

Assessment of Left Ventricular Longitudinal Function in Hypertensive Patients without Left Ventricular Hypertrophy by Mitral Annular Plane Systolic Excursion

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Abstract

Background: Hypertension is an important risk factor for many cardiovascular diseases worldwide. Assessment of left ventricular (LV) systolic function has a major diagnostic and prognostic importance in patients with hypertension. The use of mitral annular plane systolic excursion in the assessment of LV systolic dysfunction is helpful especially in cases of poor imaging quality, “since good imaging quality is needed for the modern echocardiographic techniques. **Objectives:** Detection of early subclinical LV longitudinal systolic dysfunction in hypertensive patients without LV hypertrophy (LVH) with preserved ejection fraction by mitral annular plane systolic excursion. **Patients and Methods:** A comparative case-control study which took place at Al-Yarmouk Teaching Hospital in Baghdad/Iraq from October 2018 to October 2019. The study population consisted of 60 patients without LVH and 60 healthy subjects considered as controls. Echocardiographic parameters for left ventricular systolic assessments were done for all subjects. **Results:** Mean peak annular systolic velocity was significantly lower in hypertensive patients without LVH compared to controls ($P = 0.034$). There was no significant difference between hypertensive patients without LVH and controls regarding mitral annular plane systolic excursion ($P = 0.4$). There was positive linear correlation between mitral annular plane systolic excursion and peak annular systolic velocity for hypertensive patients without LVH ($r = 0.535$, $P = 0.015$). **Conclusion:** Although there was a significant linear correlation between mitral annular plane systolic excursion and peak systolic velocity and both are considered as a surrogate for LV longitudinal systolic function, mitral annular plane systolic excursion cannot be used for assessment of LV longitudinal systolic function in patients with hypertension without LVH.

Keywords: Hypertension, mitral annular plane systolic excursion, peak annular systolic velocity

INTRODUCTION

Hypertension is one of the most common diseases all over the world. While the conventional echocardiographic techniques can recognize changes in left ventricular (LV) diastolic function associated with LV hypertrophy (LVH), global LV systolic function usually remains preserved until late in the course of the disease, making subtle changes in contractile function of the left ventricle difficult to interpret in the early stages.^[1]

Aggressive treatment can be justified to reduce the cardiovascular morbidity and mortality if the detection of LV dysfunction performed in the early stages before the development of LV hypertrophy therefore, this should be considered in the estimation of general risk of cardiovascular diseases.^[2]

Mitral annular plane systolic excursion (MAPSE) has been considered as a well-recognized clinically useful

echocardiographic parameter for the estimation of LV longitudinal function and correspond with global systolic function of left ventricle.^[3]

Echocardiographic evaluation of hypertensive patients *Different methods of left ventricular systolic function quantification*

LV function is assessed by multiple methods each has advantages and disadvantages.

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Assessment of left ventricular ejection fraction by linear M mode method

Advantages

It is easy and can be performed by less experienced examiners, it has a best temporal resolution for exact timing measurement.

Disadvantages

It has a poor quantification of regional function not good measure for global function. Wide intra and interobserver variability, poor endocardial border, tethered segment, paradoxical septal wall motion, all are drawbacks provides only information about contractility on a single slice of LV, whereas, contractility of other segments can be missed.

Assessment of left ventricular ejection fraction by biplane simpson's

Advantages

Rapid imaging assessment, portability, inexpensive, and noninvasive.

Disadvantages

Poor image quality—This does not permit a reliable endocardial border tracing and end-diastolic frames. Beat-to-beat changes of ejection fraction (EF) in the presence of arrhythmias, for example, atrial fibrillation (AF). It needs several measurements and averaging.^[4]

Myocardial velocity by tissue Doppler imaging

Advantages

Easy to apply. Less dependent on two dimensional (2D) image quality and less dependent on reader expertise. It has good correlation with LVEF. High temporal resolution and good reproducibility.^[5]

Disadvantages

Angle dependent, relying on preload and afterload, not able to find regional heart abnormalities. Confounding effect of ventricular translational, tethering effect from adjacent segment, and rotational movement.^[5]

Mitral annular plane systolic excursion

Clinical application and importance of MAPSE:

1. Simple reproducible quickly performed feasible even with suboptimal image quality even easier than measuring LVEF
2. MAPSE correlated with other parameters of LV function like LVEF.^[6] It is a surrogate measurement of LVEF and provide complementary information to it although MAPSE reflects longitudinal LV function while LVEF reflects radial function
3. It is more sensitive than other conventional echocardiographic parameters in detection of systolic dysfunction at early stage^[5]
4. MAPSE shown to be correlate with reduced LV function with age, postmyocardial infarction, heart failure, AF^[7]
5. Is not affected like tissue Doppler by tethering translation, rotational motion of the heart^[8]
6. MAPSE could have some limitations since it is angle dependent, preload and afterload dependent.

PATIENTS AND METHODS

Study design

This cross-sectional study was carried from the time period in October 2018 to October 2019 at Al-Yarmouk Teaching Hospital. Patients and controls were selected from subjects attending Echo department at the same hospital. A total number of hypertensive patients and apparently healthy subjects was (120). Sixty hypertensive patients within normal EF without LVH, and (60) healthy persons were enrolled as controls.

The patients

This group comprises 19 males and 41 females with an age range between 22 and 81 years. Blood pressure (BP) $\leq 140/90$ mmHg according to the latest classification of systemic hypertension of European Society of Cardiology/European Society of Hypertension 2018 with normal EF (EF $\geq 54\%$ in females and $\geq 52\%$ in males). Patients in this study were selected from those attending the echocardiography unit who fulfill the inclusion and exclusion criteria for this study.

Control subjects

This group included 19 males and 41 females with an age range between 21 and 73 years, all subjects in this group with BP $< 140/90$ mm Hg, no history of chronic medical illnesses (for example: hypertension, diabetes mellitus, chronic renal disease) and fulfill the inclusion and exclusion criteria for this study except they were normotensive.

Inclusion criteria

All individuals (Patients and control) with the following criteria were included in this study:

1. A known case of hypertension without LVH (for patients); with septal wall thickness < 11 mm in males and < 10 mm in females, Normotensive (for controls)
2. Normal sinus rhythm.

Exclusion criteria

All subjects (Patients and controls) with these criteria were kept out from this study:

1. Patients with reduced EF $< 54\%$ in females and $< 52\%$ in males
2. Pregnant women
3. Previous ischemic heart diseases and heart failure (no previous consultation for cardiac condition)
4. Any structural heart disease, any abnormal cardiac condition
5. Any valvular heart disease
6. Congenital heart diseases
7. Patients having AF or any rhythm disturbances
8. Patients diagnosed with diabetes mellitus
9. Malignant diseases or those with immunosuppressive therapy, chemotherapy and radiotherapy
10. Subjects with poor window.

Echocardiography

Echocardiography was performed for all subjects using a Vivid E9® system (GE Vingmed; Hortoen, Norway) with 5 MHz transducer by specialist echo cardiographer. All subjects were examined on his/her left lateral side, to make the heart lateral to sternum and forward to chest, as required by the American society of echocardiography with dimmed light room.^[9]

Assessment of left ventricular systolic function

Assessment of left ventricular ejection fraction

Linear measurements by two dimensional-guided M mode

2D guided M-mode recording at the tip of mitral valve leaflets in parasternal long-axis view following the guidelines of American Society of Echocardiography.^[9] Analysis of 3 successive cardiac cycles were done to calculate the LV end diastolic volume, the LV end systolic volume, and the LVEF by averaging the three values EF is measured from end diastolic volume (EDV) and end systolic volume (ESV) by using the following formula:

$$EF = (EDV - ESV) / EDV \text{ as in [Figure 1].}$$

Volumetric measurements of ejection fraction by Simpson's method

Modified Simpson's method (method of disks) is a modality require tracing the area of LV cavity. EF value was obtained by endocardial border tracing of the left ventricle in apical (A4C) view at the end-systole and end-diastole. These tracings eventually divide the LV cavity into a predetermined number of disks (usually 20) as seen in [Figure 2].

Assessment of left ventricular function by (mitral annular plane systolic excursion)

Mitral annular plane systolic excursion (MAPSE) measurement is a quick, simple, practical and reproducible method for LV function assessment.^[10] Mitral annular displacement was measured from apical (A4C) chambers view by using M-mode echocardiography and the cursor placed parallel with the LV lateral walls. MAPSE was calculated from the most lower point (end-diastole) to the closure of aortic valve (end of T-wave on electrocardiogram), and post systolic motion was excluded in this study [Figure 3].^[5]

Assessment of left ventricular systolic longitudinal function by tissue Doppler imaging

This was done by the measurement of peak systolic mitral annular velocity (S') which is considered as a reliable method to assess the performance of longitudinal LV fibers, which are mainly distributed within the endocardium.^[11] The analysis of mitral annular motion was done by using apical (A4C) view and placing a 5-mm sample volume at septal and lateral annular sites. Adjustment of filter and gain settings were done for optimum signal/noise ratio. Peak systolic velocity was measured according to American Society of Echocardiography recommendations^[12] [Figure 4].

Statistical analysis

Analysis of data was carried out using the available statistical package of SPSS-25 (Statistical Packages for the

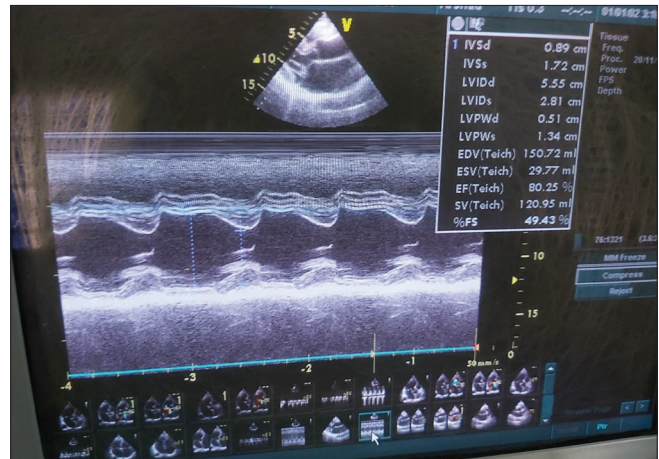


Figure 1: Examination of M-mode for the left ventricle acquired from parasternal long- axis view

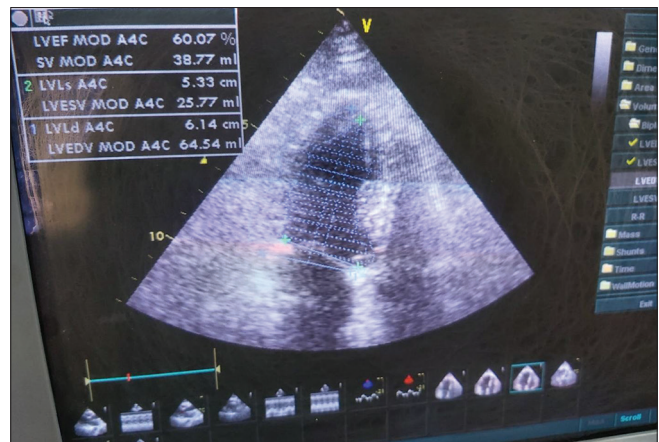


Figure 2: Example of biplane disk summation (modified method of Simpson's)

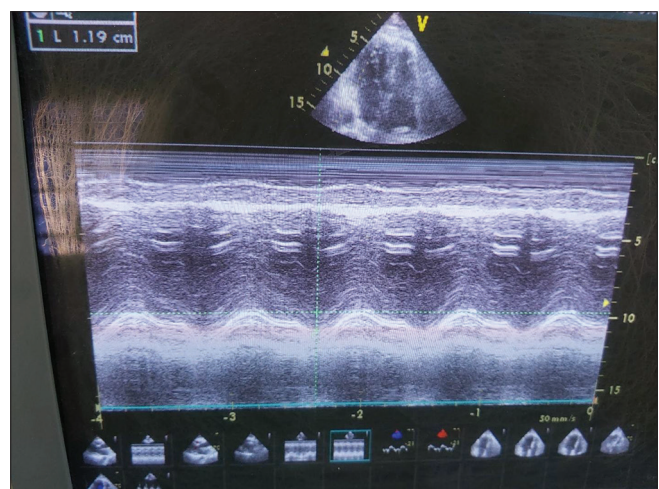


Figure 3: Examples of mitral annular plane systolic excursion (MAPSE) by M-mode image

Social Sciences-version 25). Data were presented in simple measures of frequency, percentage, mean, standard deviation,

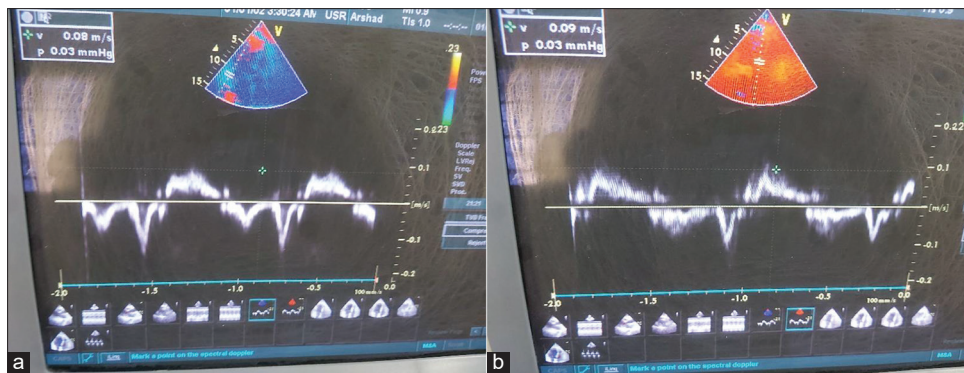


Figure 4: Measurement of peak mitral annular velocity; (a) measurement of the lateral side of the mitral annulus, (b) measurement of the septal side of the mitral annulus

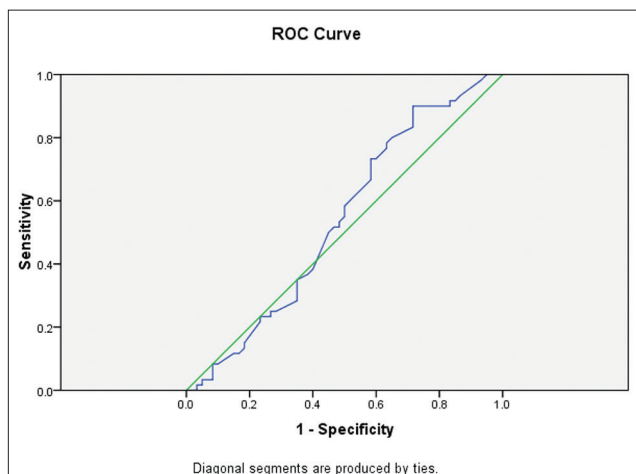


Figure 5: ROC for MAPSE prediction of HT without LVH (AUC=0.54)

and range (minimum-maximum values). The significance of difference of different means (quantitative data) were tested using Student's *t*-test for difference between two independent means or Paired-*t*-test for difference of paired observations (or two dependent means), or ANOVA test for difference among more than two independent means.^[13] The significance of difference of different percentages (qualitative data) were tested using Pearson Chi-square test (χ^2 -test) with application of Yate's correction or Fisher Exact test whenever applicable. Statistical significance was considered whenever the $P \leq 0.05$.

RESULTS

Distribution of general characteristics according to hypertension without left ventricular hypertrophy and control

There was a high significant difference between HT patients without LVH and controls regarding age, systolic blood pressure, diastolic blood pressure, Mean BP ($P = 0.0001$). A high significant increase was noticed in mean body mass index (BMI) between HT without LVH group and mean BMI of control group ($P = 0.001$). No significant differences was

Table 1: Distribution of general characteristics according to hypertension patients without left ventricular hypertrophy and controls

	HT without LVH	Control	P
Age (years)	52.7±11.6	41.4±12.1	0.0001* (S)
Gender (male/female)	19/41	19/41	1.0
BMI (kg/m ²)	33.31±6.70	29.52±5.60	0.001* (S)
SBP (mmHg)	151.12±24.0	120.33±9.44	0.0001* (S)
DBP (mmHg)	90.82±12.45	76.83±7.18	0.0001* (S)
Mean BP (mmHg)	110.9±14.77	91.33±7.25	0.0001* (S)

*Significant difference between two independent means using Student's *t*-test at 0.05 level. LVH: Left ventricular hypertrophy, HT: Hypertension, BMI: Body mass index, BP: Blood pressure, SBP: Systolic BP, DBP: Diastolic BP

Table 2: Distribution of echocardiographic measures according to hypertension patients without left ventricular hypertrophy and controls

	Mean ± SD		P
	HT without LVH	Controls	
Septal wall thickness (diastole) (mm)	8.2±1.1	7.7±1.2	0.01* (S)
MAPSE (mm)	15.5±3	15.9±2.2	0.4
EF by M-mode %	74±8.5	73.6±7.2	0.7
EF by (Simpson's) %	63.0±14.6	61.6±9.2	0.2
S' (cm/s):	0.09±0.03	0.11±0.02	0.034* (S)

*Independent sample *t*-test. S: Significant, SD: Standard deviation, EF: Ejection fraction, LVH: Left ventricular hypertrophy, MAPSE: Mitral annular plane systolic excursion, HT: Hypertension

observed between HT patients without LVH and control group regarding gender ($P = 1.0$) [Table 1].

Distribution of echocardiographic measures according to HT patients without left ventricular hypertrophy and controls

Mean septal wall thickness of HT patients without LVH was significantly higher than mean septal wall thickness of controls ($P = 0.01$). Mean S' of HT patients without LVH was significantly lower than the mean S' of controls ($P < 0.001$).

There were no significant differences in means of MAPSE, EF by (M mode, Simpson's methods) between HT without LVH group and controls [Table 2].

Cutoff points and test validity of MAPSE

The acceptable cut off points and the corresponding validity values for MAPSE level in prediction of HT without LVH was shown in Table 3 and Figure 5, cutoff MAPSE level of 15 had acceptable validity results (58.3% sensitivity, 50% specificity, 50% penalized present value, 56.2% net present value and accuracy 55%).

Pearson's correlations:

- A significant negative correlation was observed between MAPSE and BMI for HT without LVH ($r = -0.395$, $P = 0.002$)
- A positive significant correlation were observed between MAPSE and S' for HT without LVH ($r = 0.535$, $P = 0.001$)
- NO significant correlations were observed between MAPSE and EF (by M-mode or by Simpson's methods) for the HT group [Table 4].

DISCUSSION

Hypertension is a major health problem worldwide and is responsible for about 50% of all cardiovascular deaths.^[14] Cardiovascular system especially the heart undergo many physiological changes and adaptations in order to overcome this increase in BP. These physiological adaptations and furthermore, maladaptation can cause LV pressure overload and may lead to numerous complex changes in cardiac structure and function appearing as myocardial ischemia, arrhythmias and diastolic and/or systolic heart failure.^[15]

So, the main goal of this study is early detection of the subclinical changes in LV systolic function by the use of MAPSE, this may reduce the myocardial morbidity and mortality in hypertensive patients with poor imaging quality since most of the recent echocardiographic techniques require a good imaging quality.

In the current study, the age group was significantly higher in hypertensive group than the age of healthy controls ($P = 0.0001$) which means that hypertension is highly prevalent in middle and old age groups.

Our study was in agreement with Parikh *et al.*^[16] who stated that normal aging was associated with significant increases in

systolic BP ($P < 0.05$), Parikh *et al.* studied 48 normal subjects and 40 hypertensive patients (though no other cardiovascular disease or diabetes) their ages ranged from 50 to 79 years.

Regarding gender, no significant differences were observed between hypertensive group and controls, this finding was in agreement with Ayoub *et al.*^[17] study and Natori *et al.*^[18] study, the two studies reviewed in their articles that there were no significant differences in gender between hypertensive patients and controls.

In this study, high significant difference was observed between hypertensive patients and controls regarding mean BMI ($P = 0.001$). This finding agreed with Ayoub *et al.*^[17] who showed that there was a significant differences in their mean BMI between hypertensive patients and controls ($P = 0.03$).

In the current study, hypertensive patients had significantly higher mean septal wall thickness over healthy controls; ($P = 0.01$) ([although doesn't reach the definition of LVH]). Diez and Frohlich demonstrate that the mechanisms responsible for increase in septal thickness include not only a response to increase hemodynamic load from elevated blood pressure, but also from the effects of neurohormones such as catecholamines, renin-angiotensin system, endothelins, cytokines, and certain growth factors by increasing cardiomyocytes size, enhancing myocardial fibrosis, and increasing interstitial and perivascular collagen deposition.^[19]

MAPSE has promised to be a reliable, simple and easy obtainable indicator for LV function even in inexperienced hands, it reflects LV longitudinal systolic function,^[5,20] In this study, there was no significant difference in mean MAPSE in HT patients without LVH compared with mean MAPSE of controls ($P = 0.4$), this finding may be because those patients not having LVH or reduction in longitudinal fibers yet; i.e., the thickness of the LV wall was not increased enough (not reached the stage of hypertrophy) to cause a significant reduction of longitudinal fibers, Since the reduction in MAPSE is mainly due to the reduction of longitudinal fibers of the left ventricle.^[3]

Regarding peak systolic velocity (S') which is considered as an easy method for measuring the peak systolic velocity of mitral annular longitudinal movement and provides an excellent noninvasive index of global systolic function.^[21]

In the present study, there was a significant reduction in mean S' of hypertensive patients compared with mean S' of controls ($P = 0.034$) this result was in acceptance with Ayoub *et al.*^[17] who showed that a high significant reduction was

Table 3: Receiver operator characteristic coordinates for prediction of hypertension without left ventricular hypertrophy by mitral annular plane systolic excursion

Cutoff point	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
14.9	66.7	41.7	42.1	53.4	45.8
15	58.3	50	50	56.2	55
15.5	53.3	51.7	50.2	52.2	54.3

PPV: Positive predictive value, NPV: Negative predictive value

Table 4: Pearson's correlations and linear regression between mitral annular plane systolic excursion and different correlated parameters for the two hypertension subgroups

Correlations	HT without LVH
BMI (kg/m ²)	
<i>r</i>	-0.395**
<i>P</i>	0.002
EF by M-mode %:	
<i>r</i>	0.164
<i>P</i>	0.209
EF by (Simpson's)%:	
<i>r</i>	0.084
<i>P</i>	0.522
S' (cm/s):	
<i>r</i>	0.535**
<i>P</i>	0.001

*Significant correlation at 0.05 level, **Highly significant correlation at 0.01 level. BMI: Body mass index, EF: Ejection fraction, LVH: Left ventricular hypertrophy, HT: Hypertension

observed in mean S' of hypertensive patients when compared with mean S' of control group ($P = 0.01$).

MAPSE and S' are surrogates for the LV longitudinal function.^[20,22,23]

In the present study we found that there was a significant linear correlation between MAPSE and S' in all study groups; in hypertensive groups ($P = 0.001$, $r = 0.5$), and the correlation between MAPSE and S' for controls was ($P = 0.001$, $r = 0.479$), this finding agreed with Khorshid *et al.* study^[24] who studied 200 patients divided into two groups; group A included 100 patients with normal EF and group B included 100 patients with reduced EF, they found that when combining the measurement of both parameters MAPSE and S', this could increase their sensitivity and specificity for predicting normal or subnormal EF.

CONCLUSION

Although there was a significant linear correlation between MAPSE and peak systolic velocity S' and both are considered as a surrogate for LV longitudinal systolic function, MAPSE can't be used for assessment of LV longitudinal systolic function in patients with HT without LVH.

S' can be used for the assessment of subclinical LV longitudinal systolic function in hypertensive patients without LVH.

Limitations

Small sample size which is mainly limited by the exclusion criteria.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Edvardsen T, Helle-Valle T, Smiseth OA. Systolic dysfunction in heart failure with normal ejection fraction: Speckle-tracking echocardiography. *Prog Cardiovasc Dis* 2006;49:207-14.
- Cuspidi C, Ciulla M, Zanchetti A. Hypertensive myocardial fibrosis. *Nephrol Dial Transplant* 2006;21:20-3.
- Ballo P, Quatrini I, Giacomini E, Motto A, Mondillo S. Circumferential versus longitudinal systolic function in patients with hypertension: A nonlinear relation. *J Am Soc Echocardiogr* 2007;20:298-306.
- Chengode S. Left ventricular global systolic function assessment by echocardiography. *Ann Card Anaesth* 2016;19:S26-34.
- Hu K, Liu D, Herrmann S, Niemann M, Gaudron PD, Voelker W, *et al.* Clinical implication of mitral annular plane systolic excursion for patients with cardiovascular disease. *Eur Heart J Cardiovasc Imaging* 2013;14:205-12.
- Matos J, Kronzon I, Panagopoulos G, Perk G. Mitral annular plane systolic excursion as a surrogate for left ventricular ejection fraction. *J Am Soc Echocardiogr* 2012;25:969-74.
- Hernandez-Suarez DF, Lopez-Menendez F, Roche-Lima A, Lopez-Candales A. Assessment of mitral annular plane systolic excursion in patients with left ventricular diastolic dysfunction. *Cardiol Res* 2019;10:83-8.
- 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 Soc Echocardiogr* 2010;23:511-5.
- Lang RM, Badano LP, Mor-Avi V, Afilalo J, Armstrong A, Ernande L, *et al.* Recommendations for cardiac chamber quantification by echocardiography in adults: An update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *Eur Heart J Cardiovasc Imaging* 2015;16:233-70.
- Wandt B, Boj6 L, Wranne B. Influence of body size and age on mitral ring motion. *Clin Physiol* 1997;17:635-46.
- Henein MY, Gibson DG. Normal Long Axis Function. *BMJ Publishing Group Ltd*; 1999.
- Quiñones MA, Otto CM, Stoddard M, Waggoner A, Zoghbi WA, Doppler Quantification Task Force of the Nomenclature and Standards Committee of the American Society of Echocardiography. Recommendations for quantification of Doppler echocardiography: A report from the Doppler quantification task force of the nomenclature and standards committee of the American Society of Echocardiography. *J Am Soc Echocardiogr* 2002;15:167-84.
- Daniel WW, Cross CL. *Biostatistics: A Foundation for Analysis in the Health Sciences*. Wiley; 2018.
- Zanchetti A. Hypertension-related mortality and morbidity. *J Hypertens* 2015;33:1979-80.
- Tumuklu MM, Erkorkmaz U, Öcal A. The impact of hypertension and hypertension-related left ventricle hypertrophy on right ventricle function. *Echocardiography* 2007;24:374-84.
- Parikh JD, Hollingsworth KG, Wallace D, Blamire AM, MacGowan GA. Left ventricular functional, structural and energetic effects of normal aging: Comparison with hypertension. *PLoS One* 2017;12:e0177404.
- Ayoub AM, Keddeas VW, Ali YA, El Okl RA. Subclinical LV dysfunction detection using speckle tracking echocardiography in hypertensive patients with preserved LV ejection fraction. *Clin Med Insights Cardiol* 2016;10:85-90.
- Natori S, Lai S, Finn JP, Gomes AS, Hundley WG, Jerosch-Herold M, *et al.* Cardiovascular function in multi-ethnic study of atherosclerosis: Normal values by age, sex, and ethnicity. *AJR Am J Roentgenol* 2006;186:S357-65.
- Diez J, Frohlich ED. A translational approach to hypertensive heart disease. *Hypertension* 2010;55:1-8.
- Willenheimer R, Cline C, Erhardt L, Israelsson B. Left ventricular atrioventricular plane displacement: An echocardiographic technique for rapid assessment of prognosis in heart failure. *Heart* 1997;78:230-6.

21. Seo JS, Kim DH, Kim WJ, Song JM, Kang DH, Song JK. Peak systolic velocity of mitral annular longitudinal movement measured by pulsed tissue Doppler imaging as an index of global left ventricular contractility. *Am J Physiol Heart Circ Physiol* 2010;298:H1608-15.
22. 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.
23. Mogelvang R, Sogaard P, Pedersen SA, Olsen NT, Schnohr P, Jensen JS. Tissue Doppler echocardiography in persons with hypertension, diabetes, or ischaemic heart disease: The Copenhagen City heart study. *Eur Heart J* 2009;30:731-9.
24. Khorshid H, Wadea B, Sabry E. Correlation of mitral annular plane systolic excursion (MAPSE) and tissue Doppler peak systolic velocity with left ventricular systolic function. *J Cardiol Curr Res* 2017;10:349.