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Original Article

Evaluation of myocardial viability in old myocardial infarcted patients with CHF: delayed enhancement MRI vs. low-dose dobutamine stress speckle tracking echocardiography

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Abstract: The aim of this study was to explore the significance of delayed enhancement magnetic resonance imaging (DE-MRI) combined with two-dimensional speckle tracking echocardiography (STE) and low dose dobutamine stress echocardiography (LDDSE) to assess viable myocardium (VM) in the patients with old myocardial infarction (OMI) associated with congestive heart failure (CHF). Thirty five hospitalized OMI patients with regional wall motion abnormalities and left ventricular ejection fraction (LVEF) < 50% were recruited based on routine echocardiography. The results showed that DE-MRI facilitated the detection of VM, with a sensitivity, specificity and accuracy of 92.41%, 89.19% and 91.32%, respectively. In a parallel test of the two main parameters in STE, the sensitivity, specificity, and accuracy were improved from baseline to LDDSE (71.72% vs. 91.72%, 70.27% vs. 85.14%, and 71.23% vs. 89.50%, P < 0.05). A parallel test involving STE with LDDSE showed high sensitivity for VM. However its specificity and accuracy were lower than DE-MRI, even when combined with LDDSE. Therefore, combining these two methods, improves the sensitivity, specificity and accuracy for assessment of VM. The combination approach is the best option for the evaluation of VM using serial test. It provides further treatment options and prognosis of patients with OMI. LVEF is improved significantly after PCI in OMI patients with VM and CHF.

Keywords: Delayed enhancement magnetic resonance imaging, speckle tracking echocardiography, low dose dobutamine stress echocardiography, old myocardial infarction, viable myocardium, congestive heart failure

Introduction

Coronary artery disease is one of the leading causes of death. In patients with old myocardial infarction (OMI), the extent of necrosis is an important parameter determining functional outcomes and prognosis. It is well known that viable myocardium (VM) still exists in the myocardial scar tissues. After recovery of coronary artery blood flow, the ventricular function is improved [1]. Therefore, the extent of VM directly affects the prognosis of patients with OMI, especially in those diagnosed with congestive heart failure (CHF).

Cardiac magnetic resonance imaging can accurately distinguish the VM in the myocardial scar [2]. Because of its higher spatial resolution, cardiac magnetic resonance is used widely to assess myocardial viability in patients with OMI. Delayed enhancement magnetic resonance imaging (DE-MRI) with gadolinium is the most accurate and validated modality to assess myocardial viability directly. The diagnostic performance of DE-MRI for the detection of myocardial viability has been investigated [3-5]. Gerber BL, et al. have demonstrated that DE-MRI enabled determination of myocardial viability in OMI [6]. Compared with single-photon emission

computed tomography, DE-MRI is more reliable in detecting VM [7].

Routine echocardiography is a widely used diagnostic tool. However, poor temporal resolution is a limitation for accurate visual assessment of myocardial motion. Speckle-tracking echocardiography (STE) is a novel method for the analysis of myocardial deformation [8, 9]. Strain and strain rate were measured along 3 planes (circumferential, longitudinal, and radial) without angle dependency or frame rate limitation [10]. Dobutamine is used to improve the sensitivity, specificity and accuracy of VM assessment using STE. Low-dose dobutamine stress echocardiography (LDDSE) is considered effective for the detection of VM in the presence of new or worsening wall motion abnormality or a biphasic response in segments with resting wall motion abnormality.

These two methods have already been used to assess VM. However, few studies have compared the role of DE-MRI combined with STE and LDDSE (STE-LDDSE). No data are available showing the sensitivity, specificity and accuracy of the combination approach in detecting VM. Current clinical guidelines for the management of patients with OMI recommend myocardial revascularization as a valuable treatment option only in patients with significant levels of myocardial viability [11, 12]. Our aim was to compare the sensitivity, specificity and accuracy of DE-MRI combined with STE-LDDSE for the detection of VM and to explore further the clinical application of the combined strategy for the determination of VM in OMI patients diagnosed with CHF.

Methods

Study population

The study enrolled 35 consecutive patients with OMI (**Figure 1**). The patients were in sinus rhythm and not treated with percutaneous coronary intervention (PCI). Routine echocardiography revealed left ventricular ejection fraction (LVEF) less than 50%. DE-MRI was performed on all patients prior to PCI, as well as STE and LDDSE-STE. The follow-up echocardiograms were obtained at 1, 3, and 6 months after revascularization to assess the recovery of abnormal regional wall movement.

Major exclusion criteria were: significant valvular abnormalities, severe cardiac arrhythmia, cardiomyopathy, severe obstructive pulmonary disease, and previous revascularization. Device therapy or severe renal dysfunction, as well as insufficient acoustic windows in echocardiography also resulted in exclusion from the study.

Ethics statement

The study was approved by the institutional ethics committee of the Affiliated Hospital of XuZhou Medical University. The number was xyfylw201315. All the images were selected into the study after the patients' written consent.

DE-MRI

DE-MRI studies were performed using a 1.5-T whole-body MR scanner (Intera, Best, Philips, The Netherlands) with a five-element phased-array cardiac coil. Images were acquired during breath-holds of approximately 15 s using vector electrocardiographic gating. The 17-segment model (six segments for the basal and midventricular short-axis view, four segments for the apical short-axis view and one segment for the apex) images were acquired for assessment of segmental myocardial function (echo-time, 1.5 ms; recovery time, 3.1 ms; slice thickness, 8 mm; spatial resolution, 1.4×1.2 mm^2; flip angle, 60 degrees; and temporal resolution, 42 ms). After 15 min of intravenous injection of gadolinium-diethylenetriamine pentaacetic acid (0.2 mmol/kg) (Magnevist, Schering, Berlin, Germany), 8-mm short-axis slices were acquired using a prospective electrocardiographically gated gradient-echo sequence with inversion prepulse. The normal region was black, whereas the nonviable region appeared bright or hyper-enhanced.

Quantitative evaluation of delayed-enhanced images was performed using a dedicated cardiac software package (Mass software, Medis, Leiden, Netherland) (**Figures 2**, **3**).

Each myocardial segment was evaluated for the presence of hyper-enhancement. The total myocardial area and the delayed-enhanced area of each segment were traced manually. The extent of each myocardial segment was calculated as a percentage of contrast-enhanced mass relative to the total myocardial

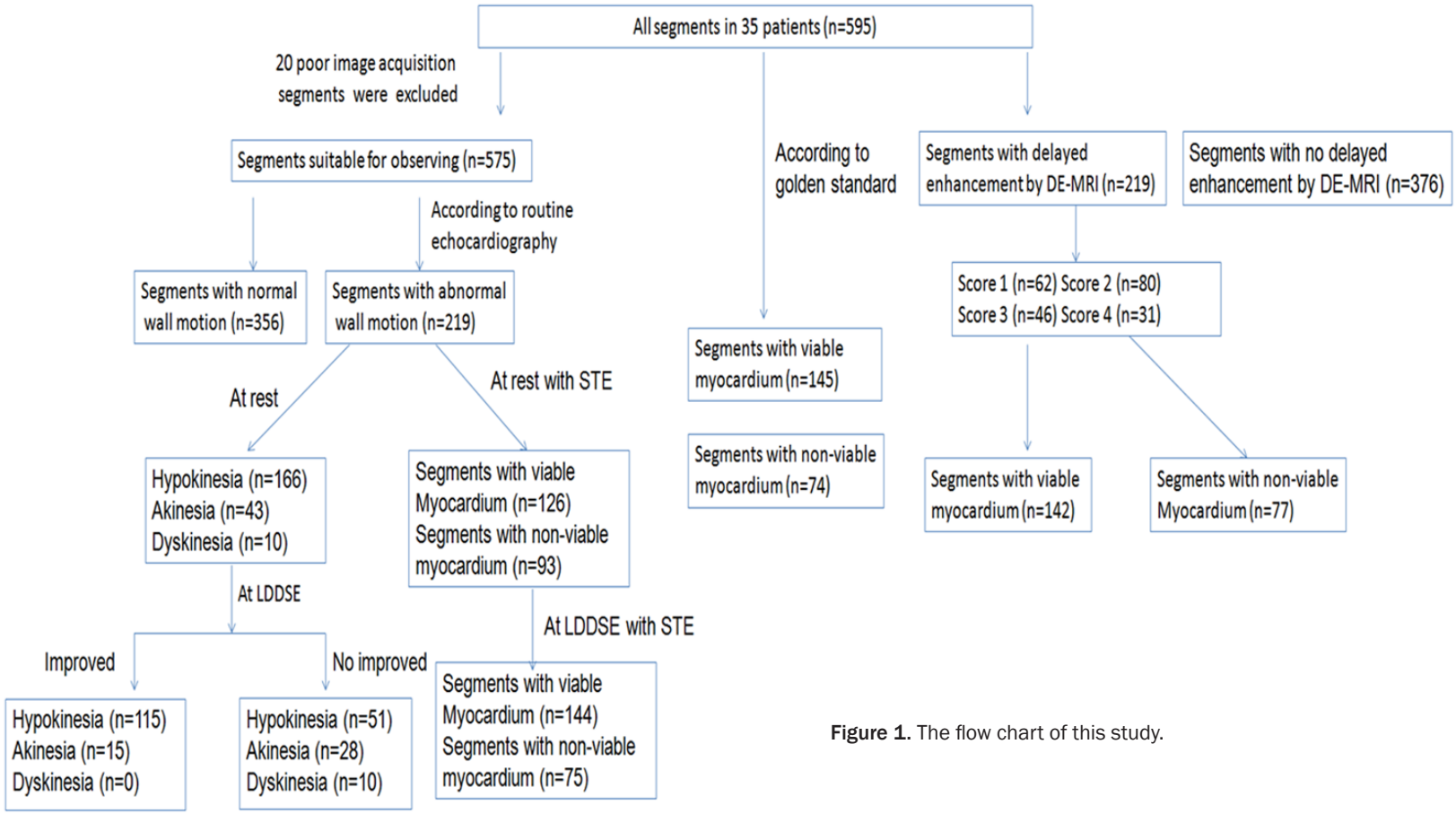

Figure 1. The flow chart of this study.

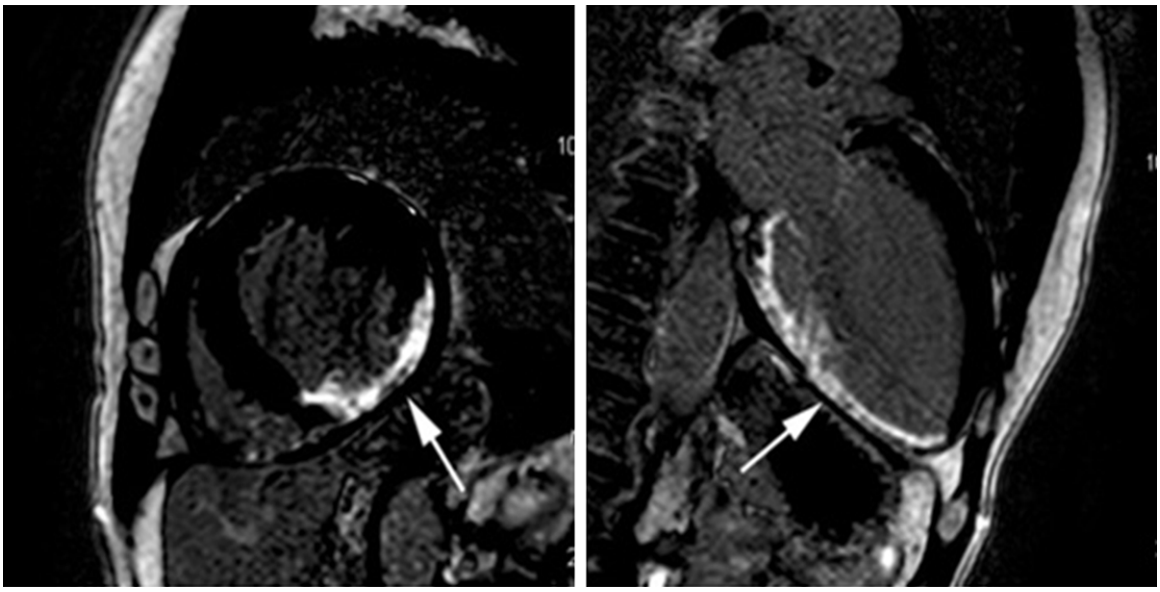

Figure 2. Example of a patient with old myocardial infarction having transmural hyper-enhancement (a hyper-enhancement score of 4, arrow). Left panel: short axis of left ventricule; Right panel: long axis of left ventricule.

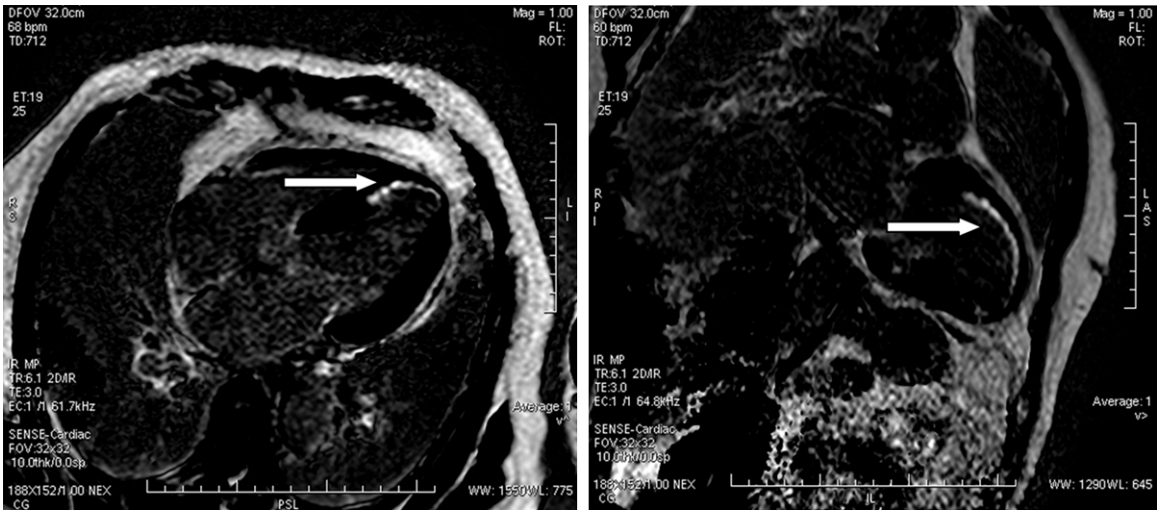

Figure 3. Example of a patients with old myocardial infarction having nontransmural hyper-enhancement (a hyper-enhancement score of 1-2, arrow).

mass of the segment (Area $_{\text{mass segment DE}}$/Area $_{\text{mass segmental myocardium}}$ × 100%). Each segment was categorized based on a five-point scale [13]: 0% hyper-enhancement (category 1), 1% to 25% hyper-enhancement (category 2), 26% to 50% hyper-enhancement (category 3), 51% to 75% hyper-enhancement (category 4), and 76% to 100% hyper-enhancement (category 5). A threshold of 50% hyper-enhancement was used to determine myocardial viability.

Echocardiography

Routine echocardiographic images were obtained using a commercially available system (Philips IE 33, Philips Medical Systems, USA) equipped with a S5-1 transducer in the left lateral decubitus position. Blood pressure measurements and 12-lead electrocardiography were recorded throughout the examination. Two-dimensional grayscale images were acq-

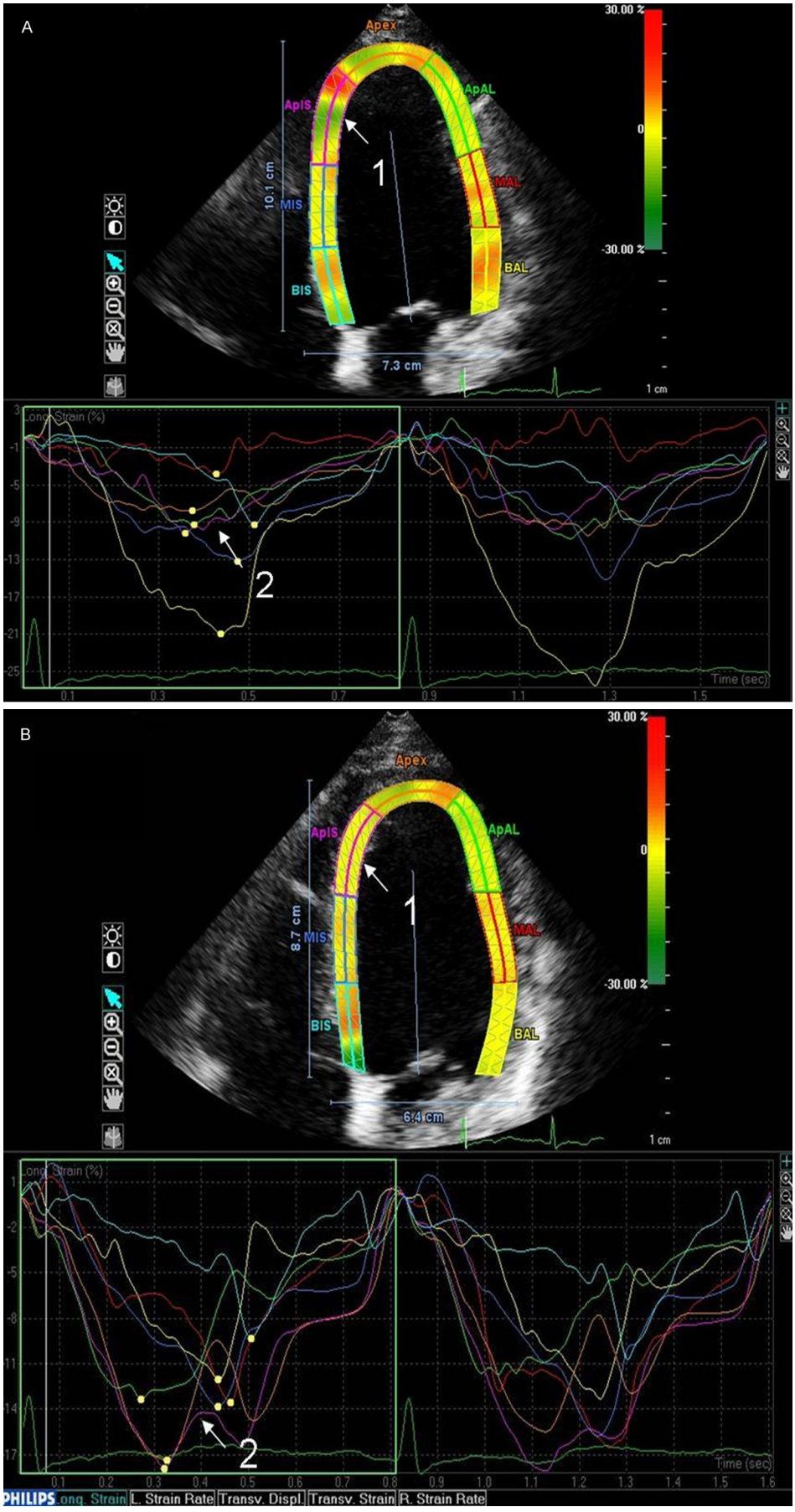
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Figure 4. Measurement of myocardial longitudinal peak systolic strain at rest (A) and LDDSE (B) using STE. Arrow 1 represents apical septal segment, arrow 2 represents longitudinal peak systolic strain-time curve of apical septal segment.

Table 1. Clinical characteristics of the study population

Parameter	Value	%
Age (years)	66.7±10	
Male	24/35	68.57
Hypertension (> 140/90 mmHg)	17/35	48.57
Diabetes mellitus	9/35	25.71
Hypercholesterolemia (total cholesterol > 5 mmol/L)	8/35	22.86
Smoking	16/35	45.71
LVEF (%)	43.24±5.71	
The time of the infarction (months)	6±2.12	
Extent of CAD (on coronary angiography)		
Infarction related artery (according to PCI)		
LAD	8	22.86
LCX	12	34.28
RCA	4	11.43
LAD+LCX	7	20.00
LAD+RCA	4	11.43

LVEF: left ventricular ejection fraction. CAD: coronary artery disease. LAD: left anterior descending. LCX: left circumflex. RCA: right coronary artery. PCI: percutaneous coronary intervention. Values are mean ± SD.

uired in the apical 4-chamber, apical 2-chamber, apical long-axis, and parasternal left ventricular short-axis view at basal, midventricular, and apical level. Images were obtained at a frame rate of 60-70 frame/s using harmonic (1/3 MHz) B-mode imaging. For each view, three consecutive cardiac cycles were acquired during a breath holding spell. In each of the 17 left ventricular segments, the wall motion was graded as 1, normal; 2, hypokinesia; 3, akinesia; or 4, dyskinesia. Echocardiographic wall motion analysis was performed repeatedly at 1, 3, 6 months after PCI. Dysfunctional segments, which were completely revascularized, were evaluated for regional recovery by two independent observers, blinded to patients' clinical data. The gold standard for judging VM was improvement in segmental motion of LV at least 1 grade after PCI in this study [14].

STE-LDDSE

Dobutamine (No.1 Biochemical Pharmaceutical Co. Ltd. Shanghai, China) was infused with a mechanical pump (TE331, Terumo, Japan) for 5 min at the following rate: 10 μg/kg/min. Subsequently, LDDSE echocardiograms were acquired and the section images were obtained similarly. Baseline and LDDSE echocardiograms were conserved to measure the deformation parameters of Strain (S) and Strain rate (Sr).

The analysis of deformation parameters was performed off-line with the aid of a commercially available speckle tracking system in Philips workstation equipped with QLAB software 8.1 (Advanced Quantification software, Philips Ultrasound, USA) (**Figure 4A**, **4B**). The left ventricle was analyzed using a standard 17-segment model [15]. After manual tracking of the endocardial borders at the end-systolic frame from the apical views and parasternal short-axis view, an automated tracking algorithm outlined the myocardium in successive frames throughout the cardiac cycle. A region of interest (ROI) was manually adjusted to include the entire myocardial thickness. Radial strain (RS), radial strain rate (RSr), circumferential strain (CS), circumferential strain rate (CSr), longitudinal strain (LS), and longitudinal strain rate (LSr) curves were depicted at rest and during LDDSE.

Statistical analysis

The statistical analysis was performed using standard software (SPSS 16.0, SPSS Inc, Chicago, Illinois). Continuous variables were expressed as mean values ± SD, categorical variables as counts and percentages. Comparison between VM segments and non-VM segments was performed using one-way ANOVA for continuous variables. A Chi-square test was employed for ratio comparisons. Receiver-operator characteristics (ROC) curves were created to assess the ability of different S and Sr parameters to determine VM, and comparison with the DE-MRI, with the optimal cutoff value based on the Youden index. P value ≤ 0.05 was con-

Table 2. The three methods assessments of VM

		Gold standard		Total
		VM	Non-VM	
DE-MRI	VM	134	8	142
	Non-VM	11	66	77
	Total	145	74	219
Parallel test of STE-based deformation parameters at rest	VM	104	22	126
	Non-VM	41	52	93
	Total	145	74	219
Parallel test of STE-based deformation parameters at LDDSE	VM	133	11	144
	Non-VM	12	63	75
	Total	145	74	219

The parallel test of STE combination of LS and LSr.

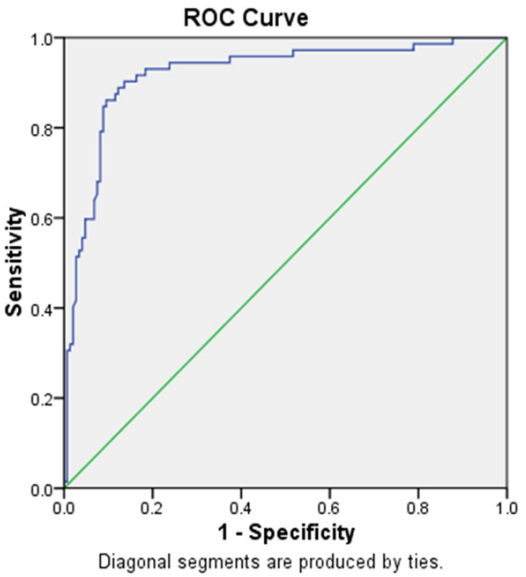

Figure 5. ROC curves to demonstrate sensitivity and specificity of DE-MRI for assessment of viable myocardium.

sidered statistically significant. A positive test result with any one of the two tests when using the combination of the two methods in parallel was deemed positive. However, in the serial test, the two tests must both yield positive results, to be considered as positive.

Results

All patients showed evidence of OMI on coronary angiography and underwent PCI (**Table 1**).

Echocardiographic wall motion analysis was repeated at 1, 3, and 6 months after PCI. The gold standard for VM was based on improved segmental movement of left ventricle at least one grade after PCI.

DE-MRI vs. the gold standard

DE-MRI of 219 out of 595 left ventricular segments revealed the following: 62 showed minor hyper-enhancement (score 1), 80 showed a hyper-enhancement score of 2, 46 scored 3, and 31 scored 4. Among the 219 segments, 142 were identified by DE-MRI as VM, and 77 as nonviable myocardium (Non-VM). The sensitivity, specificity and accuracy of DE-MRI for the assessment of VM were 92.41%, 89.19%, and 91.32%, respectively, compared with the gold standard (**Table 2**). ROC analysis revealed that the DE-MRI was a significant predictor of VM (**Figure 5**).

STE-LDDSE vs. the gold standard

Echocardiographic wall motion analysis was repeated at 1, 3, and 6 months after PCI. The gold standard for VM detection was improved segment movement of left ventricle at least one grade after PCI. In the 35 patients comprising a total of 595 left ventricular segments, 20 out of 219 segments were excluded due to poor image quality, following routine echocardiography. Compared with the gold standard, of the 219 segments at rest in parallel testing of the LS and LSr, 126 were identified as VM, while the remaining 93 were classified as non-VM (**Table 2**). Of the 219 segments screened with LDDSE in parallel testing of the two parameters, 144 were identified as VM, while the remaining 75 were classified as non-VM (**Table 2**).

Table 3. Myocardial deformation parameters of STE and STE associated with LDDSE in the segments that were designated as VM and Non-VM by the gold standard

Parameters	VM	Non-VM	*P* value
CS_{rest} (%)	-11.94±2.09	-10.46±1.62	< 0.001
CS_{LDDSE} (%)	-15.44±3.69	-12.44±1.66	< 0.001
CSr_{rest} (s^{-1})	-1.14±0.35	-0.89±0.37	0.004
CSr_{LDDSE} (s^{-1})	-1.43±0.42	-0.85±0.41	< 0.001
LS_{rest} (%)	-12.10±1.82	-10.62±1.66	< 0.001
LS_{LDDSE} (%)	-15.91±1.87	-12.64±1.96	< 0.001
LSr_{rest} (s^{-1})	-1.17±0.40	-0.89±0.27	< 0.001
LSr_{LDDSE} (s^{-1})	-1.59±0.41	-1.13±0.26	< 0.001

CS_{rest} circumferential strain at rest, CS_{LDDSE} circumferential strain at LDDSE, CSr_{rest} circumferential strain rate at rest, CSr_{LDDSE} circumferential strain rate at LDDSE, LS_{rest} longitudinal strain at rest, LS_{LDDSE} longitudinal strain at LDDSE, LSr_{rest} longitudinal strain rate at rest, LSr_{LDDSE} longitudinal strain rate at LDDSE.

Table 4. The value of the parameters in the STE for detecting the VM

Parameters	Sensitivity (%)	Specificity (%)	Accuracy (%)
CS_{rest}	55.18	64.92	58.37
CS_{LDDSE}	81.41	85.08	82.55
CSr_{rest}	66.23	62.27	64.83
CSr_{LDDSE}	86.24	73.04	81.67
LS_{rest}	66.23	68.89	67.12
LS_{LDDSE}	89.03	84.32	82.64
LSr_{rest}	65.46	71.58	67.62
LSr_{LDDSE}	90.32	88.24	90.04

The parameters of CS, CSr, LS and LSr were increased significantly (P < 0.05).

Segments of VM showed a significant difference in CS, CSr and LS, LSr with LDDSE. However, the RS showed no significant difference (**Table 3**).

Summarizes the value of the parameters in the STE for detecting the VM (**Table 4**).

The ROC curves analysis showed that all the S and Sr were significant predictors of VM (**Figure 6**).

Comparison of the ROC curves revealed that the accuracy of LS and LSr was much higher than that of RS, RSr, CS and CSr for detection of VM. Longitudinal strain (LS) and longitudinal strain rate (LSr) at rest were independent predictors of VM. The sensitivity, specificity, and accuracy of LS and LSr were 66.23%, 68.89%, and 67.12%; and 65.46%, 71.58%, and 67.62%, respectively at rest. The sensitivity, specificity, and accuracy of LS and LSr improved to 89.03%, 84.32%, and 82.64%; and 90.32%, 88.24%, and 90.04%, respectively, when combined with LDDSE (all P < 0.05).

In the parallel test, the sensitivity, specificity, and accuracy improved from baseline to LDDSE (71.72% vs. 91.72%, 70.27% vs. 85.14%, and 71.23% vs. 89.50%, P < 0.05). Compared with baseline, the LVEF increased from 43.24%±5.71% to 47.61%±5.52% after PCI (P < 0.001).

Combining DE-MRI with STE -LDDSE

In the parallel test combining DE-MRI with STE-LDDSE, the sensitivity, specificity and accuracy for the detection of VM were 93.79%, 90.54%, and 91.69%, respectively. However, with the serial tests, the sensitivity, specificity and accuracy were 91.03%, 94.59%, and 92.24%, respectively.

Reproducibility

To test the reproducibility of measurements, 10 patients were randomly selected, the RS, CS, LS (at rest and LDDSE) and DE-MRI were measured by two independent observers on the same echocardiographic images and the same delayed-enhanced images (interobserver variability). Intraobserver agreement was to repeat analysis in the 10 patients by the same observer > 3 months apart. Reproducibility was expressed as 95% limits of agreement (**Table 5**).

Discussion

Clinical implications

The availability of accurate and non-invasive methods for assessing the VM in patients with OMI is a very important factor determining clinical decision-making and prognostic evaluation. VM in the setting of myocardial contractile dysfunction includes hibernating myocardium and stunned myocardium. Pre-procedural identification of VM enables revascularization to improve left ventricular function for a favorable prognosis [16, 17].

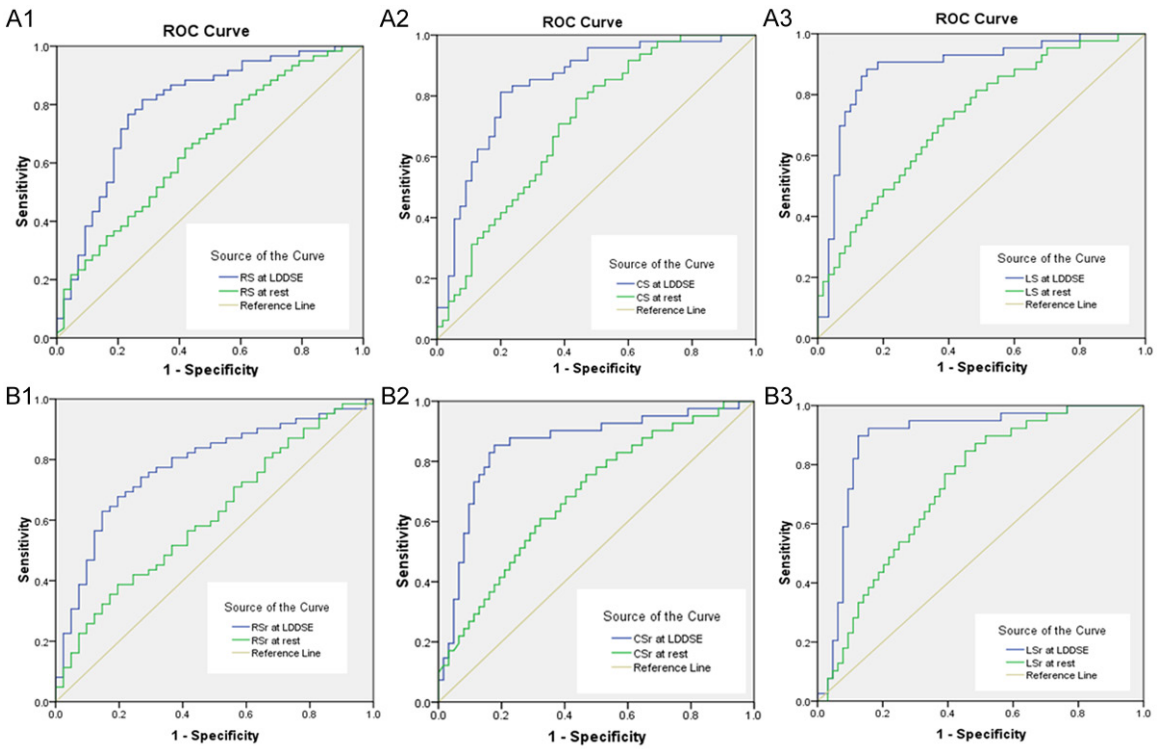

Figure 6. ROC curves to demonstrate sensitivity and specificity of S, Sr using STE at rest (A1, A2, A3) and LDDSE (B1, B2, B3) for assessment of viable myocardium.

Table 5. Reproducibility test (95% Limits of Agreement)

	RSrest	RS LDDSE	CSrest	CS LDDSE	LSrest	LS LDDSE	DE-MRI
Interobserver	-0.07 to 0.09	-0.08 to 0.13	-0.47 to 0.27	-0.66 to 2.25	-0.13 to 0.20	0.18 to 0.65	-0.16-0.06
Intraobserver	-13.60 to -13.50	-17.96 to -17.73	14.65 to 15.30	15.52 to 16.28	-13.13 to -12.87	-13.30 to -12.95	30.45 to 35.46

All $P > 0.05$.

Several imaging techniques are used to detect VM. PET is considered as the gold standard. Nuclear imaging techniques display higher sensitivity for the detection of viability, but a lower sensitivity for evaluating contractile reserve. However, they are associated with several limitations related to availability and cost.

Currently, the two gold standards for VM detection include PET and echocardiography, which improves wall motion after PCI. However, PET is not commonly used in clinical research. Therefore, the segmental motion of left ventricle improving at least 1-grade after PCI by echocardiography was selected as the gold standard for assessment of VM in this study [14].

DE-MRI for VM detection

The high diagnostic accuracy of DE-MRI for the assessment of transmural myocardial scar tissue is considered an advantage for the assessment of VM over more traditional imaging modalities [18, 19]. In animal models, studies showed a nearly exact relationship between histopathological changes and the size of myocardial infarct diagnosed by DE-MRI [20, 21]. Fieno et al. found that DE-MRI distinguished reversible from irreversible injury independent of wall motion, infarct time, and reperfusion status [22]. Human studies showed that the infarct size measured by DE-MRI was closely associated with peak cardiac enzyme release and PET results [23-25].

However, clinical trial data for the detection of VM in OMI patients are limited. Detection of the infarct area in OMI was more difficult than in acute myocardial infarcts. Substantial shrinkage occurred during the healing response and recovery of blood flow, resulting in improved left

ventricular systolic function [26]. Evidence derived from CHRISTMAS trial suggests that VM contributes to greater LVEF increase following carvedilol treatment [27]. Revascularization of the VM improved diastolic and systolic ventricular function, CHF symptoms and the arrhythmia burden in patients with OMI [11]. The value of DE-MRI for VM detection in patients with OMI was more significant.

DE-MRI is increasingly used to assess VM [28]. It not only distinguishes old infarction from viable myocardium but also necrotic myocardium from damaged microvasculature [37]. The hypothesis of delayed enhancement relates to increased distribution volume of the contrast agent due to increased interstitial space, cardiomyocyte loss and collagen scar formation [29]. Kim et al. found that the transmural enhancement was inversely proportional to the probability of regional recovery of function after revascularization [13]. Because only the necrotic myocardium was infiltrated by the contrast agent, the VM was not totally permeable to the contrast agent. Therefore, VM was assessed by transmural enhancement.

Compared with STE-LDDSE, the DE-MRI had higher sensitivity, specificity and accuracy in detecting myocardial viability. Furthermore, its specificity was marginally higher than STE-LDDSE. DE-MRI enabled the detection of VM directly. In addition, the images observed by DE-MRI were more distinctive than those obtained via echocardiography. The main advantage with DE-MRI over the other imaging modalities relates to the assessment of VM based on ventricular morphology, function and perfusion without the use of ionizing radiation and with excellent spatial resolution.

The approach not only provided an accurate method for noninvasive assessment of myocardial viability, but also allowed a better appreciation of the old concepts involving ischemic ventricular dysfunction [30]. However, the disadvantages of DE-MRI include lower availability and higher costs when compared with STE-LDDSE, more stringent requirements in terms of regular heart rhythm and controlled breathing to obtain optimal imaging compared with SPECT or PET.

STE-LDDSE for detection of VM

Semi-quantitative echocardiography is inexpensive, user-friendly and widely available for routine examination and VM detection. However, it was limited by the experience of investigator, poor precision and reproducibility. STE is an algorithm, which provides objective and reproducible quantification of global and regional myocardial function and detection of VM [31]. Previous studies have demonstrated that STE-based determination of S and Sr from the short- and long-axis of LV myocardial deformation enabled the assessment of VM in patients with OMI [32, 33].

Dobutamine is an adrenoreceptor agonist and improved myocardial systolic function by enhancing coronary blood flow at a low dose. To increase the sensitivity, specificity and accuracy, we selected the STE-LDDSE to detect VM. Li DY et al. confirmed that dobutamine infused at a rate of 10 μg/kg/min effectively improved the wall motion [34]. This study showed that advanced quantitative STE-LDDSE compared with STE alone, improved the sensitivity, specificity and accuracy of VM evaluation.

LS combined with LSr is an independent predictor of VM in the parallel test, but not in the serial test. It decreased the sensitivity obviously, but not the specificity, apparently, which might be attributed to the helical wrapping of cardiac fibers into 3 different anatomical layers [35]. The innermost subendocardial layer of fibers showed an oblique clockwise orientation in the longitudinal direction, with the most significant contribution to long-axis function. The middle layer was wrapped circumferentially, and the epicardial layer was arranged in an oblique anticlockwise direction. It contributes to thickening and short-axis function via cross-fiber shortening [36]. The blood flow in the myocardium was from the outside to the inside. Due to, the unique structure, the LS and LSr showed a significant role in VM detection by STE. STE-LDDSE might be preferable for patients with OMI undergoing conventional screening for VM in the parallel test.

Combining the two methods for VM detection

The two methods were noninvasive and offered advanced quantitative analysis for VM detection. STE-LDDSE showed high sensitivity in the parallel test. However its specificity was lower than that of single DE-MRI. DE-MRI showed high sensitivity, specificity and accuracy in the present study. Combining these two methods was an innovative approach. In the parallel

test, the sensitivity increased marginally and the specificity decreased significantly. Compared with the serial test, the sensitivity decreased minimally and the specificity increased more significantly. Therefore, DE-MRI combined with STE-LDDSE in the serial test was recommended for the detection of VM in patients with OMI. Increased specificity was accompanied by remarkable sensitivity. Combining the two methods for evaluation of VM was less expensive than PET, but with comparable accuracy. It may be a better alternative for clinical evaluation of VM.

In this study, the LVEF of patients was improved after PCI, indicating that the increased coronary blood flow enhanced the function of VM. Previous studies demonstrated that the recovery of left ventricular function occurred in 3 to 6 months after PCI suggesting that screening for VM before PCI was preferable [32].

Study limitations

The study included a relatively small sample size. We did not assess VM on segments with normal wall motion. The measurement of STE-based S and Sr depended on the quality and frame rates of echocardiography images. Low frame rates result in instability of speckle patterns, while high frame rates reduce scan-line density and image resolution. Furthermore, the technique was still limited by imaging artifacts and time-consuming offline analysis. The key disadvantages of DE-MRI relate to strict requirements for regular heart rhythm and controlled breathing to obtain optimal imaging. However, the high costs involved limit its clinical application.

Conclusions

Overall, DE-MRI is superior to STE-LDDSE for evaluation of VM in OMI patients diagnosed with CHF. LVEF also improved significantly following PCI.

1. STE-LDDSE facilitated the evaluation of VM effectively using parallel tests for LS and LSr, obviating the need for the serial test. 2. DE-MRI, due to its high specificity and accuracy, is an acceptable option for detection of VM. 3. Combining DE-MRI with STE-LDDSE in the serial test improved the specificity significantly for VM detection clinically. It offers a guideline for further treatment and prognosis of OMI patients diagnosed with CHF.

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Disclosure of conflict of interest

None.

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