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Myocardial Viability Assessment by Dobutamine Echocardiography using Speckle-Tracking: Comparison with cardiac MRI delay enhancement

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Abstract: **Background**: The use of myocardial strain imaging during dobutamine echocardiography may facilitate the prediction of myocardial viability. speckletracking echocardiography (STE) are used for myocardial strain measurement, it needs validation for prediction of viability . **Aim of the study**: To determine the accuracy of STE-based measurements of myocardial strain for the detection of myocardial viability before revascularization using MRI delayed enhancement imaging as agold standard. **Methods**: The study included 20 patients (14 males , 6 females), mean age (58±9.4 years) with ischemic heart disease and left ventricular systolic dysfunction; who were undergoing dobutamine stress echocardiography and MRI for assessment of myocardial viability ,The patients were divided into two groups according to the result of MRI delayed enhancement into viable and non-viable myocardial segments for possibility of myocardial revascularization. Speckle tracking technique (STE)were used to measure longitudinal peak systolic strain at rest and at low-dose dobutamine (LDD). **Results**: according to MRI delayed enhancement result, non-viable myocardial segments had significantly lower longitudinal peak systolic strain at LDD (-4.7) compared with rest (-6.4) by STE and viable myocardial segments had significantly higher longitudinal peak systolic strain at LDD (-15.8) compared with rest (-13.5) by STE .The performance of measurements obtained by Echo Speckle tracking at rest and after LDD in diagnosing a viable cardiac segment was tested by ROC method In addition, the LDD measurements were associated with an observed higher validity in predicting a viable cardiac segment as reflected by the higher area under ROC curve (0.873 compared to 0.78 observed with at rest measurements). **Conclusion**: peak longitudinal strain measurements with STE at LDD echocardiography can predict myocardial viability.

Keywords: STE, LDD, MYOCARDIAL, ROC.

INTRODUCTION

Coronary artery disease (CAD) is the most prevalent and single most common cause of morbidity and mortality with the resulting left ventricular dysfunction (LVD) an important complication. Worldwide, CAD accounts for 5.7 million new cases per year, of these 1.3 million in Europe alone. In addition, it imposes a substantial share of health service resources and expenses, an impaired quality of life, disability and high social cost [WHO]. In the developing world, demographic and lifestyle changes are resulting in an "epidemiological transition" from perinatal and infectious diseases to non-communicable diseases such as CAD [Crawford, M.H. *et al*., 2010]. Furthermore, LVD itself has been shown to be a powerful determinant of survival [WHO]. The myocardium is exquisitely sensitive to ischemia, with contractile dysfunction occurring shortly after an ischaemic stimulus. The degree of contractile impairment remains strongly under the influence of the severity and duration of the ischaemic event, with irreversible myocardial necrosis representing the end pathway of prolonged and significant coronary ischemia [Sutherland, K. *et al*., 2010] . Hence, the primary priority in the management of acute coronary syndromes is to limit the extent of myocardial necrosis via reperfusion therapies, such as primary angioplasty and thrombolysis, particularly in the setting of electrocardiographic evidence of transmural ischemia. Despite early intervention, patients with IHD have a predisposition to develop structural heart disease, with impairment of myocardial function leading to cardiac failure, a condition termed as "ischaemic cardiomyopathy" [Hobbs, F.D. *et al*., 2002]. The once previously held notion that LVD in patients with CAD is always irreversible has been discounted. Heyndrickx and coinvestigators first demonstrated the impact of reversible ischemia on myocardial contractile reserve. Utilising animal models, they demonstrated that short (5- or 15-minute) induced episodes of ischemia to the myocardium, with a subsequent reperfusion period (lasting 6 hours for a 5-minute episode of ischemia, and >24 hours following a 15minute episode of ischemia), resulted in regional deficits in contractile function that persisted despite reperfusion [Hurst, J. W. *et al*., 2011].This phenomenon, termed as *myocardial stunning*, was defined as a prolonged and completely reversible dysfunction of the ischaemic myocardium that continued after restoration of coronary arterial flow . Stunned myocardium was found to be responsive to inotropes in these early studies, with an increase in contractile function in response to exogenous catecholamines [Hurst, J. W. *et al*., 2011]. (Fig.1). Myocardial stunning results from a mismatch between coronary flow and myocardial

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function, and these segments are likely to recover function spontaneously over time. Myocardial stunning has also been found in clinical practice, particularly in the setting of increased myocardial demand or reduced coronary supply such as following coronary artery spasm, post myocardial infarction, or post cardiopulmonary bypass secondary to "cardiac off-time."[Wu, K. C. *et al*., 2003]. On the other hand, hibernating myocardium is the term used to refer to segments rendered dysfunctional secondary to chronically under perfused myocardium (Fig.2). Myocardial hibernation represents a condition of sustained depression of myocardial function in the setting of CAD, which is amenable to improvement in function post revascularisation. This term was first coined by Diamond and colleagues in 1978 [Kloner, R. A. *et al*., 1989]. This sustained depression in myocardial function is hypothesized to be mediated by fundamental changes in myocardial energetics and metabolism, which are both reduced to match a concomitant reduction in coronary flow reserve. An alternate hypothesis offered for the mechanism of sustained contractile depression is the *repetitive stunning hypothesis*. In this theory, multiple bouts of demand ischemia in context of flow limitation result in repetitive episodes of ischaemic myocardial dysfunction (or stunning), which eventually creates an environment of sustained depression of contractile function [ASEC].

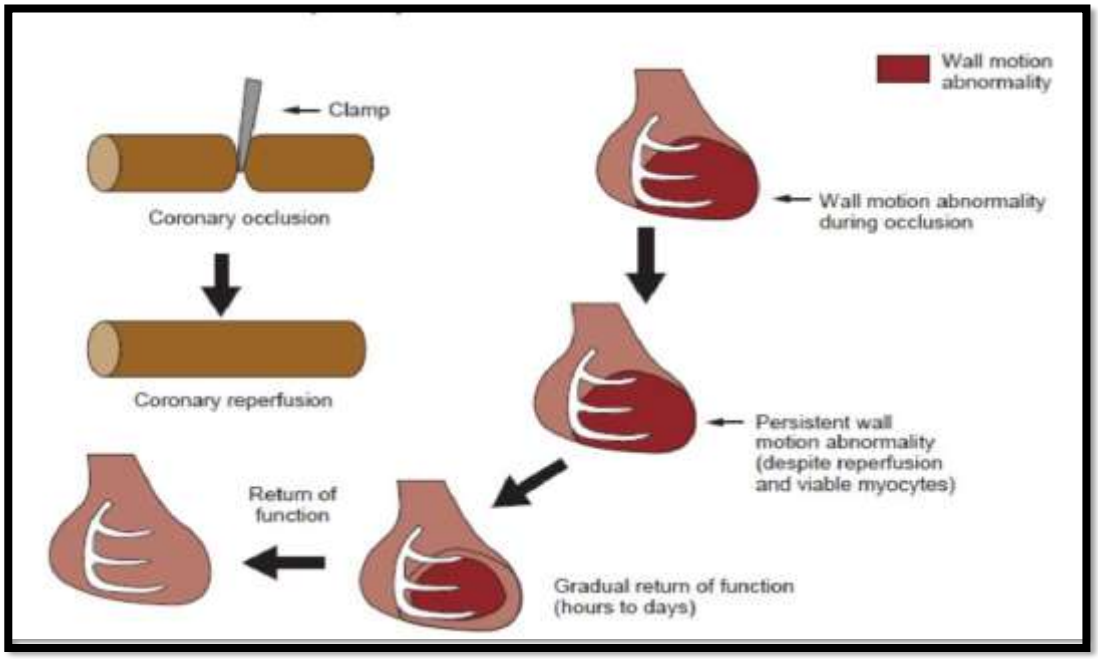

Figure (1): Pathophysiologic mechanism of myocardial stunning. wall motion abnormalities persist even after establishing coronary flow [Bonow, R. O, 1995].

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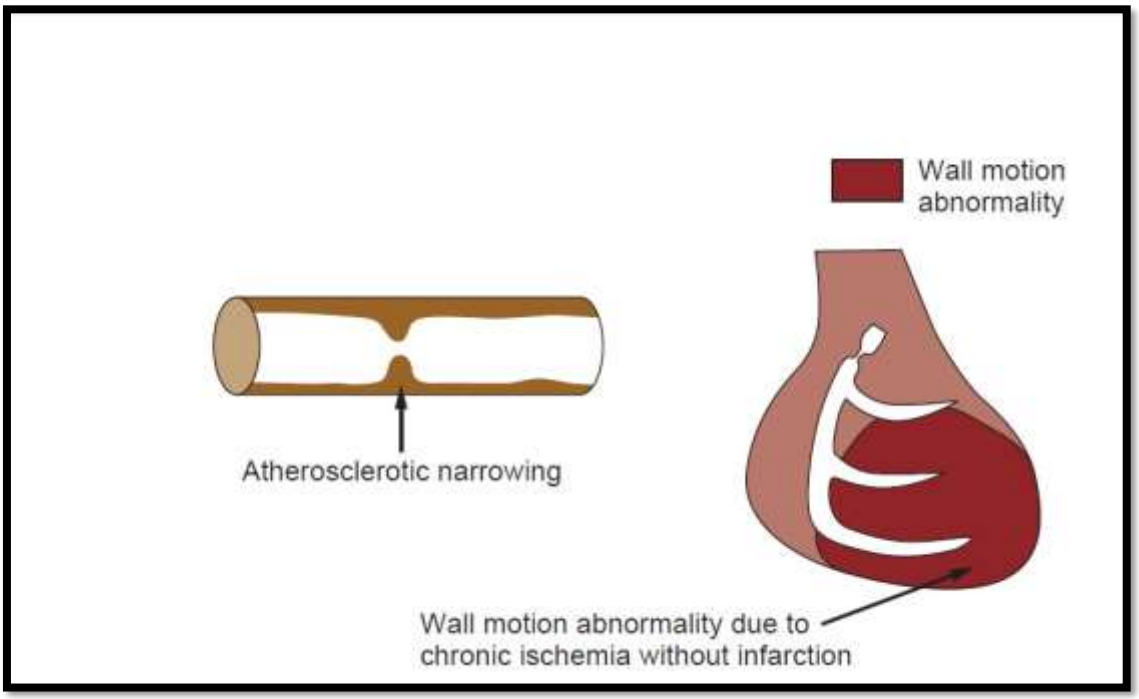

Figure (2): Pathophysiologic mechanism of myocardial hibernation. In myocardial hibernation, there is wall motion abnormality due to chronic reduced blood supply [Bonow, R. O, 1995].

In comparison between stunned and hibernating myocardium table (1) Resting myocardial perfusion is normal or near normal in stunning but is reduced in hibernation. Stunning of the myocardium is frequently represented as transient regional LV wall motion abnormality persisting for hours to days following reperfusion after short term but significant impairment of coronary blood flow. Hibernating myocardium, on the other hand, is a state of persistently impaired myocardial performance at rest due to a chronic reduction in coronary blood flow that can be restored by favorably altering the supply/demand relationship of the myocardium [Baker, D. W. *et al*., 1994].

Table 1: Blood Supply and Metabolic Activity as a Determinant of Myocardial Function [**Bonow, R. O**]

Diagnosis	Coronary Flow	Myocyte Metabolism	Prognosis
Stunned myocardium	Normal	Decreased	Spontaneous recovery of myocardial function with time
Hibernating myocardium	Decreased	Decreased	Improvement in function with revascularization

In patients with ischemic cardiomyopathy, only 40% show improvement in ejection fraction (EF) after revascularization, leaving a substantial subset with no improvement [Allman, K. C. *et al*., 2002]. The perioperative mortality rates from coronary artery bypass grafting in patients with ischemic cardiomyopathy range from 5% to more than 30% [EUROPIAN Society of Cardiology. *et al*., 2010] . Furthermore, revascularization of nonviable myocardium has not proven to be beneficial for either mortality or improvement in global LV function. In a meta-analysis of 24 viability studies, revascularization of patients without viable myocardium was associated with a trend toward higher annual mortality rate compared with medical management alone (7.7% versus 6.2%, P¼.23) [Tuttle, R. R. *et al*., 1977] . On the contrary, revascularization of viable myocardium has been shown to be associated with increased EF, decreased congestive heart failure symptoms,[EUROPIAN Society of Cardiology. *et al*., 2010] and improved survival [Tuttle, R. R] compared with those treated medically. However, patients with viable myocardium who did not undergo revascularization had annual mortality rates five times higher than similar patients who were revascularized [Tuttle, R. R. *et al*., 1977]. The survival benefit of revascularization of a viable myocardium increases with decreasing LV function as well as increasing number of viable

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segments [Tuttle, R. R. *et al*., 1977]. These data, however, emerge from a meta-analysis of retrospective studies with varying inclusion and exclusion criteria, different definitions of patients with or without viable myocardium, and inherent biases in the selection of patients for revascularization. In view of the evidence for potentially healthy myocardium, a myriad of invasive and non-invasive diagnostic techniques has been developed for the identification of myocardial viability. Indeed, the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS) recommend the detection of myocardial viability a part of the diagnostic work up for revascularization, and patients with no evidence for viability should be discouraged from procedures [Schulz, R. *et al*., 1993]. The use of myocardial viability imaging tests in an appropriate clinical setting has been given a class IIa recommendation in the American College of Cardiology / American Heart Association practice guidelines [Willerson, J. T. *et al*., 1976].

DIAGNOSTIC MARKERS OF VIABILITY

Living myocardium is characterized by preserved ventricular wall thickness, the presence of contractile reserve, cell membrane integrity, active myocyte metabolism, and the existence of blood perfusion. Diagnostic techniques for studying myocardial viability are based on detecting one or more of these markers (Fig.3). The preservation of ventricular wall thickness and contractile reserve are usually investigated using echocardiography or stress cardiac magnetic resonance image (CMRI)

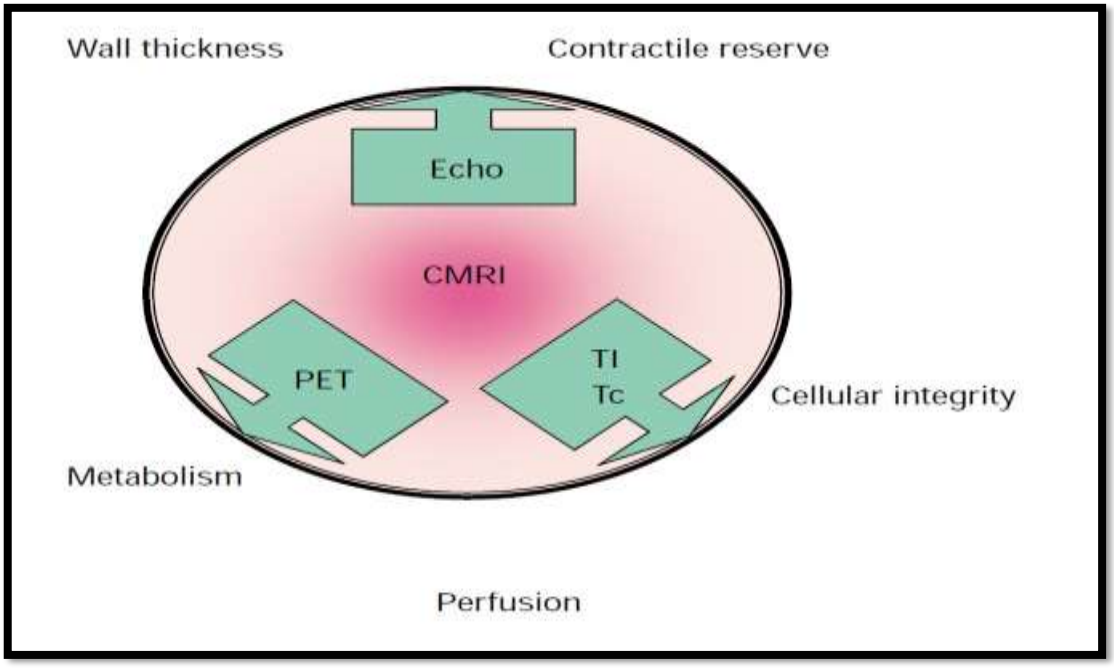

Figure (3): Diagram showing viability markers and the techniques used to explore them. Cardiac magnetic resonance imaging (CMRI) can be used to analyze all of the viability markers shown. Tl indicates thallium; Tc, technetium; echo, stress echocardiography. [**Nagueh, S. F. *et al*., 1999**]

Myocyte membrane integrity and blood perfusion can be evaluated using gammagraphy with thallium or technetium contrasts, positron emission tomography (PET), and contrast CRMI. PET and CRMI spectroscopy can detect metabolic defects in nonviable myocardium. The importance of these markers is relative, as myocardial necrosis may not be transmural and may coincide with viable myocardium in the same segment of the ventricular wall. The ideal diagnostic technique would be one which provided sufficient spatial resolution to determine the quantity of viable myocardium in the same ventricular segment. Of all the techniques mentioned, CMRI provides the best spatial resolution. The image-based diagnostic techniques used in cardiology aim to identify the presence and extent of viable myocardium using noninvasive methods. Such techniques include dobutamine echocardiography, thallium and technetium scintigraphy, PET and more recently CMRI. The choice of technique to be used will based on availability and experience. Because of its high sensitivity, PET has generally been considered the gold standard for determining

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viability; however, its limitations and cost have restricted its use. These limitations will be described later. [Nagueh, S. F. *et al*., 1999].

METHODS OF VIABILITY ASSESMENT

1. Electrocardiography

Pathologic Q waves, deep initial negative deflections of the QRS complex, were traditionally thought to be secondary to chronic transmural ischemia and representative of "dead myocardium." On subsequent analysis, it has been demonstrated that presence of pathologic Q waves has a poor correlation with the lack of residual viable myocardial tissue, with a relatively low sensitivity (41– 65%) and specificity (69–79%) relative to other imaging modalities [Poldermans, D. *et al*., 1998; Meza, M. F. *et al*., 1997]. Utility of exercise electrocardiography improves viability detection, with elevation of the ST segment during exercise in infarct-related leads being representative of viable myocardium (sensitivity 82% and specificity 100%) [Hoffmann, R. *et al*., 2002]. A similar finding is appreciated when evaluating reciprocal ST segment depression associated with exercise-induced ST elevation, with comparable sensitivity and specificity in viability recognition (84% and 100%, resp.) [Urheim, S]. Use of normalization of abnormal T waves during exercise electrocardiography for viability assessment, on the other hand, has conflicting reports in the literature, with more recent trials showing poorer sensitivities [Geyer, H. *et al*., 2010; Belghitia, H. *et al*., 2008].

2. Echocardiography

a) LV Morphology and Wall thickness

Assessment of echocardiographic parameters at rest is important in assessment of viability. Severe dilatation of the LV is a marker of nonviable myocardium, with higher end-systolic volume indices associated with poor ventricular functional recovery. These findings portend to a poorer prognosis, with left ventricular end-systolic volumes ≥130mL having a reduced 3-year survival rate [Gjesdal, O. *et al*., 2007]. The thickness of the LV wall has also been shown to be predictive of viability, with a thin LV wall representative of nonviable tissue or scar in patients with CAD [Langeland, S. *et al*., 2005]. Studies have shown that end-diastolic wall thickness less than 5-6mm indicates lack of contractile reserve [Langeland, S. *et al*., 2005], with enddiastolic wall thickness ≥5mm on two-dimensional echocardiographic measurements having a sensitivity of 100% and specificity of 28% in prediction of improvement in contractile function twelve months following surgical revascularization in patients with LV impairment (LVEF < 50%) [Gorcsan III, J. *et al*., 2011]. In keeping with these findings, Cwajg and colleagues (2000) also found that an end-diastolic wall thickness >6mm was predictive of contractile recovery following revascularizations with a sensitivity of 94% and specificity of 48%, while segments with an end-diastolic thickness of <6mm rarely have contractile reserve [Gorcsan III, J. *et al*., 2011].

b) Dobutamine Stress Echocardiography

Dobutamine stress echocardiography (DSE) is a valuable tool in the assessment of viability of the myocardium. Classically, four responses are noted in a dysfunctional myocardial response to dobutamine. These are as follows [Glaveckaitė, S. *et al*., 2009– Van Assche, L. M. R]:

(i) Biphasic response: low-dose dobutamine (defined as 5–10 μg/kg/min can increase contractility in dysfunctional segments which are still viable. At higher doses (10–40 μg/kg/min), wall motion in these segments may further improve or paradoxically diminish, reflecting tachycardia-induced ischemia. This phenomenon is referred to as a biphasic response and has been shown to be highly predictable of functional recovery post revascularizations. This finding is suggestive of limited, but present, myocardial reserve in the hibernating myocardium.

(ii) Worsening contractile function with lack of initial improvement with dobutamine: this response is suggestive of a hibernating myocardium which is supplied by a critically limited arterial supply, with no contractile reserve.

(iii) Sustained improvement with increasing dobutamine dose: this response is traditionally seen in the setting of myocardial stunning.

(iv) No response to dobutamine: this response is indicative of lack of functional reserve and, thus, lack of viable myocardial tissue.

Dysfunctional areas with resting end-diastolic wall thickness of less than 6mm are thought to reflect significant scar. They are not known to show functional improvement with DSE and do not improve post revascularizations.

DSE has been shown to have a sensitivity and specificity range for prediction of contractile recovery that is modestly high (71–97% and 63–95%, resp.), with the biphasic response having the greatest predictive capability of the four responses [Van Assche, L. M. R].

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c) **Myocardial Contrast Echocardiography**.
Myocardial contrast echocardiography (MCE) utilizes acoustically reflective high molecular weight inert gases which form microbubbles and act as a contrast agent. These bubbles remain within the intravascular space and help attenuate the borders of the left ventricle. Tissue capillary blood flow, a determinant of myocardial perfusion, is the byproduct of capillary blood volume and myocardial blood velocity.

Once the microbubbles reach a steady-state concentration, high-burs ultrasonography is used to displace the microbubbles, with subsequent replenishment within myocardial segments over the following cardiac cycle reflective of myocardial blood velocity. Segments are deemed viable if there is homogeneity of contrast intensity, which is in keeping with intact myocardial microvasculature. Nonviable segments, however, lack contrast enhancement and represent necrotic myocardial cells causing obstruction and collapse of the microcirculation [Van Assche, L. M. R– Rehwald, W. G. *et al*., 2002].

MCE has been shown to have a high sensitivity (78– 90%), however, low specificity (51–72%), of myocardial contractile recovery post revascularisation relative to DSE (which on average has a relatively high specificity but lower sensitivity) [32-35]. A combination of the two modalities seems to be optimal in echocardiographic assessment of myocardial viability (sensitivity 96% and specificity 63%) [Van Assche, L. M. R].

d)**Echocardiography Strain Analysis**.
Myocardial deformation indices, including tissue Doppler imaging (TDI) and strain assessment, are new echocardiographic modalities in the assessment of myocardial function, which allow for a more complete appraisal of myocardial motion and overcome traditional challenges of two-dimensional echocardiography regarding regional myocardial assessment [Schinkel, A. . *et al*., 2007; Kim, R. J. *et al*., 1999]. Strain is defined as the deformation of an object relative to its original location, with strain rate being reflective of the gradient of the velocities between the two locations. This information can be quantified via tissue Doppler imaging TDI or two-dimensional speckle tracking. Myocardial deformation (strain) and deformation rate (strain rate) provide multidimensional evaluation of myocardial mechanics (longitudinal, radial, and circumferential function) and have the added advantage of being able to detect subtle wall motion abnormalities of regional function that do not decrease global LVEF [Wang, C. *et al*., 2016; Laryza, Z. *et al*., 2015]. This, in part, is reflected by the fact that strain rate imaging is of lower load dependence and hence provides a better measure of contractility. Additionally, it is not affected by global myocardial displacement and the tethering effect of neighboring wall segments which encumber standard two-dimensional visual assessments. Both TDI and speckle-tracking echocardiography have been shown to be facilitative in prediction of myocardial viability. This is of relevance given the limitations of subjective assessment of wall thickness as well as operator dependence with traditional two-dimensional stress echocardiographic methods. Bansal and colleagues (2010) revealed that longitudinal and circumferential strain and strain rate measurements at rest and low-dose dobutamine concentrations were predictive of functional recovery post revascularizations using strain-based imaging. Furthermore, only tissue velocity imaging was found to have incremental value over wall motion analysis [Loïc, B. *et al*., 2014]. Based on a study by Hoffmann, *et al*., (2002), an increase of peak systolic strain rate greater than or equal to 0.23/s had a sensitivity of 83% and specificity of 84% in discerning viable myocardium as determined by 18FDG [Martin H. *et al*., 2013]. Additionally, radial strain >9.5% was associated with a sensitivity of 83.9% and specificity of 81.4%, whereas a change in longitudinal strain >14.6% provided a sensitivity of 86.7% and specificity of 90.2% in detection of viable myocardium using strain imaging with adenosine stress echocardiography in a small trial by Ran and colleagues (2012) [Roes, S.D. *et al*., 2009]. Further work into the field is in progress, with several larger trials underway. Advantages of echocardiography include ease of procedure and widespread availability as well as its noninvasive qualities. Furthermore, with DSE, there is an ability to monitor functional response to accurate up titration of inotropic therapy. Limitations of echocardiography include its high operator dependency with resultant inter- and intra-observer variability. Patients with comorbidities such as obesity, chronic obstructive airflow limitation, and thoracic chest wall abnormalities limit the acoustic window and thus impair LV views. Furthermore, with respect to DSE, assessment relies heavily on subjective visual interpretation of wall motion abnormalities.

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3. Single-Photon Emission CT (SPECT)
(SPECT) is a modality which utilises radionuclide-labeled tracer compounds to measure myocardial uptake. Initial acquisition signifies delivery of the tracer throughout the circulation. The images acquired following this (usually 4–24 hours later) reflect myocardial sarcolemmal integrity [Bochenek, T. *et al*., 2011]. Primary tracers include 99mTc-sestamibi, 99mTctetrofosmin, and 201Thallium. These molecules are lipophilic and permeate through myocardial cellular membranes via passive diffusion or active uptake from Na+/K+ ATPase systems. Intracellular retention, however, requires intact function of the mitochondrion with preservation of the action potential, and as such serves as a marker of viability. These tracer agents emit high-energy photons, which are captured via gated SPECT, and provide information of global LV function and viability of the myocardium [Bochenek, T. *et al*., 2011]. Viability assessment with SPECT can be performed at rest, following physical exercise or chemical coronary stress. With stress testing, physical exertion or chemical agents (specifically, dipyridamole or adenosine) are used. Imaging is performed immediately following the test, with delayed imaging repeated 3 to 4 hours later, allowing for adequate redistribution of the tracer agent. If warranted, imaging may be repeated at 24 hours after stress (termed as late distribution imaging). Viability is seen with myocardial segments which reveal defective uptake immediately following stress, with subsequent replenishment of uptake at 3 to 4 hours. Critically hypoperfused myocardial segments may still be viable if defective uptake is seen at this delayed time-point, warranting repeat imaging at 24 hours after stress to allow for redistribution of the tracer to significantly hypoperfused myocardial regions. Nonviable myocardium reveals fixed defective uptake throughout a 24-hour imaging cycle SPECT has been shown to provide a higher sensitivity (64–72%) however lower specificity (45–88%) than modalities based on evaluation of residual contractile recovery Primary limitations include cost, ionising radiation exposure, low spatial resolution, and attenuation artefacts. These artefacts can be removed via integration of multislice CT and SPECT.

4. Positron Emission Tomography.
Positron emission tomography (PET) imaging is based on the shift of myocardial perfusion energetics, whereby chronically under perfused myocardial tissue shifts from utilization of free fatty acids (that require high oxygenation for use) to that of glucose metabolism, which uses a more anaerobic process at the expense of poor energetic efficiency. This translates into uptake of perfusion tracers in myocardial segments which are hypo perfused. Perfusion tracers, including 13N-labeled ammonia (13NH3) and 18Ffluorodeoxyglucose (18FDG), are utilised in standard practice.

Regions are classified according to the degree of "flow metabolism" matching, which is reflected by concordance between myocardial blood flow and 18FDG uptake. Regions of myocardium where there is a concordance between reduction of myocardial blood flow and 18FDG uptake (flow metabolism match) reflect irreversible myocardial injury. In contrast, areas where FDG uptake (reflective of metabolism) is preserved or increased despite perfusion deficits reflect viable myocardium

Primary advantages of PET over SPECT include better spatial resolution and superior average sensitivity and specificity (88% and 73%, resp.) [Weinmann, H. J. *et al*., 1984]. Reduced availability of PET scanners and the variability of FDG uptake are the primary limitations. Many factors, including cardiac output, sympathetic activity, heart failure status, and degree of ischemia, impact FDG uptake and, thus, scan quality.

5. Cardiovascular Magnetic Resonance
Several cardiovascular magnetic resonance (CMR) techniques have been proposed for the assessment of myocardial viability. These techniques include resting CMR (which provides information on end-diastolic wall thickness [EDWT]), dobutamine stress CMR (DSMR) which provides information on contractile reserve (CR), and delayed contrast-enhanced CMR (DE-CMR) (which provides information on scar tissue). Compared with conventional cardiac diagnostic tests, there are advantages and disadvantages in using MRI to assess myocardial viability (Table 2).

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Table 2: Advantages and disadvantages of using CMR to assess myocardial viability

Advantages	Disadvantages
• High resolution (approximately 1 mm) • Relatively simple imaging protocol • Gadolinium agents are well tolerated • Can assess viability with and without stress • Comprehensive exam of function, perfusion, and viability is practical • Better reproducibility • Not dependent on anatomy • No ionizing radiation • Possible to differentiate epicardial and endocardial processes • Good sensitivity and specificity of integrated assessment protocols	• Image quality may be suboptimal if the patient has arrhythmias • Best imaging done during breath holds, respiratory artefacts can degrade images • Claustrophobia prevents some subjects from completing the study • Many obese patients cannot fit into many scanners used for cardiac imaging makers • Contraindications currently include pacemakers and defibrillators • Limited availability • Relative high cost • Comparatively long study times

a. Testing CMR to assess LV end-diastolic wall thickness

CMR is now considered gold standard for the evaluation of LV volume and mass, as well as myocardial wall thickness and thickening. As in other imaging modalities, the LV is divided into 17 segments, each of which can be attributed to a coronary artery (Fig. 4). Due to scar formation and loss of myocytes after MI, the myocardium becomes thinned. Therefore, the measurement off end diastolic wall thickness EDWT may give information about the viability of dysfunctional myocardium. This, however, is only true for the chronic setting, as in the acute state, wall thickness may even increase due to interstitial edema. Histological data of transmural scar confirm an EDWT of 6 mm or less in chronic infarction.

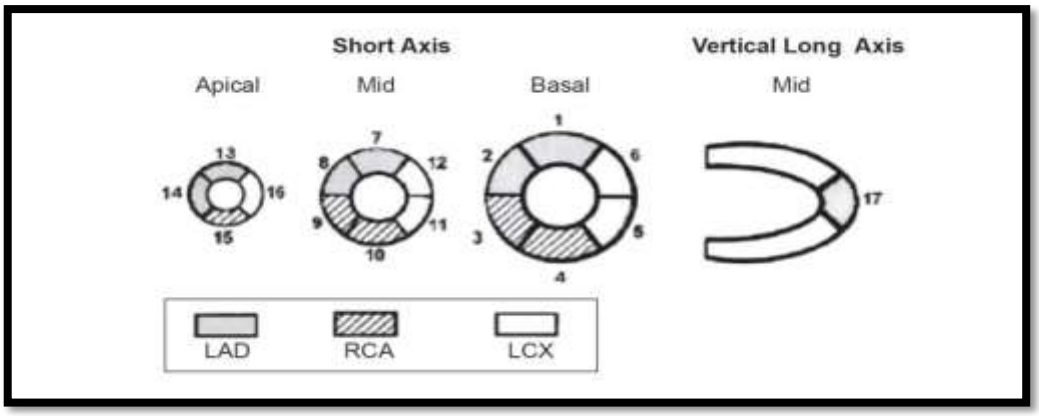

Figure (4): Assignment of the 17 myocardial segments to the territories of the left anterior descending (LAD),right coronary artery (RCA), and the left circumflex coronary artery (LCX) [48]

b. Dobutamine stress CMR to assess contractile reserve

There is a large body of evidence by echocardiography that the assessment of myocardial contractile reserve (CR) is a good predictor of contractile improvement after revascularization in chronic infarction as dysfunctional but viable myocardium will respond to adrenergic stimulation. However, several limitations of dobutamine echocardiography have been shown, for example, reduced accuracy in severely depressed LV Similar to echocardiography, CMR can assess endocardial motion and wall thickening before and during the infusion of low-dose dobutamine (LDD) (5–10 μg/min/kg); however better image quality is obtained in patients with reduced image quality in echocardiography For the assessment of viability, quantification is recommended to document improvement, especially in cases where stimulated myocardium is improved in comparison to rest, but may still be classified as hypokinetic. A minimal EDWT of >5 mm with resting thickening or resting akinesis with an improvement of systolic

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wall thickening of ≥2 mm during dobutamine stimulation are the CMR diagnostic criteria for viable myocardium.

c. Delayed contrast-enhanced CMR to assess scar tissue

Contrast hyper enhancement on delayed rest MR images is defined as regions with increased intensity on T1-weighted images acquired more than 5 min after the intravenous administration of a contrast agent.

The contrast agent applied in CMR is a gadolinium chelated contrast agent with paramagnetic properties. This metabolically inert molecule is a freely diffusible agent that has extracellular distribution and accentuates the difference in tissue relaxation characteristics between infarcted and normal myocardium. Following intravenous administration, the contrast agent diffuses rapidly from the intravascular to the extracellular compartment, but not into intact cells. The hypothesis of enhancement is the increased distribution volume of the contrast agent in the acute setting, due to cell death, and in the chronic setting due to an increased interstitial space due to cell loss and scar formation and an altered washin and wash-out kinetic (Fig. 5).

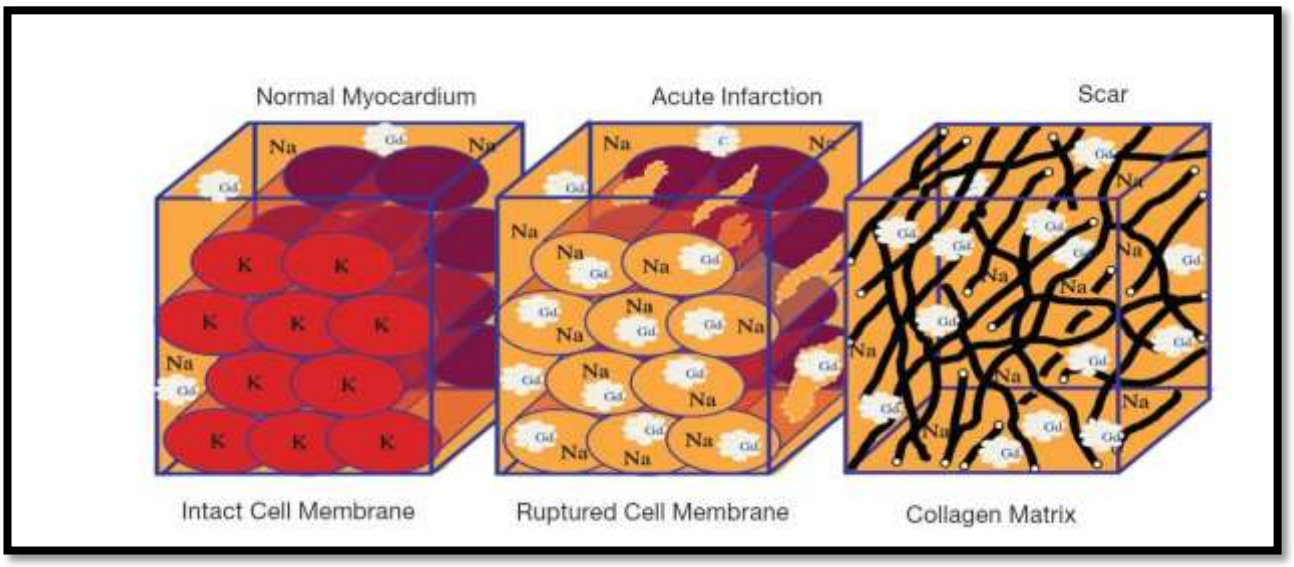

Figure (5): Mechanisms of hyper enhancement in acute and chronic myocardial infarction [Bonow, R. O, 1995].

Depending on the dose, 10 to 15 minutes after injection, a "late" steady-state phase is reached when gadolinium chelated contrast agents have washed out of normal myocardium but remain in scarred or acutely infarcted tissue. With current T1weighted inversion recovery scans, myocardial scar should appear bright against a uniformly dark background of normal myocardium (Fig. 6). This has led to the aphorism that "bright is dead".

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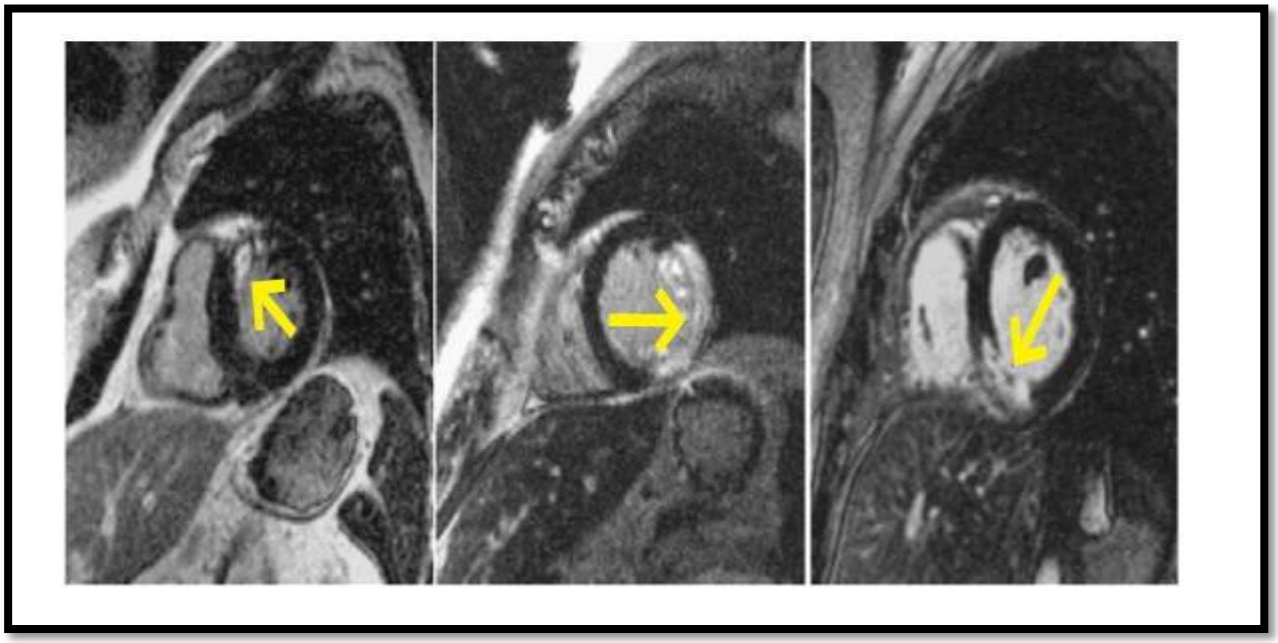

Figure (6): Short-axis DE-MRI images in three patients with acute myocardial Infarction. The arrows point to the hyper enhanced region, which was in the appropriate infarct-related artery perfusion territory [Bonow, R. O, 1995] .

The clinical validation of DE-CMR imaging has been comprehensive and of sufficient quality that the method is accepted as a CMR standard for viability assessment.

Kim *et al*. found that the transmural extent of infarction was inversely proportional to the probability of regional recovery of function after revascularization. This study provided the first clinical evidence that DE-CMR imaging was able to assess viability with recovery of function after revascularization as the study endpoint.

This study also provided pathophysiological insight into the role of sub endocardial and transmural MI. Kim *et al*., found that the transmural extent of myocardial scarring predicted the probability of recovery of function: improvement of function decreased progressively as the transmurality of scar tissue increased. In particular, 78% of dysfunctional segments without contrast enhancement improved in function, as compared to 2% of segments with scar tissue extending >75% of the LV wall .

Using a cut-off value of 25% transmurality of scar tissue, the positive and negative predictive values would be 71 and 79%, respectively, for regions with any degree of dysfunction and 88 and 89%, respectively, for regions with akinesia or dyskinesia. Changing the cut-off value to 75% transmurality, none of the segments with at least severe hypokinesia at basel would be considered to have increased contractility after revascularization, yielding a negative predictive accuracy of 100%. In this study [56], 90% of the regions with hyperenhancement of 51 to 75% of tissue before revascularization did not improve after revascularization; therefore, the transmural extent of >50% seems to be the threshold.

Pooling of the five available studies (total 178 patients) using DE-CMR to predict recovery of regional function after revascularization revealed a mean sensitivity of 84% with a mean specificity of 63% , and PPV and NPV of 72 and 78%.

From studies mentioned above, it is reasonable to conclude that DE-CMR imaging is an excellent clinical tool for assessing the transmural extent of MI. DE-CMR can predict recovery of function after revascularization and is capable of determining myocardial viability in the setting of chronic CAD. It correlates with SPECT imaging but has significant advantages in resolution for detecting small subendocardial infarctions.

AIM OF THE STUDY

To determine the relative accuracy speckle-tracking echocardiography (STE) based measurements of myocardial strain (peak longitudinal systolic strain) for the detection of myocardial viability before revascularization using cardiac MRI as a gold standard. The purpose of the present study was to compare longitudinal strain assessed by two dimension speckle tracking with

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scar tissue on contrast-enhanced magnetic resonance imaging (MRI) in patients with chronic ischemic left ventricular (LV) dysfunction.

PATIENTS AND METHODS

Study Population and Protocol

This study included 20 consecutive patients with ischaemic left ventricular dysfunction presented to IBN ALBITAR –cardiac Centre BAGHDAD-IRAQ, in the period from February 2016 to December 2016 for assessment of myocardial viability, Informed consents were obtained from all patients and the study protocol was approved by the local ethics committee of our hospital.

The study protocol consisted of 2D transthoracic echocardiography to assess segmental (regional) peak longitudinal systolic strain using automated functional imaging (AFI) at rest and after low dose dobutamine and also, cine MRI was performed in BAGHDAD MEDICAL CITY to evaluate segmental LV function.

Contrast-enhanced MRI was performed to assess the extent and transmurality of scar tissue. Subsequently, segmental (regional) peak longitudinal systolic strain was compared with the segmental transmural extent of scar tissue on contrastenhanced MRI, and the optimal cutoff value for regional peak longitudinal systolic strain at rest and after low dos dobutamine to discriminate between viable and non viable myocardial segments.

Exclusion Criteria

Patients with Significant valvular heart disease; Contraindication to dobutamine (including: Unstable patients such as those with decompensated heart failure or unstable angina, aortic stenosis, hypertrophic cardiomyopathy, arrhythmias that interfere with interpretation of dobutamine stress echocardiography) , Patients with bad echo window or when echo study protocol cannot be completed. Intracranial clips, claustrophobia, Device therapy or severe renal dysfunction; refusal to participate in the study.

Clinical Evaluation

A detailed medical history was obtained from every subject and risk factors of CAD were established. Subjects were also evaluated by physical examination and 12-lead electrocardiography.

Conventional Transthoracic Echocardiographic Assessment

2D Transthorasic echocardiography examination was performed at IBNALBETAR CARDIAC CENTRE IN BAGHDAD under supervision of Dr IMAN ALOBAIDY with a Vivid E9 of GE Healthcare equipped with STE technology using a multi-frequency (1 - 5 MHz) X5-1 matrix array probe. All the patients were examined in the left lateral decubitus position and echocardiographic images were acquired from the standard views (parasternal long-axis, parasternal short axis at papillary muscle level, apical 4-chamber, apical 5-chamber and apical 2-chamber).

Recordings and calculations of different cardiac chambers and ejection fractions were made according to the recommendations of the American Society of Echocardiography. In each of the 17 left ventricular segments (figure 7) the wall motion was graded as 1, normal; 2, hypokinesia; 3, akinesia; or 4, dyskinesia.

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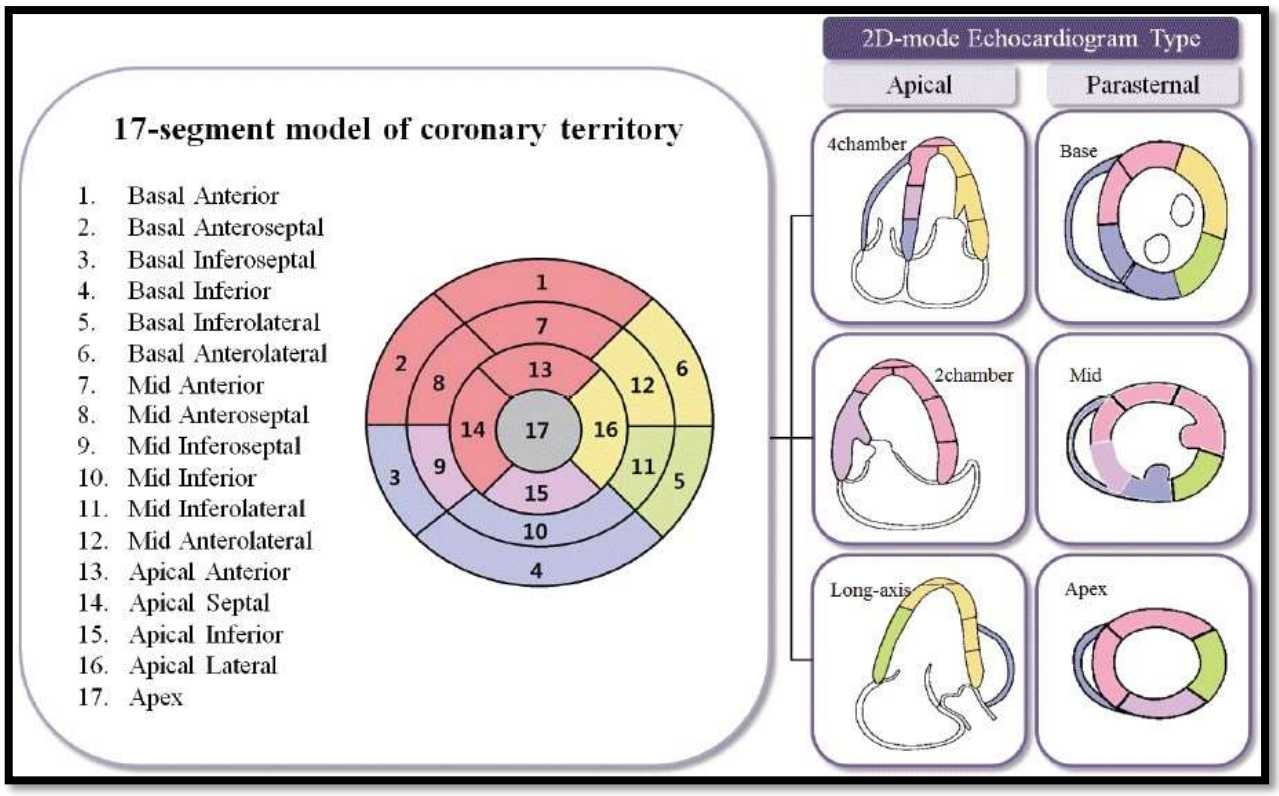

Figure (7): 17 segment cardiac model for assessment of dysfunctional cardiac segment

Low Dose Dobutamine Echocardiography

Beta-blockers, calcium antagonists and nitrates were discontinued in patients at least 48 hours before low dose dobutamine echocardiography. Low dose dobutamine (LDD) infusion was administered using automated infusion pump. Dobutamine was delivered intravenously at dose adjusted according to patient body weight (table 3) using 3 minutes staged protocol starting from 5 μg/kg/min for three minutes, then 10 μg/kg/min for another three minutes period, then 3 minutes recovery without dobutamine. Images were acquired from apical four, two & three chamber views, with superimposition of speckle tacking data at the 2D images.

The recorded 2D image loops were digitally stored at rest, at 5 μg/kg/min and at 10 μg/kg/min LDD echocardiography for later offline analysis. Patients were continuously monitored by ECG and blood pressure measurement during LDD test. Dobutamine infusion was inteded to be terminated if one of the following had occurred:

- Severe chest pain or intolerable side effects.
- ST-segment elevation >1 mm in leads without a Q wave.
- Horizontal ST-segment depression > 2 mm in any lead.
- Significant ventricular arrhythmias such as ventricular tachycardia or frequent polymorphic premature ventricular beats or supraventricular arrhythmias such supra ventricular tachycardia or atrial fibrillation.
- Uncontrolled systemic hypertension with systolic blood pressure of≥ 220 mmHg or symptomatic drop in blood pressre of more than 40 mmHg .

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Table 3: Dobutamine infusion according to body weight (50 ml=250mg ;1ml =5000microgram dobutamine)

Dobutamine	**5 µg/kg/min**	**10 µg/kg/min**
Body weight (KG)	Ml/h	Ml/h
50	3	6
51-52	3.1	6.2
53-54	3.2	6.4
55	3.3	6.6
56-57	3.4	6.8
58-59	3.5	7
60	3.6	7.2
61-62	3.7	7.4
63-64	3.8	7.6
65	3.9	7.8
66-67	4	8
68-69	4.1	8.2
70	4.2	8.4
71-72	4.3	8.6
73-74	4.4	8.8
75	4.5	9
76-77	4.6	9.2
78-79	4.7	9.4
80	4.8	9.6
81-82	4.9	9.8
83-84	5	10
85	5.1	10.2
86-87	5.2	10.4
88-89	5.3	10.6
90	5.4	10.8
91-92	5.5	11
93-94	5.6	11.2
95	5.7	11.4
96-97	5.8	11.6
98-99	5.9	11.8
100	6	12

2-D Speckle Tracking Echocardiography Study

The following views were taken for later analysis; apical 4 chamber view, apical 2 chamber view, and apical long axis view. Longitudinal deformation had been assessed by speckle tracking, being measured the peak systolic longitudinal strain for the 17 segment LV model from the apical 4-chambers, 2-chambers and long axis views, with high frame rates (> 60 frames/s). End-systole was defined as aortic valve closure in the apical long-axis view .Automated delineation of endocardial borders was obtained through marking the mitral annulus level and at the apex on each digital loop. The area of interest was manually adjusted if automated delineation was not optimal. Segments with poor image acquisition or artifacts were excluded due to inability to measure longitudinal strain. Segmental longitudinal strain was calculated as the percentage of lengthening or shortening and the results for each plane were displayed on ball eye map as in figure (8) wich stored for both at rest , 5 µg/kg/min and 10 µg/kg/min for further evaluation and analysis .

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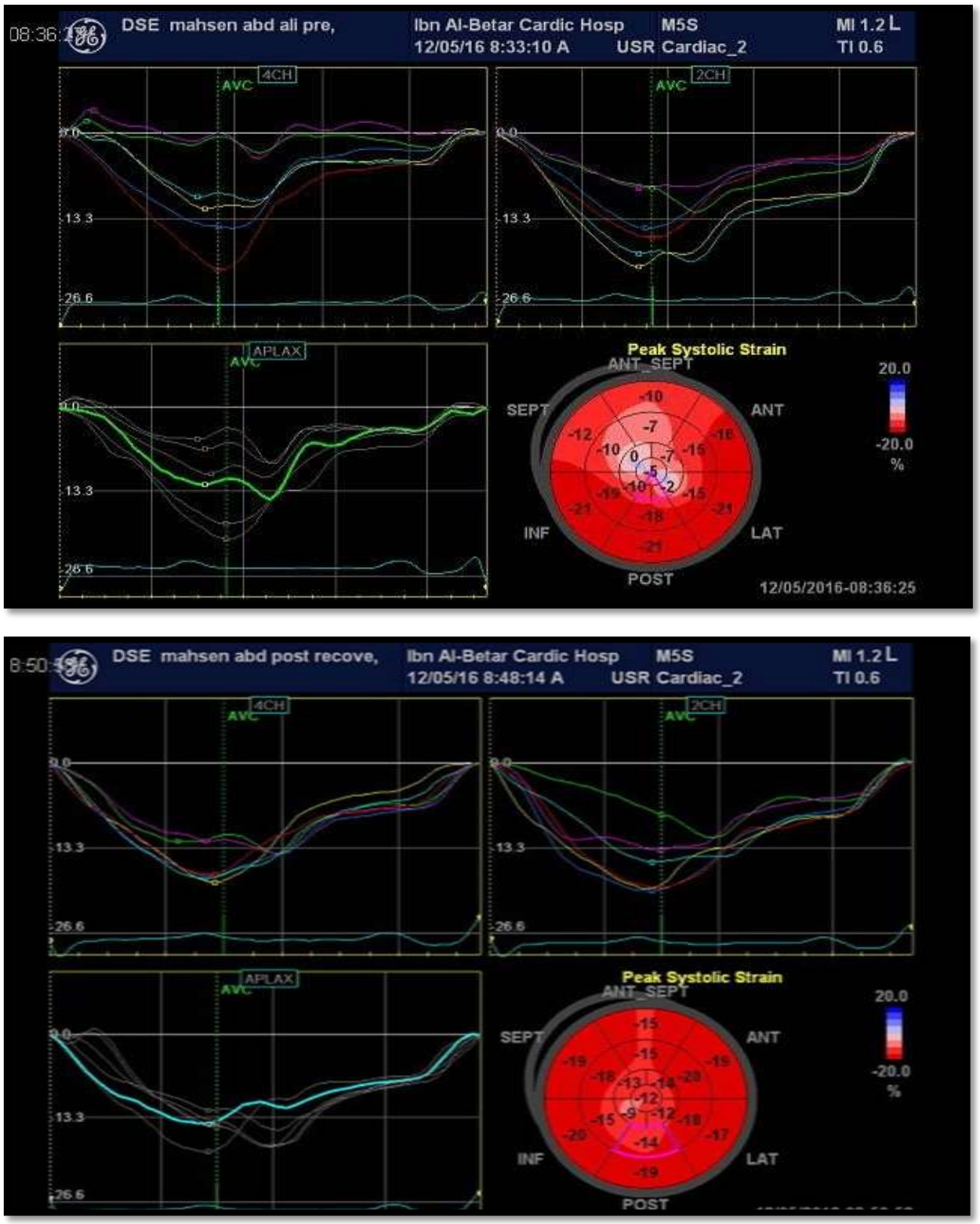

Figure (8): Segmental Peak longitudinal strain by speckle tracking at rest (TOP) and at LDD (Bottom) in Bull's eye map

Delay enhancement-MRI (DE-MRI)

DE-MRI studies were performed in BAGHDAD medical city department of radiology and MRI using a 1.5-T whole-body MRI scanner (Siemens Germany). Images were acquired during breath-holds of approximately 15 s. The 17-segment model images were acquired for assessment of segmental myocardial function. After 15 min of intravenous injection of gadolinium-diethylenetriamine pentaacetic acid (0.2 mmol/kg). The normal region was black, whereas the nonviable region appeared bright or hyper-

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enhanced. The extent of each myocardial segment was calculated as a percentage of contrast-enhanced mass relative to the total myocardial mass of the segment (Area mass segment DE/Area mass segmental myocardium × 100%). A threshold of 50% hyper-enhancement was used to determine myocardial viability (figure 9)

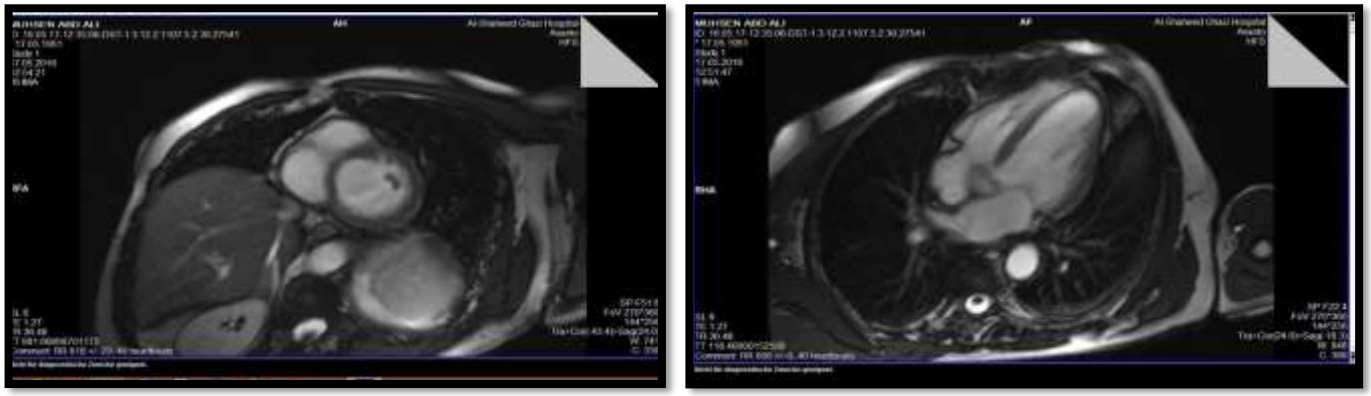

Figure (9): DE MRI image of patient with old myocardial infarction having transmural hyper-enhancement.

RESULTS

This study included 20 consecutive patients presented to IBN ALBITAR hospital - BAGHDAD-IRAQ, in the period from February 2016 to December 2016 for assessment of myocardial viability. Statistical analysis use SPSS version 20 was used for data entry, mean and standard deviation was used to represent the continuous data. Independent student T test and Receiver-operator characteristics (ROC) curves were created to assess the ability of different strain parameters to determine viable myocardium VM, with the optimal cutoff value based on the Youden index. P-value≤0.05 was considered significant The clinical characteristics of study population including mean age of 58±9.4 years, with left ventricular systolic dysfunction by conventional two dimensional transthoracic echocardiography with mean ejection fraction of 43.24±5.71, male patients represents 14 out of 20 (70%), those with diabetes 9 out of 20 (45%) , hypertensive patients was 11 of 20 (55%) , hypercholesterolemia 7 of 20 (35%) , smokers was 8 of 20 (40%) , obesity with body mass index (BMI) of >30kg/m2 was 7 of 20 (35%) as shown in table (4) .

Table 4: Clinical characteristics of the study population

Clinical characteristics of the study population	VALUE	%
Age(YEARS)	58±9.4	
Gender(male)	14/20	70
Diabetes mellitus	9/20	45
Hypercholesterolemia (total cholesterol > 5 mmol/L)	7/20	35
Hypertension(> 140/90 mmHg)	11/20	55
Smoking	8/20	40
Obesity body mass index (BMI) of >30 kg/m2.	7/20	35
Ejection Fraction %	43.24±5.71	

Echocardiographic speckle tracking analysis was done both at rest and after low dose dobutamine. The gold standard for non-viable myocardium detection is delayed gadolinium enhancement by cardiac MRI > than 50 % .

The mean peak longitudinal systolic strain value for basal cardiac segment show the viable segment at rest (-13.8±6) and The mean strain value for viable segment after low dose dobutamine (-16.1± 5.7) . The mean peak longitudinal systolic strainvalue for non-viable segment at rest (-5.4 ± 7.8) and The mean peak longitudinal systolic strain value for non-viable segment after low dose dobutamine (-2.8± 9.6). Mean peak longitudinal systolic strain value difference between low dose

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dobutamine and at rest is 2.6 for non-viable segments and -2.3 for viable one .as shown in table (5) and figure (10).

Table 5: Myocardial deformation parameters of STE and STE associated with LDD in the segments that were designated as Viable Myocardium and Non- Viable Myocardium by cardiac MRI (Basal Segments)

	Viable myocardium		**P (t-test)**
	Non-viable	**Viable**	
Echo Speckle Tracking at rest (average shortening)			<0.001
Range	(-15 to 7)	(-27 to 7)	
Mean	-5.4	-13.8	
SD	7.8	6	
SE	1.59	0.61	
N	24	96	
Echo Speckle Tracking after low dose Dobutamine (average shortening)			<0.001
Range	(-14 to 18)	(-28 to 4)	
Mean	-2.8	-16.1	
SD	9.6	5.7	
SE	1.95	0.58	
N	24	96	
Mean difference between low dose dobutamine and at rest	2.6	-2.3	
P (Paired t-test)	0.15[NS]	<0.001	

STE = Speckle Tracking Echocardiography; LDD = Low dose dobutamine ; MRI= magnetic resonance image

The mean peak longitudinal systolic strain value for mid cavity cardiac segment show the viable segment at rest (-13.2±5.4) and The mean peak longitudinal systolic strain value for viable segment after low dose dobutamine (-15.4± 5.7) . The mean peak longitudinal systolic strain value for non-viable segment at rest (-9.1 ± 5.3) and The mean peak longitudinal systolic strain value for non viable segment after low dose dobutamine (-6.9± 7.3) . Mean difference between low dose dobutamine and at rest is 2.2 for non viable segments and -2.2 for viable one as shown in table (6) and figure (10).

Table 6: Myocardial deformation parameters of STE and STE associated with LDD in the segments that were designated as Viable Myocardium and Non- Viable Myocardium by cardiac MRI (Midcavity Segments)

	Viable myocardium		**P (t-test)**
	Non-viable	**Viable**	
Echo Speckle Tracking at rest (average shortening)			<0.001
Range	(-18 to 5)	(-28 to 3)	
Mean	-9.1	-13.2	
SD	5.3	5.4	
SE	0.92	0.58	
N	33	87	
Echo Speckle Tracking after low dose Dobutamine (average shortening)			<0.001
Range	(-17 to 11)	(-29 to 7)	
Mean	-6.9	-15.4	
SD	7.3	5.7	
SE	1.26	0.61	
N	33	87	
Mean difference between low dose dobutamine and at rest	2.2	-2.2	
P (Paired t-test)	0.025	<0.001	

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STE = Speckle Tracking Echocardiography; LDD = Low dose dobutamine ; MRI= magnetic resonance image

The mean peak longitudinal systolic strain value for apical cardiac segment show the viable segment at rest (13.6±8.5) and The mean strain value for viable segment after low dose dobutamin (-15.8± 8.7) . The mean strain value for non viable segment at rest (-5 ± 6) and The mean strain value for non viable segment after low dose dobutamine (-4.2 ± 6.5) . Mean difference between low dose dobutamine and at rest is 0.8 for non viable segments and -2.2 for viable one as shown in figure (10) and table (7).

Table 7: Myocardial deformation parameters of STE and STE associated with LDD in the segments that were designated as Viable Myocardium and Non- Viable Myocardium by cardiac MRI (Apical Segments)

	Viable myocardium		**P (t-test)**
	Non-viable	**Viable**	
Echo Speckle Tracking at rest (average shortening)			<0.001
Range	(-15 to 9)	(-29 to 4)	
Mean	-5	-13.6	
SD	6	8.5	
SE	0.87	1.18	
N	48	52	
Echo Speckle Tracking after low dose Dobutamine (average shortening)			<0.001
Range	(-18 to 8)	(-32 to 4)	
Mean	-4.2	-15.8	
SD	6.5	8.7	
SE	0.93	1.2	
N	48	52	
Mean difference between low dose dobutamine and at rest	0.8	-2.2	
P (Paired t-test)	0.16[NS]	<0.001	

STE = Speckle Tracking Echocardiography; LDD = Low dose dobutamine ; MRI= magnatic resonance image

The mean strain value for overall cardiac segment show the viable segment at rest (-13.5±6.4) and The mean strain value for viable segment after low dose dobutamine (-15.8± 6.4) . The mean strain value for non-viable segment at rest (-6.4 ± 6.5) and The mean strain value for non-viable segment after low dose dobutamine (4.7± 7.6) . Mean difference between low dose dobutamine and at rest is1.7 for non-viable segments and -2.3 for viable one as shown in figure (11) and table (8).

Table 8: Myocardial deformation parameters of STE and STE associated with LDD in the segments that were designated as Viable Myocardium and Non- Viable Myocardium by cardiac MRI (Overall cardiac Segments)

	Viable myocardium		**P (t-test)**
	Non-viable	**Viable**	
Echo Speckle Tracking at rest (average shortening)			<0.001
Range	(-18 to 9)	(-29 to 7)	
Mean	-6.4	-13.5	
SD	6.5	6.4	
SE	0.63	0.42	
N	105	235	
Echo Speckle Tracking after low dose Dobutamine(average shortening)			<0.001
Range	(-18 to 18)	(-32 to 7)	
Mean	-4.7	-15.8	
SD	7.6	6.4	

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SE	0.74	0.42	
N	105	235	
Mean difference between low dose dobutamine and at rest	1.7	-2.3	
P (Paired t-test)	0.004	<0.001	

STE = Speckle Tracking Echocardiography; LDD = Low dose dobutamine ; MRI= magnatic resonance image

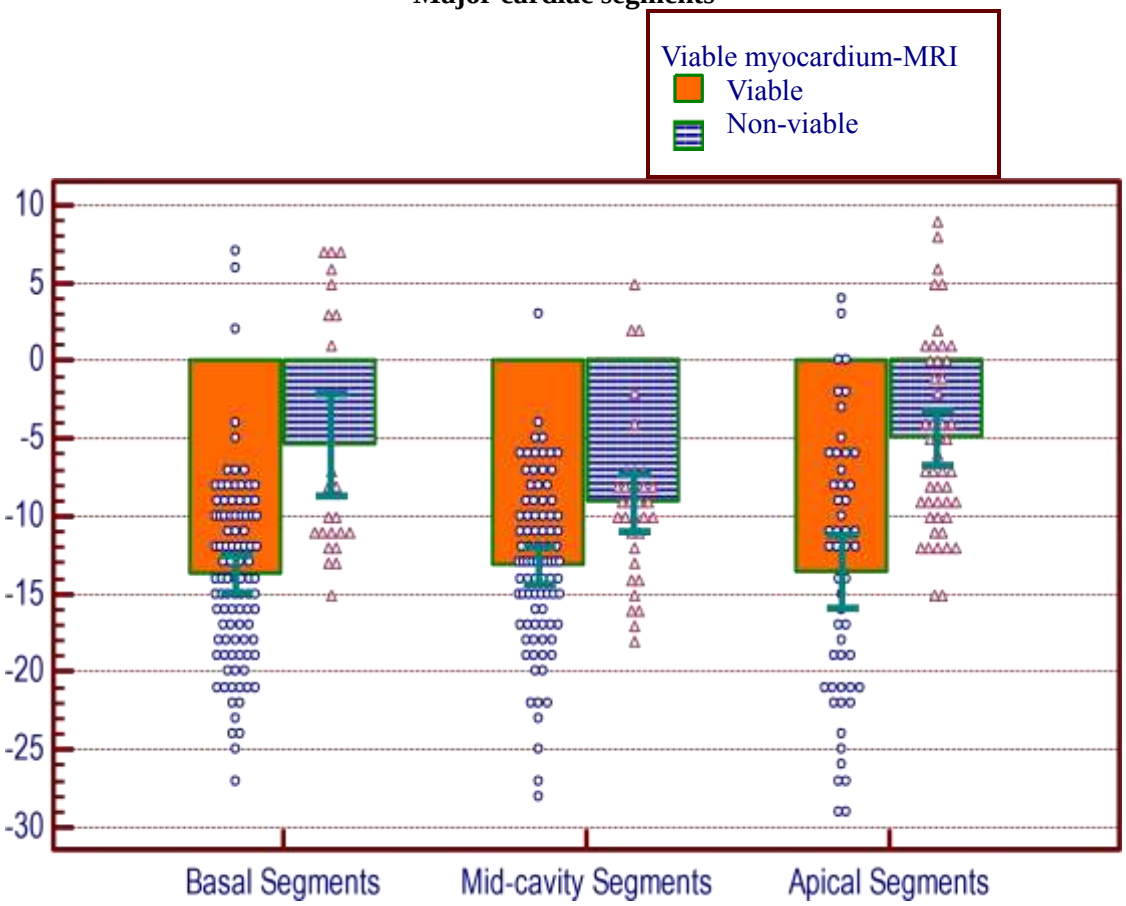

Figure (10): Myocardial Viability Assessment by Dobutamine Echocardiography using speckle tracking. Comparison with cardiac MRI delay enhancement for basal, mid cavity, apical cardiac segment.

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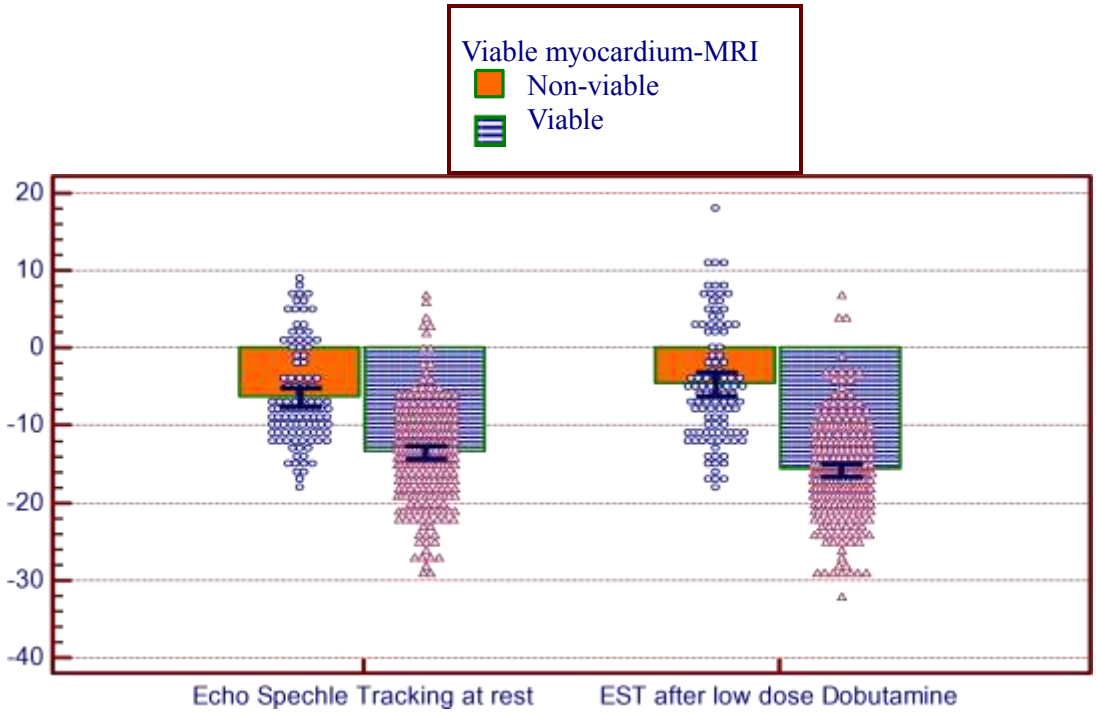

Figure (11): Myocardial Viability Assessment by Dobutamine Echocardiography using speckle tracking. Comparison with cardiac MRI delay enhancement for overall cardiac segment.

The performance of measurements obtained by Echo Speckle tracking at rest and after low dose dobutamine in diagnosing a viable cardiac segment was tested by ROC method.

As shown in(figure12) and (table 9), both measurements were associated with a good to very good test (ROC area being significantly higher than 0.5). In addition, the low dose dobutamine measurements were associated with an observed higher validity in predicting a viable cardiac segment as reflected by the higher area under ROC curve (0.873 compared to 0.78 observed with at rest measurements).

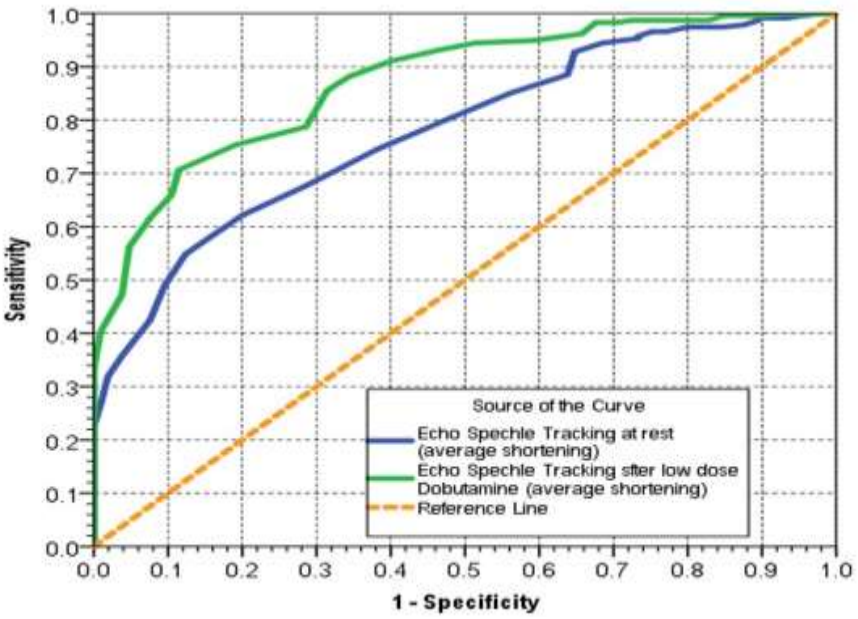

Figure (12): ROC curve showing the trade-off between sensitivity (rate of true positive test results) and 1-specificity (rate of false positive test results) for Echo Speckle tracking at rest and after low dose dobutamine when used as test to predict a viable heart segment differentiating it from a non-viable segment (overall cardiac segments).

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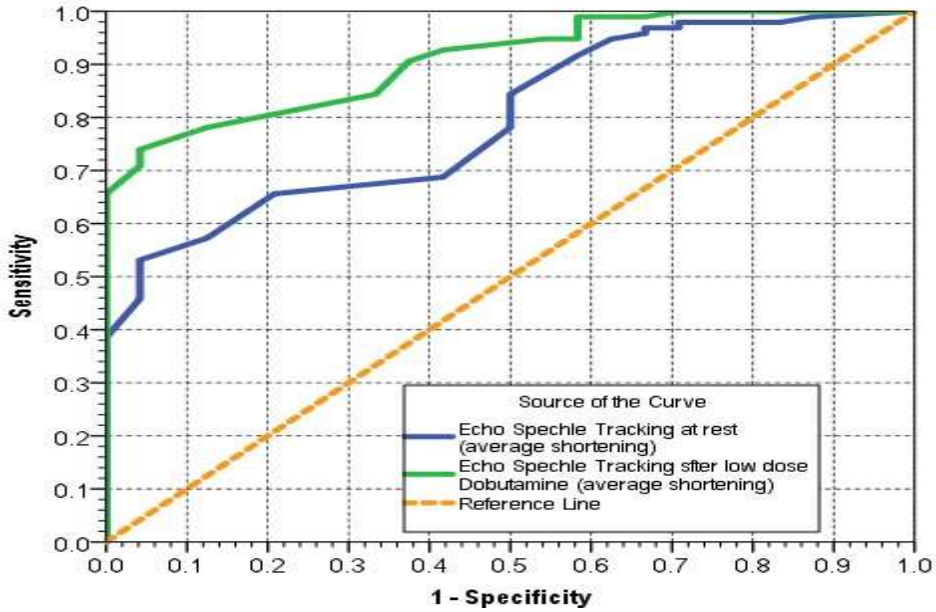
Table 9: Area under ROC curve for Echo Speckle tracking at rest and after low dose dobutamine when used as test to predict a viable heart segment differentiating it from a non-viable one(overall cardiac segments).

	AUROC	P
Echo Speckle Tracking at rest (average shortening)	0.780	<0.001
Echo Speckle Tracking after low dose Dobutamine (average shortening)	0.873	<0.001

In(figure13) and (table 10), which for basal segments, the low dose dobutamin measurements were associated with an observed higher validity in predicting a viable cardiac segment as reflected by the higher area under ROC curve (0.908 compared to 0.796 observed with at rest measurements).

In (figure14) and (table 11), which for mid cavity segments ,the low dose dobutamine measurements were associated with an observed higher validity in predicting a viable cardiac segment as reflected by the higher area under ROC curve (0.834 compared to 0.694 observed with at rest measurements).

In (figure15) and (table 12), which for apical segments ,the low dose dobutamine measurements were associated with an observed higher validity in predicting a viable cardiac segment as reflected by the higher area under ROC curve (0.850 compared to 0.779 observed with at rest measurements).



Figure(13): ROC curve showing the trade-off between sensitivity (rate of true positive test results) and 1-specificity (rate of false positive test results) for Echo Speckle tracking at rest and after low dose dobutamine when used as test to predict a viable heart segment differentiating it from a non-viable one. (Basal segments only)

Table 10: Area under ROC curve for Echo Speckle tracking at rest and after low dose dobutamine when used as test to predict a viable heart segment differentiating it from a non-viable one. (Basal segments only)

	AUROC	P
Echo Speckle Tracking at rest (average shortening)	0.796	<0.001
Echo Speckle Tracking after low dose Dobutamine (average shortening)	0.908	<0.001

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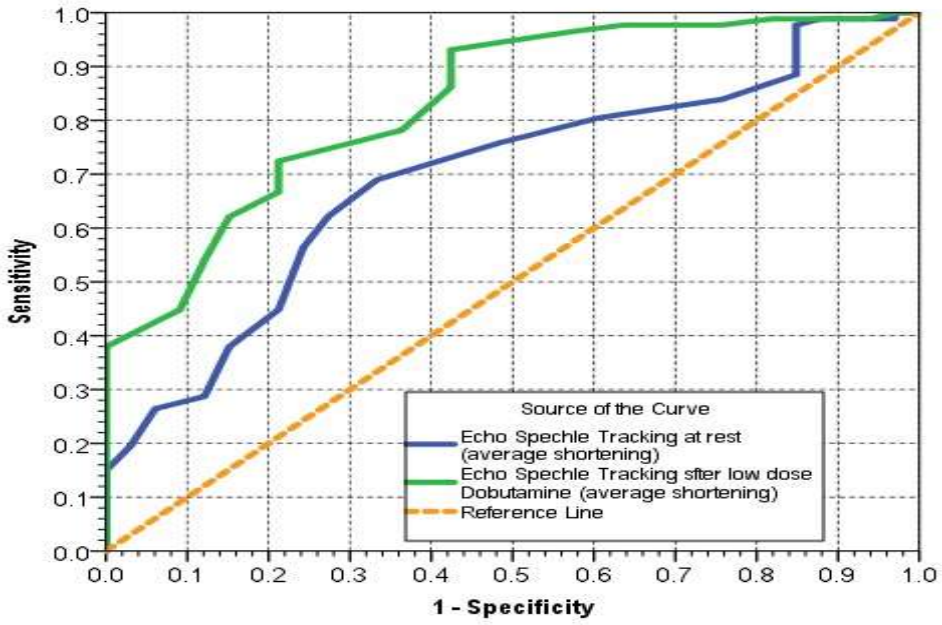

Figure (14): ROC curve showing the trade-off between sensitivity (rate of true positive test results) and 1-specificity (rate of false positive test results) for Echo Speckle tracking at rest and after low dose dobutamine when used as test to predict a viable heart segment differentiating it from a non-viable one .(Mid cavity segments only)

Table 11: Area under ROC curve for Echo Speckle tracking at rest and after low dose dobutamine when used as test to predict a viable heart segment differentiating it from a non-viable one.(Mid cavity segments only).

	AUROC	P
Echo Speckle Tracking at rest (average shortening)	0.694	0.001
Echo Speckle Tracking after low dose Dobutamine (average shortening)	0.834	<0.001

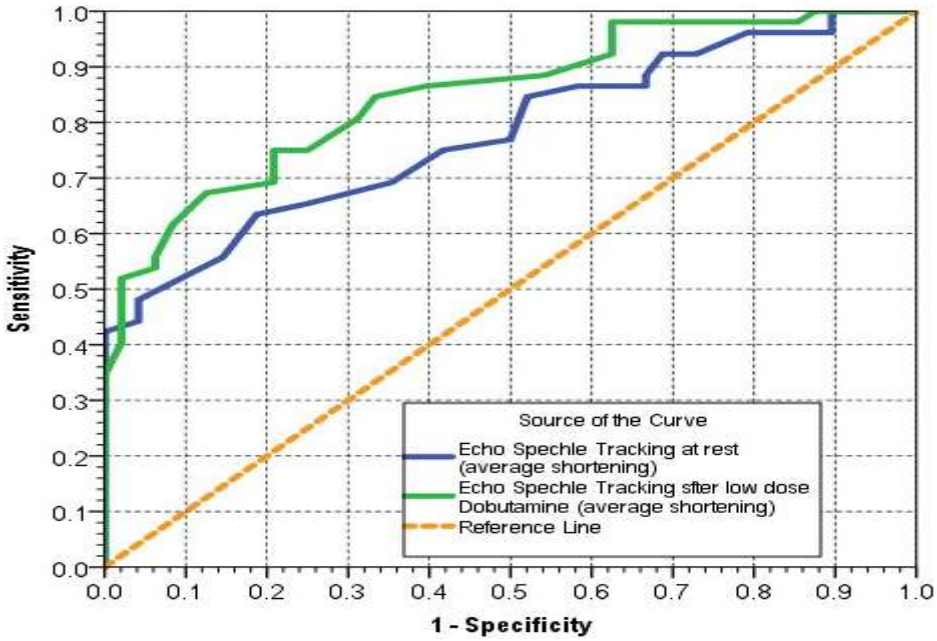

Figure (15): ROC curve showing the trade-off between sensitivity (rate of true positive test results) and 1-specificity (rate of false positive test results) for Echo Speckle tracking at rest and after low dose dobutamine when used as test to predict a viable heart segment differentiating it from a non-viable one.(Apical segments only)

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Table 12: Area under ROC curve for Echo Speckle tracking at rest and after low dose dobutamine when used as test to predict a viable heart segment differentiating it from a non-viable one. (Apical segments only)

	AUROC	P
Echo Speckle Tracking at rest (average shortening)	0.779	<0.001
Echo Speckle Tracking after low dose Dobutamine (average shortening)	0.850	<0.001

As shown in (table 13), the optimum cut-off value for Echo Speckle tracking measurements at rest for predicting a viable myocardial segment is <-11.5 for overall cardiac segments mean peak longitudinal strain value. This cut-off value is associated with the highest accuracy (67.6%) at rest (77.1) after low dose dobutamine in classifying a tested cardiac segment into two categories viable or non-viable. This cut-off value is 62.1% sensitive and 80% specific in predicting a viable cardiac segment at rest and 75.3% sensitive and 81% specific after low dose dobutamine . The cut-off value of the at rest Echo measurements associated with highest specificity is <-18.5 testing positive at this cut-off value (obtaining an Echo measurement of -19 or lower) would establish viability in the tested segment with 100% confidence level in any clinical context.

Table 13: Validity parameters for Echo Speckle tracking at rest and after low dose dobutamine when used as test to predict a viable heart segment differentiating it from a non-viable segment

Positive if < cut-off value	PPV at pretest			
	Sensitivity	Specificity	Accuracy	probability = 50%
Echo Speckle Tracking at rest (average shortening)				
-18.5 (Highest specificity)	22.6	100.0	46.5	100.0
-11.5 (Optimum cut-off)	62.1	80.0	67.6	75.6
Echo Speckle Tracking after low dose Dobutamine (average shortening)				
-18.5 (Highest specificity)	33.6	100.0	54.1	100.0
-11.5 (Optimum cut-off)	75.3	81.0	77.1	79.8

Table 14: The rate of myocardial viability by segment location

	Total	Viable myocardium-MRI	
Cardiac segments	**N**	**N**	**%**
basal anterior	20	15	75.0
basal anteroseptal	20	15	75.0
basal inferoseptal	20	15	75.0
basal inferior	20	15	75.0
basal inferolateral	20	16	80.0
basal anterolateral	20	20	100.0
mid anterior	20	15	75.0
mid anteroseptal	20	12	60.0
mid inferoseptal	20	13	65.0
mid inferior	20	16	80.0
mid inferolateral	20	16	80.0
mid anterolateral	20	15	75.0
apical anterior	20	11	55.0
apical septal	20	10	50.0
apical inferior	20	8	40.0
apical lateral	20	10	50.0
apex	20	13	65.0
Total	340	235	69.1
Major cardiac segments Basal Segments	120	96	80.0
Mid-cavity Segments	120	87	72.5
Apical Segments	100	52	52.0

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In table (14) show the distribution of viable myocardial segment detected by cardiac MRI delayed enhancement in the study group in which 340 total cardiac segment from which 235 segment was viable 69.1% distributed as 96 out of 120 (80%) for basal segments, of 120 mid cavity segments 87 was viable (72.5%) and of 100 apical segment 52 (52%) was viable.

Table 15: count of viable segments per subject

Count of viable segments	N	%	Cumulative Percent
17	2	10.0	10.0
16	1	5.0	15.0
14	1	5.0	20.0
12	7	35.0	55.0
11	2	10.0	65.0
10	3	15.0	80.0
9	3	15.0	95.0
8	1	5.0	100.0
Total	20	100.0	

In table (15) show count of total viable segments detected by MRI delayed enhancement that detected in study group with cumulative percentage.

DISCUSSION

Since introduction of myocardial revascularization methods such as coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI), the issue of identifying dysfunctional yet viable myocardium has arisen as very important factor in determining clinical decision-making and prognostic evaluation.

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. 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.

Christoph Klein, *et al*, in (study of assessment of myocardial viability With contrast-enhanced magnetic resonance imaging Comparison With Positron Emission Tomography), Thirty-one patients with ischemic heart failure (ejection fraction, 28±9%) were imaged with PET and MRI , Sensitivity and specificity of MRI in identifying patients and segments (n=1023) with matched flow/metabolism defects was 0.96 of 1.0 and 0.86 of 0.94, respectively. In conclusion In in patient with ischemic heart failure, MRI hyper enhancement as a marker of myocardial scar closely agrees with PET data. Although hyper enhancement correlated with areas of decreased flow and metabolism, it seems to identify scar tissue more frequently than PET, reflecting the higher spatial resolution.

Schinkel, *et al*. 2007. conducted a systematic review comparing the diagnostic accuracy of five cardiac imaging modalities (PET, dobutamine echocardiography, thallium-201 and technetium-99m scintigraphy ,and cardiac MRI) for the evaluation of viable myocardium and assessment of patient outcomes. The systematic review included 151 studies published from 1980 to January 2007 that assessed at least one of the following patient outcomes: regional functional recovery; global LV functional recovery; improvement in heart failure symptoms and exercise capacity; and long-term prognosis. When regional functional recovery was used as the gold standard, cardiac MRI had the highest sensitivity (95%) followed by PET (92%).

Kim, *et al*., 1999, found that the transmural enhancement was inversely proportional to the probability of regional recovery of function after revascularization.

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. However, the disadvantages of DE-MRI include lower availability and higher costs when compared with STE-LDDSE, more stringent

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requirements in terms of regular heart rhythm and controlled breathing to obtain optimal imaging compared with SPECT or PET.(Wang, C. *et al*., 2016)

This study include fourty Patients with ischemic heart disease presented for assessment of myocardial viability for possibility of myocardial revascularization. Myocardial segments in this study were classified into viable and non-viable groups according to the results of delay enhancement MRI . echocardiographic measure using speckle tracking technique (STE) parameters during low dobutamine (LDD) echocardiography were evaluated as markers of viability.

In the current study, we found lower peak systolic strain values at rest using STE in the non-viable segments compared to the viable groups of the corresponding territory. An increase of strain values in response to LDD was detected in the viable group but not in the non-viable ones.

Regarding strain values, A cut-off point to predict myocardial viability using the ROC curve. At ≥-5.6 % peak longitudinal systolic strain by STE at LDD chosen as a cut-off point, the sensitivity of 88% and a specificity of 80 % .

The results of the current study are in agreement with those of Larysa *et al*, 2015. who assess myocardial viability by STE in patients with coronary artery disease and type 2 diabetes mellitus, LV myocardial segments were analyzed by STE before and one year after revascularization, and they found that, patients with coronary artery disease and type 2 diabetes mellitus had lesser degree of LV functional recovery one year after revascularization compared to those without type 2 diabetes mellitus. Assessments of LV myocardial viability using STE is recommended for patients selection before revascularization and further follow up.(Laryza, Z. *et al*., 2015)

Chaofan Wang, *et al*., 2016 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). 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%, $P < 0.05$.

Loïc Bière, *et al*., 2014. were assessed the value of STE performed early after a first ST-segment elevation myocardial infarction in order to predict infarct size and functional recovery at 3-month follow-up. Longitudinal strain >−6.0% within the infarcted area exhibited 96% specificity and 61% sensitivity for predicting the persistence of akinesia at 3-month follow-up. Speckle-tracking strain imaging performed early after a STEMI is easy-to-use as a marker for persistent akinetic territories at 3 months. and this was compatible to our findings except a cut of point value because they depend on Late gadolinium-enhanced cardiac magnetic imaging as a gold slandered for myocardial viability.

Martin, H. *et al*., 2013. were compare the speckle tracking echocardiography derived systolic longitudinal strain with rest single photon emission computed tomography perfusion imaging and to define the optimal cut-offs for peak longitudinal systolic strain to discriminate transmural scar on contrast-enhanced magnetic resonance imaging (ceCMR). Correlation was found between regional peak longitudinal systolic strain and DE on ceCMR. The peak longitudinal systolic strain optimal cutoff -5.3% identified segments with delayed enhancement >75% on ceCMR (sensitivity 83.1%, specificity 84.6%). STE enabled identification of LV non-viable segments. In comparison with rest myocardial SPECT perfusion imaging, STE is more accurate in predicting non-viable myocardium, and this was compatible to our findings.

Roes, S.D. *et al*, in 2009. compare longitudinal strain assessed by two dimensional speckle tracking with scar tissue on contrast-enhanced magnetic resonance imaging (MRI) in patients with chronic ischemic left ventricular (LV) dysfunction who found that a regional longitudinal strain cutoff value of -4.5% distinguished non transmural from transmural infarction with high sensitivity and specificity (81.2% and 81.6%, respectively).

Bochenek *et al*, 2011 found that peak systolic longitudinal strain is a powerful predictor of myocardial recovery and this was also compatible with our findings.

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This study has some limitations which should be addressed in further studies

- An improved contractile performance is commonly considered the gold-standard for assessing viable myocardium. We did not examine patients after revascularization. However a recent study by Kim *et al* showed the predictive value of MRI for functional recovery.
- Small sample size
- Only longitudinal STE parameters analyzed and measurement of STE-based Strain 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.

CONCLUSIONS

Low dose dobutamine stress Echocardiography using speckle tracking technique (STE) is simple , safe and easy bed side technique to predict myocardial viability with high sensitivity and specifity as compared with MRI delay enhancement Overall, STE-LDDSE is superior rest STE for evaluation of viable myocardium in patient with ischaemic left ventricular dysfunction

RECOMMENDATION

1-An improved contractile performance is commonly considered the goldstandard for assessing viable myocardium. We did not examine patients after revascularization.

2-Only peak longitudinal strain STE parameter analyzed ,the evaluation of other strain parameter like strain rate, circumferential and radial strain is recommended .

3-Larger sample size . Combination of multiple viability assessment technique and compare with result after revascularization carry great hope for best result

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