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Research Paper

Estimation of Left Ventricular Ejection Fraction by Real-Time Three Dimensional Echocardiography in Comparison to Other Linear and Volumetric Methods in Coronary and Valvular Heart Diseases

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ABSTRACT:

BACKGROUND:
More dependence on real-time three dimensional echocardiography, is in practice in the assessment of LV systolic function in coronary and valvular heart disease.

OBJECTIVE:
To investigate the accuracy of linear M-MODE and volumetric (BIPLANE and TRIPLANE) echocardiographic method versus the REAL-TIME 3DE in assessment of regional and global LV systolic function (depending on the high agreement of RT -3DE with CMR which is the gold standard in assessment of LV systolic function) and to start orientation to this issue in our centers.

PATIENTS AND METHOD:
This study included 60 patients with coronary heart disease and valvular heart disease who were admitted in Iraqi center for cardiac disease, for whom the LV systolic function is assessed by EF% by using 3 methods which are M-mode, biplane, triplane methods and compare it with RT-3D echocardiography.

RESULTS:
There is a significant difference between RT-3D echocardiography and old measures, (M-mode , sensitivity and specificity was 74.3% , 95.2% respectively) and that of (Biplane was 97.4%, 95.2% respectively), while there is no significant difference with triplane method in the assessment of LV systolic dysfunction by EF% in coronary and valvular heart disease as it was (97.4% , 100% respectively)

CONCLUSION:
Real-time three dimensional echocardiography provides more valuable and accurate clinical information that empowers echocardiographers with new levels of confidence in the diagnosis of LV systolic dysfunction in coronary and valvular cardiac disease.

KEYWORD: Left ventricular EF%, Real-time 3dimensional echo, linear ,volumetric measurement.

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INTRODUCTION:

Left ventricular (LV) volumes and ejection fraction (EF) are important predictors of cardiac morbidity and mortality. They provide valuable prognostic information which is particularly useful in the selection of therapy or determination of the optimal time for surgery. It represents an indicator of myocardial pump performance; however, it is strongly influenced by loading conditions [(1)], geometric assumptions, paradoxical septal motion, irregular heart rhythm and sinus heart rhythm whether it is so fast or very slow may affect the reproducibility[(2,3)]. Two-dimensional (2D) echocardiography is the most widely used non-invasive method for assessment of LV systolic function; however, it has several limitations in measuring LV volumes and EF since the formulas for quantifications are based on geometrical assumptions. Three-dimensional (3D) echocardiography has been available for almost two decades, although the use of this modality has not gained wide spread acceptance. It can overcome the above mentioned limitation in LV volume and EF evaluation since it is not based on geometrical assumption. It has been shown in several studies, to be more accurate and reproducible with low inter- and intra-observer variability in comparison to 2D echocardiography regarding the measurements of LV volumes and EF [4,5].

PATIENTS AND METHOD:

Across sectional study was conducted to evaluate LV systolic function for sixty patients, 38 patients with coronary heart disease prepared for CABG and 22 patients with valvular heart disease prepared for valve replacement, LV EF% was measured according to the ASE guidelines for all of them by four methods 2D guided M-mode, 2D Biplane (Simpson's method), 3D Guided- Triplane and RT-3DE(4D). The total time (acquisition and analysis) needed for each one of these methods was calculated.

Exclusion criteria:

1.Congenital heart disease.
2. Patients with poor acoustic window.
3.Vavular heart disease with ischemic heart disease
4. Patients with irregular heart rhythm.

Echocardiography was performed using VIVID E9 GE HEALTH CARE (Horten, Norway), using Matrix Phased Array Sector probe (4V-D), frequency (1.5-4.0 MHZ) foot print 20*42 mm.

RESULTS:

Sixty patients with Coronary heart disease prepared for CABG and Valvular heart diseases prepared for valve replacement had been selected from those who visited the center at time of data collection. The overall mean age of the study population was (57.58 ± 11.22) years ranging from (18-80) years. Of the total study sample 60 patients and distribution of the study population by gender 43 male (72%) and 17 female (28%). 38 patients of the study population (63%) had Ischemic heart disease and 22 patients (34%) had valvular heart disease. RT-3DE evaluation of LVEF% of our study patients is used according to ASE classification 2005. 21 patients (35%) had normal LV function, 14 patients (23%) had mild LV dysfunction, 23 patients (39%) had moderate LV dysfunction while only 2 patients (3%) had severe LV dysfunction.

We found that 2D Guided M-mode sensitivity and specificity in detection of LV systolic dysfunction i.e. <55% was 74.3% and 95.2% respectively giving negative predictive value of 66.6% and positive predictive value 96.6%, 2D- Biplane sensitivity and specificity was 97.4% and 95.2% respectively, giving negative predictive value of 95.2% and positive predictive value of 97.4% while 3D-guided triplane was 97.4% and 100% respectively, giving negative predictive value 95.2% and positive predictive value of 97.4%. (We considered RT-3DE as standard method depending on its high agreement with CMR which represents the gold standard method for assessment of LV systolic function worldwide although it is not available in our country). From other point of view the mean value of difference in IHD between RT-3DE and 2D-Guided M-mode, 2D-Biplane, 3D Guided–Triplane, was (<0.001, 0.004, and 0.481) respectively. While the mean value of difference in VHD between RT-3DE and 2D-Guided M-mode, 2D-Biplane, 3D-Guided Triplane was (< 0.001, 0.025, 0.266) respectively. Also the time need for (data acquisition and analysis) for 2D- guided M-mode, 2D- Biplane, 3D -guided Triplane and RT-3DE was(2 min, 4 min, 5 min, and 5min) respectively.

Table1: Comparison of M-mode echo study findings versus the standardized three dimensional echo study results.

		Three dimensional echo study		Total
		LV dysfunction	Normal LV function	
M-mode echo study findings	Positive	29	1	30
	Negative	10	20	30
	Total	39	21	60

Sensitivity = (29/39) ×100 = 74.3%
Specificity = (20/21) ×100 = 95.2%
Positive predictive value = (29/30) ×100 = 96.6%
Negative predictive value = (20/30) ×100 = 66.6 %

Table 2: Comparison of Simpson's echo study findings versus the standardized three dimensional echo study results.

		Three dimensional echo study		Total
		LV dysfunction	Normal LV function	
Simpson's echo study findings	Positive	38	1	39
	Negative	1	20	21
	Total	39	21	60

Sensitivity = (38/39) ×100 = 97.4%
Specificity = (20/21) ×100 = 95.2%
Positive predictive value = (38/39) ×100 = 97.4%
Negative predictive value = (20/21) ×100 = 95.2 %

Table 3: Comparison of Triplane echo study findings versus the standardized three dimensional echo study results.

		Three dimensional echo study		Total
		LV dysfunction	Normal LV function	
Triplane echo study findings	Positive	38	0	38
	Negative	1	21	22
	Total	39	21	60

Sensitivity = (38/39) ×100 = 97.4%
Specificity = (21/21) ×100 = 100%
Positive predictive value = (38/38) ×100 = 100%
Negative predictive value = (21/22) ×100 = 95.4%

Table 4: The mean differences of ejection fraction between M-mode and Three dimensional echo studies in VHD.

Variable	Categories	N	Mean ± S.D	Paired t-test	df	P value
Ejection fraction	M-mode	22	55.77 ± 13.7	4.32	21	<0.001**
	3D	22	53.68 ± 13.24			

**p- value ≤ 0.01 was significant *p-value ≤ 0.05 was significant

Table 5: The mean differences of ejection fraction between Simpson`s and Three dimensional echo studies in VHD.

Variable	Categories	N	Mean ± S.D	Paired t-test	df	P value
Ejection fraction	Simpson`s	22	54.22 ± 12.89	2.421	21	0.025*
	3D	22	53.68 ± 13.24			

*P value ≤ 0.05 was significant **p value ≤ 0.01 was significant

Table 6: The mean differences of ejection fraction between triplane and Three dimensional echo studies in VHD.

Variable	Categories	N	Mean ± S.D	Paired t-test	df	P value
Ejection fraction	Triplane	22	53.68 ± 13.24	1.142	21	0.266
	3D	22	53.68 ± 13.24			

*p value ≤ 0.05 was significant **p value ≤ 0.01 was significant

Table 7: The mean differences of ejection fraction between M-mode and Three dimensional echo studies in IHD.

Variable	Categories	N	Mean ± S.D	Paired t-test	df	P value
Ejection fraction	M-mode	38	51.94 ± 12.05	4.549	37	<0.001**
	3D	38	44.94 ± 10.56			

*pvalue ≤ 0.05 was significant **p value ≤ 0.01 was significant

Table 8: The mean differences of ejection fraction between Simpson`s and Three dimensional echo studies in IHD.

Variable	Categories	N	Mean ± S.D	Paired t-test	df	P value
Ejection fraction	Simpson`s	38	46.55 ± 9.95	3.03	37	0.004**
	3D	38	44.94 ± 10.56			

*pvalue ≤ 0.05 was significant **p value ≤ 0.01 was significant

Table 9: The mean differences of ejection fraction between Triplane and Three dimensional echo studies in IHD.

Variable	Categories	N	Mean ± S.D	Paired t-test	df	P value
Ejection fraction	Triplane	38	45.10 ± 10.69	0.712	37	0.481
	3D	38	44.94 ± 10.56			

*p value ≤ 0.05 was significant **p value ≤ 0.01 was significant

Table 10: Time of data acquisition and analysis of each method.

Method	M-mode	Simpson˙s	Triplane	3D
Time	2 min	4 min	5 min	5 min

DISCUSSION:

According to our results we found that M-mode sensitivity and specificity in detection of LV systolic dysfunction were 74.3% and 95.2% respectively, giving positive predictive value (96.6%) and negative predictive value (66.6%), 2D Biplane sensitivity and specificity and its positive predictive value and negative predictive value were 97.4%, 95.2%, 97.4%, and 95.2% respectively while those of 3D-guided triplane were 97.4%, 100%, 100%, and 95.4% respectively. So all three methods have high specificity to detect normal LV systolic function, as those three methods are more representative, accurate, reproducible when there is normal geometry of LV thus, 2D and triplane provide a global assessment in a symmetrically contracting LV, while the low sensitivity of M-mode to detect LV dysfunction is related to that it depends on a single plane, and does not reflect the true minor axis dimension, so the severity of LV dysfunction may be underestimated if only a normal region is interrogated or overestimated if M-mode beam transits through the wall motion abnormalities exclusively [6].

The sensitivity of 2D Biplane and 3D-guided triplane, to detect LV systolic dysfunction that means the EF% less than 55% is high. However, the 2D biplane method was less efficient in assessing the real severity of LV dysfunction [7,8,9]. We could not find data about sensitivity, specificity and or predictive values for any of these tests in comparison to others.

In patients with coronary artery disease, we found significant difference between EF% assessed by M-mode and that obtained by RT-3DE (p-value was <0.001) as there is a regional wall motion abnormality and four cases had apical aneurysm, and the M-mode provides information about contractility along single line so the severity of dysfunction may be underestimated if only a normal region is interrogated or overestimated if M-mode beam transit through the wall motion abnormalities exclusively, and also it does not reflect the true minor axis dimension. The previously used Teichholz or Quinones methods of calculating LV EF% from LV linear dimensions may result in inaccuracies as a result of the geometric assumptions required to convert a linear measurements to a three dimensional volume as the heart is a cone shape [10,11]. Accordingly, the use of linear measurements to calculate LV EF is not recommended for clinical practice, as it is abandoned from ASE Guidelines since 2005 [6].

In agreement with our findings and understanding of our results, R Shull MD et al. found that M-mode overestimate the (EDV,ESV,SV) pre and post cardiopulmonary bypass so there is a significant difference as compared to the RT-3DTEE and thermo dilution data (which is a gold standard for LV volume measurements) [12].

Also Lu , X , Xie ,M et al. (2008) showed that MM provides the most efficient assessment of LV indices but is the least accurate and reproducible technique compared with 2DE and 3DE . Three dimensional echocardiography using both automated and manual analysis algorithm, is superior to MM and 2DE for measurement of LV indices [13].

We also, found a significant difference between EF% assessed by 2D-Biplane and that measured by RT-3D (p-value was < 0.004) and this reading is nearly similar to what Dorosz JL et al. (2012) found in which the difference in variance was statistically significant (p < 0.001) for all 3 measurements. (EDV, ESV, EF %) between 2D Biplane method and RT-3D method [14]. Also, Buck T et al. (1997) reported the superiority of RT-3DE above M-mode and Biplane method in determination of chamber size and systolic function in patient with LV aneurysm as compared to the CMR [15].

This may be related to that LV volumes are calculated using some assumptions made about the shape of LV which are not always valid ,particularly in a heart with regional LV dysfunction and LV aneurysm because it can evaluate only four walls of the LV (anterior, inferior, lateral, and septum),and wall motion abnormalities in the anteroseptal, and posterior(inferolateral) walls cannot be evaluated in the recommended biplane method and some parts of the endocardial border are not well delineated ,causing uncertainty in deciding where to trace the outline of LV cavity, as the trabeculations, papillary muscles and false tendons may cause mistake in the tracing so this result in intra-observer variability of LV volumes and EF%. Another cause of such variability is the choice of frame at end diastole and end systole also sometime foreshortening of LV cavity lead to underestimation of LV volume. Also Lu, X, Xie, M, et al. (2008), showed that three-dimensional echocardiography using both automated and manual analysis algorithm is superior to MM and 2DE for measurements of LV indices [13]. We found that there is no significant difference between the mean EF% of 3D-guided triplane and that of RT-3DE in coronary heart disease and this is similar to the result of Holger Thiele 1 et al [16], and also similar to the result of Stephan Stoebe1 et al(2012) [17] and this is related to that triplane method covers 3 apical view A2C,A3C,A4C which means that the anterior, inferior, anteroseptal, inferolateral, inferoseptal, and anterolateral walls are represented in one cycle which decrease artifact , intra -observer variability and decrease foreshortening .

In patients with valvular heart disease, we found that there is no significant difference between RT-3DE and 3D Guided- triplane as the (p<0.266), so there is high agreement between them , but there is a significant difference between M-MODE and RT-3DE (p<0.001), and 2D (Biplane method) with RT-3DE was (p<0.025). And this is nearly similar to the result of Eder V et al. (2012) in which the correlation between EF evaluated by 3DE and 2DE was modest (r=0. 55; P=0.001 for the whole group) [18]. and this may be explained by that geometry may change not only in IHD but also in valvular heart disease as global reduction of systolic function is frequently accompanied by regional variation [19].

This may be related to that remodeling process which is the change in size, geometry and function can also occur in valvular heart disease, hypertension, DCM without ischemia. Remodeling may be compensatory in chronic pressure overload because of systemic hypertension or aortic stenosis resulting in concentric hypertrophy (increased wall thickness, normal cavity volume, and preserved EF). Compensatory LV remodeling also occurs in chronic volume overload associated with mitral or aortic regurgitation, which induces a ventricular architecture characterized by eccentric hypertrophy, LV chamber dilatation, and initially normal contractile function. Pressure and volume overload may remain compensated by appropriate hypertrophy, which normalizes wall stress in such a way that hemodynamics and EF remain stable during the long term. However, in some patients, chronically increased afterload cannot be normalized indefinitely and the remodeling process becomes pathologic. Transition to pathologic remodeling is heralded by progressive ventricular dilatation, distortion of cavity shape, and disruption of the normal geometry of the mitral annulus and subvalvular apparatus resulting in mitral regurgitation. The additional volume load from mitral regurgitation escalates the deterioration in systolic function and development of heart failure. LV dilatation begets mitral regurgitation and mitral regurgitation begets further LV dilatation, progressive remodeling, and contractile dysfunction [6].

Our result may differ from Lang RM et al. (2005) opinion which reported that “Although linear measures of LV function are problematic when there is a marked regional difference in function, in patients with uncomplicated hypertension, obesity, or valvular diseases, such regional differences are rare in the absence of clinically recognized MI. Hence, EF% and its relationship to end-systolic stress, often provide useful information in clinical studies” [20].

The accuracy and inter- and intraobserver reproducibility of left ventricular volumes derived from three dimensional data sets exceed that of two-dimensional imaging. The magnitude of improvement in accuracy is not always at a level likely to result in a change in clinical decision. but other studies agree with the changes in clinical decision making 10-15% of the patients especially in patients with EF% between (25-50) % [5].

Also The total time (acquisition and analysis) used for MM, 2D Biplane, 3D-guided triplane, RT-3DE measurements was (2min, 4min, 5min, and 5min) respectively, so M-mode was the least compared with 2DE and 3D-guided triplane, RT-3DE, and this may explain why we still insist on using of M-mode in regard to the high load of patients in echo department of most hospitals. The total time for 3DE using the semi-automated algorithms was similar to that of triplane method and not significantly different compared with that for 2DE, and this is similar to that of Lu, X, Xie, M, et al. (2008)[13]. This time difference may not be important if we put in mind the higher accuracy of 3D guided –Triplane and RT-3DE results and their implication on treatment decision.

Furthermore, the learning scale and speed of doing the echo study by these new methods are expected to be increasingly better if we start to use them routinely in our echo labs.

Limitation of study

1. Limited number of patients because of time limitation as we used a demonstration unit set with time limited license activation for RT-3DE modality.
2. The absence of gold standard method like CMR
3. Need to evaluate different heart diseases
4. Its feasibility is limited by multibeat acquisition, which requires an optimal breath-hold and a regular heart rhythm.

CONCLUSION:

1. M-mode method has high specificity but modest sensitivity to detect LV dysfunction while 2D –Biplane, and 3D-guided Triplane has high specificity and sensitivity in detection of LV systolic dysfunction.
2. There is a significant difference between RT-3DE and both 2D-guided M-mode, 2D-Biplane method in assessment of LV global and regional systolic dysfunction, while there is no significant difference between RT-3DE and 3D-guided Triplane method.
3. Also, the time needed for data acquisition for each of the three method is nearly similar while it is shorter by M-MODE.

Recommendation

1. For many imaging departments, the transition from linear measurements by M-MODE and the available volumetric modality which is 2D (biplane) to Multiplane or Real time –three dimensional imaging in routine practice involves crossing a bridge between two distinct ways of approaching the key areas of clinical interpretation, reporting, application technique, and overall workflow. This inevitably involves a learning curve which will be of benefit in clinical decision making surgical planning, workflow efficiency and this is highly worthwhile investment.

2.The adoption of this techniques in the clinical laboratory may be limited by inexperienced personnel. An interactive teaching course with rehearsal and direct mentoring appears to overcome this limitation and may improve the acceptance of this technique, as the demand for 3DE will grow accordingly and is likely to soon be incorporated into mainstream cardiac guidelines .

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