Available online at *www.ujpronline.com*
Universal Journal of Pharmaceutical Research
An International Peer Reviewed Journal
ISSN: 2831-5235 (Print); 2456-8058 (Electronic)

RESEARCH ARTICLE

CORRELATION BETWEEN TISSUE DOPPLER IMAGING AND LEFT VENTRICULAR SYSTOLIC FUNCTION AMONG YEMENI PATIENTS AT MILITARY CARDIAC CENTRE

Suhail Abdullah Sallam[1], Noor Aldeen Al-Jaber[1], Somaia Ganah[1], Nawal Mohammed Al-Hababi[2], Emad Hassan Al-Shamahi[2], Esmail Mohammed Saad Al-Dabis[1], Hassan Abdulwahab Al-Shamahy[1*]
[1]*Yemen Medical Specialist Council, Ministry of Health and population, Yemen.*
[2]*Opthalmology Department, Faculty of Medicine and Health Sciences, Sana'a University, Republic of Yemen.*

Article Info:

Article History:
Received: 5 April 2026
Reviewed: 8 May 2026
Accepted: 10 June 2026
Published: 15 July 2026

Cite this article:
Sallam SA, Al-Jaber NA, Ganah S, Al-Hababi NM, Al-Shamahi EH, Al-Dabis EMS, Al-Shamahy HA. Correlation between tissue doppler imaging and left ventricular systolic function among Yemeni patients at Military Cardiac Centre. Universal Journal of Pharmaceutical Research 2026; 11(3): 21-26.
http://doi.org/10.22270/ujpr.v11i3.1569

***Address for Correspondence:**
Dr. Hassan A. Al-Shamahy, Yemen Medical Specialist Council, Ministry of Health and population, Yemen. Tel: +967-1-239551
E-mail: *shmahe@yemen.net.ye*

Abstract

Background and objective: High rates of morbidity and mortality are associated with heart failure, and these rates rise as the population ages. The purpose of the study was to compare left ventricular ejection fraction (LVEF) using Simpson's technique and systolic myocardial velocity (Sm) using tissue Doppler imaging (TDI) in Yemeni patients with heart failure (HF).
Method: This study was conducted at the Military Cardiac Centre in Sana'a, Yemen, offering diagnostics, therapeutics, and surgical services to the Yemeni population. It was a 1:2 unmatched case-control study conducted from April 1 to September 30, 2025, involving a total of 180 participants (60 cases with an ejection fraction < 55% and 120 controls with an ejection fraction > 55%). Participants provided verbal consent and underwent clinical examinations, including electrocardiography.
Results: The study compares ejection fraction (EF) results across different measurement methods, showing mean EF values of 42.25 (M mod), 37.41 (Simpson), and 38.33 (eyeballing), with a significant *p*-value (<0.001) between cases and controls. In systolic left ventricle (LV) parameters, case means for S med (6.6) and S lat (7.26), along with MAPSE M (9.41) and MAPSE I (11.44), were recorded with a significant *p*-value (<0.001). Correlations were noted for S med (0.62) and S lat (0.60), with odds ratios (26.17–17.70) and confidence intervals (*CI*=3.59–2.99).
Conclusions: This study finds a strong positive correlation between TDI-derived S′ velocity and left ventricular ejection fraction (LVEF), identifying S′ as a reliable marker of systolic function. It also supports MAPSE as an effective and clinically relevant marker, especially in low-resource settings.
Keywords: Heart failure, left ventricular ejection fraction, Simpson's method, systolic myocardial velocity, tissue doppler imaging, Yemen.

INTRODUCTION

Heart failure is a syndrome with high morbidity and mortality rates, and these rates increase with the aging population[1]. Since there are no other criteria for measuring cardiac contraction function (the systolic heart function), the left ventricular ejection fraction (LVEF) is widely used as a standard for assessing cardiac function in clinical practice[2]. Regarding prongostication, measuring the LVEF can be helpful in some cases, as it is dependent on preload, after load, heart rate, contraction force, and asynchrony. The left ventricular (LV) walls do not have an even distribution of myocardial fibers[3]. While the fibers in the centre of the wall are oriented circumferentially and are primarily in charge of LV radial axis contraction, subendocardial and subepicardial muscle bundles are aligned longitudinally. The heart's pumping motion and longitudinal contraction are caused by the cardiac muscles' longitudinal fibers[4,5]. Since the atrioventricular ring is connected to the longitudinally oriented fibers at the heart base, the atrioventricular ring's movement can be used to gauge changes in the longitudinal axis[3].
Given the foregoing, longitudinal systolic myocardial function can be measured using tissue Doppler imaging (TDI). TDI is an echocardiography technique that analyses systolic and diastolic myocardial velocities

derived from mitral annuli in order to evaluate the global and regional LV longitudinal functions that are independent of the picture quality or the geometric shapes of the left ventricle[6,7]. In predicting the normal global LV function, a cutoff value of systolic velocity (S') greater than 7.5 cm/s exhibited an 88% specificity and a 79% sensitivity. Systolic myocardial velocity (Sm) measured by TDI has recently been considered as a substitute technique for evaluating the heart's systolic function[8-11].

To my knowledge, no studies have been published in Sana'a, Yemen, examining the relationship between tissue Doppler imaging and left ventricular systolic function, although one study was conducted in Aden, Yemen[12-16]. The overall aim of the current study is to correlate and evaluate the blood flow velocity (Ś) measured by tissue Doppler in assessing left ventricular function. Specifically, it aims to correlate and evaluate other systolic parameters (the mean systolic intensity index and the extended systolic intensity index) in assessing left ventricular function. Additionally, the study aims to compare different methods for assessing ejection fraction (M-mode, Simpson's method, and visual assessment).

PATIENTS AND METHODS

Study setting: This study was conducted at the Military Cardiac Centre in Sana'a - Yemen. The Cardiac Centre was opened in 2008. It provides many diagnostics, therapeutic and surgical services for all Yemeni population.

Study design: The study was both descriptive and an un-matched hospital based 1: 2 case control study, it was achieved during the period from 1 April to 30 September 2025. A structured questionnaire was prepared. Verbal consent was obtained from the patient before participation in the current study; and underwent clinical examination electrocardiography.

Case definition: Any patient preformed echocardiography in Military Cardiac Centre and his Ejection fraction less than 55%.

Control definition: Any patient preformed echocardiography in Military Cardiac Centre and his Ejection fraction more than 55%.

Population and sample of the study: The total of 180 study population of them 60 cases and 120 control 1:2 ratio who underwent Military Cardiac Centre during the period of study. During period six months from 1 April 2024 – 30 September 2025.

Inclusion criteria: Any patient came to Military Cardiac Centre in Sana'a – Yemen searching for Echocardiography assessment.

Exclusion criteria: Patients suffering from valvular heart diseases and pediatrics patients.

Sample size calculation: A sample size of 180 (60 case-patients and 120 controls) was calculated using the method by Epi-Info 7.2. This was calculated based on an alpha of 0.05, at two side confidence level of 95%, power of 80%.

Date collection: All patients who underwent cardiac surgery in Military Cardiac Centre between 1 April 2024–30 September 2025 was included in this study. Questionnaire based on patient age, sex, socio economic data, medical history and electrocardiogram collected for all patients who underwent Military Cardiac Centre searching for Echocardiography assessment during the period of study.

Echocardiographic examination: A competent cardiologist conducted the echocardiographic exams. As recommended by the American Society of Echocardiography (ASE), the same echocardiography machine (Mindray) was used to measure the patients when they were in the left lateral decubitus position in standard precordial positions. The conventional echocardiographic evaluation, which includes 2D (two-dimensional), PW (pulsed-wave) Doppler, colour Doppler, TDI, and M-mode echocardiography, was performed on all instances. Three approaches were used to calculate EF.

M-mode: The left ventricle's end-diastolic and end-systolic diameters, interventricular septum thickness, and posterior all thickness were assessed using M-mode echocardiography from the parasternal long axis (perpendicular to the ventricle's long axis at the level of the mitral valve). The Teicholz method (Teicholz EF)=(LV end-diastolic dimension)−(LV end-systolic dimension)/(LV end diastolic dimension) was utilised to estimate the ejection fraction using these measurements.

Simpson method: The apical 4- and 2-chamber pictures in the end-diastole and end-systole were used to trace the endocardial contours. The modified Simpson EF (Simpson EF)=(LV end-diastolic volume) −(LV end-systolic volume)/(LV end-diastolic volume) was used to compute the end-diastolic and end-systolic dimensions.

Eye balling (visual assessment): The visual EF was calculated by assessing the parasternal long and short-axis, apical 4- and 2-chamber views through at least three cardiac cycles. EF consider normal if it is more than 55% according to British Society of Echocardiography.

TDIś: was measured by obtaining A4C (apical four chamber) view, then adjust sample volume to be in alignment with medial mitral annulus first then with lateral one as).

Data management: The data were keenly observed and systematically cleaned. Specific checks on the coding and categorization of variables. These include harmonizing date formats, using the same unit for age, and correcting spelling mistakes.

Statistical analysis: IBM SPSS 23.0 was used for statistical analysis. Frequency tables were used to determine the prevalence of categorical variables, and the mean and standard deviation were used to represent continuous variables. Cross tabulations were used to compare categorical variables and Fisher's exact test or the chi-square tests were used to determine significance. The differences in the means of normal continuous variables between two groups were compared using a student's t-test. Statistical significance was defined as a *p*-value of less than 0.05.

Ethical consideration: The Military Cardiac Centre ethical team granted permission to conduct this study. Patient-identifying information was not entered on the data collection sheet in compliance with patient confidentiality guidelines, and each patient under study was given a unique patient identification number (PIN). Patient confidentiality could always be maintained because only the researcher knew the PIN.

RESULTS

A total of 60 TDI case patients were involved in study, the male represent 82% (49) where female represent 18%. Most TDI case patient was from age group ≥ 61 years which represent 63% (38) followed by 41-60 years age group 30% (18).

Figure 1 shows that the most TDI case patient was from Sana'a governorate which represent 27% (16) followed by Dhamar governorate 15% (9). The most TDI case patient performed cardiac intervention was PCI intervention which represent 28% (17) and 10 % (6) performed CABG intervention.

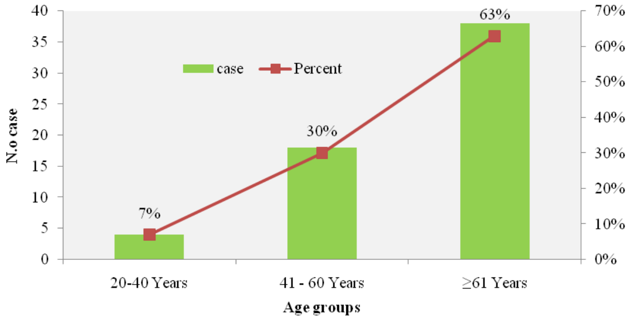

Figure 1: Distribution of TDI case patients by age groups (n=60).

Table 1: Baseline demographic and clinical characteristics of TDI study population (n=180).

Parameters	Total	Cases	Control
Number, n (%)	180(100)	60(33)	120(67)
Male/Female, n (%)	113(63)/67(37)	49(82)/11(18)	64(53)/56(47)
Age, mean ±SD	53.32±14.54	59.66±12.05	50.15±14.56
BMI (kg/m^2)	24.81±4.93	24.55±4.01	24.95±5.34
D.M Yes, n (%)	55 (31)	19 (32)	36 (30)
HTN Yes, n (%)	78 (43)	28 (47)	50 (42)
IHD Yes, n (%)	91 (51)	45 (75)	46 (38)
Smoker Yes, n (%)	29(16)	11(18)	18(15)
x smoker Yes, n (%)	87(48)	29(48)	58(48)
Qat using Yes, n (%)	128(71)	44(73)	84(70)
xQat using Yes, n (%)	30(17)	12(20)	18(15)

Analytical study

Table 1 show the demographic and clinical characteristics of both cases and controls; 33% (60) were cases and 67% (120) were controls. Males were 63%; the mean age of cases was 59.6 years (ranged 23-81 years); the mean age of controls was 50.1 years (ranged 21-75 years); and the mean BMI of cases was 24.55±4.01, and the mean BMI of the control was 24.95±5.34 D.M. represents 31% (55); the control represents 30% (36). HTN represents 43% (78); the control represents 42% (50). IHD represents 51% (91); the control represents 38% (46). The total number of smokers represents 16%, with 18% coming from cases and 15% from controls. The total of QAT users represents 71% (128) of them, with 73% from cases and 70% from control.

Table 2: Comparison of the EF result by different measurement method among case and control groups of study population, (n=180).

Methods	Cases n (60)	Control n (120)	*p* value
EF M	42.25±8.92	62.13±4.98	0.0001
EF simp	37.41±9.40	57.98±4.91	0.0001
EF Eye	38.33±9.14	57.66±4.71	0.0001

Table 3: Comparison of Systolic LV parameters among case and control groups of study population, (n=180)

LV Parameter	Case	Control	*p* value
S med	6.6±2.24	9.61±1.53	0.0005
S lat	7.26±2.56	10.66±1.92	0.0001
MAPSE M	9.41±2.97	13.96±2.44	0.0001
MAPSE L	11.44±3.16	16.30±2.72	0.0001
EPSS	13.66±7.31	5.55±1.30	0.0001

Table 2 shows the comparison of EF result by use different measurement methods where the mean of EF result of case by M mod method was (42.25±8.92), by Simpson method 37.41 SD±9.40) and by eyeballing (38.33±9.14) with statistical significant *p* value (<0.001) between case and control result. Table 3 shows the comparison of Systolic LV parameters among case and control where the mean of S med and

S lat of cases were (6.6±2.24 - 7.26 ±2.56) respectively and the mean of MAPSE M and MAPSE I of cases were (9.41±2.97-11.44±3.16) respectively which the mean of EPSS of case was (13.66±7.31) with statistical significant *p* value (<0.001) between case and control result. Table 4 shows the correlation of systolic LV ejection fraction with echocardiographic parameters, in which the correlation of S med and S lat were (0.62–0.60) with odds ratio and CI (26.17–17.7: CI 3.59–2.99), respectively, and the correlation of MAPSE L and MAPSE M were (0.41–0.51) with odds ratio and CI (9.95–12.82: CI 1.68 –2.12), respectively, in which the correlation of EPSS was (0.67 odds ratio 31.27: CI 1.85) with statistical significance *p* value (<0.001) between all parameters.

Table 4: Correlation of systolic LV ejection fraction with echocardiographic parameters among study population, (n=180).

Parameters	Correlation	Odd ratio	95% CI	*p* value
EPSS	0.67	9.18–43.30	0.59–1.85	<0.001
MPASE L	0.41	1.76–6.37	0.26–0.50	<0.001
MAPSE med	0.51	8.59–50.83	0.78–1.62	<0.001
S lat	0.60	13.57–253	0.63–1.99	<0.001
S med	0.62	7.78–145	1.05–2.63	<0.001

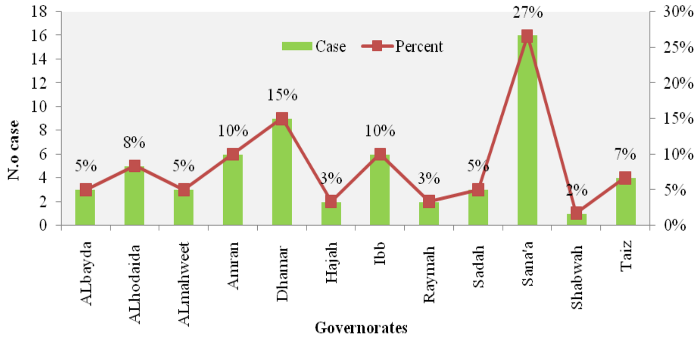

Figure 2: Distribution of TDI case patients by governorate (n=60).

DISCUSSION

The present study demonstrates a significant positive correlation between mitral annular systolic velocity (S′) measured by tissue Doppler imaging (TDI) and left ventricular ejection fraction (LVEF). Higher S′ velocities were associated with higher LVEF values, supporting the concept that longitudinal myocardial contraction plays a major role in global ventricular systolic performance. Because TDI directly measures the velocity of longitudinal myocardial fibers, the observed correlation emphasizes the importance of these fibers as indicators of systolic dysfunction.

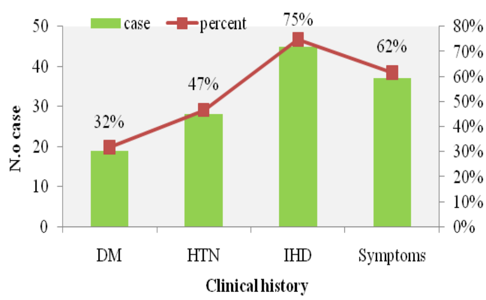

Figure 3: Distribution of TDI case patients by symptoms and clinical history.

Our findings are consistent with previous research showing that reduced S′ velocity is strongly associated with impaired LVEF and early systolic dysfunction. Earlier studies has shown that S′ is a sensitive parameter for detecting both overt and subclinical systolic impairment, even when LVEF remains within normal limits[17-21]. The agreement between our results and the existing evidence reinforces the clinical utility of S′ as a simple, quantitative, and reproducible measure of systolic function. In particular, TDI-derived S′ has been shown to remain reliable even in situations where image quality is suboptimal or when other echocardiographic measurements are technically challenging.

The clinical implications of these findings are significant. Because longitudinal myocardial fibers deteriorate earlier than radial or circumferential fibers, S′ velocity reduction may precede a detectable decline in LVEF[22]. This makes S′ a valuable parameter for early detection of cardiomyopathy, hypertensive heart disease, ischemic heart disease, and chemotherapy-induced cardiotoxicity. Additionally, the simplicity and rapid acquisition of TDI measurements allow clinicians to use S′ as a practical bedside tool in emergency settings, critical care units, and resource-limited environments that lack advanced imaging techniques. This study also demonstrates a significant positive correlation between mitral annular plane systolic excursion (MAPSE) and left ventricular ejection fraction (LVEF). This finding suggests that MAPSE, a simple M-mode echocardiographic parameter, can serve as a reliable surrogate marker of global left ventricular systolic function. The strong association observed supports the concept that longitudinal myocardial fibers, primarily located in the sub-endocardium, play a major role in ventricular systolic performance[23,24].

Our results are consistent with previous studies that have shown MAPSE to be a sensitive indicator of systolic dysfunction, particularly in conditions affecting longitudinal contraction. Earlier research[23,24] similarly demonstrated a strong correlation between reduced MAPSE values and impaired LVEF. The agreement between our findings and existing literature reinforces the potential role of MAPSE as a rapid, reproducible, and clinically useful tool in routine echo-cardiographic evaluation. This study also high-lights the clinical value of MAPSE in early detection of systolic dysfunction. Longitudinal fibers are typically affected earlier than circumferential fibers, meaning MAPSE reduction may precede a measurable decline in LVEF. Therefore, MAPSE provides an opportunity for early intervention, parti-cularly in patients with hypertension, ischemic heart disease, and cardio-myopathies[25].

The present study demonstrates a significant inverse correlation between E-point septal separation (EPSS) and left ventricular ejection fraction (LVEF). As EPSS increases, LVEF decreases, indicating impaired left ventricular systolic function. This relationship supports the clinical observation that wider separation between the anterior mitral valve leaflet and the interventricular septum reflects reduced stroke volume and weakened ventricular contraction. Obtained findings are consi-stent with early foundational work showing EPSS as a rapid and reliable marker of systolic dysfunction. Previous studies have reported that an EPSS greater than 7 mm is commonly associated with reduced ejection fraction, and our results align closely with these thresholds. Similar to earlier research[25,26], the current study reinforces the strong discriminatory power of EPSS in identifying reduced systolic per-formance. The clinical significance of EPSS lies in its simplicity, high reproducibility, and minimal depen-dence on image quality. EPSS can be obtained quickly using standard M-mode imaging, making it particularly useful in critically ill patients or scenarios requiring rapid assessment. Furthermore, unlike more advanced parameters such as global longitudinal strain, EPSS does not require specialized software or extensive operator expertise. For these reasons, EPSS remains a valuable tool for screening and triaging patients with suspected left ventricular dysfunction.

The present study compared left ventricular ejection fraction (LVEF) measured by three commonly used echocardiographic techniques: M-mode, Simpson's biplane method, and visual estimation ("eyeballing"). Overall, Simpson's biplane method produced the most accurate and representative values for global systolic function, consistent with its status as the guideline-recommended reference standard. Because it relies on endocardial tracing of two orthogonal apical views, Simpson's method minimizes geometric assumptions and provides a more realistic approximation of ventri-cular shape. In contrast, M-mode tended to produce higher LVEF values compared with Simpson's method. Many studies show the same finding. This difference is expected, as M-mode calculates systolic function based on linear dimensions from a single parasternal long-axis cut, assuming the left ventricle is a symmetrical prolate ellipse. Such geometric assumptions often fail in conditions with regional wall motion abnormalities, asymmetric remodeling, or dilated ventricles. Previous studies have similarly reported that M-mode may over-estimate LVEF, particularly in patients with ischemic heart disease or non uniform ventricular geometry[27,28].

Visual estimation ("eyeballing") showed reasonable agreement with Simpson's method in our study, especially among experienced operators. This finding is concordant with many studies as well[27]. This aligns with existing evidence suggesting that expert visual assessment can be surprisingly reliable when perfor-med by trained cardiologists. Eyeballing remains valuable for rapid bedside evaluation, particularly in emergency or critical care settings where time is limited. In addition, this is supported by earlier studies.[28,29]. However, it is inherently subjective and depends heavily on operator experience, image quality, and familiarity with a wide range of normal and abnormal echocardiographic patterns. In less experie-nced hands, visual estimation showed wider variability and tended to either over- or underestimate LVEF, supporting the need for formal quantitative methods whenever feasible.

Several factors may explain discrepancies between the three techniques. Variations in endocardial definition, image quality, ventricular geometry, and operator skill each contribute to measurement differences. Additio-nally, load conditions at the time of imaging such as heart rate, blood pressure, and intravascular volume may affect visual impressions and linear measurements more than Simpson's method[28,29].

Limitations of the study

Although this study is well-designed, some limitations should be considered. Tissue Doppler imaging is angle-dependent, and inaccurate alignment of the ultrasound beam may lead to measurement errors. Inter-examiner variability may also affect consistency, particularly among less experienced examiners.

CONCLUSIONS

This study demonstrates a strong positive correlation between TDI-derived S′ velocity and LVEF, indicating S′ as a reliable marker of left ventricular systolic function. Similarly, MAPSE is supported as an effective marker for its ease of use and clinical relevance, particularly in settings with limited imaging resources. EPSS shows a strong inverse correlation with LVEF, confirming its utility in emergency and resource-limited environments. The study concludes that Simpson's biplane method is the most accurate for measuring LVEF, while M-mode may overestimate function. Visual estimation is useful but should accompany quantitative methods. Future studies are encouraged to explore the prognostic value of S′, MAPSE, and EPSS in clinical decision-making.

ACKNOWLEDGEMENTS

The authors are grateful to Sana'a City's Military Hospital for their kind cooperation.

DATA AVAILABILITY

The related author can provide the empirical data supporting the study's conclusions upon request.

CONFLICT OF INTEREST

Regarding this project, there are no conflicts of interest.

AUTHOR'S CONTRIBUTIONS

Sallam SA: formal analysis, conceptualisation, data organisation, clinical exams. **Al-Jaber NA:** supervision, critical review. **Ganah S:** supervision, critical review. **Al-Hababi NM:** supervision, critical review. **Al-Shamahi EH:** data analysis. **Al-Dabis EMS:** data analysis. **Al-Shamahy HA:** data analysis. Final manuscript was checked and approved by all authors.

REFERENCES

1. Jaffé Kannel WB, Belanger AJ. Epidemiology of heart failure. Am Heart J 1991; 121(3 Pt 1):951-7. *https://doi.org/10.1016/0002-8703(91)90225-7*
2. Sanderson JE, Fraser AG. Systolic dysfunction in heart failure with a normal ejection fraction: Echo-Doppler measurements. Prog Cardiovasc Dis 2006; 49(3):196-206. *https://doi.org/10.1016/j.pcad.2006.08.005*
3. Alam M, Wardell J, Andersson E, *et al*. Effects of first myocardial infarction on left ventricular systolic and diastolic function with the use of mitral annular velocity determined by pulsed wave Doppler tissue imaging. J Am Soc Echocardiogr 2000; 13(5):343-52. *https://doi.org/10.1067/mje.2000.104393*
4. Lundbäck S. Cardiac pumping and function of the ventricular septum. Acta Physiol Scand Suppl 1986; 550 :1-101.
5. Jones CJ, Raposo L, Gibson DG. Functional importance of the long axis dynamics of the human left ventricle. Br Heart J 1990; 63(4):215-20. *https://doi.org/10.1136/hrt.63.4.215*
6. Sutherland GR, Bijnens B, McDicken WN. Tissue Doppler echocardiography: Historical perspective and technological considerations. Echocardiography 1999; 16 (5):445-53. *https://doi.org/10.1111/j.1540-8175.1999.tb00091.x*
7. Waggoner AD, Bierig SM. Tissue Doppler imaging: A useful echocardiographic method for the cardiac sonographer to assess systolic and diastolic ventricular function. J Am Soc Echocardiogr 2001;14(12):1143-52. *https://doi.org/10.1067/mje.2001.115391*
8. Gulati VK, Katz WE, Follansbee WP, Gorcsan J 3rd. Mitral annular descent velocity by tissue Doppler echocardiography as an index of global left ventricular function. Am J Cardiol 1996; 77(11):979-84. *https://doi.org/10.1016/S0002-9149(96)00033-1*
9. Nagueh SF, Bachinski LL, Meyer D, *et al.* Tissue Doppler imaging consistently detects myocardial abnormalities in patients with hypertrophic cardio-myopathy and provides a novel means for an early diagnosis before and independently of hypertrophy. Circulation 2001; 104(2):128-30. *https://doi.org/10.1161/01.CIR.104.2.128*
10. Wandt B, Fornander Y, Egerlid R. Maximal longitudinal contraction velocity in assessment of left ventricular systolic function: A pulsed tissue Doppler and M-mode study. Echocardiography 2004;21(7):587-92. *https://doi.org/10.1111/j.0742-2822.2004.03159.x*
11. Arques S, Roux E, Sbragia P, *et al.* Accuracy of tissue Doppler echocardiography in the diagnosis of new-onset congestive heart failure in patients with levels of B-type natriuretic peptide in the midrange and normal left ventricular ejection fraction. Echocardiography 2006; 23 (8):627-34. *https://doi.org/10.1111/j.1540-8175.2006.00281.x*
12. D'Andrea A, D'Andrea L, Caso P, *et al*. The usefulness of Doppler myocardial imaging in the study of the athlete's heart and in the differential diagnosis between physio-logical and pathological ventricular hypertrophy. Echo-cardiography 2006; 23(2):149-57. *https://doi.org/10.1111/j.1540-8175.2006.00186.x*
13. Saxena N, Rajagopalan N, Edelman K, *et al*. Tricuspid annular systolic velocity: A useful measurement in determining right ventricular systolic function regardless of pulmonary artery pressures. Echocardiography 2006; 23(9):750-5. *https://doi.org/10.1111/j.1540-8175.2006.00305.x*
14. Duzenli MA, Ozdemir K, Soylu A, *et al*. The effect of isolated left bundle branch block on the myocardial velocities and myocardial performance index. Echocar-diography 2008; 25 (3): 256-63. *https://doi.org/10.1111/j.1540-8175.2007.00579.x*
15. Vinereanu D, Lim PO, Frenneaux MP, Fraser AG. Reduced myocardial velocities of left ventricular long-axis contraction identify both systolic and diastolic heart failure-a comparison with brain natriuretic peptide. Eur J Heart Fail 2005;7(4):512-9. *https://doi.org/10.1016/j.ejheart.2004.07.014*
16. Obeid FA. Systolic myocardial velocity by tissue doppler imaging versus left ventricular ejection fraction by Simpson's Method in Yemeni patients with heart failure. Yemeni J Med Sci 2019; 13:30-34. *https://doi.org/10.20428/YJMS.13.1.A4*
17. Francula-Zaninovic S, Nola IA. Management of measurable variable cardiovascular disease' risk factors. Curr Cardiol Rev 2018; 14(3): 153-163. *https://doi.org/10.2174/1573403X14666180222102312*
18. Pollock JD, Makaryus A. N. Physiology 2022, Cardiac Cycle. StatPearls Publishing.
19. Flint A. C, Conell C, Ren X, *et al*. Effect of systolic and diastolic blood pressure on cardiovascular outcomes. The New Eng Med 2019; 381(3): 243-251. *https://doi.org/10.1056/NEJMoa1803180*
20. Kashani A, Barold SS. Significance of QRS complex duration in patients with heart failure. J American College Cardiol 2005; 46(12), 2183-2192. *https://doi.org/10.1016/j.jacc.2005.01.071*
21. Obando MA, Marra EM, Wide QRS. Complex Tachycardia. StatPearls Publishing 2022.
22. Ashley EA, Niebauer J. Cardiology explained. London: Remedica; 2004. Chapter 3, Conquering the ECG. *https://www.ncbi.nlm.nih.gov/books/NBK2214.*
23. Sattar Y, Chhabra L. Electrocardiogram 2022. In StatPearls. Publishing.
24. Fukuta H, Little WC. The cardiac cycle and the physiologic basis of left ventricular contraction, ejection, relaxation, and filling. Heart Failure Clin 2008; 4(1), 1-11. *https://doi.org/10.1016/j.hfc.2007.10.004*
25. Mitchell JR, Wang JJ. Expanding application of the Wiggers diagram to teach cardiovascular physiology. Advances Physiology Education 2014; 38(2): 170-175. *https://doi.org/10.1152/advan.00123.2013*
26. Berman M. N, Tupper C, Bhardwaj A. Physiology 2022, Left Ventricular Function. StatPearls Publishing.
27. Bastos MB, Burkhoff D, Maly J, *et al.* Invasive left ventricle pressure-volume analysis: Overview and practical clinical implications. Europ Heart J 2020; 41(12): 1286-1297. *https://doi.org/10.1093/eurheartj/ehz552*
28. Burkhoff D. Pressure-volume loops in clinical research: A contemporary view. J American College Cardiol 2013; 62(13); 1173-1176. *https://doi.org/10.1016/j.jacc.2013.05.049*
29. van der Velde E. T, van Dijk A. D, Steendijk P, *et al*. Left ventricular segmental volume by conductance catheter and Cine-CT. European Heart J 13 Suppl E 1992; 15-21. *https://doi.org/10.1093/eurheartj/13.suppl_E.15*