Zagazig University Medical Journal
www.zumj.journals.ekb.eg
https://doi.org/10.21608/zumj.2024.328604.3644 Volume 31, Issue 1, January. 2025

Manuscript ID **ZUMJ-2410-3644**
DOI **10.21608/ZUMJ.2024.328604.3644**

Review Article

Speckle Tracking Echocardiography and Its Role in Detection of Remodeling Among Patients with Coronary Artery Disease

Ahmed Shafeea Ammar, Mohammad Mostafa Al-Daydamony, Mahmoud Ali Ahmed Elabyad *, Mohammed Salah Ghareeb
Cardiology Department, Faculty of Medicine, Zagazig University, Zagazig, Egypt

***Corresponding author:**
Mahmoud Ali Ahmed Elabyad

Mail:
Drelabyad91@yahoo.com

Submit Date **15-10-2024**
Revise Date **20-10-2024**
Accept Date **21-10-2024**

ABSTRACT

Background An initial assessment method for coronary artery disease (CAD) is echocardiography, which aids medical professionals in the diagnosis and prognostication of cardiac conditions. Visual assessment of wall motion anomalies, however, is not always successful in differentiating between myocardial ischemia that is less obvious or brief. Since it can locate ischemic territories in accordance with coronary lesions and identify subtle myocardial damage, speckle tracking echocardiography (STE) is a widely accessible noninvasive tool that can quickly and easily provide additional information over basic echocardiography. This allows for a clear visualization with a "polar map" that is useful for differential diagnosis and management. As a result, it has been used more often in both acute and chronic coronary syndromes with stress and rest echocardiogram, demonstrating positive outcomes in terms of left ventricular remodeling, clinical outcome prediction, CAD prediction, and the presence and measurement of new or residual ischemia. This review's objective is to present the most recent data on STE's value in CAD assessment and follow-up. Conclusions: Beyond ECG and biomarkers, echocardiography is a milestone for the evaluation of CAD in acute and chronic settings. STE could provide an additive value over visual wall motion assessment both for diagnostic and prognostic assessment, and the inclusion of LVGLS in clinical diagnostic workup of these patients is supported by plenty of evidence and clear advantages overweighing the intrinsic limitations of STE technique. However, further studies are needed to confirm the potential value of other chambers' strain.

Keywords: Speckle Tracking, Echocardiography, Coronary Artery Disease.

INTRODUCTION

In most labs, the visual identification of endocardial wall motion anomalies and the assessment of left ventricular (LV) ejection fraction are used in the echocardiographic evaluation of regional myocardial function, which is crucial to the diagnosis and treatment of ischemic heart disease. Nevertheless, this method is dependent on the operator, subjective, and requires full vision of the endocardium. It is also affected by heart rate and cardiac workload. Consequently, an objective, thorough, noninvasive method of measuring cardiac contractility and function that has a reasonable degree of interpretive variability is required [1]. More recent indices, such as myocardial strain and strain rate (SR), may be able to get beyond these restrictions. A process that requires energy and happens in both the systole and diastole of the heart, myocardial deformation is represented by strain and heart rate, respectively. Detecting regional myocardial dysfunction is made sensitively possible by abnormalities of myocardial deformation, which are observed early in the development of several pathophysiologic conditions, including ischemia [2].

By using velocity gradients along the cardiac tissue, tissue Doppler also enables the indirect computation of myocardial deformation. This makes it possible to quantify myocardial strain and strain rate (SR) and to accurately characterize cardiac deformation. These deformation indices are direct measures of cardiac contractility since they are unaffected by the tethering phenomenon [3].

A novel noninvasive ultrasound technique for measuring myocardial mechanics is called speckle tracking echocardiography, or STE. By monitoring natural acoustic reflection and interference patterns within a predetermined ultrasonic window, it assesses tissue mobility. An image processing algorithm is used to monitor these pixels, known as kernels, which are groups of 20–40 pixels that include markers or fingerprints known as speckles [4]. As a result, this modality analyzes tissue motion and deformation independently of angle. Therefore, tissue Doppler strain, which indirectly calculates strain from velocity gradients, is not as reliable as STE, which evaluates myocardial deformation or strain directly. Doppler derived strain is highly dependent on the angle of interrogation, making it unpredictable in the parasternal long axis and short axis planes and likely only reliable in the apical imaging planes[5].

What is strain and strain rate?

Strain: A hypothetical one-dimensional object, such as a line, can only deform in one direction either it will shorten or lengthen and strain is defined as the deformation of an item normalized to its initial shape. Below is an illustration of this. Since strain is the definition of the relative amount of deformation, it can be expressed as follows:

$$\varepsilon = \frac{L - L_0}{L_0}$$

Where ε = strain, L0 = baseline length and L = instantaneous length at the time of measurement**[6].**

The deformation of two-dimensional (2D) objects is not restricted to a single direction of stretching or shortening. A two-dimensional item can exhibit normal strain, which is the lengthening or shortening of the object along the x or y axis, and shear strain, which is the distortion caused by the relative movement of the top to lower border or the right to left border. Two normal strains and two shear strains make up the four components of strain in two dimensions [7]. As a percentage change from the original dimension, strain (ε) is a dimensionless index of deformation. The rate of this deformation is measured by SR, which is represented in units of seconds. It is measured in s -1 [2].

Types of strains:

Myocardial deformation can be observed in three directions: longitudinal, circumferential, and radial. while the myocardium shortens longitudinally, decreases circumferentially, and thickens radially during systole, end diastole should be used as a fixed reference point [8]. Consequently, there are three basic categories of strains: 1. Circumferential strain (CS) 2. Longitudinal strain (LS) 3. Strain radial (RS). Figure (1) shows that the myocardial deformation is positive radially (positive RS) and negative longitudinally and circumferentially (negative LS and CS).

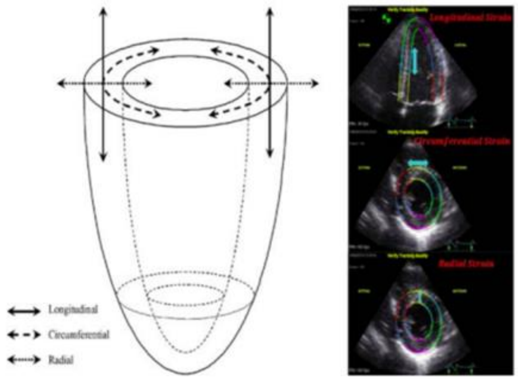

Figure (1): 1A to C: STE, diagrammatic representation of speckles in left ventricle wall and their relative motion to each other depicting longitudinal strain in 4C (A), circumferential strain (B), and radial strain (C) in short axis views **[9].**

The typical ranges for LS are −15% to −20%, CS<20% and −25%, RS<30% and 40%, and the peak systolic SR is −1.1/sec to −1.11/sec [10]. Regional myocardial function can be best measured using strain; however, with the advent of speckle tracking, a new parameter known as "global strain" has been proposed for assessing LV performance globally. Global longitudinal strain, which may be seen in an apical picture, represents the longitudinal deformation along the entire LV wall. An average GLS value is obtained by combining the data from the three apical perspectives; figure (2) [11].

Other measurements: Such as peak systolic strain, end-systolic strain, post-systolic strain (PSS), and peak strain, as illustrated in figure (3). Given that it directly affects derived metrics like post-systolic shortening, it is clear that the definition of end-systolic of particular importance is important **[7].** While 2D-STE is an effective and verified method, it relies on the presumption that speckles can be precisely tracked during the cardiac cycle and will always stay inside the boundaries of the 2D picture planes. The three-dimensional mobility of the heart chambers may make this assumption invalid in some situations. One of the three components of displacement vectors cannot be measured by 2D-STE, which has a negative impact on the accuracy of the derived strain indices. Based on the concepts of acquiring 3D echo pictures with a wide angle matrix array transducer operating in the "full volume" mode, 3D-STE has recently been developed. Speckles moving through the image plane can be tracked using 3D-STE [13].

Clinical Applications of Speckle Tracking Echocardiography Prognostic Implications: Lower GLS has been demonstrated to be a strong and reliable predictor of vascular events in the general population, including stroke and myocardial infarction, as well as the beginning of new atrial fibrillation. **[14].**

Myocardial disease: Different myocardial disorders, including as hypertension, myocarditis, ischemia, infarction, and CMP, cause increased collagen deposition that leads to fibrosis, or they may result in myocardial infiltration, such as amyloidosis or glycogen storage disease. The following are some of the different cardiac conditions that impact the myocardium and can be assessed using strain and twist mechanics; Coronary artery diseases (CADs), such as ischemic CMP and viability tests, acute and chronic ischemia, and acute infarction. Hypertension. Diabetic dilated pupil. Cardiac hypertrophic disease. CMP restrictions. CMP related to diabetes. Amyloidosis. Heart valve disorders. Dyssynchrony. HFpEF stands for heart failure with maintained EF [15].

Coronary Artery Disease: Assessing regional dysfunction in CAD patients is arguably the most useful clinical use of strain measures. The existence of ischemia can be determined by longitudinal strain. Furthermore, promising results regarding strain measurement's capacity to forecast ischemia extent and distinguish between transmural and non-transmural scar were documented [11]. Myocardial ischemia is thought to be identified by the presence of post systolic strain, which is defined as localized myocardial shortening following aortic valve closure. Early research employing TDI-derived data has shown the existence of PSS in regions with ischemia insult[16]. An ischemic event's prolonged PSS persistence was linked to a more severe coronary blockage. Though PSS is an extremely sensitive indicator of regional dysfunction, it is crucial to remember that it is never exclusive to any one pathology; rather, PSS must always be evaluated in the context of either pathology, clinical conditions, or both. Resting PSS may indicate myocardial scarring, ischemia, or other problems. Nonetheless, PSS that arises during stress echocardiography can increase the accuracy of CAD detection because it is most likely induced by ischemia; figure (4) [17]. Recently, the evaluation of regional cardiac deformation at a layer-specific level has been made easier by a unique use of multilayer speckle-tracking TTE. The endocardial, mid-wall, and epicardial layers that make up the LV wall are not always uniformly deformed. When cardiac perfusion is normal, the endocardial layer uses more oxygen than the epicardial layer, and when perfusion is impaired, it receives less collateral flow. Consequently, ischemia can affect the endocardial layer of the left ventricle more easily than the epicardial layer.Without the requirement for medication or exercise loading, multilayer speckle-tracking TTE can aid in the early diagnosis of ischemia myocardium since it produces quantitative strain measurements of the LV endocardial and epicardial layers. **[18]**.

*Acute MI:*According to the extent of the infarcted region, longitudinal strain (LS) is markedly decreased in the infarcted segments; figure (5). Whereas the CS and RS are likewise compromised in transmural MI, only the LS are diminished in subendocardial infarcts, while the CS and RS are preserved. With a sensitivity of 70% and specificity of 71.2 %, it has been demonstrated that a segmental RS cutoff of 16.5% and CS <11.1% may distinguish between non-transmural and transmural infarction **[19].**

Longitudinal strain in patients with STEMI using speckle tracking echocardiography. Correlation with peak infarction mass and ejection fraction: The global peak systolic longitudinal strain was found to exhibit a strong negative association with the size of the infarct by MPI. In terms of GLS, the big myocardial infarction size (≥30% of LV mass) was defined as -11.5%, with a sensitivity of 93% and a specificity of 67% [21]. Speckle tracking analysis of echocardiographic predictors of left ventricular remodeling following acute ST elevation myocardial infarction. It was discovered that the 2D global longitudinal strain was an independent parameter for the unfavorable remodeling of the left ventricle. Patients with STEMI frequently have LV remodeling, which may indicate a poor prognosis for an acute myocardial infarction [22].

The prognostic significance of left ventricular global longitudinal strain differs for myocardial infarctions caused by diabetes and non-diabetes. After STEMI, diabetic individuals have equal infarct size and LVEF at baseline and follow-up, but they exhibit more impaired LV GLS at both baseline and follow-up 6 months [23]. This contrasts with a matched group of patients without diabetes. The prognostic significance of left ventricular global longitudinal strain varies depending on whether an anterior or non-anterior myocardial infarction occurs. According to a study, GLS significantly predicts the 2-year outcome in MI with anterior walls, however there is less of a correlation between GLS and mortality in MI without anterior walls. GLS was a more sensitive predictor of death in individuals with anterior MI than in those without anterior MI, according to a significant interaction between the infarction territory and GLS [24].

Detection of ischemia: For patients to receive effective treatment, coronary artery disease (CAD) must be ruled out as soon as symptoms appear. In individuals at risk of developing CAD, left ventricular (LV) longitudinal strain, determined using 2D (STE), has become a noninvasive diagnostic of both global and localized LV dysfunction. Since patients with severe CAD have >70% stenosis in the epicardial arteries or >50% stenosis in the left main in symptomatic patients, current evidence supports the use of GLS in the detection of moderate to severe obstructive CAD, which is defined as those with >50% stenosis in the coronary arteries. GLS may function as an early adjunctive marker of myocardial ischemia and supplement current diagnostic algorithms **[25]**.

Prediction of ventricular arrhythmias after MI: Asynchronous LV deformation can be evaluated via strain imaging (e.g., by measuring the time to peak strain). A synchronization issue in CAD patients, known as mechanical dispersion and defined as the standard deviation of the time to peak regional shortening, could be used to identify patients at high risk of developing arrhythmias. Figure (6) shows an illustration of a greater mechanical dispersion resulting from ischemia in comparison to a normal myocardium. **[11].**

*Hypertension***:** The comprehension of the variations in deformation patterns associated with concentric LV hypertrophy and concentric remodeling has been improved using speckle tracking echocardiography. For several years during the early stages, the LV-EF is retained. In patients with hypertensive heart involvement, the torsional mechanics of the CS, RS, and LV are intact, but the longitudinal stresses are compromised. Nonetheless, there is a decrease in the early diastolic untwisting velocity, which in certain investigations correlates with the extent of hypertrophy **[26].**

Hypertrophic cardiomyopathy: Myocardial disarray, which causes both diastolic and systolic dysfunction, is the pathognomonic hallmark of high cardiac mass. STE has demonstrated LS reduction with comparatively intact CS. Numerous investigations have shown that the apical variation loses the typical apical to base gradient and has lower apical strain values compared to strain values in the basal segments **[27].**

Diabetes mellitus: Strain echocardiography allows for the early diagnosis of myocardial dysfunction in patients with long-standing diabetes who are asymptomatic from a cardiac standpoint, as seen by impairment of LS. **[28]**.

Dilated Cardiomyopathy: It has been demonstrated that impairment of all three directional strains (LS, CS, and RS) is linked to dilated cardiomyopathy. Significant reductions in the apex and base of the rotational mechanics also result in a decrease in the untwisting velocity and apical twist. Comparatively asymptomatic patients have been found to have higher strain and SR levels than those with noticeable symptoms. Some patients may exhibit a reversal of the typical pattern, rotating clockwise at the LV apex and counterclockwise at the LV base. **[29].**

Heart Failure and Dyssynchrony: Heart failure syndromes are distinguished by a range of clinical entities and varying presentations depending on the temporal course. Understanding the mechanics of HF has been greatly aided by speckle tracking strain echocardiography. The characteristic feature of HFpEF is decreased LS with intact apical rotational mechanics; however, the patterns of CS and RS may vary. However, LV torsion and peak untwisting rate are similarly decreased when HF condition advances from diastolic to systolic dysfunction [30]. Restrictive cardiomyopathy and Pericardial Diseases The role of the pericardium in facilitating LV TWISTS deformation: While the LS, CS, and RS are intact, there is a noticeable deficit in LV torsion in cases of congenital lack of the pericardium. The apical twist, CS, and RS are significantly reduced in constrictive pericarditis, although the LS is largely retained [31]. Conversely, LS is significantly attenuated in restrictive CMP, such as cardiac amyloidosis, although CS, RS, and LV torsion are largely unaltered until late stages and contribute to maintaining the LV-EF. However, CS, RS, and torsional mechanics become involved as the illness process continues to advance [32].

Valvular Heart Disease: The LV dilates appropriately in response to the rise in the volume load caused by mitral and aortic regurgitation. The preservation of LV-EF indicates that this contributes to the maintenance of the LV systolic function. This can be a cover for a subclinical malfunction. However, the left ventricle (LV) exhibits wall enlargement in response to an increase in the pressure load caused by aortic stenosis. The LV-EF is maintained, and wall stress can be reduced thanks to the LV muscle's enhanced thickness. When subclinical left ventricular dysfunction is identified in valvular heart disease, adequate early intervention can be implemented [33].

Patients with aortic stenosis (AS) showed a very large reduction in peak longitudinal systolic strain when compared to the control group. Therefore, even when the EF% is retained, patients with severe AS exhibit subclinical LV systolic dysfunction. In individuals with AS, 2D speckle tracking seems to be helpful in identifying subclinical LV failure [34].

Congenital Heart Disease: When treating several congenital cardiac conditions that call for biventricular repair, an objective and quantitative assessment of RV mechanics is crucial. This involves transposition of great vessels, particularly following atrial switch surgery, pulmonary atresia with intact IVS, and cTGA. In congenital cardiac lesions requiring single ventricular repair (Fontan's Repair), objective assessment of the dominant ventricle function is very crucial, particularly in the cases of single ventricle, tricuspid atresia, complex double outlet RV (DORV), and AV canal anomalies. **[35].**

CONCLUSION:

Echocardiography is a major advancement in the assessment of CAD in both acute and chronic conditions, going beyond ECG and biomarkers. The inclusion of LVGLS in the clinical diagnostic workup of these patients is supported by a wealth of evidence and clear advantages overweighing the intrinsic limitations of STE technique, suggesting that STE could provide an additive value over visual wall motion assessment for both diagnostic and prognostic assessment (Figure 2). To validate the possible significance of the strain in other chambers, more research is necessary. It is quite probable that future experts will reach a consensus to determine reference values for LV strain parameters in CAD, leading to a final standardization of their use.

Conflict of interest: The authors declare no conflict of interest.

Funding sources: The authors have no funding to report.

REFERENCES

1. Li L, Zhang PY, Ran H, Dong J, Fang LL, Ding QS. Evaluation of left ventricular myocardial mechanicsby three-dimensional speckle tracking echocardiographyin the patients with different graded coronary artery stenosis. Int J Cardiovasc Imaging. 2017; 33 (10): 1513-20.
2. Smiseth OA, Torp H, Opdahl A, Haugaa KH, Urheim S. Myocardial strain imaging: how useful is it in clinical decision making?.Eur Heart J. 2016; 37(15):1196-207.
3. Lervik LCN, Brekke B, Aase SA, Lønnebakken MT, Stensvåg D, Amundsen BH, et al. Myocardial Strain Rate by Anatomic Doppler Spectrum: First Clinical Exp erience Using Retrospective Spectral Tissue Doppler from Ultr a High Frame Rate Imaging.Ultrasound Med Biol. 2017; 43(9):1919-29.
4. Di Salvo G, Pergola V, Fadel B, Al Bulbul Z, Caso P. Strain Echocardiography and Myocardial Mechanics: From Basi cs to Clinical Applications.J CardiovascEchogr. 2015; 25(1):1-8.
5. Westholm C, Johnson J, Sahlen A, Winter R, Jernberg T. Peak systolic velocity using color-coded tissue Doppler imaging, a strong and independent predictor of outcome in acute coronary syndrome patients. Cardiovasc Ultrasound, 2013; 11:9.
6. Dandel M, Lehmkuhl H, Knosalla C, Suramelashvili N, Hetzer R. Strain and strain rate imaging by echocardiography basic concepts and clinical applicability. CurrCardiol Rev, 2009; 5(2):133-48.

7. Voigt JU, Pedrizzetti G, Lysyansky P, Marwick TH, Houle H, Baumann R, et al. Definitions for a common standard for 2D speckle tracking echocardiography: consensus document of the EACVI/ASE/Industry Task Force to standardize deformation imaging.Eur Heart J Cardiovasc Imaging, 2015; 16(1):1-11.
8. Buccheri S, Monte I, Mangiafico S, Bottari V, Leggio S, Tamburino C. Feasibility, reproducibility, and agreement between different speckle tracking echocardiographic techniques for the assessment of longitudinal deformation. Biomed Res Int. 2013:297895.
9. Arias-Godínez JA, Guadalajara-Boo JF, Patel AR, Pandian NG. Function and mechanics of the leftventricle: from tissue Doppler imaging to three dimensional speckle tracking.ArchCardiol Mex. 2011; 81(2):114-25.
10. Abduch MCD, Alencar AM, Mathias Jr W, Vieira MLDC. Cardiac mechanics evaluated by speckle tracking echocardiography. Arq Bras Cardiol, 2014; 102 (4): 403-12.
11. Mirea O, Duchenne J, Voigt JU. Recent advances in echocardiography: strain and strain rate imaging.F1000Res. 2016; 29; 5.
12. Radwan H and Hussien E. Value of global longitudinal strain by two dimensional speckle tracking echocardiography in predicting coronary artery disease severity. Egypt. Heart J., 2017; volume 99 Issue 2, Pages 95-101.
13. Ahn HS, Kim YK, Song HC, Choi EJ, Kim GH, Cho JS, et al. The impact of preload on 3-dimensional deformation parameters: principal strain, twist and torsion. Cardiovasc Ultrasound. 2017; 15(1):22.
14. Russo C, Jin Z, Sera F, Lee ES, Homma S, Rundek T, et al. Left Ventricular Systolic Dysfunction by Longitudinal Strain Is an Independent Predictor of Incident Atrial Fibrillation: A community Based Cohort Study. Circ Cardio vasc Imaging. 2015; 8(8):e 003520.
15. Chopra HK. Strain and strain rate imaging clinical implications. Cardiology Update: a text book of cardiology. 2014; chapter 52;314-5.
16. Ozawa K, Funabashi N, Nishi T, Takahara M, Fujimoto Y, Kamata T, et al. Determination of best post-systolic shortening parameters on resting TTE for detection of left ventricular ischemic segments quantitatively confirmed by invasive fractional flow reserve.Int J Cardiol. 2016; 222:27-30.
17. Asanuma T and Nakatani S. Myocardial ischaemia and post- systolic shortening. Heart, 2015; 101(7):509-16.
18. Nishi T, Funabashi N, Ozawa K, Takahara M, Fujimoto Y, Kamata T, et al. Resting multilayer 2D speckle-tracking transthoracic echocardiography for the detection of clinically stable myocardial ischemic segments confirmed by invasive fractional flow reserve. Part 1: Vessel-by-vessel analysis. Int J Cardiol. 2016; 218:324-32.
19. Eitan A, Kehat I, Mutlak D, Lichtenberg G, Amar D, Agmon Y. Longitudinal two- dimensional strain for the diagnosis of left ventricular segmental dysfunction in patients with acute myocardial infarction.Int J Cardiovasc Imaging, 2018; 34(2):237-49.
20. Citro R, Bossone E, Kuersten B, Gregorio G, Salustri A. Tissue Doppler and strain imaging: anything left in the echo- lab?. Cardiovasc Ultrasound. 2008; 6:54.
21. Ismail AM, Samy W, Aly R, Fawzy S, Hussein K. Longitudinal strain in patients with STEMI using speckle tracking echocardiography. Correlation with peak infarction mass and ejection fraction. The Egyptian Journal Of Critical Care Medicine, 2015; 3 (2-3): 45- 53.
22. Hsiao JF, Chung CM, Chu CM, Lin YS, Pan KL, Chang ST, et al. Two-Dimensional Speckle Tracking Echocardiography Predict Left Ventricular Remodeling after Acute Myocardial Infarction in Patients with Preserved Ejection Fraction. PLoS One. 2016; 11(12):e0168109.
23. Hoogslag GE, Abou R, Joyce E, Boden H, Kamperidis V, Regeer MV, et al. Comparison of Changes in Global Longitudinal Peak Systolic Strain After ST- Segment Elevation Myocardial Infarction in Patients With Versus Without Diabetes Mellitus. Am J Cardiol. 2015; 116(9):1334-9.
24. Jang SY, Yang DH, Kim NK, Kim CY, Bae MH, Lee JH, et al. Difference in the Prognostic Impact of Left Ventricular Global Longitudinal Strain between anterior and Nonanterior Myocardial Infarction. Echocardiography, 2016; 33(7):984-90.
25. Liou K, Negishi K, Ho S, Russell EA, Cranney G, Ooi SY. Detection of Obstructive Coronary Artery Disease Using Peak Systolic Global Longitudinal Strain Derived by Two-Dimensional Speckle-Tracking: A Systematic Review and Meta-Analysis. J Am Soc Echocardiogr. 2016; 29 (8):724-35.

26. Tadic M, Cuspidi C, Bombelli M, Grassi G. Hypertensive heart disease beyond left ventricular hypertrophy: are we ready for echocardio-graphic strain evaluation in everyday clinical practice? J Hypertens. 2018; 36(4):744-53.
27. Suzuki R, Mochizuki Y, Yoshimatsu H, Niina A, Teshima T, Matsumoto H, et al. Early detection of myocardial dysfunction using two-dimensional speckle tracking echocardiography in a young cat with hypertrophic cardio-myopathy. JFMS Open Rep. 2018; 4(1):20:55.
28. Shepherd DL, Nichols CE, Croston TL, McLaughlin SL, Petrone AB, Lewis SE, et al. Early detection of cardiac dysfunction in the type 1 diabetic heart using speckle- tracking based strain imaging. J Mol Cell Cardiol. 2016; Jan; 90:74-83.
29. Murtaza G, Virk HU, Khalid M, Rahman Z, Sitwala P, Schoondyke J, et al. Role of Speckle Tracking Echocardiography in Dilated Cardiomyopathy: A Review. Cureus. 2017; 9(6):e1372.
30. Liu S, Guan Z, Jin X, Meng P, Wang Y, Zheng X, et al. Left ventricular diastolic and systolic dyssynchrony and dysfunction in heart failure with preserved ejection fraction and a narrow QRS complex. I.. nt J Med Sci, 2018; 15(2):108-14.
31. Madeira M, Teixeira R, Costa M, Gonçalves L, Klein AL. Two- dimensional speckle tracking cardiac mechanics and constrictive pericarditis: systematic review. Echocardiography. 2016; 33(10):1589-99.
32. Rocha AM, Ferreira SG, Nacif MS, Ribeiro ML, Freitas MR, Mesquita CT. Speckle Tracking and Transthyretin Amyloid Cardiomyopathy. Arq Bras Cardiol, 2017; 108(1):21-30.
33. Unger P, Clavel MA, Lindman BR, Mathieu P, Pibarot P. Pathophysiology and management of multivalvulardisease.Nat Rev Cardiol. 2016; 13 (7): 429-40.
34. Cengiz B, Şahin ŞT, Yurdakul S, Kahraman S, Bozkurt A, Aytekin S. Subclinical left ventricular systolic dysfunction in patients with severe aortic stenosis: A speckle-tracking echocardiography study. Turk Kardiyol DernArs, 2018; 46(1):18-24.
35. Cheung YF. Functional assessment for congenital heart disease. Korean Circ J. 2014; 44(2): 59-73.

Citation

Ammar, A., Al-Daydamony, M., Ahmed Elabyad, M., Ghareeb, M. Speckle Tracking Echocardiography and Its Role in Detection of Remodeling Among Patient with Coronary Artery Disease. *Zagazig University Medical Journal,* 2024; (113-120): -. doi: 10.21608/zumj.2024.328604.3644