

Estimation Of Left Ventricular Ejection Fraction Using Mitral Annular Displacement Derived By Speckle Tracking Echocardiography In Patients With Different Heart Diseases

Dr .Mohammed Ameen Kadhim, Dr .Amal N. AL- Marayati and Dr . Ghazi F. Haji

ABSTRACT

Background: Speckle tracking echocardiography (STE)-derived mitral annular displacement (MAD) utilizes the speckle tracking technique to measure strain vectors, which provides accurate estimates of left ventricular ejection fraction (LVEF).

Objectives: To validate the accuracy of mitral annular displacement (MAD), assessed by Speckle Tracking Echocardiography (STE), as a surrogate for determination of left ventricular systolic function in comparison to 2-Dimensions Simpson method in patients with different heart diseases.

Methods : This cross-sectional study included patients who referred to outpatient department of Ibn Albitar Center for Cardiac Surgery, Baghdad, Iraq, between October 2012 and April 2013. STE continuously tracked annular motion throughout the cardiac cycle in the apical 4- and 2-chamber views. LVEF for each patient was measured by both Simpson method and STE-derived MAD.

Results: This study included 100 patients, of them (35%) had ischemic heart disease (IHD), (10%) had dilated cardiomyopathy (DCM), (10%) had valvular heart disease (VHD), (25%) had normal echocardiography, and (20%)

had hypertensive heart disease (HHD). There was significant correlation between EF % (derived by MAD) and EF % (derived by Simpson method) in patients with different heart diseases. This correlation was good in normal subjects ($r=0.673$), and those with IHD ($r=0.896$), DCM ($r=0.724$) and VHD ($r=0.935$), while in HHD it was moderately correlated ($r=0.455$). There was slight under-estimation of LVEF derived by MAD (a mean value of difference 0.846 %; $p =0.022$). In subgroup analysis, this difference was seen only in patients with HHD (a mean value of difference 3.145 %; $p <0.001$), while it was absent in other subgroups.

Conclusion: STE-derived MAD provides easy, fast, and accurate assessments of global longitudinal systolic function. LVEF derived by MAD was correlated well with LVEF derived by Simpson method in patients with different heart diseases.

Key words: ventricle, ejection fraction, echocardiography

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Corresponding author to Dr : Ghazi F. Haji- E
mail:ghaz_ihaji@yahoo.com, Mobile:07904376288*

The assessment of left ventricular (LV) systolic function is indispensable in the management and prognosis of cardiac patients.¹ Radial shortening is predominantly dependent upon the contraction of circumferential myocardial fibers in the mid-wall, whereas longitudinal shortening is governed by both longitudinal subendocardial and subepicardial fibers.^{2,3} Because the subendocardium is more vulnerable to ischemia and interstitial fibrosis, a decrease in longitudinal function might be a sensitive marker for subclinical alterations in LV systolic performance.⁴⁻⁷

Accurate assessment of LVEF by 2D trans-thoracic echocardiography (TTE) is time-intensive and limited by poor image quality, because of its dependence on endocardial tracing, and by the frequent use of foreshortened apical views. The recognition of these limitations has led to the development of alternative echocardiographic methods for the assessment of LV systolic function. One proposed method involves the use of mitral annular displacement (MAD),⁸⁻¹¹ which is fast and does not depend on endocardial definition and thus can be easily performed in the majority of patients.¹²

The aim of our study is to validate the accuracy of mitral annular displacement (MAD), assessed by Speckle Tracking Echocardiography (STE), As a surrogate for determination of left ventricular systolic function in comparison to 2-D Simpson method in patients with different heart diseases.

patients: This cross-sectional study included patients who referred to outpatient department of Ibn-Al bitar Center for Cardiac Surgery, Baghdad, Iraq, between October 2012 and April 2013. ECG was done for all patients. IHD was determined when a patient had evidence of previous myocardial infarction. VHD included moderate to severe aortic valve stenosis and mitral valve regurgitation. HHD was determined by the presence of left ventricular hypertrophy (LVH) and history of hypertension. DCM was determined by the presence of LV dilation and dysfunction in the absence of ischemia. Patients with mitral valve replacement, atrial fibrillation, left bundle branch block, and congenital heart disease were excluded from this study. Also patients with poor TTE window were excluded.

Echocardiography: Echocardiography was performed by

single operator using a commercially available ultrasound machine (iE33, Philips Medical Systems) equipped with a broad-band transducer. Two-dimensional echocardiography measured LV dimensions and wall thickness according to the recommendations by the American Society of Echocardiography. ¹³LVEF was measured for all patients using biplane Simpson method.

Assessment of long-axis function by STE-derived MAD:

STE measured strain vectors and assessed long-axis function. Longitudinal shortening was measured in the apical 4- and 2-chamber views. All participants underwent two-dimensional Doppler imaging with a harmonic transducer, and the obtained images were stored as digital cine loops and analyzed by Off-line QLAB software (Philips Medical Systems). The frame rate was optimized to achieve a frame rate >60 Hz. In the apical 2-chamber view, the anterior and inferior aspects of the mitral annulus and the apical myocardium were selected. In the apical 4-chamber view, the hinge points of the mitral valve leaflets with the septal and lateral aspects of the mitral annulus and the apical myocardium were selected. Three regions of interest (ROI) or points were placed. ROIs were tracked during cardiac motion; then, we measured the motion of the annular ROI toward the apex individually and the displacement of the midpoint between the two annular ROIs. Displacement of the midpoint toward the apex was directly expressed in millimeters. The total displacement was expressed as a ratio of the longitudinal chamber length at end-diastole in order to normalize the displacement of left ventricular length in individual ventricular size. MAD was derived from the mean values obtained in the apical 4- and 2-chamber views. Parametric images of mitral annulus excursion at diastole and systole were also provided. Displacement, which appears from end diastole to end systole, was displayed as a color band (color kinesis) and quantitatively confirmed by reduced amplitude of the time curves, resulting in lower STE-derived MAD values. The maximum displacement was included in this study. LVEF % (derived by MAD) is calculated by the formula ¹²

$$EF = -0.074 * MAD^2 + 5.6 * MAD + 0.34$$

in the 2-chamber view and

$$EF = -0.055 * MAD^2 + 5.2 * MAD + 3.3$$

in the 4-chamber view. And the mean value for the above two equations was considered.

Statistical analysis: Statistical analysis was performed with commercially available software (SPSS 18.0 software). All continuous data are reported as mean ± standard deviation (SD), and categorical data as frequencies. The correlation between EF % (derived by MAD) and EF % (derived by Simpson) in different heart diseases was assessed by Pearson correlation coefficient and the significance of difference is tested by Bland-Altman analysis. The level of p < 0.05 was considered statistically significant.

Results:This study included 100 patients, of them (35%) had ischemic heart disease (IHD), (10%) had dilated cardiomyopathy (DCM), (10%) had valvular heart disease (VHD), (25%) had normal echocardiography, and (20%) had hypertensive heart disease (HHD). Patient's characteristics and echocardiographic characteristics are shown in Table 1 and 2 respectively. Mitral annular tracking and the quantification of STE-derived MAD were achieved in all subjects within 15 seconds. Among the 100 patients studied, 69 were men, 61 had hypertension, 42 had diabetes and 35 had IHD. The mean age was 53.0±12.8 years. LVEF (derived by MAD) was significantly lower in the patients with DCM (34.83±3.74%) and in those with IHD (43.08±9.25%) compared to patients with HHD (61.4±3.32 %) and those with normal echocardiography study (64.5±2.36%)

The correlation between EF % (derived by MAD) and EF % (derived by Simpson) in different heart diseases was shown in table 3. This table show significant correlation between the two methods in assessing LVEF in different heart diseases. This correlation was good in normal echocardiography patients (r = 0.673), and those with IHD(r = 0.896), DCM (r = 0.724) and VHD (r = 0.935), while in HHD it was less well correlated (r = 0.455). A Bland-Altman analysis (figure 1) showed slight under-estimation of LVEF derived by MAD in comparison to that derived by Simpson (a mean value of difference 0.846 %; p =0.022).

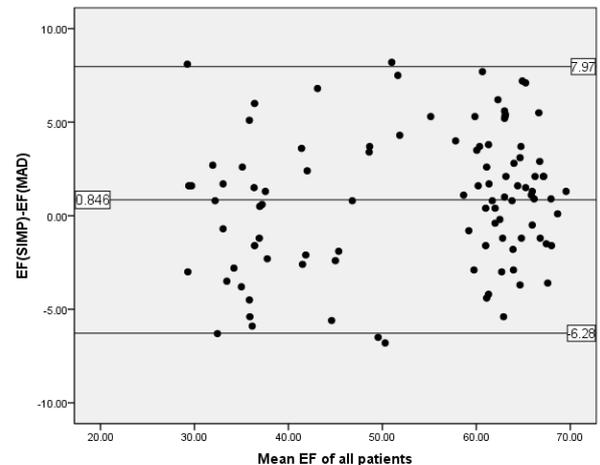


Figure 1.A Bland-Altman analysis showed a mean value of difference 0.846 %; p =0.022, and the 95% limits of agreement ranged from (-6.28% to 7.97%)

Note :Mean EF=[EF(SIMP)+EF(MAD)]/2

Table-1- Patients characteristics

	Echocardiographic data					Total
	Normal	HHD	IHD	DCM	VHD	
Age(mean±SD)	49.2±6.4	57.6±10.9	60.4±9.3	32.9±11.0	47.3±14.9	53±12.8
Sex (male)	60%	85%	74.2%	60%	50%	69%
Hypertension	28%	100%	88.5%	0%	30%	61%
Diabetes	8%	25%	94.2%	0%	20%	42%
IHD	0%	0%	100%	0%	0%	35%
Total	25	20	35	10	10	100

HHD;hypertensive heart diseases. IHD;ischemic heart diseases.
DCM;dilated cardiomyopathy.VHD;valvular heart disease

Table 2: Echocardiographic characteristics

Echocardiography	EF%(simpson) Mean ± SD	EF % (MAD) Mean ± SD	Correlation coefficient (r)	P value
Normal	64.9±2.90	64.5±2.36	0.673	< 0.001
HHD	64.5±2.66	61.4±3.32	0.455	0.043
IHD	43.21±10.07	43.08±9.25	0.896	0.001
DCM	35.07±3.44	34.83±3.74	0.724	0.017
VHD	61.02±8.34	60.44±10.06	0.935	0.001
Total	53.87±13.44	53.03±12.85	0.963	< 0.001

HHD;hypertensive heart diseases. IHD;ischemic heart diseases.
DCM;dilated cardiomyopathy.VHD;valvular heart diseases

Discussion: LVEF is a most extensively investigated echocardiographic parameter and a clinically useful index for assessments of systolic function.¹⁴ Several studies have been conducted on STE derived MAD and its relation to EF measured by TTE or CMR^{12, 15}. Our study showed significant correlation between EF % (derived by MAD) and EF % (derived by Simpson), in normal subjects (r=0.673), and those with IHD(r=0.896), DCM (r=0.724) and VHD (r=0.935), while in HHD it was less well correlated (r=0.455). These results are comparable to a study conducted by Suzuki et al¹⁵, which showed a good correlation between EF % (derived by MAD) and that derived by simpson method in patients with IHD (r=0.733), and DCM (r=0.614), while in HHD patients there was poor correlation (r=0.301). Tsang et al.¹² have conducted a study on patients with reduced LVEF (the mean LVEF, 41%) and demonstrated that STE-derived MAD can accurately estimate LVEF. Vinereanu D et al.⁴ reported that patients with asymptomatic diastolic dysfunction and those with diastolic heart failure had impaired longitudinal systolic function even though they had preserved LVEF ≥50%. Patients with HHD tend to have deteriorated longitudinal systolic function despite preserved LVEF. The majority

of HHD patients with preserved LVEF have subclinical systolic dysfunction.^{16, 17} Nishikage T et al.¹⁸ has demonstrated that 10% of the asymptomatic hypertensive patients with preserved LVEF have impaired longitudinal function. Nishimura K et al.¹⁹ has demonstrated that radial strain in the inner half layer of the LV wall decreases in hypertensive patients. These findings reflect subendocardial fiber impairments.

In the current study, the under-estimation of EF derived by MAD in patients with HHD with preserved LVEF who have probably subclinical longitudinal systolic dysfunction. The strong correlation between STE-derived MAD and LVEF was not found in these patients, supporting the theory that LVEF is not always correlated well with longitudinal systolic function in all heart disease.

Table 3: correlation between left ventricular EF % (by Simpson) and left ventricular EF% (by MAD) in different heart diseases

	Echocardiographic data					Total
	Normal	HHD	IHD	DCM	VHD	
PWT(cm) Mean ± SD	0.77±0.08	1.28±0.12	0.97±0.18	0.72±0.10	1.08±0.33	0.97±0.25
SWT(cm) Mean ± SD	0.77±0.08	1.29±0.13	1.00±0.18	0.72±0.10	1.08±0.33	0.98±0.26
LVDD(cm) Mean ± SD	4.76±0.29	4.65±0.36	5.85±0.63	6.5±0.59	5.24±0.67	5.34±0.81
LVSD(cm) Mean ± SD	3.02±0.23	2.98±0.27	4.57±0.74	5.38±0.60	3.43±0.63	3.83±1.02
EF%(M-mode) Mean ± SD	66.1±3.05	65.4±3.08	43.96±9.41	35.31±4.82	63.11±9.36	54.85±13.66
EF%(Simpson) Mean ± SD	64.9±2.90	64.5±2.66	43.21±10.0	35.07±3.44	61.02±8.34	53.87±13.44
EF % (MAD) Mean ± SD	64.5±2.36	61.4±3.32	43.08±9.25	34.83±3.74	60.44±10.06	53.03±12.85

HHD;hypertensive heart diseases. IHD;ischemic heart diseases. DCM;dilated cardiomyopathy.VHD;valvular heart diseases

Two-dimensional STE can quantify myocardial strain simultaneously in different LV segments with angle-independent ultrasound beam using tracking acoustic pixels equally distributed within the myocardial wall. Global longitudinal strain is linearly related with biplane LVEF in patients with coronary artery disease.²⁰ In the current study, the good correlation between LVEF (derived by MAD) and LVEF (derived by Simpson) was found in the patients with coronary artery disease. In the present study, LVEF and longitudinal function were not identical in all patients (table 2), but rather reflected different aspects of systolic left ventricular function. The correlation between longitudinal function and LVEF was found in patients with HHD, which was probably multifactorial. The patients with HHD had a relatively narrow range of LVEF, which affected the ability of STE-derived MAD to distinguish these patients (table 3). Some patients with diastolic dysfunction have preserved LVEF and reduced longitudinal function. The weak correlation attributes to the fact that diastolic dysfunction

can be related to reduced longitudinal function even in patients with preserved LVEF. Yip et al.²¹ and Vinereanu et al.⁴ have demonstrated the clear correlation between the S wave (The peak systolic mitral annular velocity) and E wave (early diastolic mitral flow velocity) with r value 0.7-0.8. This finding suggests that energy generated during systole should be converted to restoring forces, leading to early diastolic suction and filling.^{22,23} An increase in the A wave (late diastolic mitral flow velocity) leads to a descent of the base of the heart, further longitudinal stretch. It may in turn increase longitudinal systolic velocities through the Frank-Starling mechanism. Patients with HHD without left ventricular systolic dysfunction demonstrated decreased longitudinal strain and increased circumferential strain, resulting in maintained LVEF.²⁴ Therefore, a compensatory increase in circumferential shortening may be essential for maintaining LVEF, even in the presence of a decrease in longitudinal shortening.²⁵

STE-derived MAD can be performed in most patients because echo-dense structure easily detects the mitral annulus. STE-derived MAD can also visualize and track the mitral annulus even in patients who have poor image qualities with inadequate visualization in the endocardium and the LV apex. It takes only 15 s to complete the whole procedure including tracking, measuring, and reporting STE-derived MAD; therefore, it provides fast, user-friendly, and accurate estimation of LVEF in the majority of patients compared with a cardiac magnetic resonance EF reference.¹²

Study limitations: The unavailability of cardiac MRI which was the gold standard for LVEF assessment is the major limitation of the study. In order to put our theory into practice, more patients with various LVEF and of different heart diseases should be included. Further studies with more data accumulation are thus called for.

Conclusion: STE-derived MAD provides easy, fast, and good assessments of global longitudinal systolic function. LVEF derived by MAD was correlated well with LVEF derived by Simpson method in patients with different heart diseases with slight under-estimation of LVEF especially in patients with hypertensive heart disease.

Recommendation: We recommend the use of STE-derived MAD for evaluation of longitudinal LV systolic function, which can be performed in most patients and especially useful in those with poor image quality.

References:

- 1- Thomas JD, Popović ZB. Assessment of left ventricular function by cardiac ultrasound. *J Am CollCardiol.* 2006; 48(10):2012-25.
- 2- Ballo P, Quatrini I, Giacomini E, Motto A, Mondillo S. Circumferential versus longitudinal systolic function in patients with hypertension: A nonlinear relation. *J Am SocEchocardiogr* 2007; 20: 298-306.
- 3- Wandt B, Bojö L, Hatle L, Wranne B. Left ventricular contraction pattern changes with age in normal adults. *J Am SocEchocardiogr* 1998; 11: 857 - 863.
- 4- Vinereanu D, Nicolaidis E, Tweddel AC, Fraser AG. "Pure" diastolic dysfunction is associated with long-axis systolic dysfunction: Implications for the diagnosis and classification of heart failure. *Eur J Heart Fail* 2005; 7: 820 - 828.
- 5- Yu C, Lin H, Yang H, Kong S, Zhang Q, Lee S. Progression of systolic abnormalities in patients with "isolated" diastolic heart failure and diastolic dysfunction. *Circulation* 2002; 105: 1195- 1201.
- 6- Vinereanu D, Nicolaidis E, Tweddel A, Mädler C, Holst B, Boden L, et al. Subclinical left ventricular dysfunction in asymptomatic patients with Type II diabetes mellitus, related to serum lipids and glycatedhaemoglobin. *ClinSci (Lond)* 2003; 105: 591 - 599.
- 7- Wang M, Yip GW, Wang AY, Zhang Y, Ho PY, Tse MK, et al. Tissue Doppler imaging provides incremental prognostic value in patients with systemic hypertension and left ventricular hypertrophy. *J Hypertens* 2005; 23: 183 - 191.
- 8- Frielingsdorf J, Schmidt C, Debrunner M, Tavakoli R, Genoni M, Straumann E, et al. Atrium-driven mitral annulus motion velocity reflects global left ventricular function and pulmonary congestion

- during acute biventricular pacing. *J Am SocEchocardiogr* 2008;21:288-93.
- 9- Elnoamany MF, Abdelhameed AK. Mitral annular motion as a surrogate for left ventricular function: correlation with brain natriuretic peptide levels. *Eur J Echocardiogr* 2006;7:187-98.
- 10- Roberson DA, Cui W. Tissue Doppler imaging measurement of left ventricular systolic function in children: mitral annular displacement index is superior to peak velocity. *J Am SocEchocardiogr* 2009;22:376-82.
- 11- Yuda S, Inaba Y, Fujii S, Kokubu N, Yoshioka T, Sakurai S, et al. Assessment of left ventricular ejection fraction using long-axis systolic function is independent of image quality: a study of tissue Doppler imaging and m-mode echocardiography. *Echocardiography* 2006;23:846-52.
- 12- Tsang W, Ahmad H, Patel AR, Sugeng L, Salgo IS, Weinert L, et al. Rapid estimation of left ventricular function using echocardiographic speckle-tracking of mitral annular displacement. *J Am SocEchocardiogr.* 2010;23(5):511-5.
- 13- Lang RM, Bierig M, Devereux RB, Flachskampf FA, Foster E, Pellikka PA, et al. Recommendations for chamber quantification: a report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. *J Am SocEchocardiogr.* 2005;18:1440-1463.
- 14- Vasan RS, Benjamin EJ, Larson MG, Leip EP, Wang TJ, Wilson PW, et al. Plasma natriuretic peptides for community screening for left ventricular hypertrophy and systolic dysfunction: the Framingham heart study. *JAMA.* 2002;288:1252-1259.
- 15- Suzuki K, Akashi Y, Mizukoshi K, et al. Relationship between left ventricular ejection fraction and mitral annular displacement derived by speckle tracking echocardiography in patients with different heart diseases. *J Cardiol* 2012;60:55-60.
- 16- Koulouris SN, Kostopoulos KG, Triantafyllou KA, Karabinos I, Bouki TP, Karvounis HI, et al. Impaired systolic dysfunction of left ventricular longitudinal fibers: a sign of early hypertensive cardiomyopathy. *ClinCardiol.* 2005;28:282-286.
- 17- Mizuguchi Y, Oishi Y, Miyoshi H, Iuchi A, Nagase N, Oki T. Concentric left ventricular hypertrophy brings deterioration of systolic longitudinal, circumferential, and radial myocardial deformation in hypertensive patients with preserved left ventricular pump function. *J Cardiol.* 2010;55:23-33.
- 18- Nishikage T, Nakai H, Lang RM, Takeuchi M. Subclinical left ventricular longitudinal systolic dysfunction in hypertension with no evidence of heart failure. *Circ J.* 2008;72:189-194.
- 19- Nishimura K, Okayama H, Inoue K, Saito M, Yoshii T, Hiasa G, et al. Direct measurement of radial strain in the inner-half layer of the left ventricular wall in hypertensive patients. *J Cardiol.* 2011;
- 20- Delgado V, Mollema SA, Ypenburg C, Tops LF, van der Wall EE, Schalij MJ, et al. Relation between global left ventricular longitudinal strain assessed with novel automated function imaging and biplane left ventricular ejection fraction in patients with

- coronary artery disease. *J Am SocEchocardiogr.* 2008;21:1244-1250
21. Yip GW, Zhang Y, Tan PY, Wang M, Ho PY, Brodin LA, et al. Left ventricular long-axis changes in early diastole and systole: impact of systolic function on diastole. *ClinSci (Lond).* 2002;102:515-522
 22. Rademakers FE, Buchalter MB, Rogers WJ, Zerhouni EA, Weisfeldt ML, Weiss JL, et al. Dissociation between left ventricular untwisting and filling. Accentuation by catecholamines. *Circulation.* 1992;85:1572-1581
 23. Yun KL, Niczyporuk MA, Daughters GT, Ingels NB, Stinson EB, Alderman EL, et al. Alterations in left ventricular diastolic twist mechanics during acute human cardiac allograft rejection. *Circulation.* 1991;83:962-973
 24. Carasso S, Yang H, Woo A, Vannan MA, Jamorski M, Wigle ED, et al. Systolic myocardial mechanics in hypertrophic cardiomyopathy: novel concepts and implications for clinical status. *J Am SocEchocardiogr.* 2008;21:675-683
 25. Mizuguchi Y, Oishi Y, Miyoshi H, Iuchi A, Nagase N, Oki T. The functional role of longitudinal, circumferential, and radial myocardial deformation for regulating the early impairment of left ventricular contraction and relaxation in patients with cardiovascular risk factors: a study with two-dimensional strain imaging. *J Am SocEchocardiogr.* 2008;21:1138-1144