Original Article

The correlation between myocardial perfusion scintigraphy and three-dimensional echocardiography in ejection fraction and cardiac volumes for determination of the nearest filtering parameters

ABSTRACT

End-diastolic volume (EDV), end-systolic volume (ESV), and ejection fraction (EF) are cardiac volumes that have crucial roles in diagnosis of cardiovascular diseases (CVD) in patients. There are differences between these mentioned parameters in echocardiography (Echo) and myocardial perfusion scintigraphy (MPS) in clinical practice. In this study, we determined the nearest filtering parameters in the analysis of MPS data in comparison with three-dimensional echocardiography (3DE). All of patients were in this study, and 3DE and MPS were performed for all patients at rest phase in the same day. MPS images were analyzed through quantitative gated single photon emission computer tomography (SPECT) software with Butterworth filter which was a fixed order (order = 5) and variable cutoffs (COs) of 0.3, 0.35, 0.4, 0.45, and 0.5. The EDV, ESV, and EF values were measured by 3DE and MPS and compared. Based on the above different COs, the ESVs of MPS were 15.5 ± 18 mL, 18 ± 20 mL, 21 ± 22.5 mL, 22 ± 23 mL, and 22.5 ± 23.5 mL, respectively, while ESV of 3DE was 44.4 ± 23.5 mL. It was observed as a significant difference between MPS and 3DE for ESV. The EDVs of MPS were 61.3 ± 24.5 ml, 64 ± 26.5 ml, 68 ± 29.5 ml, 72 ± 31 ml, and 76 ± 32.2 ml, respectively, while EDV of 3DE was 105 ± 30 ml, which was significantly different between two methods. The EFs of MPS were 79% ± 14%, 76% ± 13%, 73.5% ± 12%, 73.5% ± 11%, and 74% ± 11%, respectively. The EF of 3DE was 58.4% ± 10% ml. It was statistically significant difference in values of EF between SPECT analysis parameters and 3DE. It was interesting when the COs increased from 0.3 to 0.5; the cardiac volumes increased while the EF decreased. The measured ESV and EDV values were lower in females than males while the EFs of females were higher than males. Finally, we demonstrate that the nearest Cos for measuring of EF and cardiac volumes for analysis of MPS data in comparison with 3DE are 0.45 and 0.5, respectively.

Keywords: Echocardiography, ejection fraction, end-diastolic volume, end-systolic volume, myocardial perfusion scintigraphy

INTRODUCTION

The exact measurement of end-diastolic volume (EDV), end-systolic volume (ESV), and ejection fraction (EF) have been crucial roles for diagnosis of cardiovascular diseases (CVD) and the selection of an optimal treatment strategy.[1-4] Echocardiography, as a noninvasive procedure, is commonly used for determinations of EF, EDV, and ESV. The main challenge in echocardiography (Echo) is highly operator-dependent procedure. Sometimes, there is markedly difference between two operator's reports about EF and volumes, and even,

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there is apparent difference between two measurements of a skilled cardiologist in separate times. Another limitation of Echo is inability to define the endocardial border in some patients with poor image quality.[5]

Myocardial perfusion scintigraphy (MPS) with gated mode not only reveals information about myocardial perfusion but also provides valuable data about systolic and diastolic myocardial function including the regional wall motion, regional wall thickening, EF, EDV, and ESV.[6-11] However, it is associated with limitations such as radiation hazardous to patients and personne[12,13] in comparison with Echo, the MPS is less operator dependent. Moreover, this method works in patients in whom ultrasound methods fail because of a poor acoustic window.[14] Applying different analysis parameters in MPS during image processing result in various measurements for the EF and cardiac's volumes.

Since values of EF, EDV, and ESV are differently measured by Echo and MPS, and also there are different measured values of these parameters by applying different filtering parameters during analyzing of MPS data, then we designed a study to determine the nearest filtering parameter in analysis of MPS data.

MATERIALS AND METHODS

Patient selection

In this study, we prospectively enrolled consecutive patients who were referred for MPS owing to clinical indication. 3DE was performed within 1 h before rest phase of MPS. To prevents unnecessary radiation exposure to personnels and physicians. the MPS carried out after performing of three dimensional echocardiography. All patients were conducted for both 3DE and rest phase of MPS. This study was approved by Ethical Committee of Mazandaran University of Medical Sciences, Sari, Iran (2142).

Gated single photon emission computer tomography myocardial perfusion scintigraphy

Rest MPS acquisition was started after 45–60 min of the intravenous injection of 740–925 MBq 99mtechnetium-methoxyisobutylisonitrile. Data acquisition was obtained with a dual-head single photon emission computer tomography (SPECT) system with the detectors oriented at 90° (Dual-Head Variable-Angle signature E.CAM; Siemens, Germany) equipped with a low-energy high-resolution collimator. A total of 32 projections (step-and-shoot mode, 25 s per view) were obtained over a 180° arc commencing from the right anterior oblique to left posterior oblique view. We used a zoom factor of 1.45 and gating at 16 frames per cardiac cycle. The images were stored in a 64 × 64 matrix in the computer, and then, EF, EDV, and ESV were measured using software package from Cedars-Sinai medical center quantitative gated SPECT after reconstruction by filtered backprojection with a Butterworth filter (a fixed order of 5 and variable increasing cutoffs [CO] of 0.3, 0.35, 0.4, 0.45, and 0.5).

Three-dimensional echocardiography

3DE was performed by Siemens Prime Acuson SC 2000 equipped with 4D transthoracic probe (4Z1C probe). Initially, a high-quality 2D image was achieved from apical four-chamber view, and border of LV was determined by left ventricle analysis software; then, EF, EDV, and ESV were measured (Siemens, Germany) in patients.

Statistical analysis

Statistical analysis was performed with SPSS software (SPSS Statistics for Windows, version 17.0; SPSS Inc., Chicago, IL, USA). Quantitative continuous variables are expressed as mean ± standard deviation, and categorical variables are presented as counts (percentage). The Wilcoxon test was used for the comparison of EF, EDV, and ESV values that were measured with Echo and SPECT.

RESULTS

Patient

Ninety-seven patients (43 male and 54 female) were enrolled in this study consequentially. The average age of participant was 57.58 ± 1.7 years (female: 57 ± 10 years and male: 58 ± 13 years). There is no statistically difference in age between two genders ($P = 0.308$).

End-systolic volume

The ESV values were calculated as 15.5 ± 18 mL, 18 ± 20 mL, 21 ± 22.5 mL, 22 ± 23 mL, and 22.5 ± 23.5 mL based on different COs of 0.3, 0.35, 0.4, 0.45, and 0.5 and fixed order of 5, respectively. The calculated ESV of 3DE was 44.4 ± 23.5 mL. It was observed significant differences in the measured values of ESV between all above-mentioned COs of MPS and 3DE ($P < 0.000$) [Figure 1].

End-diastolic volume

Based on different COs of 0.3, 0.35, 0.4, 0.45, and 0.5 and fixed order of 5, the calculated EDV was 61.3 ± 24.5 ml, 64 ± 26.5 ml, 68 ± 29.5 ml, 72 ± 31 ml, and 76 ± 32.2 ml, respectively. The calculated EDV was 105 ± 30 mL according to 3DE. There was statistically significant difference in the measured values of EDV between all different SPECT analysis parameters and 3DE ($P < 0.000$) [Figure 2].

Ejection fraction

Based on different COs of 0.3, 0.35, 0.4, 0.45, the EF values

were calculated as 79% ± 14%, 76% ± 13%, 73.5% ± 12%, 73% ± 11%, and 74% ± 11%, respectively. The calculated EF of 3DE was 58% ± 10%. It was observed significant differences in the measured values of EF between all above-mentioned COs of MPS and 3DE ($P < 0.000$) [Figure 3].

There was no statistically significant difference in measured values of EF between COs of 0.3 and 0.35 ($P = 0.1$). There was statistically nonsignificant difference in measured values of EF between COs of 0.4, 0.45, and 0.5. However, it was observed significant differences in measured values of EF between COs of 0.3 and 0.35 with 0.4, 0.45, and 0.5 ($P < 0.000$).

Patients with ejection fraction < 50% based on echocardiography

Nineteen patients were categorized as a subgroup with EF <50% based on 3DE. The EF was 43.8% ± 6% in this subgroup according to the 3DE, while the calculated EFs of MPS were 71% ± 18%, 72% ± 18%, 70% ± 17%, 70% ± 17%, and 70% ± 17% based on COs of 0.3, 0.35, 0.4, 0.45, and 0.5, respectively.

Patients with end-systolic volume above 25 mL based on myocardial perfusion scintigraphy data and cutoff of 0.4

Twenty-seven patients were categorized as a nonsmall ESV subgroup based on ESV >25 mL from MPS and CO 0.4. The EF was 57.5% ± 12.5% in this subgroup according to the 3DE. While the EFs of MPS were 62% ± 10%, 60.4% ± 9%, 60.7% ± 8%, 65% ± 12.5%, and 63% ± 10% based on COs of 0.3, 0.35, 0.4, 0.45, and 0.5, respectively [Figure 4].

It was observed a significant difference in EF values between 3DE and CO of 0.3 ($P < 0.00$); but, there were nonsignificant differences in EF values between 3DE and other COs. Except CO of 0.3, there were no significant difference between each CO and other COs. In this subgroup, the closest COs to Echo were 0.35 and 0.4.

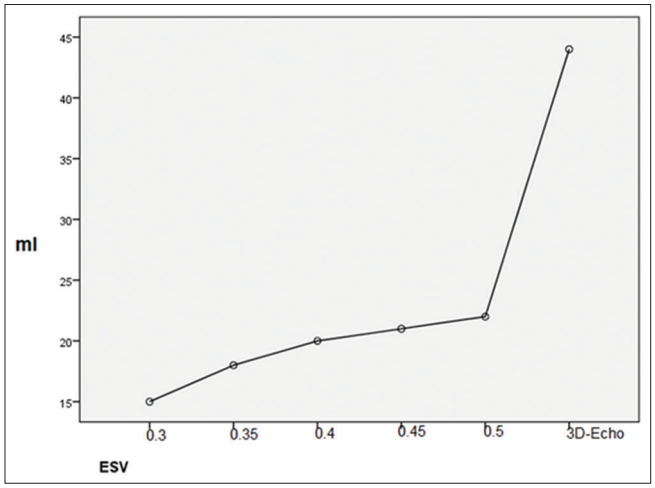

Figure 1: End-systolic volume based on different cutoff

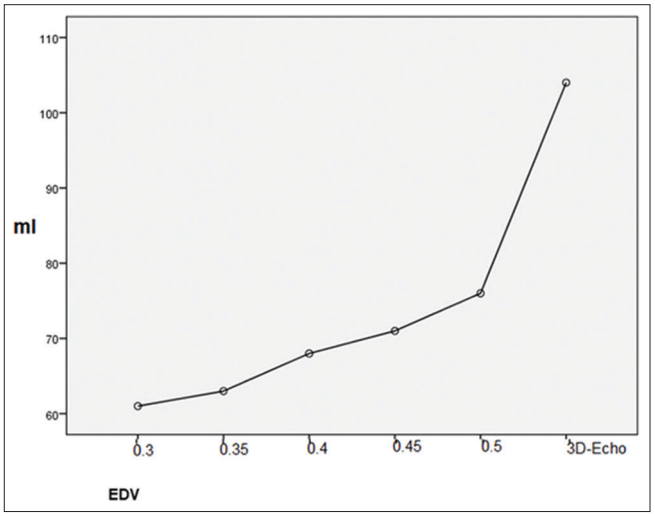

Figure 2: End-diastolic volume based on different cutoff

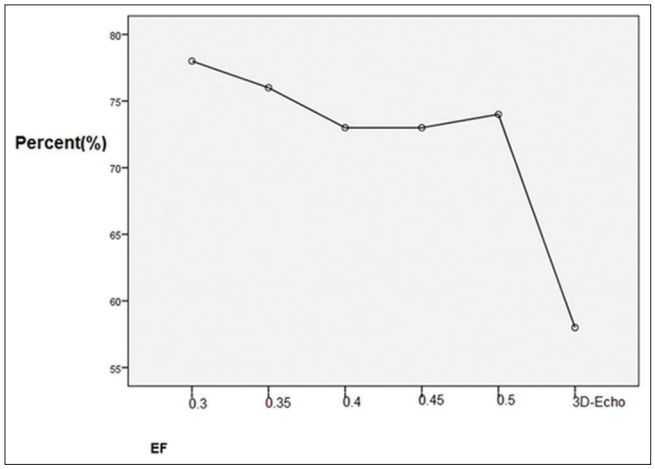

Figure 3: Ejection fraction based on different cutoff

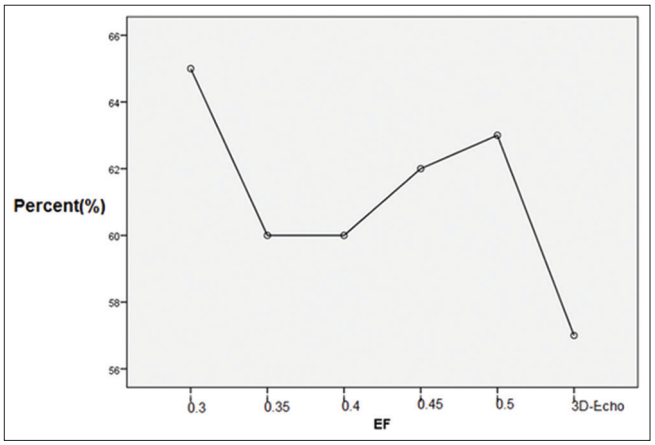

Figure 4: Ejection fraction based on cutoff of 0.4

Comparison of ejection fraction of myocardial perfusion scintigraphy and three-dimensional echocardiography between male and female

The EFs of Echo were 58.2% ± 10.6% and 58.4% ± 9% in male and female, respectively. The EFs of MPS for COs of 0.3, 0.35, 0.4, 0.45, and 0.5 were 73% ± 14%, 68% ± 11%, 66.5% ± 11%, 68% ± 10%, and 68.5% ± 10.5% for male and 83.6% ± 12.5%, 82.5% ± 10.2%, 79% ± 9.5%, 78% ± 9%, and 78.5% ± 9% for females, respectively for male and females, respectively.

when compared EF of all patients, there was a statistically significant difference in EF of MPS between two genders in all COs ($P < 0.0001$), while there was no significant difference in EF of 3DE between two genders. However; there was significant difference in EF of MPS and 3DE between males in all COs ($P < 0.0001$) and also there was significant difference in EF of MPS and 3DE between females in all COs ($P < 0.0001$). in addition, there was significant difference in EF of MPS and 3DE between males in one hand and females in the other hand when compared to together in all COs ($P < 0.0001$).

DISCUSSION

In this study, the nearest filtering parameter in analysis of MPS data was determined for calculation of EF, EDV, and ESV values in comparison with 3DE. The findings demonstrated the increasing of CO from 0.3 to 0.5 of Butterworth filter during image processing of MPS is correlated to increased ESV (18 ± 15 mL to 23.5 ± 22.5 mL) in all groups of patients. The ESVs were markedly increased from CO 0.3 to 0.35 as compared to other COs values. This finding is probably due to the blurring of LV cavity at the end systole that is caused by radiation scattering of adjacent walls that results in underestimation of ESV. The nearest CO was 0.5 for calculation of MPS's ESV in comparison with 3DE. The same results were observed for EDV.

This study demonstrated that increasing of CO from 0.3 to 0.5 of Butterworth filter during image processing of MPS is accompanied by decreasing in EF (79% ± 14 − 74% ± 11%) in all groups of patients. The nearest CO was 0.45 for calculation of MPS's EF in comparison with 3DE's EF, although these differences were insignificant between COs of 0.4, 0.45, and 0.5.

As a whole, in this study, there was statistically significant difference between the measured values of EF of MPS among the different applied COs, and also it was observed significant differences in the measured values of EF between the different applied COs and 3DE by head to head comparison. in a subgroup of patients with EF <50% based on 3DE, the selection of above mentioned COs did not significantly affect on the calculated values of EF of MPS. Moreover, This research demonstrated that in a subgroup of patients with ESV greater than 25ml (defined as "nonsmall ESV" patients' subgroup), except in CO of 0.3, the selection of other above mentioned COs did not significantly affect on the calculated values of EF of MPS.

Lipiec *et al*. showed that the differences in EF measurements between MPS and 3DE were observed in patients with small left ventricular cavity (ESV <25 mL) by a factor 20%.[15] Danesh-Sani *et al*. applied Butterworth filter backprojection with CO value of 0.35 cycle/cm and order of 5 for analysis of MPS study and then they compared the calculated values of MPS and 2DE. In this study, there was no significant difference in ESV, EDV, and EF between MPS and 2DE in patients with ESV >25 mL. There was significant difference in ESV, EDV, and EF between MPS and 2DE in patients with ESV <25 mL.[16]

Cosyns *et al.* compared contrast-enhanced 3DE (RT3DE) with MPS for the evaluation of left ventricular function. They demonstrated that the mean EDV values of MPS, triplane contrast RT3DE, and full-volume contrast RT3DE groups were 143 ± 65 mL, 128 ± 60 mL, and 132 + 62 mL ($P < 0.001$). They demonstrated that the mean ESV values of MPS, triplane contrast RT3DE, and full-volume contrast RT3DE groups were 88 ± 62 mL, 75 ± 54 mL, and 80 ± 57 mL ($P < 0.001$). The mean MPS's EF was 44% ± 16% with scintigraphy that was insignificantly different with both triplane contrast RT3DE (45% ± 15%) and full-volume contrast RT3DE (45% ± 15%).[14] Berk *et al*. demonstrated that the EF, EDV, and ESV values of MPS were 27% ± 9%, 212 ± 71 mL, and 160 ± 67 mL, respectively, in patients with dilated cardiomyopathy. With Echo, these values were 29% ± 8%, 197 ± 56 mL, and 139 ± 47 mL, respectively. A good correlation was observed between MPS and 2DE ($r = 0.72$, $P < 0.01$) in measured values of EF. The correlations for EDV and ESV were wider limits of agreement ($r = 0.71$, $P < 0.01$ and $r = 0.71$, $P < 0.01$, respectively) and with significantly higher values with MPS ($P < 0.01$).[17] The mean EDV values were 86 ± 30 mL and 139 ± 35 mL on MPS and 2DE, respectively. The mean ESV values were 36 ± 21 mL and 63 ± 19 mL on MPS and 2DE. The mean values for EF were 62% ± 13% and 55% ± 8% on MPS and 2DE. They observed significant difference between two techniques in all measured values.[18]

For comparing of MPS and Echo, in all previously mentioned studies, the authors used a single CO for analysis of MPS study but we applied different COs.

CONCLUSION

Our study demonstrated that increasing of CO from 0.3 to 0.5 of Butterworth filter during image processing of MPS is

accompanied by increasing in EDV and ESV and decreasing in EF in all groups of patients; therefore, applying different CO usually creates significantly different values for cardiac volumes and EF, which is more prominent for cardiac volumes. There was statistically significant difference between measured EDV, ESV, and EF values by 3DE and MPS in all COs. In patients with ESV ≥25 mL, except in CO = 0.3, the measured EF values from other COs were no significantly differed to EF measured by 3DE. The measured values of EDV and ESV in female were lower than the male in all COs, while the EF of female was higher than male. Finally, in comparison with 3DE, for analysis of MPS data, we demonstrated that the nearest COs for measuring of EF and cardiac volumes (EDV and ESV) were 0.45 and 0.5, respectively.

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Conflicts of interest

There are no conflicts of interest.

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