The Use of Real Time Three Dimensional Echocardiography in Assessment of Regional Wall Motion Abnormalities in Comparison to Two Dimensional Echocardiography: Validated by Coronary Angiography

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Abstract

Background: Real-time three-dimensional echocardiography (RT3DE) is a novel imaging technique that offers a rapid acquisition with multiple simultaneous views of the left ventricle (LV). These features make it more attractive than the subjective two-dimensional echocardiography (2DE) visual method for assessment of regional wall motion abnormalities (RWMA).

Aim of Work: We aimed to evaluate a new semi-automatic assessment of RWMA based on parametric imaging (PI) of RT3DE compared to traditional visual assessment of 2DE, and validated by coronary angiography.

Methods: The study included 100 myocardial infarction (MI) patients having STMI and NSTMI. RWMA were assessed by both conventional 2DE and PI of RT3DE according to the 17 segment LV model. Coronary angiography was performed for all patients and the angiographic data was used as the gold standard to compare the diagnostic ability of both methods for RWMA detection.

Results: There was a good agreement between PI of RT3DE and 2DE in assessment of RWMA of all 5 segments supplied by LCX, 5 of 7 segments supplied by LAD, and 3 of 5 segments supplied by RCA.

Sensitivity of RT3DE was significantly higher than 2DE (60.71% vs 47.32%, \( p=0.001 \)) for detection of RWMA in LAD lesions, while modest non-significantly higher RT3DE sensitivity was detected in LCX and RCA lesions (66.33% vs 54.00%, \( p=0.074 \)) and (62.77% vs 53.88%, \( p=0.140 \)) respectively. There was no significant difference between RT3DE and 2DE specificity for LAD, LCX, and RCA lesions (89.68% vs 90.07%, \( p=0.865 \)), (87.42% vs 89.14%, \( p=0.063 \)) and (79.06% vs 80.62%, \( p=0.568 \)) respectively.

Sensitivity of RT3DE for correct identification of increased WMSI was significantly higher than 2DE in NSTMI (\( p=0.031 \)) and was near significant in STMI patients (\( p=0.063 \)).

Conclusion: Parametric imaging of RT3DE can be used for assessment of RWMA with good agreement to visual assessment of conventional 2DE. Compared to 2DE, RT3DE has better sensitivity to detect RWMA in segments supplied with LAD. It has also better sensitivity than 2DE in assessment of WMSI in patients with NSTMI.

Key Words: Parametric imaging – Real-time three-dimensional echocardiography – Regional wall motion abnormalities.

Introduction

ECHOCARDIOGRAPHY is the most frequently used modality to study left ventricular (LV) wall motion abnormalities in ischemic heart. It is indeed used in emergency rooms and intensive care units [1]. Multiple two-dimensional (2D) views of the LV must be obtained from more than one window to completely visualize all segments using conventional 2DE assessment of regional wall motion abnormalities (RWMA) which is operator dependent and time-consuming [2]. Real-time three-dimensional echocardiography (RT3DE) volumetric data sets can capture a plethora of information at the level of each myocardial segment over the entire cardiac cycle. Qualitative methods suffer from high inter-observer variability in assessment of RWMA which is crucial in patients with ischemic heart disease. Quantitative 4-D semi-automated...
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Segmentation techniques permit color coding of individual cardiac segments to be displayed either as a surface or as parametric maps in cine format over the entire cardiac cycle [3].

Advanced 3D Quantification (3DQ) offers new parametric imaging (PI) for enhanced quantitative and qualitative assessment of ischemia (excursion display) and dyssynchrony (timing display). The first allows a bull’s eye representation of wall excursion whereby dark areas represent reduced excursion and bright blue areas are those that exhibit the largest systolic radial excursion. On the contrary, the red areas represent the dyskinesia [4]. The present study aimed to examine the value of PI of RT3DE as a new technique for detection of RWMA compared to visual assessment by 2DE, using coronary angiography as a validation reference.

Material and Methods

Out of 146 patients with documented STMI or NSTMI myocardial infarction (MI) and scheduled for coronary angiography in our cardiology department, 100 patients were included in the study starting from May 2009 till March 2011. The other 46 patients were excluded due to poor echo image quality (23), abnormal interventricular septal motion caused by bundle branch block or pacemaker implantation (5), coronary angiography showing significant left main disease (4), and recent myocardial infarction (<2 weeks) (2). Meanwhile, non-significant lesions (50%) at different coronary artery territories were detected in 12 patients. Data of these patients was excluded for further analysis in a larger group of patients. Written consents were obtained from patients before participation in the study. The investigational protocol was approved by the Ethical Committee.

Before enrollment in the study, all patients were subjected to full history taking, examination of 12-lead surface ECG, and documentation of previous MI (raised Troponin-I, CK-MB, ECG changes). Then, echocardiographic data were collected from both 2D and RT3DE to assess LV function and RWMA. All echocardiographic data were verified by two experienced cardiologists and regional wall motion was scored accordingly. Finally, coronary angiography was performed within 24 hours after echocardiographic assessment. The ability of each method to correctly identify the culprit artery per patient was determined. When the majority of RWMA were located in the territory supplied by a culprit artery, the patient was considered correctly diagnosed and vice versa. The sensitivity and specificity of both echocardiographic methods were determined versus the angiographic findings as a gold standard.

Echocardiographic assessment

Echocardiographic evaluation was done using Philips iE 33 device, soft ware level 2.1.0.507 equipped with scan-head s5-1. Pure wave crystal x3-1 frequency range 3 to 1MHz 3D matrix array transducer was used to obtain full-volume 3D data. Visual assessment of RWMA of both 2D and RT3DE was done according to the 17 segment LV model of the American Society of Cardiology (ASE). The left anterior descending (LAD) was considered to supply segments 1, 2, 7, 8, 13, 14 and 17. The right coronary artery (RCA) supplies segments 3, 4, 9, 10 and 15 when dominant. The left circumflex coronary artery (LCX) supplies segments 5, 6, 11, 12 and 16 [5]. The segmental wall motion was scored as follows: 1, normal; 2, hypokinetic; 3, akinetic; 4, dyskinetic. The global wall motion score index (WMSI) was then calculated by dividing the sum of individual segmental scores by the number of segments.

a- Two dimensional echocardiography:

Apical two-chamber and four-chamber views were utilized to calculate LV end diastolic and systolic volumes, and EF% (LVEDV, LVESV, EF%) by modified Simpson’s method [6].

Using 2DE, standard images were obtained from 3 short axis views (basal, mid, apical LV) and 3 apical views (apical 4-chamber, 2-chamber, and 3-chamber). The segmental wall motion was scored and WMSI was calculated as previously described.

b- RT3DE echocardiography:

For RT3DE assessment, data were obtained from the apical 4-chamber view while the patient is in left lateral position where the entire left ventricular cavity was included within the pyramidal scan volume. A full volume scan was acquired in harmonic mode from 3 consecutive R wave triggered volumes during an end-expiratory breath-hold.

Analysis of RT3DE datasets were performed on a QLAB workstation using the 3DQ-Advanced quantification software package (3DQ-Advanced, version 5.0, Philips) as previously described [7]. Parametric imaging was applied to identify myocardial velocity and excursion at different segments [8]. Bull’s eye representation of wall excursion was used for assessment of RWMA. A gradation of
colors was applied; Blue: Positive motion, Black: No motion, Red: Dyskinetic motion.

Fig. (1) shows an example of a patient with normal wall motion (1a), and a patient with LAD lesion (1b). The segmental wall motion was scored, and then WMSI was calculated as previously described [9].

Coronary angiography

Finally coronary angiography was performed in the standard techniques for visualization of the coronary arteries in different views for all patients within 24 hours from the echo assessment. A luminal narrowing of ≥50% was considered significant. The angiographic data of all patients was used as the gold standard to compare the diagnostic ability of the 2 echocardiographic methods for detection of RWMA according to 17-segment model of ASE. Correct identification of abnormal segmental contraction was considered when it was detected in the territory supplied by the culprit artery, and incorrect when it was detected in a non-culprit artery territory. Accordingly, the ability of each method to correctly identify the culprit artery per patient was determined.

Statistical analysis

- Descriptive statistics:

  Mean, standard deviation (±SD), median, minimum and maximum values (range) were calculated for numerical data. Frequency and percentage were used for non-numerical data.

- Analytical statistics:

  Independent-Samples student " t" test was used to assess the statistical significance of the difference between the two study group means. Correlation analysis (using Pearson's method) was done to assess the strength of association between two quantitative variables. The correlation coefficient denoted symbolically " r" defines the strength and direction of the linear relationship between two variables. Paired t-test was used to assess the statistical significance of the difference between two means measured twice for the same study group.

  Chi-Square test was used to examine the relationship between two qualitative variables. McNemar test was used to assess the statistical significance of the difference between a qualitative variable measured twice for the same study group. Kappa statistics was used to compute the measure of agreement between the two echocardiographic methods.

  p-value: level of significance :  

  \( p > 0.05 \): Non significant (NS), \( p < 0.05 \): Significant (S), \( p < 0.01 \): Highly significant (HS).

Results

The study included 100 patients (65 males, 35 females) with MI (76% STMI, 24% NSTEMI) aged 54.88±9.68 years. Clinical and demographic data of the study population is summarized in Table (1). Fourteen of these patients had normal coronary angiography. Out of 86 patients with significant coronary artery disease (CAD), 53 had single vessel disease (SVD); 37 in LAD; 8 in LCX; 8 in RCA. Thirty three had multivessel disease (MVD); 5 in LAD and LCX, 11 in LAD and RCA, 6 in LCX and RCA, and 11 in all of LAD, LCX and RCA.

There was a good agreement between PI of RT3DE and 2DE in assessment of RWMA of all the 5 segments supplied by LCX (kappa (κ) coefficient was 0.437, 0.432, 0.444, 0.489 and 0.416 for segments 5, 6, 11, 12 and 16 respectively), all segments supplied by LAD except for segments 2 and 14 (kappa (κ) coefficient was 0.552, 0.475, 0.407, 0.465, and 0.503 for segments 1, 7, 8, 13 and 17 respectively), and 3 of 5 segments supplied by RCA (kappa (κ) coefficient was 0.458, 0.580, 0.611 for segments 3, 4 and 9 respectively).

PI of RT3DE had significantly higher sensitivity than 2DE for detection of RWMA in the presence of significant LAD lesion (60.71% vs 47.32%, \( p = 0.001 \)) as shown in (Fig. 2), while there was no significant difference between sensitivity of both methods in case of significant LCX (66.33% vs 54.00%, \( p = 0.074 \)) and RCA lesions (62.77% vs 53.88%, \( p = 0.140 \)) (Table 2). Meanwhile, specificity of both methods was comparable for detection of LAD, LCX and RCA lesions (89.68% vs 90.07%, 87.42% vs 89.14%, and 79.06% vs 80.62% respectively), \( p > 0.05 \) for all.

Mean WMSI scores calculated by the RT3DE were significantly higher than 2DE (1.41±0.23 versus 1.36±0.23, \( p = 0.012 \)). Using McNemer test, sensitivity of RT3DE for correct identification of increased WMSI was significantly higher than 2DE in NSTEMI (\( p = 0.031 \)) and was near significant in STMI patients (\( p = 0.063 \)) (Table 3). On the other hand, a significant negative correlation was detected between WMSI and EF% assessed by both RT3DE (\( r = -0.837 \)) and 2DE (\( r = -0.814 \); \( p = 0.0001 \) for both (Fig. 3).
Table (1): Patients characteristics.

<table>
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HTN = Hypertension.
D.M = Diabetes mellitus.

Table (2): Comparison of sensitivity of RT3DE and 2DE among cases with significant LAD, LCX and RCA lesions.

<table>
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<td>LAD</td>
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<td>34.89</td>
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<td>RCA</td>
<td>53.88</td>
<td>36</td>
<td>36.03</td>
<td>-1.512</td>
<td>0.140</td>
<td>NS</td>
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Fig. (1): Parametric imaging obtained from RT3DE; Lower panel shows excursion map display (blue: Normal, dark blue: Hypokinetic, black: Akinetic, red: Dyskinetic) while upper panel shows timing map display (green: Normal, red: Delayed contraction, blue: Early contraction.)
Discussion

- There was a good agreement between PI of RT3DE and 2DE in assessment of RWMA of most segments supplied by significantly stenosed coronaries.
- Sensitivity of RT3DE tended to be higher than 2DE in detection of RWMA in the presence of significant CAD. However, the difference between the 2 methods was significant only in LAD lesions.
- Sensitivity of RT3DE for correct identification of RWMA was generally higher than 2DE in both NSTMI and STMI patients.

Using RT3DE full volume dataset, a large amount of data can be obtained from a single acquisition of apical 4-chamber view. Assessment of RWMA can be done by color coding of individual segments displayed on PI Bull eye map. RT3DE have many advantages over visual 2DE assessment of RWMA. It is quantitative, provides rapid image acquisition, requires lower level of operator skills, and avoids LV foreshortening by correct alignment of imaging planes [10].

In the present study, agreement between the 2 echocardiographic techniques was validated by coronary angiography which was done to all patients. Sensitivity and specificity of both methods versus the angiographic findings as a gold standard were determined afterwards. Our results identified a good agreement between PI of RT3DE and conventional 2DE in assessment of RWMA of all segments supplied by LCX and most of segments supplied by LAD (5 of 7), and RCA (3 of 5). Cainai et al., 2006 [11] have used off-line 3D color-encoding of RT3DE images and reported an agreement with expert visual interpretation of 2DE associated with 91% sensitivity, 80% specificity, and 84% accuracy. The results of previous studies [12,13] evaluating PI generated from different echocardiographic techniques have also demonstrated its ability to identify myocardial ischemia correctly with good agreement to black and white 2DE images. Other investigators [14,15] used parametric images derived from contrast-enhanced echocardiograms to increase accuracy of RWMA in patients with poor acoustic windows and they reported improved diagnostic accuracy of inexperienced readers, and more objective detection of RWMA. However, these new techniques are not available for routine assessment.

Sensitivity and specificity of both 2DE and RT3DE were more commonly studied using dob-
utamine stress echocardiography (DSE) than resting echocardiography. The reported range of sensitivity for detection of CAD by 2D DSE varies from a low of 54% to a high of 95% [16-19].

In the present study, resting echocardiographic assessment of RWMA revealed comparable specificity of visual 2DE and PI of RT3DE. Meanwhile, PI of RT3DE recorded higher sensitivity than 2DE for detection of RWMA in the presence of significant LAD, RCA, and LCX lesions. However, the difference between the 2 methods was significant only in LAD lesions lesion (60.71% vs 47.32%, p=0.001). This is probably due to the fact that the LAD territory is in the near field of the transducer and, therefore, is less sensitive to ultrasound attenuation, as suggested by some studies [20,21]. In agreement with our results, Aggeli et al., 2007 [22] have reported higher sensitivity of RT3D than 2D DSE for detection of myocardial ischemia when validated with angiographic data. This was more evident in the LAD territory in particular, where RT3DE had higher regional wall-motion scores. In another study, when SPECT was used as reference, myocardial ischemia could be adequately evaluated only in the LAD coronary territory, using contrast parametric images generated from real-time perfusion adenosine stress echocardiography [13].

On the other hand, a higher WMSI was calculated by RT3DE vs 2DE. Comparable results were observed by Ahmad et al., 2001 [2] using RT3DE DSE which was explained by visualization of all segments in a more complete and simultaneous pattern using RT3DE. We also found that the ability of RT3DE for correct diagnosis of abnormally increased WMSI was significantly higher than 2DE in NSTMI (p=0.031) and was near significant in STMI patients (p=0.063) (Table 4). This can be attributed to higher sensitivity of RT3DE to detect RWMA in less significant stenosis that was generally found in NSTMI lesions.

Meanwhile, a significant negative correlation was detected between WMSI and EF% assessed by both RT3DE and 2DE (Fig. 3). Other investigators have also reported that patients with a low LVEF have higher rates of increased WMSI [23-25]. This was also associated with increased rates of MI and cardiac death [9]. More recently, it was suggest that LVEF evaluation using the echocardiographic WMSI method is accurate and correlates well with standard magnetic resonance imaging planimetric assessment [26].

The authors of the present study declare that they have no competing interests.

**Limitations:**

RT3DE is an evolving technology which has some limitations; it has lower temporal and spatial resolution than 2DE and requires longer analysis time [10]. Although coronary angiography was performed to all patients, some territory mismatch can happen due to anatomical variability; therefore incorrect interpretation is possible in these cases. We agree with Gudmundsson et al., 2010 [13] that even if the parametric images are quantitatively generated, there is still a visual and, therefore, subjective component, since the echocardiographer has to be meticulous in defining the apical point and the points around the mitral valve. On the other hand, the reader of the images has to decide carefully the degree of kinesia according to the color map grading. However, compared to studies with merely visual analysis, our results show good agreement (kappa) and generally higher sensitivity.

**Recommendations:**

The RT3DE technique we used can be easily applied using commercially available devices. It can be mastered quickly by cardiologists and echocardiographers trained in routine 2DE. The ability to visualize all LV segments from a single acquisition makes echocardiographic performance technique less demanding and less time-consuming. With advances in transducer technology, smaller matrix footprints, and automated softwares, 3D full LV volume image acquisition can be obtained with a single beat that is less prone to artifacts [10]. Meanwhile, larger clinical trials validated by coronary angiography are needed to establish the efficacy of PI of RT3DE in detection of CAD.

**Conclusion:**

Evaluation of parametric images generated from RT3DE full volume dataset may correctly identify ischemia in patients with significant CAD with good agreement to visual assessment by conventional 2DE. It has better sensitivity to detect RWMA in segments supplied with LAD. It also has better sensitivity than 2DE in assessment of WMSI in patients with NSTMI.

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References


