrease, and a typical T wave evolution process;(3) Troponin TNI or creatine kinase isoenzyme CK-MB significantly increased and had dynamic changes. Exclusion criteria: 8 cases of acute heart failure, 11 cases of atrial fibrillation, 8 cases of third-degree atrioventricular block, 5 cases of bundle branch block, 11 cases of multiple ventricular premature beats, 5 cases of severe malignant arrhythmia, 8 cases of poor image quality, 5 cases of patients or family members who did not agree to participate, the flow chart of selected patients is shown in figure 1. According to symptom onset to balloon time (S-TO-B), they were divided into two groups, 78 patients in group A (S-TO-B≤6h group) and 42 patients in group B (6h<S-TO-B<12h group).All patients underwent routine ECG and laboratory examination. Echocardiography was performed immediately, 3 hours, 24 hours, 1 week and 1 month after PCI. This paper conforms to the ethical principles of the Helsinki declaration.The study plan was approved by the institutional review committee of affiliated hospital of Jiangsu university, and each patient signed the informed consent form.

2. Research methods

1. Angiography and PCI Coronary angiography and PCI were performed by the right femoral artery or radial artery with the application of cardiovascular digital subtraction angiography, and the surgery was performed by standard coronary an

giography and stent implantation.

2. Plasma cTnI and BNP Plasma cTnI levels were measured before and after surgery at 8, 12, 16, 20, 24 and 30 h. The preoperative BNP values were recorded.

3. Echocardiography

3.1 Image acquisition: Imaging was performed with Vivid E9 (General Electric, Milwaukee, WI, USA), frequency 3.5 MHz, equipped with EchoPac (version 201) workstation. Ask the patient to lie on the left side, connect the ECG, calm breathing, and hold the breath at the end of breath if there is lung interference. Adjust the depth and sector size, in the two-dimensional ultrasound mode, the Simpson biplane method was used to measure the left ventricular end-diastolic volume (LVEDV) , the left ventricular end-systolic volume (LVESV), and the left ventricular ejection fraction (LVEF) was automatically calculated. Dynamic images of apical four-chamber view (4CH), two-chamber view (2CH) and apical left ventricular long axis (APLAX) were obtained respectively. All images shall be stored for at least 3 cardiac cycles with frame rate > 50 frames / s, and all data shall be stored in hard disk for offline analysis.

3.2 Image analysis: Strain parameters were analyzed using a new EchoPac workstation with myocardial layer-specific software (201.x.x, GE Healthcare, Milwaukee, WI) and with automatic function imaging (AFI). Select a stable cardiac cycle, open the 2D train interface, the system automatically tracks and generates the region of interest according to the contour of left ventricular endocardium recorded by the operator, and adjusts the width of the region of interest to ensure the analysis effect. According to the region of interest, the software automatically divides the left ventricular myocardium into Intima, media and adventitia. According to the results of coronary angiography and coronary artery blood supply relationship [3], the affected segments were screened out to obtain the longitudinal systolic strain of the subendocardial, middle and subepicardial myocardium of the affected segments(TLSendo, TLS-mid, TLS-epi). The left ventricular global longitudinal strain (GLS) was obtained by AFI technique. All parameters were the average of three cardiac cycle analysis results.

4. Major adverse cardiovascular events (MACE)

The MACE events within one month after PCI were recorded, including death, reinfarction, revascularization, angina pectoris and heart failure.

5. Repeatability test

Ultrasound images of 20 patients were randomly selected immediately after surgery, and the analysis of TLSendo, TLSmid, TLSepi, GLS, and LVEF was performed by two uninformed and trained sonographers to evaluate the variation among the observers. One of the doctors repeated the measurements 2 weeks later to evaluate the variation in the observers.

6. Statistical analysis

SPSS 20.0 software was used for statistical analysis. All data were tested for normality (Kolmogorov-Smirnow test) and homogeneity of variance (Levene test).

The measurement data of normal distribution are expressed as mean ± standard deviation (X±S), the measurement data of non-normal distribution are expressed as median (P25,P75), and the counting data are expressed as percentage. For measurement data conforming to normal distribution, independent sample t test was used for comparison between two groups, non-normal distribution measurement data were tested by non-parametric test (Mann-Whitney U test), and Chi-square test was used for comparison between two groups of counting data. One-way ANOVA was used to compare the repeated measurements, and S-N-K was used for subgroup analysis. The optimal cut-off point of each parameter was evaluated by ROC curve, and the area under curve (AUC), sensitivity, specificity and Yoden index of each parameter were calculated. Correlation coefficient (ICC) was used for intra-observer and inter-observer differences, and $P<0.05$ was considered statistically significant.

Results

1. Comparison of basic clinical data between the two groups

There was no significant difference in age, gender, height, weight, smoking history, hypertension, diabetes, blood lipid, systolic blood pressure, diastolic blood pressure and heart rate between the two groups ($P > 0.05$). S-TO-B in group A was significantly lower than that in group B ($P < 0.05$), as shown in Table 1.

Table 1
Comparison of general data of patients

Variable	Group A(78 cases)	Group B(42 cases)	Total (120 cases)	T(χ2)	P*
Age(yrs)	61.18 ± 12.73	61.36 ± 11.95	61.24 ± 12.41	1.13	0.67
Male(%)	66/12	35/7	101/19	0.03	0.85
Height(cm)	166.10 ± 20.27	168.43 ± 7.18	166.92 ± 6.88	0.72	0.47
Weight(kg)	68.45 ± 15.16	70.80 ± 9.55	69.27 ± 13.48	0.91	0.36
Smoking/n(%)	30(38.4)	18(42.9)	48(40.0)	0.22	0.64
hypertension/n(%)	23(29.5)	14(33.3)	37(30.8)	0.19	0.66
Diabetes/n(%)	18(23.1)	7(16.7)	25(20.8)	0.68	0.41
Dyslipidemia/n(%)	22(28.2)	16(38.1)	38(31.7)	1.23	0.27
Systolic blood pressure, mmHg	124.53 ± 21.29	130.95 ± 18.41	126.78 ± 20.48	1.65	0.10
Diastolic blood pressure, mmHg	75.00 ± 14.51	79.55 ± 9.72	76.59 ± 13.17	1.82	0.07
Heart rate(beats/minute)	78.03 ± 15.57	76.83 ± 19.63	77.60 ± 17.03	0.37	0.71
TNI, ng/ml	11.40(1.35,30)	11.75(5.32,23.25)	11.50(2.50,28.00)	-	0.56
BNP, pg/ml	253.80 ± 455.21	314.50 ± 300.28	275.29 ± 406.76	0.78	0.44
S-TO-B(min)	240(160,300)	600(480,900)	300(180,540)	-	P < 0.001
*Between group A and group B					

2. Comparison Of Coronary Angiography Results

Among the 120 patients, 111 were treated with drug-eluting stents, 8 with PCI without stents, 1 with thrombus aspiration, and 8 with collateral circulation. In group A, there were 11 cases of single-vessel disease, 19 cases of two-vessel disease, and 48 cases of three-vessel disease. While in group B, there were 9 cases of single-vessel disease, 8 cases of two-vessel disease, and 25 cases of three-vessel disease. There was no significant difference between the two groups ($P > 0.05$), as shown in Table 2. In this study, we focused on the culprit vessels, including 59 cases of LAD, 22 cases of LCX, 46 cases of RCA, 798 involved segments (25 of which were excluded due to insufficient image quality for the analysis of wall motion). The diagnostic results of AFI were in good agreement with those of coronary angiography, and there were 15 cases of new clinical phenomena such as arrhythmia and hypotension after the operation.

Table 2
.Comparison of coronary angiography results

Group	Cases	Coronary artery occlusion [case (%)]		
		Single branch	double branch	three branches
Group A	78	11	19	48
Group B	42	9	8	25
Total	120	20	27	73
$\chi 2$		1.24		
P*		0.54		
*Between group A and group B				

3. Comparison Of Clinical Prognosis Between The Two Groups

There were statistically significant differences in TIMI 3 blood flow rate, cTnI peak and total MACE events one month after operation between group A and group B ($P < 0.05$), while there were no statistically significant differences in total MACE events in hospital and LVEF in one month after operation, as shown in Table 3.

Table 3
Comparison of clinical prognosis of patients

Variable	Group A(78 cases)	Group B(42 cases)	Total (120 cases)	T(χ2)	P*
TIMI 3 blood flow /n (%)	70(89.7)	32(76.1)	102(85)	3.93	0.047
cTnI peak/(μg/L)	28.20 ± 33.50	43.66 ± 38.10	30.90 ± 35.26	2.30	0.02
Total hospitalized MACE/n (%)	1(1.3)	2(4.8)	3(2.5)	1.36	0.24
Total MACE/during follow-up/n(%)	2(3.8)	5(11.9)	7(5.8)	4.34	0.04
LVEF 1 month after operation	58.45 ± 8.70	57.23 ± 8.51	57.89 ± 8.61	0.73	0.47
*Between group A and group B					

4. Comparison Of Echocardiographic Parameters

The value of LVEF immediately after operation was 55.41 ± 8.54, there was no significant difference between the two groups ($P > 0.05$). In group A, LVEF gradually recovered after PCI, while in group B, LVEF slightly decreased 3 hours after PCI, and then gradually recovered. One month after the operation, 3 patients leak, 117 patients were followed up. The average level of LVEF was 57.89 ± 8.61. The LVEF of group A was slightly higher than that of group B, but there was no statistical difference between the two groups.

In group A, TLSendo, TLSmid, TLSepi and GLS increased gradually, especially in TLSendo. In group B, the above parameters decreased 3 hours after vessel opening compared with the immediate postoperative level, and TLSendo significantly increased, but the increase was smaller than that in group A, as shown in Table 4, Fig. 2,3. Table 5 shows the absolute value of the changes of TLSendo, TLSmid, TLSepi and GLS 1 week after the operation and immediately after the operation. The results show that the longitudinal strain of left ventricular endocardium and epicardium myocardium increases significantly than TLSmid, while the change range of GLS measurement is small.

Table 4
Comparison of strain parameters of patients during hospitalization

Variable	Time	Group A(78 cases)	Group B(42 cases)	Total (120 cases)	T	P*
LSendo	Immediately.post	-11.03 ± 7.82a	-10.85 ± 7.52	-10.97 ± 7.22	0.12	0.90
	3 hrs. post	-11.34 ± 7.32b	-9.63 ± 7.50	-10.88 ± 7.38	1.21	0.23
	24 hrs. post	-13.73 ± 8.43	-11.40 ± 8.05	-12.85 ± 8.25	0.84	0.40
	1 week. post	-15.63 ± 8.08	-12.45 ± 8.42	-13.91 ± 8.23	2.03	0.045
TLSmid	Immediately.post	-10.91 ± 7.51a	-10.70 ± 7.44	-10.78 ± 7.46	0.15	0.88
	3 hrs. post	-10.93 ± 7.38b	-9.36 ± 7.50	-10.02 ± 7.42	1.10	0.27
	24 hrs. post	-12.83 ± 7.21	-11.12 ± 7.42	-11.99 ± 7.25	1.23	0.22
	1 week. post	-14.65 ± 7.83	-11.47 ± 8.26	-13.10 ± 7.99	2.08	0.039
TLSepi	Immediately.post	-9.65 ± 7.30a	-8.90 ± 6.89	-9.21 ± 7.06	0.55	0.59
	3 hrs. post	-9.77 ± 7.98b	-8.12 ± 6.57	-8.89 ± 6.89	1.15	0.25
	24 hrs. post	-11.64 ± 7.87	-10.22 ± 6.66	-11.01 ± 7.69	0.99	0.32
	1 week. post	-13.95 ± 8.23	-11.02 ± 6.59	-12.19 ± 7.19	1.99	0.049
GLS	Immediately.post	-14.95 ± 5.44	-14.32 ± 4.64	-14.73 ± 5.16	0.64	0.53
	3 hrs. post	-14.99 ± 4.85	-13.76 ± 3.94	-14.56 ± 4.54	1.41	0.16
	24 hrs. post	-15.33 ± 5.06	-13.82 ± 4.17	-14.85 ± 4.79	1.65	0.10
	1 week. post	-16.52 ± 5.24	-15.52 ± 4.48	-16.20 ± 4.94	1.05	0.30
LVEF	Immediately.post	55.90 ± 8.48	54.90 ± 8.69	55.41 ± 8.54	0.61	0.54
	3 hrs. post	56.25 ± 8.68	54.87 ± 7.78	55.78 ± 8.64	1.01	0.31
	24 hrs. post	57.04 ± 8.68	56.83 ± 7.75	56.97 ± 8.34	0.13	0.90
	1 week. post	58.08 ± 8.71	57.17 ± 8.38	57.67 ± 8.59	0.55	0.58

*Between group A and group B;a means that mmediately. Post is statistically significant to 1 week. Post ;b means that 3 hrs. Postt is statistically significant to 1 week. Post

Table 5
Comparison of the difference of strain parameters between the patients 1 week after the operation and the patients immediately after the operation

	Group A(78 cases)	Group B(42 cases)	Total (120 cases)	T	P*
LSendo	4.53 ± 4.97	1.71 ± 4.22	2.94 ± 5.04	3.12	0.000
TLSmid	3.74 ± 4.56	0.77 ± 4.15	2.32 ± 4.51	3.50	0.000
TLSepi	4.30 ± 4.15	2.12 ± 4.16	2.98 ± 4.15	2.74	0.007
GLS	1.55 ± 2.59	1.22 ± 2.54	1.39 ± 2.55	0.67	0.50
*Between group A and group B					

To evaluate the predictive value of strain parameters on left ventricular function changes after revascularization in patients with myocardial infarction, the gold standard of heart function improvement was defined as the increase of LVEF ≥ 5% at 1 month postoperatively than immediately postoperatively[4].ROC curves of TLSendo, TLSmid, TLSepi, GLS, BNP and TNI were drawn to predict changes in heart function. The AUC areas were 0.87, 086, 0.82, 0.68, 0.55 and 0.55, respectively.Compared with other variables, TLSendo increase of 4.50% is the most accurate parameter to predict the significant improvement of left ventricular systolic function in patients with STEMI one month after operation. The sensitivity and specificity are 80.0% and 86.0% respectively, as shown in Table 6 and Fig. 4.

Table 6
ROC curves of LVEF increased by 5% at 1 month after operation for each parameter estimation

Variable	Cut-off value	sensitivity	specificity	Yoden index	AUC	95%CI	P
TLSendo	4.50	0.80	0.86	0.66	0.87	0.791–0.945	0.000
TLSmid	3.55	0.71	0.93	0.64	0.86	0.790–0.940	0.000
TLSepi	4.35	0.76	0.84	0.59	0.82	0.731–0.911	0.000
GLS	0.90	0.74	0.63	0.36	0.68	0.571–0.793	0.003
BNP	140.50	0.54	0.62	1.16	0.55	0.443–0.664	0.343
TNI	5.72	0.68	0.46	1.13	0.55	0.440–0.661	0.371

Table7. Inter-observer and intra-observer variability						
Characteristic	Inter-observer			Intra-observer		
	ICC	95 % CI	P value	ICC	95 % CI	P value
TLSendo	0.93	0.81–0.97	<0.001	0.94	0.84–0.98	<0.001
TLSmid	0.92	0.82-0.97	<0.001	0.93	0.83–0.96	<0.001
TLSepi	0.91	0.82-0.96	<0.001	0.90	0.79–0.97	<0.001
GLS	0.90	0.80-0.96	<0.001	0.91	0.81-0.96	<0.001
LVEF	0.93	0.80-0.97	<0.001	0.91	0.79-0.96	<0.001

Discussion

Time is cardiac myocyte, cardiac myocyte is life. Opening infarct related vessels within 6 hours after acute myocardial infarction can save the most dying myocardium, improve left ventricular function and reduce mortality. Although reperfusion 6 hours after the onset of the disease can't save the dying myocardium, it can prevent the left ventricular remodeling and increase the stability of the ECG by increasing the rigidity of the infarct wall and promoting the healing of the infarct.

S-TO-B refers to the time from the onset of symptoms to the first balloon dilation in the coronary artery, reflecting the total time of ischemia in patients with acute myocardial infarction receiving direct PCI, which is directly related to the prognosis [5]. Magnetic resonance imaging, tissue doppler, and speckle tracking have been used to study the changes in systolic and diastolic function after PCI in STEMI patients [6–8]. Katarzyna[9] et al performed PCI on 97 patients with STEMI, and measured the left ventricular segmental systolic function on the 1st, 2nd, 3rd, 7th, 30th and 180th days after the operation with speckle tracking technology. They found that most of the local systolic function recovery occurred on the first two days, especially within 24 h after the successful reperfusion treatment, but their study did not group according to S-TO-B. In our study, patients were divided into two groups according to S-TO-B time: S-TO-B ≤ 6 h group and 6h < S-TO-B < 12 h group. Speckle tracking technique was used to observe the changes of regional and global left ventricular function of the injured myocardium immediately, 3 hours, 24 hours and 7 days after STEMI, to evaluate the systolic function of left ventricle from local and global aspects, to clarify the changes of cardiac structure and function after ischemia-reperfusion, and to provide a new way for clinical evaluation of the prognosis of STEMI patients.

In this study, we found that TLSendo, TLSmid and TLSepi in group A recovered gradually after revascularization, indicating that revascularization of infarct related vessels within 6 hours after acute myocardial infarction can achieve effective or complete reperfusion at the level of myocardial cells, save the most dying myocardial cells, and improve cardiac function. Short term and small-scale infarction only has slight structural damage and myocardial stunning, so local and overall function can be improved [10].The strain parameters of group B showed a decreasing trend 3 hours after the operation compared with those immediately after the operation, then recovered gradually, but the increasing degree was smaller than that in group A. The reason for this phenomenon may be the reperfusion injury of reperfusion myocardium after the opening of blood vessels, or it may be the longtime of ischemia in group B and the irreversible injury of myocardial cells. Even though the blood vessels were opened, there were still some patients who did not reach the level of myocardial perfusion, which caused myocardial metabolism disorder, and myocardial function continued to deteriorate. Long term and large-scale myocardial infarction may lead to severe myocardial necrosis, left ventricular remodeling and heart failure [11].

At present, TIMI blood flow, LVEF and other methods are used to evaluate the opening of blood vessels or long-term prognosis of patients. In this study, the TIMI grade 3 blood flow rate of patients with S-TO-B < 6 h was significantly higher than that of patients with 6h < S-TO-B < 12 h.TIMI grading is a common method to evaluate the success of reperfusion, but it can only measure the epicardial blood flow qualitatively, and it is mainly judged by the observer, with poor repeatability. LVEF can evaluate the whole left ventricular function, but it can't evaluate the local cardiac function. LVEF is not sensitive to detect the subtle changes of local cardiac function. LVEF is based on the change of the volume of the chamber, which is usually secondary to the change of the deformation of the heart. The two-dimensional strain reflects the size of myocardial deformation, that is, the intrinsic characteristics of the heart itself. Therefore, the two-dimensional strain can detect the potential damage of left ventricular systolic function before the change of LVEF [12–13].In this study, there was no significant difference in LVEF between patients with STEMI immediately and 3 hours, 24 hours, 7 days and 1 month after operation, suggesting that conventional echocardiography is not sensitive to evaluate slight changes in systolic function.

Traditionally, the thickness of the entire myocardial wall has been considered in the analysis of myocardial function, regardless of the differences in the myocardial layer. Related studies have shown that the layered strain technique based on 2D-STI can be used to evaluate the differences in the functional effects of various layers of myocardium caused by ischemia or necrosis. The evaluation of myocardial deformation by layered strain technique and cardiac magnetic resonance markers has high accuracy in the evaluation of myocardial deformation [14–16], which can analyze the strain of the myocardium in each layer of the left ventricular wall and sensitively reflect the functional changes of myocardium. Previous studies have shown that 2D strain parameters, whether longitudinal strain, radial strain or circumferential strain, can more reflect myocardial ischemia in patients with coronary heart disease sensitively [17], but radial and circumferential strain cannot be accurately measured and reproducibility is poor[18].

Studies on animal models of myocardial infarction [19] and reperfusion of myocardial infarction have shown that the endocardium is first affected by ischemia, with the most significant changes in longitudinal strain. Previous studies have confirmed that the detection of myocardial longitudinal strain is highly sensitive to myocardial ischemia [20], so this study focuses on the study of longitudinal strain. Analysis of parameters before discharge and immediately after surgery showed that TLSendo and

TLSepi increased significantly after PCI. The possible reason is that the longitudinal myocardial fibers of the left ventricular wall are mainly distributed under the endocardium and epicardium of the free wall of the left ventricle, which control the longitudinal movement of the myocardium. The middle layer is circular myocardial fibers, which control the circular movement. Therefore, the longitudinal strain of the myocardium under the endocardium and epicardium is more sensitive to ischemia than that of the middle myocardium, and the recovery after revascularization is more obvious.

The prognosis of patients with acute myocardial infarction is affected by a variety of factors [21]. In this study, there were no significant differences in age, gender, cardiovascular risk factors between the two groups of patients with myocardial infarction, except S-TO-B, which were significant differences. Therefore, the potential influence of other factors on the prognosis of patients was excluded. ROC curve analysis showed that TLSendo was the most powerful strain parameter for identifying viable myocardium, with a 4.50% increase in TLSendo as the threshold. It was the most accurate parameter for the significant improvement of left ventricular systolic function one month after STEMI, with a sensitivity and specificity of 80.0% and 86.0%, respectively. TLSendo reflects the local strain of ischemic myocardium, which can better predict the recovery of cardiac function in patients with myocardial infarction than the overall strain GLS of the left ventricle. The recovery of cardiac function in group B was lower than that in group A, and the incidence of MACE events (heart failure, malignant arrhythmia, death) was significantly higher than that in group A. Therefore, early opening of infarct-related vessels can reduce the area of myocardial infarction, protect cardiac function and improve the prognosis of patients.

Limitations

The study was a single-center study with a large number of patients. Image analysis and acquisition are mainly through Ge vivid e 9. Due to the difference of data from different machines, the patients included in this study are acute myocardial infarction with limited image quality, so its clinical application may be limited to some extent. This study only analyzed the peak strain of longitudinal systole, but not the peak strain of radial and circumferential systole. The patients included in this study inevitably took anticoagulants and vasoactive drugs during the operation, which may have some influence on the results of this study. The three-layer myocardium does not necessarily have a linear boundary, but the software will layer it linearly by default, which may also affect the results of the study.

Conclusions

Tthe layered strain technique can evaluate the myocardial strain in patients with ST-segment elevation myocardial infarction and identify the effect of S-TO-B on the prognosis of STEMI patients, predicting which segment injuries will improve and which are irreversible. The time course of cardiac function recovery in STEMI patients monitored by layered strain technique has important influence on early risk assessment, treatment strategy selection and prognosis assessment. The clinical treatment effect of STEMI patients is closely related to S-TO-B, so early opening of infarct related vessels will benefit patients greatly[12].However, shortening S-TO-B also requires strengthening the management of shortening the time from symptom onset to hospital arrival, which requires increasing public education and awareness of symptoms and signs of acute myocardial infarction.

Abbreviations

2D-STI
Two-dimensional speckle tracking imaging ;ICC = Interclass correlation coefficient;
GLS
Global longitudinal strain;LAD = Left anterior descending coronary artery; LCX = Left circumflex coronary artery;LVEF = Left ventricle ejection fraction;MACE = major adverse cardiovascular events; PCI = Percutaneous coronary intervention;RCA = Right coronary artery;ROC = Relative operating characteristic curve;STEMI = ST elevation myocardial infraction; S-TO-B = onset of symptoms to the first balloon dilation;TLSendo = Territorial longitudinal strain of endocadium;TLSmid = Territorial longitudinal strain of midmyocardium;TLSepi = Territorial longitudinal strain of epicardium

Declarations

Ethical Approval and Consent to participate The study plan was approved by the institutional review committee of affiliated hospital of Jiangsu university, and each patient signed the informed consent form.ChiCTR-DDD-17012790. Registered June 2, 2017, http://www.chictr.org.cn/showproj.aspx?proj=21890

Consent for publication Each author consents to the publication of the article.

Availability of data and materials The data and materials used in this study are available from the corresponding author or the first author on reasonable request.

Competing interests The authors declare that they have no conflict of interest.

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Authors' contributions YL and FZ designed this study as the first author and corresponding author. XC, and LX were involved in image acquisition and analysis in this study.CZ and TF carried out the statistical analysis. All authors read and approved the final manuscript.

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Figures

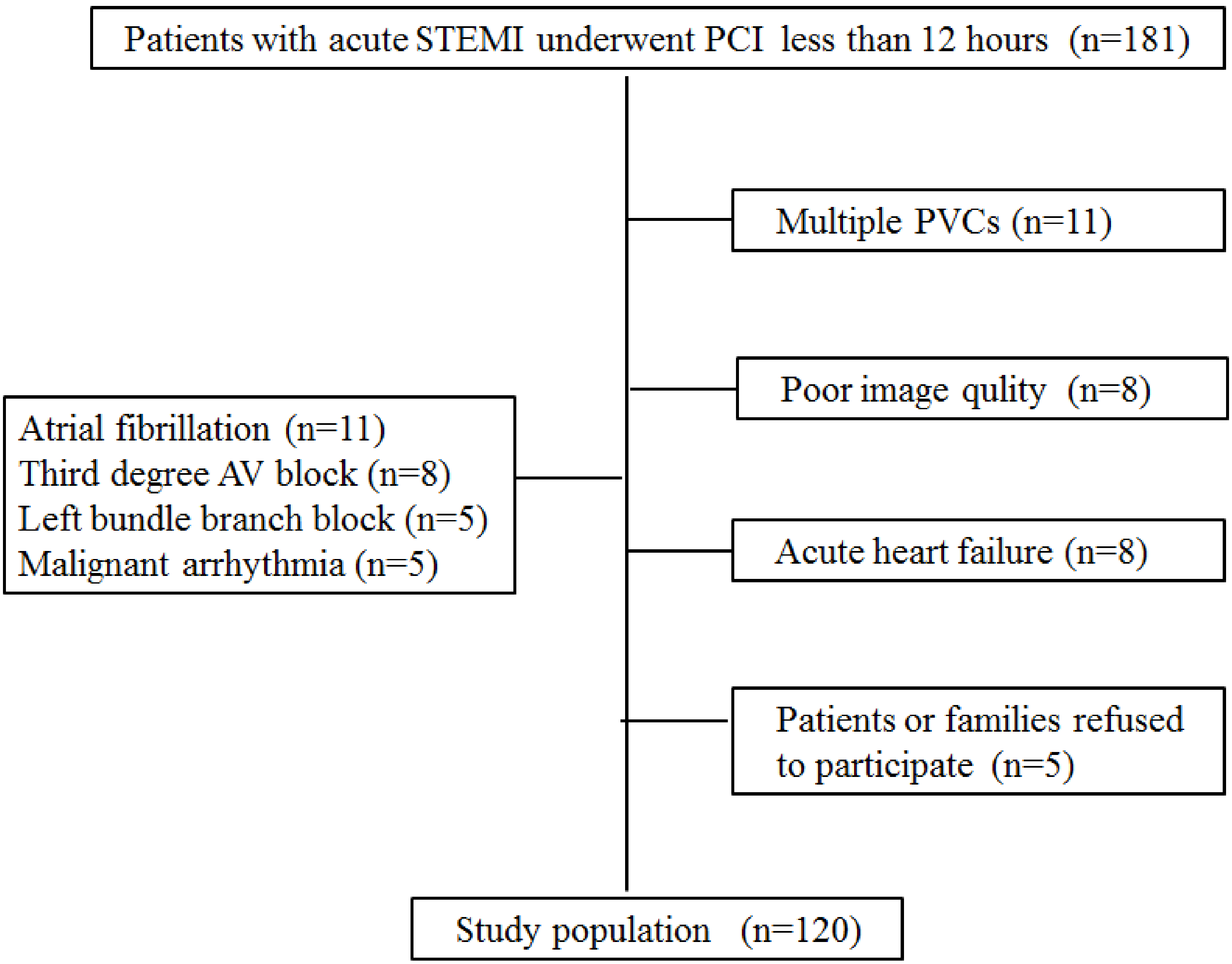


Figure 1

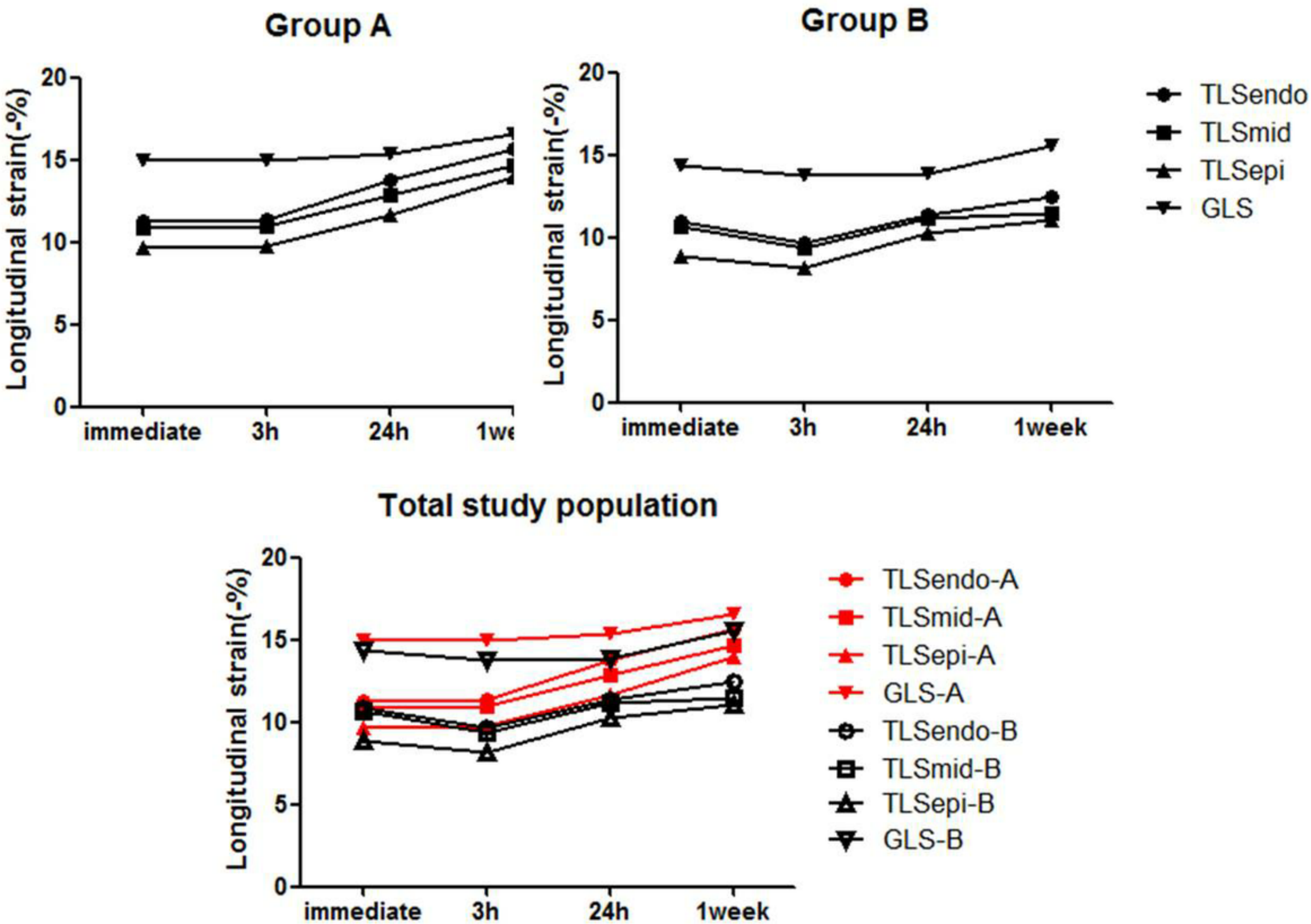

Group A
Longitudinal strain(-%)
0
5
10
15
20
immediate
3h
24h
1we
Group B
Longitudinal strain(-%)
0
5
10
15
20
immediate
3h
24h
1week
TLSendo
TLSmid
TLSepi
GLS
Total study population
Longitudinal strain(-%)
0
5
10
15
20
immediate
3h
24h
1week
TLSendo-A
TLSmid-A
TLSepi-A
GLS-A
TLSendo-B
TLSmid-B
TLSepi-B
GLS-B

Figure 2

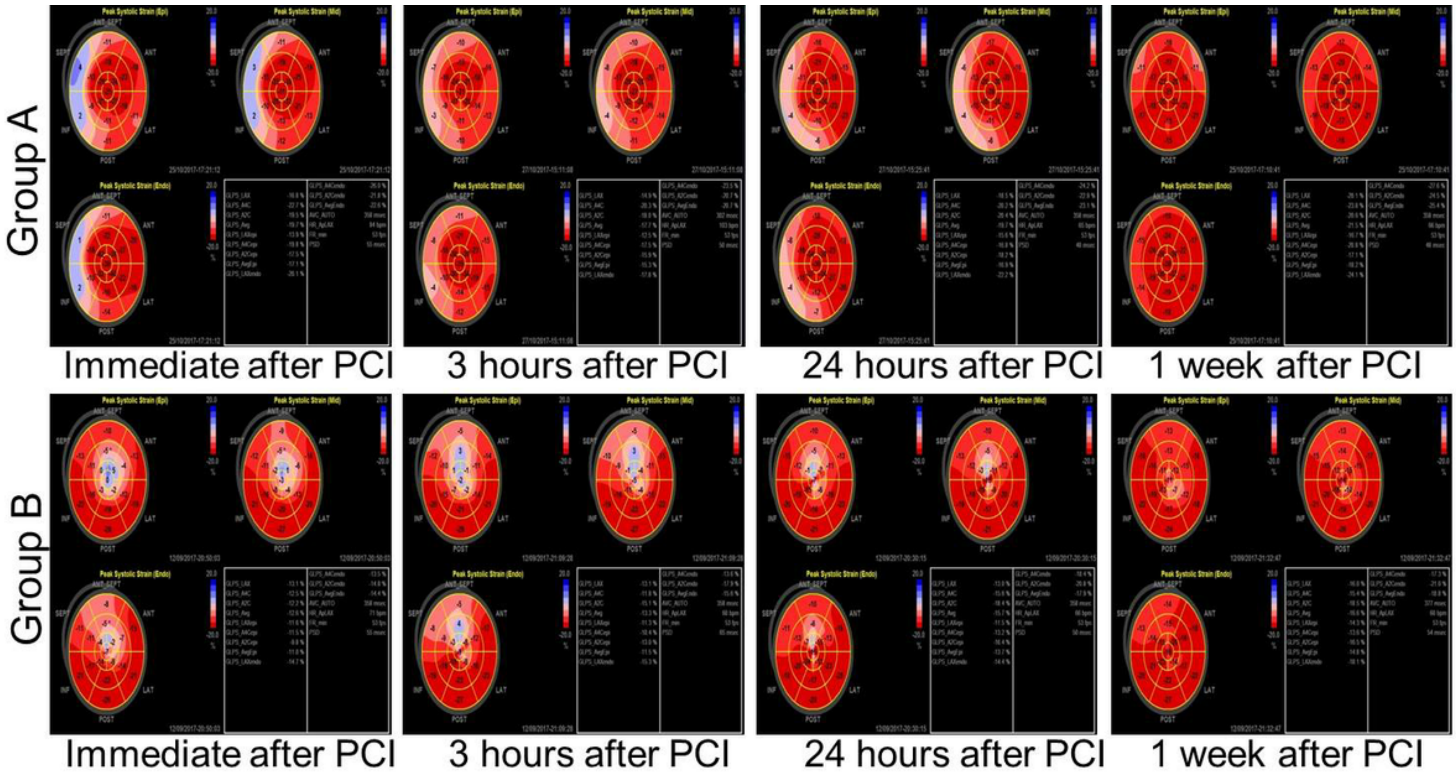
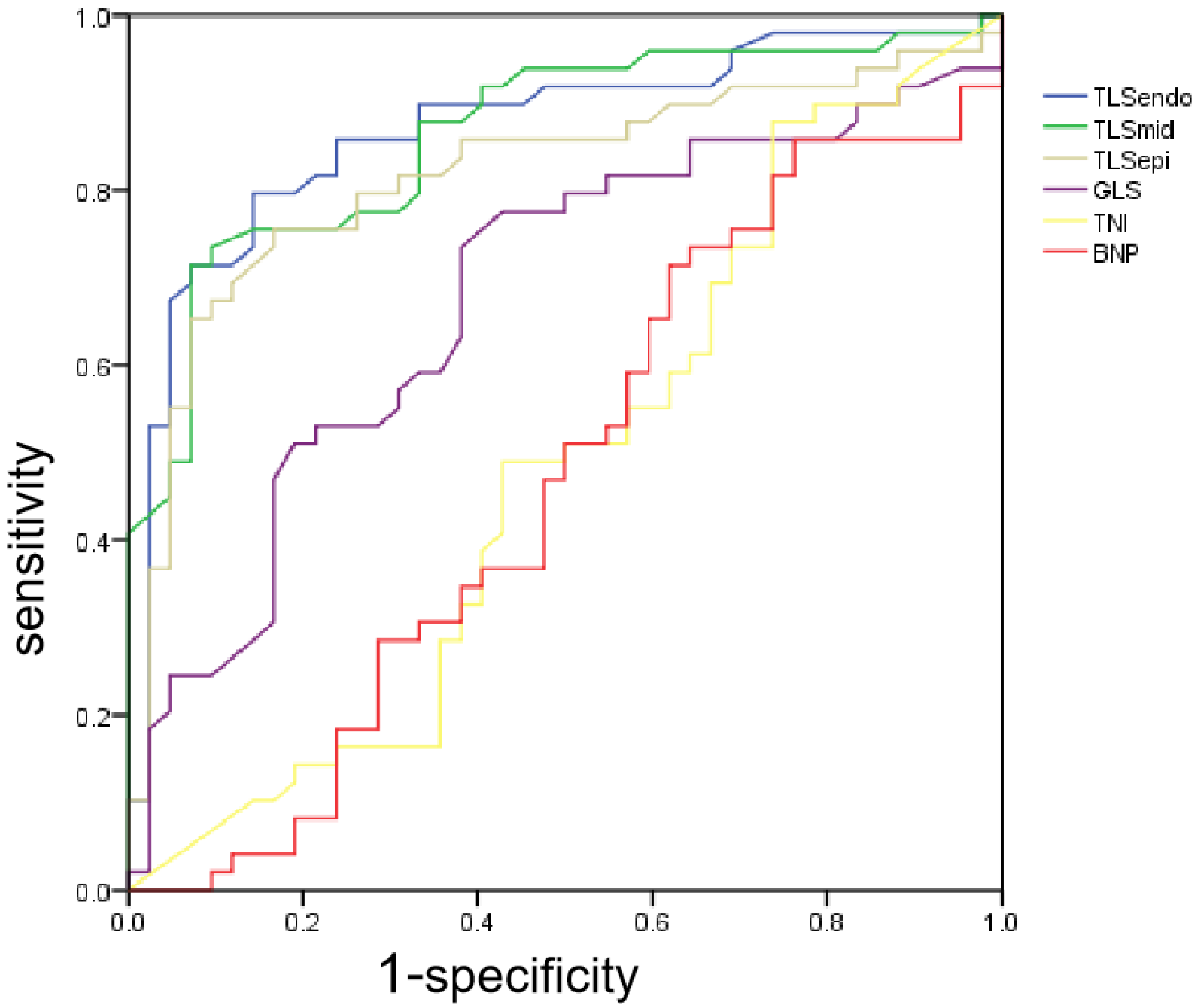

Group A
Immediate after PCI
3 hours after PCI
24 hours after PCI
1 week after PCI
Group B
Immediate after PCI
3 hours after PCI
24 hours after PCI
1 week after PCI

Figure 3



1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
sensitivity
1-specificity
TLSendo
TLSmid
TLSepi
GLS
TNI
BNP

Figure 4