

Received: 2016.08.25
Accepted: 2016.09.12
Published: 2017.05.17

Postoperative Assessment of Myocardial Function and Microcirculation in Patients with Acute Coronary Syndrome by Myocardial Contrast Echocardiography

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Data Interpretation D
Manuscript Preparation E
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Source of support: This project was supported by the Science and Technology Plan Program of Heilongjiang Province "Application of Transmyocardial Laser Revascularization Combined with Gene Transfection of Hepatocyte Growth Factor in Treatment of "No hope" Coronary Heart Disease" (No. GC05C40303), and the Science and Technology Research Project of Education Department of Heilongjiang Province project "Study on the Key Techniques of Using Pattern Recognition Method for Analysis of Lymphoma Bone Marrow" (No. 12541527)

Background: Postoperative myocardial function and microcirculation of acute coronary syndrome (ACS) was assessed by myocardial contrast echocardiography (MCE).


Material/Methods: Eighty-nine ACS patients treated with percutaneous coronary intervention (PCI) were detected by MCE and two-dimensional ultrasonography before and a month later after PCI respectively. Their myocardial perfusion was evaluated by myocardial contrast score (MSC) and contrast score index (CSI); cross-sectional area of microvessel (A), average myocardial microvascular impairment (β), and myocardial blood flow (MBF) were analyzed by cardiac ultrasound quantitative analysis (CUSQ), and fractional flow reserve (FFR) change was observed. Left ventricular ejection fraction (LVEF), left ventricular end-diastolic dimension (LVEDD), and left ventricular end-systolic dimension (LVESD) were observed; the index of microcirculatory resistance (IMR), FFR, and coronary flow reserve (CFR) were detected to evaluate coronary microcirculation.

Results: None of the 89 patients experienced no-reflow. Patients with normal myocardial perfusion mostly had normal or slightly decreased ventricular wall motion after PCI. A month after the operation, there was an increase in A, β , MBF, LVEF, E/A, IMR, FFR, and CFR (all $P < 0.05$), while LVEDD, LVESD, diastolic gallop A peak, E/Ea, E/Ea \times S, and Tei decreased (all $P < 0.05$). LVEF and IMR were in positive correlations with A. LVEF, IMR, FFR and CFR were positively correlated with β and MBF (both $r > 0$, $P < 0.05$), while E/Ea \times Sa and Tei were negatively correlated with β and MBF ($r < 0$, $P < 0.05$).

Conclusions: MCE can safely assess post-PCI myocardial function and microcirculation of ASC.

MeSH Keywords: **Anterior Spinal Artery Syndrome • Anterior Wall Myocardial Infarction • Echocardiography**

Full-text PDF: <http://www.medscimonit.com/abstract/index/idArt/901233>

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Background

Acute coronary syndromes (ACS) arise from coronary atherosclerosis with superimposed thrombosis, which plays a key role in the pathogenesis of the life-threatening ACS, bringing about ST-segment elevation myocardial infarction (STEMI), non-STEMI, and unstable angina; especially the latter if acute chest pain occurs at rest [1]. Rare non-atherosclerotic causes of ACS include coronary arteritis, dissection, trauma, thromboembolism, cocaine abuse, congenital anomalies, and complications of cardiac catheterization [2]. In the USA alone, more than 400 000 people die of coronary artery disease annually, and more than 1 000 000 have ACS in total [3]. Although effective treatments are available, ACS still carries the burden of economic impact and unacceptably high mortality [4]. Immediate percutaneous coronary intervention (PCI) has long been recommended for high-risk ACS [5]. However, it always causes no-reflow and myocardial reperfusion injury phenomenon, threatening patients' lives [6]. Therefore, timely detection of myocardial function of ACS patients undergoing PCI is required to ensure optimal treatment. Assessment of the coronary microvasculature is a key issue in the clinical setting, given that microvascular dysfunction itself has a predictive value for cardiovascular events, and the index of microcirculatory resistance is an invasive method of interrogating the microvasculature [7]. Hence, post-PCI assessment of microcirculation and myocardial function has been an important research focus in cardiovascular imaging.

Myocardial contrast echocardiography (MCE) is a relatively new technique that utilizes microbubbles, which, following intravenous administration, remain entirely intravascular, mimic red blood cell rheology, and thus allow assessment of myocardial perfusion [8]. Contrast agents contain a gas with low diffusibility and solubility and a shell of lipids, albumin, or galactose to prolong their life span [9]. The microbubbles have a smaller diameter than that of red blood cells, resist arterial pressure, and remain intravascular in the intact circulation. These properties allow opacification of the left ventricular cavity, passage of the pulmonary vasculature, and imaging of myocardial perfusion [10]. Contrast echocardiography, extensively investigated in several large multicenter trials [11–13], has been found to be safe and well-tolerated in both critically and non-critically ill patients [14]. Recent studies have demonstrated the ability of MCE to detect myocardial viability and following vasodilator stress, and also can determine ischemic burden and coronary flow reserve [15–17]. Therefore, it is used for diagnosis and prognosis of many cardiac diseases, including Takotsubo cardiomyopathy, anterior myocardial infarction, and coronary artery disease [18–20], but few studies have investigated the value of MCE in assessing post-PCI myocardial function and microcirculation of patients with ACS. Therefore, we hypothesized that MCE may also be able to accurately assess post-PCI

myocardial function and microcirculation. The aim of this study was to investigate the clinical usefulness of MCE for ACS in a post-PCI therapeutic regimen.

Material and Methods

Ethics statement

This study was approved by the Ethics Committee of the First Affiliated Hospital of Harbin Medical University, and all patients were informed and signed the informed consent.

Object of study

From January 2013 to June 2015, 89 ACS patients who were treated by PCI in the Cardiology Department of the First Affiliated Hospital of Harbin Medical University were enrolled into our study. These 89 patients, whose average age was 55.8 ± 9.5 (44–69) years, included 61 males and 28 females, and there were 40 cases of myocardial infarction and 49 cases of unstable angina pectoris. There were 37 occlusions of the coronary artery, of which 23 were left anterior descending branches and 14 were right coronary arteries, which reached TIMI3 grade of blood flow and had no residual stenosis, dissection, or thrombosis after the operation. All patients met the ACS diagnostic code of the American College of Cardiology and American Heart Association (ACC/AHA) guidelines (2007 Edition) [21], and were confirmed by coronary radiography. Patients who met the following criteria were excluded: recent fever and all kinds of acute and chronic infections; previous stroke, thieroma, or history of rheumatic connective tissue disease; severe heart, liver, or renal insufficiency; active internal bleeding within the last month, including head injury, cardiopulmonary resuscitation, surgery, no-oppression great vessels with centesis previously or bleeding tendency; severe and uncontrolled hypertension on admission ($>180/110$ mmHg); pregnant and lactating women; patients with left ventricular ejection fraction $<40\%$; and patients with poor compliance or incomplete clinical data.

MCE examination and image acquisition

Imaging was performed using a color Doppler ultrasonic diagnostic apparatus (Phillips iE 33) 1 month after the operation (inside set with contrast agent myocardial imaging procedure software, S5-1 probe at a frequency of 2.5–3.5 MHz). The myocardial contractility and coronary microcirculation drugs were out of the circulation by 12 h later as shown by MCE. Patients were in left lateral decubitus position and were monitored by electrocardiography (ECG) and using a color Doppler ultrasonic diagnostic apparatus with S5-1 probe recorded the image of apical 4-chamber heart section, 2 heart chambers, and long

axis and short axis section of left ventricle under basic condition at the frequency of 2.5–3.5 MHz. After inspection of the static ultrasound, the image was shown by the contrast myocardial imaging procedure. The infusion channel was opened by the left elbow median vein and 2.4 ml of contrast was administered by slow intravenous injection over a period of 2 min, then with a slow drip irrigation of 5-ml saline infusion. Meanwhile, we carried out the continuous dynamic acquisition. During the testing process, attention must be paid to whether the subjects have any adverse reactions, recording the time from the injection of contrast into the left elbow median vein to the beginning of myocardial development with visual observation, observing the apical 4-chamber and 2-chamber heart images, papillary muscle horizontal left ventricular short axis section, observing the filling of ultrasound microbubbles in the heart chamber and myocardium, and periodically applying ultrasonic emission with high mechanical index (flash) to break microbubbles in the myocardium for observation of myocardial reperfusion. At the same time, hemodynamics changes before and after contrast – heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP) and resting oxygen saturation (O₂SAT) – and adverse reactions were recorded to evaluate the safety of SonoVue. The ventriculus sinister segment was carried through segmental wall movement scoring (WMS) according to 17-segment piecewise cardiogram method recommended by American Society of Ultrasound [22]: 1 point, normal movement; 2 points, decrease of mild exercise; 3 points, obvious reduction of movement; 4 points, disappearance of movement; and 5 points, reverse movement. The acquired dynamic image was played back after inspection and the results were analyzed by 2 independent cardiac ultrasound doctors. We obtained satisfactory left ventricular and myocardial visualization in all patients. After 8–40 (average of 12.23 ± 6.75) s of intravenous injection, the left chamber was visible. In another 3–5 cardiac cycles, using a flash with high mechanical index, ultrasound fragmented the microbubbles after visualization of left ventricular myocardial allowed observing the condition of myocardial perfusion again. The cross-sectional area of a microvessel (A) and average myocardial microvascular lesion (β) were determined and myocardial blood flow (MBF) was calculated with $A \times \beta$.

Analysis of MCE

According to the 17 ventriculus sinister segment piecewise method, there were a total of 254 segments of myocardial reperfusion related to 37 blood supply areas of coronary artery occlusion. Myocardial contrast score (MCS) [23] was: 1 point, good perfusion and the contrast medium of full uniform filling in myocardial; 0.5s point, the decrease of perfusion and uneven shade of contrast medium; and 0 points, non-perfusion and no contrast medium filling. The contrast score index (CSI) [24] is defined as the sum of the myocardial contrast score

in revascularization-related segments divided by the sum of segments, and the definition of CSI <0.5 was no-reflow (NR).

Determination of cardiac function

Cardiac ultrasonography using an HP 5500 ultrasonic diagnostic apparatus 1 month before and after the operation was manipulated by staff. Patients were placed on the left side in supine and horizontal position, with left ventricular long axis view, papillary muscle short axis, apical 2-chamber and 4-chamber view, respectively, to measure the value of the same cardiac cycle of the left ventricular-diastolic dimension (LVEDD), left ventricular end-systolic dimension (LVESD), and calculate the value of the left ventricular ejection fraction (LVEF). The lower apical 4-chamber view of the heart and blood flow display of color Doppler flow imaging (CDFI) made the acoustic beam and direction of blood flow parallel. According to pulsed wave (PW) spectrum Doppler method, the sample volume was placed at the tip of the mitral valve; a flow pulse Doppler image of mitral orifice was recorded, and the value of early diastolic E peak, late diastolic A peak velocity, and E/A ratio were calculated. The apical 4-chamber view and the apical 2-chamber view of the heart were obtained by pulsed-wave tissue Doppler imaging (PW-TDI) mode. They showed mitral valve annulus, including left ventricular anterior wall site, posterior mitral annular space site, left ventricular lateral wall site, and left ventricular inferior wall site. The points of the organization Doppler image were acquired to measure the value of mitral annular early diastolic Ea peak, late diastolic Aa peak, and systole Sa peak velocity, and to calculate the value E/Ea, E/Ea \times Sa. We measured the time from the stopping point of mitral annulus motion spectrum Aa wave to the starting point of the next periodic motion spectrum Ea wave (a) and the duration time of mitral annular systolic frequency spectrum Sa wave (b), Tei index, was calculated by the formula of (a–b)/b.

Detection of index of microcirculatory resistance (IMR), fractional flow reserve (FFR), and coronary flow reserve (CFR)

The IMR value of arteriae coronaria sinistra rami anterior descendens and arteriae coronaria dextra, FFR and CFR of rami anterior descendens of all patients were detected before and after the PCI operation. The specific detection methods of IMR were as follows: first, pressure wire was placed horizontally *in vitro*, making the sensor of pressure guide wire fronts in zero calibration, which was placed in saline at room temperature. Through the 6F guiding catheter, the sensor of the pressure guide wire was pushed to the guide tube opening, and the EQUALIZE value was ± 10 . Then the next step can be carried out. If the EQUALIZE value was not in this interval, the relevant factors needed to be discovered (e.g., the position of the transducer must be in agreement with the heart level).

The pressure guide wire was sent to the infarct related artery (IRA) remote after the EQUALIZE was successful (the distance of guide tube opening >5 cm). Then, the Radi Analyzer system was used to determine the CFR interface. Before the determination of IMR, a bullet-type guided duct was pre-pushed with 3 ml of physiological saline at room temperature. For example, the sensor of the pressure guide wire showed the temperature dropped >2°C, and the average transmission time (TmnBase) was measured at baseline level 3 times. Adenosine triphosphate (ATP) was pumped at the speed of 140 ug/Kg/min, making the coronary artery reach the maximum congestion state. After pumping ATP for 90 s, room temperature physiological saline was injected 3 times (<0.25 s), each time pushing 3 ml to the distal coronary artery, which reached the average transmission time (Tmn_{Hyp}) of maximum congestion state. Because Tmn_{Hyp} and Pd were determined at the time of maximum of vascular congestion, hemodynamic changes were ignored so minimal microcirculation resistance could be determined and IMP value could be calculated as $Pd \times Tmn_{Hyp} \times (Pd - Pw) / (Pa - Pw)$.

Statistical analysis

SPSS 21.0 statistics software was used to analyze data. Measurement data all obeyed normal distribution, indicated by mean ± standard deviation (SD). The comparison with before and after contrast and before and after surgery of the same patients was analyzed through use of the paired *t* test. We used Pearson correlation analysis and *P*<0.05 showed a significant difference.

Results

General information and image effect

There were 89 patients, with an average age of 56.72±7.33 years, 61 (68.54%) were males; 35.96% (32/89) were smokers, 58.43% (52/89) had hypertension history, 21.35% (19/89) had diabetes, 39.33% (35/89) had hyperlipidemia, 20.22% (18/89) had coronary heart disease, and 53.93% (48/89) had excessive BMI. Table 1 shows the data on heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), total cholesterol (TC), triglycerides (TG), and glutamate (Glu). We obtained satisfactory imaging in all patients, without adverse reactions. Figure 1A and 1B show normal perfusion and perfusion reduction.

Safety evaluation

HR, blood pressure, and oxygen saturation had no significant change during the process of injecting acoustic contrast and after injection (*P*>0.05; Table 2). The ECGs of all patients revealed

Table 1. General information of patients.

Data	Patients (n=89)
Age (year)	56.72±7.33
Gender (male/female)	61/28
Smoking (Yes/No)	32/57
History of hypertension (Yes/No)	52/37
Diabetes (Yes/No)	19/70
Hyperlipidemia (Yes/No)	35/54
Family history of coronary heart disease (Yes/No)	18/71
Excessive weight index (Yes/No)	48/41
HR (bpm)	74.68±10.72
SBP (mmHg)	136.58±17.27
DBP (mmHg)	78.76±11.56
LDL-C (mmol/L)	3.61±0.44
HDL-C (mmol/L)	1.92±0.30
TC (mmol/L)	4.13±0.42
TG (mmol/L)	1.56±0.26
Glu (mmol/L)	4.45±0.32

Data are mean ±SD or number. HR – heart rate; SBP – systolic blood pressure; DBP – diastolic blood pressure; LDL-C – low-density lipoprotein cholesterol; HDL-C – high-density lipoprotein cholesterol; TC – total cholesterol; TG – triglycerides; Glu – glutamate.

that SonoVue contrast medium had no effect on ECG, and no patients had chest tightness, chest pain, headache, nausea, feeling abnormalities, or other adverse reactions.

Analysis of MCE results

There were 89 patients who had no NR phenomenon and CSI greater than or equal to 0.5, with the average CSI point 1.27±0.39. However, in the opening vascular blood supply area of 254 myocardial segments, MCE showed that there were 171 segments in patients with normal perfusion (1 point) (67.3%), 83 segments in poor perfusion (0.5 point), and 0 segments in no perfusion (0 point) (total: 32.7%). The results showed that the perfusion effect of 32.7% existed in the TIMI 3 grade of myocardial segments (Figure 2).

Relationship between myocardial perfusion level and WMS

The 83 segments of MCE for 0.5 points included 54 segments (65.06%) of WMS showing 1~2 points and 27 segments



Figure 1. Results of myocardial perfusion imaging of patients. (A) Represents the image of normal myocardial perfusion image; (B) Represents the image of the myocardial perfusion reduction.

Table 2. Effect of SonoVue contrast-medium on hemodynamics of the patients (n=89, $\bar{x}\pm s$).

Index	Before contrast-medium	After contrast-medium	t	P
HR (beats/min)	74.68±10.72	73.43±9.85	0.85	0.396
SBP (mmHg)	136.58±17.27	134.66±15.52	0.82	0.414
DBP (mmHg)	78.76±11.56	80.51±10.24	1.13	0.264
O2SAT (%)	97.00±1.70	96.42±1.74	1.91	0.060

HR – heart rate; SBP – systolic blood pressure; DBP – diastolic blood pressure; O2SAT – resting oxygen saturation.

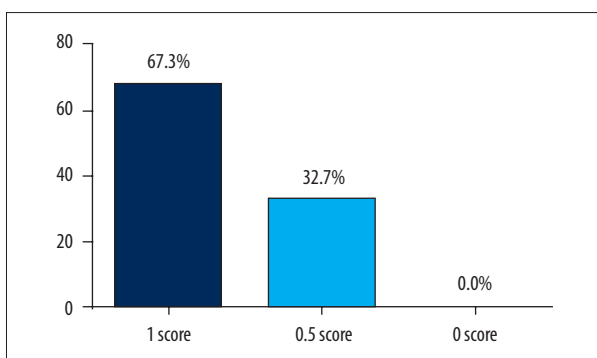


Figure 2. Results of myocardial contrast echocardiography.

(34.94%) showing 3~5 points. The 171 segments of MCE for 1 point included 142 segments (83.04%) of WMS for 1~2 points and 29 segments (16.96%) for 3~5 points. Statistical analysis showed that the wall motion in people with normal myocardial perfusion (MCE=1 point) after PCI therapy presented normal movement (WMS=1~2 points). Comparing the poor perfusion and non-perfusion groups, a significant difference was found in comparison of distribution of WMS (Table 3).

Parameters of myocardial contrast before and after the operation

Myocardial contrast parameters of all patients before and after surgery are shown in Table 4. A, β , and MBF for preoperative

Table 3. Results of myocardial perfusion and WMS after PCI.

WMS	MCE=0.5 point	MCE=1 point	t	P
1~2 points	54 (65.06%)	142 (83.04%)	8.53	0.004
3~5 points	27 (34.94%)	29 (16.96%)		

PCI – percutaneous coronary intervention; WMS – wall movement scoring; MCE – myocardial contrast score.

Table 4. Comparison of myocardial contrast parameters before and after operation.

Index	Before operation	1 month after operation	t	P
A (dB)	26.83±2.74	30.47±4.80	6.5	<0.001
β (/s)	1.02±0.43	1.28±0.62	3.34	0.001
MBF (dB/s)	27.43±11.94	39.13±19.97	6.2	<0.001

A – Cross-sectional area of microvessel; β – average myocardial microvascular lesion; MBF – myocardial blood flow.

Table 5. Comparison of cardiac function indexes before and after operation.

Index	Before operation	1 month after operation	t	P
LVEF (%)	63.42±8.17	66.57±7.76	2.71	0.008
LVEDD (mm)	45.05±4.60	43.26±4.60	2.05	0.044
LVESD (mm)	29.19±6.51	26.47±5.98	1.99	0.049
E (m/s)	0.75±0.20	0.82±0.25	1.98	0.051
A (m/s)	0.86±0.23	0.79±0.18	2.37	0.020
E/A	0.84±0.43	1.11±0.51	2.31	0.023
E/Ea	9.52±3.60	8.91±3.89	2.03	0.046
E/Ea×Sa	1.06±0.47	0.96±0.42	2.48	0.015
Tei	0.57±0.19	0.49±0.20	3.00	0.004

LVEF – left ventricular ejection fraction; LVEDD – left ventricular end-diastolic dimension; LVESD – left ventricular end-systolic dimension; E – early diastolic E peak velocity; A – late diastolic A peak velocity; Ea – Ea peak velocity in early diastolic mitral annular; Sa – systolic Sa peak velocity; Tei – Tei index.

Table 6. Comparison of CFR, FFR and IMR before and after operation.

Index	Before operation	1 month after operation	t	P
IMR	23.49±5.35	26.17±6.04	3.07	0.003
FFR	0.72±0.11	0.96±0.06	45.13	<0.001
CFR	1.58±0.57	2.73±1.08	24.14	<0.001

IMR – index of microcirculatory resistance; FFR – fractional flow reserve; CFR – coronary flow reserve.

patients were for 26.83±2.74, 1.02±0.43, and 27.43±11.94, respectively, and these parameters were significantly increased 1 month after the operation ($P<0.05$), at 30.47±4.80, 1.28±0.62, and 39.13±19.97, respectively.

Comparison of cardiac function indexes before and after the operation

Compared with pre-operation, LVEF and E/A of patients were obviously increased (both $P<0.05$), while LVEDD, LVESD, late diastolic A peak velocity, E/Ea, E/Ea×Sa, and Tei were significantly

decreased at 1 month after the operation (all $P<0.05$). There was no obvious difference in early diastolic E peak velocity for patients before and after the operation ($P>0.05$) (Table 5).

Comparison of IMR, FFR, and CFR before and after the operation

IMR, FFR, and CFR results of all patients before and after the operation are shown in Table 6. Before the operation, IMR, FFR, and CFR of patients were 23.49±5.35, 0.72±0.11, and 1.58±0.57, respectively. IMR, FFR, and CFR of patients at 1 month after

Table 7. Correlation between myocardial function, microcirculation and myocardial contrast parameters after operation.

Index	A		β		MBF	
	r	P	r	P	r	P
LVEF (%)	0.22	0.042*	0.63	<0.001*	0.64	<0.001*
LVEDD (mm)	-0.03	0.795	-0.14	0.186	-0.08	0.0484
LVESD (mm)	-0.07	0.484	-0.04	0.691	-0.09	0.393
E (m/s)	-0.06	0.532	0.05	0.662	0.02	0.825
A (m/s)	-0.2	0.066	-0.15	0.158	-0.17	0.109
E/A	0.13	0.215	0.07	0.491	0.09	0.418
E/Ea	0.02	0.884	0.17	0.122	0.14	0.205
E/Ea×Sa	-0.2	0.055	-0.23	0.032*	-0.29	0.005*
Tei	-0.05	0.674	-0.33	0.002*	-0.31	0.003*
IMR	0.25	0.021*	0.66	<0.001*	0.7	<0.001*
FFR	0.04	0.661	0.57	<0.001*	0.56	<0.001*
CFR	0.11	0.295	0.35	0.001*	0.35	0.001*

LVEF – left ventricular ejection fraction; LVEDD – left ventricular end-diastolic dimension; LVESD – left ventricular end-systolic dimension; E – early diastolic E peak velocity; A – late diastolic A peak velocity; Ea – Ea peak velocity in early diastolic mitral annular; Sa – systolic Sa peak velocity; Tei – Tei index; IMR – index of microcirculatory resistance; FFR – fractional flow reserve; CFR – coronary flow reserve; * indicates $P < 0.05$.

the operation were significantly increased, at 26.17 ± 6.04 , 0.96 ± 0.06 , and 2.73 ± 1.08 , respectively ($P < 0.05$).

Correlation analysis

The correlation results between myocardial contrast parameters after the operation and myocardial function and microcirculation are shown in Table 7. LVEF and IMR were positively correlated with A ($r > 0$, $P < 0.05$); LVEF, IMR, FFR, CFR were positively correlated with β and MBF ($r > 0$, $P < 0.05$); but E/Ea×Sa and Tei were in negatively correlation with β and MBF ($r < 0$, $P < 0.05$). Moreover, LVEDD, LVESD, E, A, and E/A had no correlation with A, β , and MBF (all $P > 0.05$). The correlation of LVEF, IMR, and FFR with β and MBF is shown in Figure 3.

Discussion

ACS has high prevalence and death rates; therefore, rapid and accurate assessment is quite important for better diagnosis and treatment [25]. MCE allows both myocardial perfusion and function to be evaluated at the bedside, and is more accurate in ACS assessment than conventional ECG criteria, troponin I, and myocardial perfusion imaging (MPI) [26]. PCI has recently become one of the most effective treatments for ACS, and can improve MBF and decrease the incidence of complications [23].

Thus, assessment of PCI postoperative status is necessary, and MCE is considered to be a good choice for this assessment.

Our study is the first to assess postoperative myocardial function and microcirculation using MCE to show improvement in postoperative status. TIMI-3 flow is unreliable in showing successful microvascular perfusion, and some patients show no-reflow by MCE [27]. With analyzed replenishment or refill curves, myocardial perfusion was quantitatively assessed by MCE [28]. Compressible microbubbles were used in MCE, in which destruction and gradual refill into the myocardium is essential for evaluation of myocardial perfusion and function [29]. During perfusion assessment by MCE, with low-power imaging in 10~15 cycles, a sequence of high-powered impulses are sent into the myocardium, and perfusion assessment is made by observing replenished rate of microbubbles [30]. Coronary microcirculation was evaluated by the signal of microbubbles, and myocardial perfusion was quantified by replenishment curves of contrast [31]. The signal of the myocardium was visually detected as contrast intensity, indicating the density convergence of microbubbles within, and then MCE can detect MBF and LVEF, as well as CFR [32]. A previous study found that a higher level of MBF is required for abnormal coronary auto-regulation and excessive demand of myocardial oxygen [33]. This study found that, at 1 month after PCI, the values of MBF, LVEF, CFR, and FFR were higher than preoperative status, and even showed

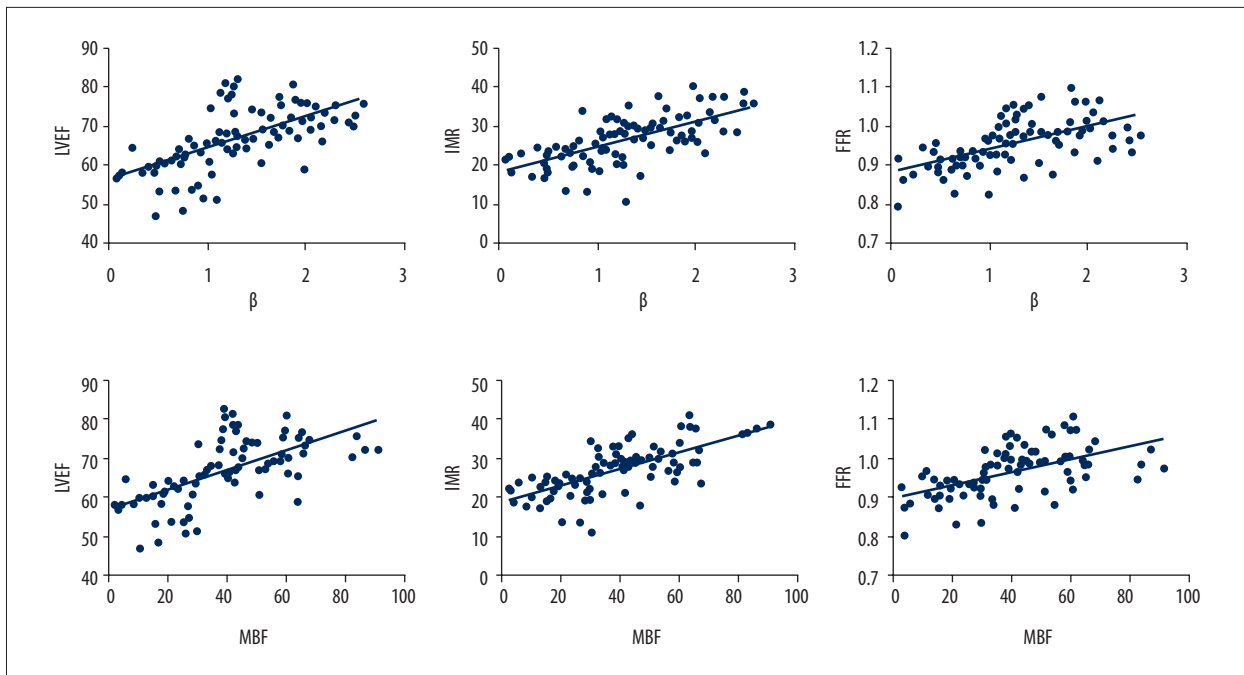


Figure 3. The correlation between LVEF, IMR, FFR, β , and MBF. LVEF – left ventricular ejection fraction; IMR – index of microcirculatory resistance; FFR – fractional flow reserve; β – average myocardial microvascular lesion; MBF – myocardial blood flow.

that A and β were rising. Thus, the postoperative status of myocardial function and microcirculation was improved after PCI, as shown by assessment with MCE.

Correlation analysis indicated that LVEF, IMR, FFR, and CFR were positively correlated with MBF. CFR is an increased coronary blood flow from elemental status to the status of maximal coronary vasodilation, and therefore effectively indicates microcirculation [23]. In a previous study, CFR was used to assess microcirculatory disturbance after PCI [34]. As an invasive index of microvascular status, IMR associated with true microvascular resistance can evaluate microcirculatory function with less influence of epicardial arterial stenosis [35]. LVEF is not only considered to be good at predicting clinical outcomes in STEMI patients, but also is indicated to be an independent predictor of patients after primary percutaneous coronary intervention (pPCI) with all-cause death [36]. FFR is a reproducible and validated measure of CFR, and improves prognoses of PCI on the basis of angiographic severity by FFR-guided PCI [37]. Based on the above information, the study made a correlation analysis and found a positive correlation between LVEF, IMR, FFR, CFR, and MBF, as well as a positive correlation between LVEF, IMR, and A. Therefore, with these indexes, MCE can qualitatively evaluate PCI postoperative status of myocardial function and microcirculation in ACS patients.

We also found changes in LVEDD, LVESD, E/A, Tei, and some other indexes. LVEDD was assessed for functional recovery in

echocardiography analyses in a previous study [38], and LVESD can predict postoperative LVEDD recovery [39]. Another index for evaluating LV diastolic dysfunction is E/A [40]. Tei index, also known as myocardial performance index (MPI), has been used for general evaluation of heart function [41]. These indexes were assessed in the study for evaluating myocardial function after PCI in ACS patients, showing that LVEDD, LVESD, and Tei were increased, but E/A was decreased. Thus, it is similar to MCE assessment for indicating improved postoperative myocardial function in ACS.

Conclusions

MCE parameters are associated with myocardial function and microcirculation in postoperative ACS patients, and can qualitatively evaluate their postoperative status, thus contributing to prompt development of a reasonable clinical strategy. MCE should be more widely used in the cardiovascular disease for better diagnosis and treatment. The limitations of the present study are its small sample size and short follow-up period, as well as the possible subjectivity of determining MCE grade, which might have affected the results. These limitations need to be addressed in further research.

Conflict of interest

There are no conflicts of interest to disclose for all authors.

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