Detection of Left Ventricular Remodeling in Acute ST Elevation Myocardial Infarction after Primary Percutaneous Coronary Intervention by Two Dimensional and Three Dimensional Echocardiography

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Abstract

**Background:** Left ventricular remodeling (LVR) after ST-elevation myocardial infarction (STEMI) harbinger poor prognosis. Three-dimensional echocardiography (3DE) is more accurate than 2D echo for the assessment of left ventricle (LV) shape. We assessed LV geometry with 3D ECHO 6 months after STEMI in patients who had primary angioplasty. **Materials and Methods:** In this prospective study, morphological and functional analysis of LV with 3D ECHO (volumes, LVEF, 3D sphericity index [SI]) was assessed up to 7 days and 6 months in 42 STEMI patients. The LVR was considered for increase >15% of the end diastolic volume of the LV (LVEDV) 6 months after the STEMI, compared to the LVEDV up to 7 days of it. **Results:** Sixteen (38%) patients had LVR. 3D Echocardiographic measurements up to 7 days after the acute myocardial infarction (AMI) 1-LVEDV in ventricular remodeling group was 99.8 ± 19.1 ml and in no ventricular remodeling group was 87 ± 18.2 mL (P = 0.037); 2-LVEF was 0.48 ± 0.01 and 51 ± 0.02 (P <.001); 3D-SI was 0.41 ± 0.05 and 31 ± 0.05 (P < 0.001) II-after 6 months: 1-LVEDV in remodeling group was 114.2 ± 19.5 mL and no remodeling group was 94.2 ± 18.6 (P = 0.002); 2-LVEF was 0.58 ± 0.01 and 59 ± .01 (P = 0.003); 3D-sphericity was 0.35 ± 0.05 and 28 ± .05 (P < 0.001). **Conclusion:** LVR was observed in 38% of the patients 6 months after AMI. The 3D SI has been associated with occurrence of LVR and can differentiate patients with and without subsequent development of LVR accurately and early on its basis.

**Keywords:** Left ventricular remodeling, three-dimensional echocardiography, three-dimensional sphericity index

**INTRODUCTION**

The prognosis of the patients bearing acute myocardial infarction (AMI) with ST-segment elevation is related to the cardiac mechanics and to the geometry of the left ventricle (LV) as well.[1]

The percentage of dilatation of the LV (ventricular remodeling) and the myocardial performance mirrored by the variation of the ventricular volumes (ejection fraction) are aspects of great prognostic importance in the clinical evolution of the patients after AMI.[2]

Left ventricular (LV) remodeling after AMI comprises infarct expansion, LV dilatation, and hypertrophy.[3] Korup et al. have reported that LV dilatation starts within 3 h of AMI with no further progression in the first 6 days.[4]

The analysis of the volumes, of the geometry, and of the left ventricular function, has been carried out over the past decades with the use of the two-dimensional echocardiogram/echocardiography (2D ECHO).[5] However, this method presents limitations related to the morphological and functional analysis of the cardiac structures by virtue of the limitation of the spatial planes of observation, of the geometric inferences for the calculation of the ventricular volumes and of the possibility of shortening–“foreshortening”–of the

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The 3D echocardiogram (3D ECHO) allows for the structural analysis of the heart from multiple spatial planes of observation. The 3D echocardiographic analysis of the LV, when compared to the 2D analysis, presents a finer proximity with the measurements obtained with methods of a better spatial resolution, such as the 64-channel ultrarapid computed tomography and the nuclear magnetic resonance. The aim and objective of this study is measurements of end diastolic volume of the LV (LVEDV), end systolic volume of the LV (LVESV), EF, and SI by 2D and 3D echocardiography and the nuclear magnetic resonance.

Calculation of LV volume by 3D echocardiography (3DE), however, is up to three times more accurate than 2DE. Volumetry by 2DE depends on geometric assumptions and is subject to image-plane positioning errors. Hence, it is not accurate in LVs that are distorted in shape, such as after AMI. The 3DE also provides for the analysis of the geometric modification of the LV through the gauging of the 3D sphericity index (3D SI). This new index relates the ventricular volume to the hypothetical left ventricular volume should the LV present a spherical shape. A number of studies in the literature have related this new index of ventricular geometric analysis to the left ventricular remodeling (LVR) after MI. The “gold standard” noninvasive technique for the reproducible quantification of LV size and function is cardiac magnetic resonance (CMR) imaging. However, CMR is expensive, not widely available, and cannot be used in patients treated for heart failure with implantable devices.

Recent advances in real-time 3DE (RT-3DE), have bridged the gap, offering highly accurate (compared to CMR) analysis of LV size and function at the bedside. RT-3DE avoids geometrical assumptions about the shape of the LV and image manipulation can minimize underestimations of LV size due to foreshortening. Semi-automated endocardial detection software creates a mathematical model or “cast” of the LV, improving the accuracy of volume calculation enabling serial measurements of stroke volume and cardiac output.

Currently, 3D transthoracic echocardiography (TTE) and transesophageal echocardiography assessment of LV volumes and ejection fraction is recommended over the use of 2DE, as it has been clearly demonstrated to provide more accurate and reproducible measurements.

**Aims and objective**

The aim and objective of this study is measurements of end diastolic volume of the LV (LVEDV), end systolic volume of the LV (LVESV), EF, and SI by 2D and 3D echocardiography up to 7 days after MI and 6 months in follow-up to detect left ventricular remodeling.

**Inclusion criteria**

The patient was eligible for the study if having presented at least two of the following criteria for the diagnosis of MI:

1. Clinical picture that is compatible with AMI with in 12 h of chest pain
2. Elevation of the ST segment >1 mm in at least two derivations on electrocardiography of 12 derivations
3. Dosage of markers of myocardial necrosis compatible with AMI.

Apart from the criteria for the diagnosis of AMI, the patient should present: hemodynamic stability on realization of the percutaneous coronary intervention (PCI); signing of the free informed consent form for the realization of the study.

**Exclusion criteria**

Patients were excluded on the basis of poor acoustic windows in ECHO, atrial fibrillation, frequent extra systoles or other significant arrhythmias, failure to give informed consent, coronary/hemodynamic instability, cardiac surgery scheduled in the near future, preexisting haemodynamically significant valvular heart disease, cardiomyopathy, serious noncardiovascular disease, probable difficulties for follow-up.

**Materials and Methods**

A total of 45 patients of acute ST elevation MI (STEMI) who were planned for primary PCI were chosen for study at SMS Medical College and associated Hospital, Jaipur, from August 2015 to December 2016 with the later exclusion of 3/45 (6.66%) patients from the initial series as a result of image deemed as inadequate on the echocardiographic analysis. The research protocol was approved by the Institution’s Ethics Committee. Informed consent was obtained from the patients.

**Echocardiography**

Detailed history, physical examination, and echocardiography (2D and 3D) were done up to 7 days after STEMI and 6 months in follow-up. LVEDV; LVESV; LVEF, by Simpson rule method by 2DE as per American Society echocardiography Recommendations. The left ventricular diameters were measured using the 1D mode guided by the 2DE. The 2D SI of the LV was also calculated, taking in consideration the relation between the long and short axis of the LV (apical four chamber projection, in diastole).

**Three dimensional echocardiography**

TTE was performed using a commercially available echocardiographic system (IE33 and IE 33 X matrix; Philips Medical System). RT-3D images were acquired by two different probes, X3-1 and X5-1; when RT-3D images were acquired using the X3-1 probe, 2D images were acquired with standard S5-1 cardiology probe, while both 2D and RT-3D images were acquired with the same probe when X5-1 was employed. All echocardiographic images were stored digitally; LV volume measurements were systematically performed offline with QLAB advanced software package (QLAB 8.1, Philips Medical System), by two independent observer. The acquisition of the 3D images was carried out after the 2D echocardiographic study. The 3D images were obtained in expiratory apnea – with the image attached to the electrocardiographic record. The 3D echocardiographic images were acquired from reference points of the LV, while taking in...
consideration the mitral valve ring and the ventricular apex, in sagittal and coronal projections. 3D LV volumes and EF were measured from the 3D full-volume data set. Using the onboard QLab software (QLAB 8.1, Philips Medical System), the full volume data of the LV was organized into orthogonal four-, two-chamber, and short-axis views. End-diastolic and end-systolic frames were selected. Mitral annular and apical points were placed on these images. Semi-automated LV endocardial border detection software on QLab outlined the endocardial borders in these three planes. The software then used sequence analysis to track the endocardium in all frames and then automatically calculate a true 3D EDV, ESV, and EF from the moving 3D endocardial shell. The endocardial borders could be adjusted manually if the endocardial border tracking was deemed inadequate, and the sequence analysis repeated.

The 3D SI of the LV corresponds to the ratio between the LVEDV and the volume which the LV would present (had its shape been spherical), in accordance with the expression below: 3D SI of the LV: $\frac{\text{LVEDV}}{4/3 \pi \left(\frac{D}{2}\right)^3}$ where, LVEDV: EDV of the LV (measured with 3D ECHO). The diameter of the LV measured in the apical four-chamber projection [Figure 1].

The LVR has been considered on the occurrence of increase ≥15% of the LVEDV 6 months after the AMI, as compared to the LVEDV up to 7 days after the event.

### Statistical analysis

Data were analyzed with SPSS program (version 19, SPSS Inc. Chicago, IL, USA). Continuous data are summarized in the form of mean and standard deviation. The difference in mean was analyzed using *t*-test. Categorical data are expressed in frame of proportion and analyzed using Chi-square test. Pearson correlation coefficient was calculated for determining the correlation between two variables. Kappa statistics was calculated to determine agreement between 2D and 3D ECHO. The level of significance was kept 95% all statically analysis and $P < 0.05$ was taken as statistically significant.

**Results**

Within the period between August 2015 and December, 2016, 45 patients were studied in a prospective fashion, with the later exclusion of 3/45 (6.66%) patients from the initial series as a result of image deemed as inadequate on the echocardiographic analysis.

Thus, out of the 42 patients considered for the study, 32 (76%) men, with a mean age range of 51 ± 12 (37–73) years, which have been affected by AMI with elevation of the ST segment, have received treatment by primary PCI within 12 h from the onset of symptoms (implantation of coronary endoprosthesis-Stent) and followed by optimum medical therapy (angiotensin converting enzyme inhibitors, beta blockers, aspirin, and clopidogrel, statins) were enrolled in the study.

The majority of the patients of the study presented the previous history of systemic arterial hypertension (52.38%), smoking (42.85%), and close to ¼ of them presented diabetes mellitus, or a history of dyslipidemia [Table 1].

The clinical baseline characteristics of the study population showed no significant differences between the remodeling and no remodeling group in respect to age ($P = 0.61$), gender ($P = 0.20$), the presence of diabetes ($P = 0.817$), hypertension ($P = 0.476$), dyslipidemia ($P = 0.823$), smoking status ($P = 0.819$), involved coronary artery ($P = 0.490$), and secondary coronary lesions ($P = 0.657$) as presented in Table 1.

The 3D echo analysis of the left ventricular global and regional contractility demonstrated that patients who developed postinfarction LV remodeling tend to have at lower ejection fraction (48% vs. 51%, $P = 0.001$), larger EDVs (99.8 ml vs. 87.1 ml, $P = 0.037$), higher SI (0.41 vs 0.31 $P < 0.001$) at baseline than patients who did not develop LVR [Table 2].

The progression of the LVEDV of the total population of the study ($n = 42$) 6 months after the AMI is demonstrated in the Figure 2.

In the group of patients with remodeling of the LV, we have observed an increase of 15.5%, $P < 0.05$, of the LVEDV (analysis with 3D ECHO), and of 8.1% of the LVEDV with a 3D echocardiographic analysis, 6 months after the MI.

The variation of the 3D SI (3D) of the LV up to 7 days and 6 months after the MI for the total population of the study ($n = 42$) is demonstrated in the Figure 3.

The analysis of correlation (Pearson: $r$) between the 3D SI (3D) and the EDVLVEDV, up to 7 days and 6 months after the MI (AMI), in the total population of the study ($n = 42$), is demonstrated in the Table 3.

Remodeling of the LV has been observed in 38% of the patients affected by AMI. The correlation between the 3D SI measured up to 7 days after the AMI and the LVEDV within 6 months has been 0.67($P < 0.001$) Table 3.
For the group of patients with remodeling of the LV, the correlation between the 3D SI measured 6 months after the AMI and the LVEDV after 6 months has been 0.79, ($P<0.001$). 3D SI at both times (up to 7 days after AMI and 6 months after AMI) is moderate to strongly, positively correlated with 3D LVEDV [Table 3].

The low kappa value indicates poor agreement between 2D and 2D ECHO for determining ventricular remodeling and was also not found to be statistically significant [Table 4].

**DISCUSSION**

The LVR after the occurrence of AMI reflects the mechanical modifications of adaptation of the LV in the face of the ischemic event, being a factor of important prognosis in the clinical evolution of the patients. The left ventricular dilatation, as well as the reduction in the ejection fraction of the LV and the functional class represent important factors of poor prognosis, related to the heart failure after AMI. The low kappa value indicates poor agreement between 2D and 2D ECHO for determining ventricular remodeling and was also not found to be statistically significant [Table 4].

Successful revascularization of AMI should restore the function of damaged myocardium when performed within the recommended time frame. This restoration of circulation should prevent the development of ventricular remodeling, process with a powerful negative impact on the evolution of patients.

In the present study, 38% of the patients have presented pieces of echocardiographic evidence of ventricular remodeling, in spite of their presenting a small reduction of the LVEF within the hospitalization period ($0.48 \pm 0.01$ upon 3D ECHO, $0.50 \pm 0.05$ on 2D ECHO), and of their all being within a Class I or II of Killip.
Table 2: Echocardiographic measurements and serum dosages of creatine kinase-MB of the patients who have developed remodeling of the left ventricle (n=16), and of the patients who have not developed remodeling of the left ventricle (n=26), 6 months after myocardial infarction

| Parameters                        | 1st ECHO up to 7 days after AMI | P       | 2nd ECHO 6M after AMI | P       |
|-----------------------------------|---------------------------------|---------|-----------------------|---------|
|                                   | Ventricular remodeling group (n=16) | No ventricular remodeling (n=26) |         | Ventricular remodeling group (n=16) | No ventricular remodeling (n=26) |
| 3D ECHO LVEF                      | 0.48±0.01 (0.36-0.64)          | <0.001  | 0.58±0.01 (0.37-0.70) | 0.003   |
| 3D ECHO LVESV (mL)                | 44.3±7.9 (30.9-58.3)           | 0.314   | 45.8±8.1 (32.2-59.1) | 0.488   |
| 3D ECHO LVEDV (mL)                | 98.9±19.1 (74.3-102.8)         | 0.037   | 114.2±19.5 (74.3-121.3) | 0.002 |
| 3D sphericity index               | 0.41±0.05 (0.29-0.42)          | 0.001   | 0.35±0.05 (0.25-0.37) | 0.001   |
| 2D ECHO LVDD (cm)                 | 5.1±0.3 (4.5-6.1)              | 0.202   | 4.7±0.2 (4.5-5.4)     | 0.001   |
| 2D ECHO LVEF                      | 0.50±0.5 (0.42-0.61)           | 0.066   | 0.58±0.06 (0.42-0.64) | 0.059   |
| 2D ECHO LVEDV (mL)                | 104.9±22.3 (59.2-103.4)        | 0.665   | 116.1±21.9 (58.8-128.3) | 0.672   |
| Sphericity index-2D               | 1.77±0.13                      | 0.801   | 1.83±0.11             | 0.369   |
| CK-MB (ng/mL) NV (0-3.40)         | 92.1±77.8 (5.9-256)            | 0.951   |                       |         |

Table 3: Correlation Pearson: r, confidence interval 95%, between the three-dimensional sphericity index and the end-diastolic volumes of the left ventricle, up to 7 days and 6 months after the myocardial infarction (acute myocardial infarction) in the total population of the study (n=42)

| Parameter                          | 3D ECHO LVEDV | 3D ECHO LVEDV 6M | r | P       |
|------------------------------------|---------------|------------------|---|---------|
| 3D sphericity index up              | 0.81          | <0.001           | 0.67 | <0.001 |
| to 7 days after the AMI             | (0.518-0.921) | (0.372-0.881)    |     |         |
| 3D sphericity index                 | -             | 0.79             | <0.001 |         |
| 6 month                             | (0.631-0.911) |                  |     |         |

Table 4: Agreement between findings of three-dimensional and two-dimensional echocardiogram

| 3D ECHO-ventricular remodeling     | 3D ECHO-no ventricular remodeling | Total |
|------------------------------------|----------------------------------|-------|
| 2D ECHO-ventricular remodeling     | 5                                | 3     | 8     |
| 2D ECHO-no ventricular remodeling  | 11                               | 23    | 34    |
| Total                              | 16                               | 26    | 42    |

κ=0.218, P=0.114 NS. The low kappa value indicates poor agreement between 2D and 3D ECHO for determining ventricular remodeling and was also not found to be statistically significant. ECHO=Echocardiogram, NS=Not significant, 2D ECHO=2D ECHO, 3D ECHO=3D ECHO, 3D=Three-dimensional, 2D=Two-dimensional

This percentage of LVR has been similar to the findings of a study with 33 patients in which the 3D echocardiographic analysis has identified LVR in 13 (39%) of the patients studied.\[1\]

It has also been verified that the LVR would not have been diagnosed should the volumetric analysis had been carried out with the use of the 2DE (we have observed an average increase of 8.1% in the LVEDV with the 2D echocardiographic analysis).

The possibility of an early detection of the LVR takes on importance in the sense of a more aggressive pharmacological treatment for the prevention of the progression of the ventricular dilatation.

In relation to the new 3D echocardiographic indices meant for the study of the function and of the geometry of the LV (3D SI), a diverse behavior has been observed in relation to the LVR within 6 months after the AMI. The most striking difference between patients with and without subsequent LV remodeling was a significantly higher 3D SI and indexed LV volumes at baseline in patients with subsequent LV remodeling. The 3D SI at baseline is far more sensitive than LV volumes and EF. Its reproducibility was reasonable given the fact that it is dependent on measurement variability in both EDV and the LV major end-diastolic long-axis length.\[1]\]

It has been verified the association between the 3D SI and the LVR, in a similar fashion in two previous studies with 19 and 33 patients affected by AMI.\[1,15\] In the study with 33 patients, it has been demonstrated that values above 0.25 for the 3D SI would present a sensibility of 100%, a specificity of 90%, a positive predictive value of 87%, and a negative predictive value of 100%, for the forecast of left ventricular remodeling.

In the present study, in the group of patients with remodeling of the LV, the correlation (r) between the 3D SI measured up to 7 days after the AMI and the LVEDV in 6 months has been 0.67, P=0.001. The time difference between the two studies is related to the observation period after the AMI – in the study...
with 33 patients, the analysis has been carried out 12 months after the event and in our study, the analysis has been made after 6 months.

Thus, with the progression of the development and of a more uneventful use of the 3D echocardiographic analysis, it is believed that this technique of imagery might replace the 3D echocardiographic investigation in the clinical follow-up of the patients affected by MI.

**Limitations of the study**

The number of patients studied has been small, thus calling for other analyses with a larger number of patients.

The temporal aspect is important for the morphological and functional alterations of the LV. The study shall be repeated in a longer period (12 and 24 months) after the ischemic event.

**Conclusion**

In this study of patients affected by AMI with ST segment elevation, treated by primary PCI, the remodeling of the LV has been observed in 38% of the patients affected by AMI.

The 3D SI has been associated with occurrence of remodeling of the LV. Unlike the traditional 2D “sphericity or shape indices,” the 3D SI can predict, accurately and early in the subacute phase after AMI, which patient is likely to undergo LV remodeling. Among clinical, electrocardiographic, and echocardiographic variables, it was by far the strongest predictor of subsequent remodeling.

The accuracy, speed, and predictive value of 3DE make it an ideal technique for assessment, risk stratification, and follow-up after AMI.

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**Conflicts of interest**

There are no conflicts of interest.

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