Section A -Research paper

Evaluation of Left Atrial Functions by Left Atrial Strain

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Abstract:

Left atrial (LA) strain (ε) and ε rate (SR) analysis by two-dimensional speckle tracking can represent a new tool to evaluate LA function.

Keywords: Left Atrial Strain, Speckle Tracking, Echocardiographic.

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Introduction:

There is no single parameter that best defines LA function and a variety of parameters have been previously defined Transmitral peak A wave velocity, its velocity time integral and atrial fraction are well described measures of LA contractile function. The LA ejection force, based on Newtonian principles, incorporates peak A velocity and was used as a marker of LA function. Subsequently, tissue Doppler derived A' velocity was utilised as a less load dependent measure of LA contractile function, demonstrating good correlation with traditional Doppler and LA volumetric measurements. Colour tissue Doppler analysis was able to evaluate segmental LA function, demonstrating temporal changes with improved LA function following cardioversion. However, using these measures mandates the presence of sinus rhythm (SR). The LA function index (LAFI) was derived to evaluate LA function even in atrial fibrillation (AF). Additionally, volumetric measures including the LA ejection fraction (LAEF) and LA expansion index (LAEI) have been utilised, both in SR and AF. **(1)**

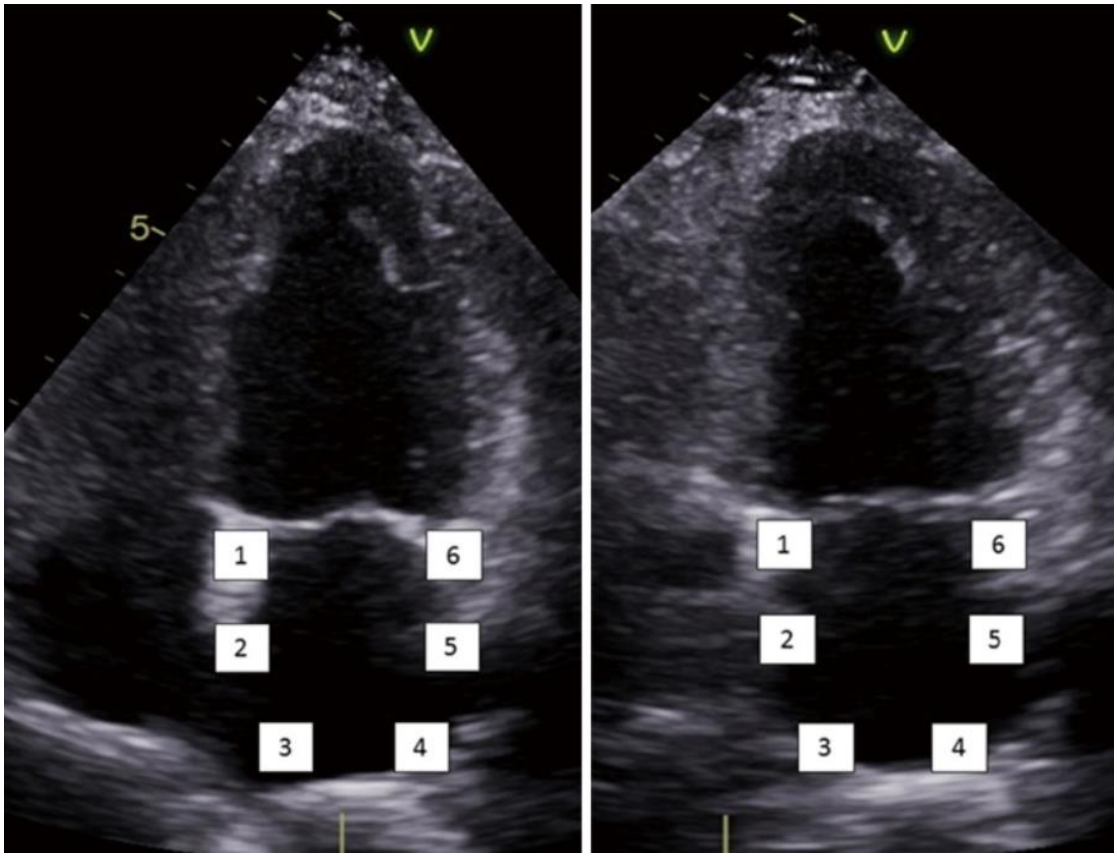
More recently, strain analysis has been utilised for evaluation of LA function. Strain evaluates myocardial deformation while strain rate examines the rate of change in strain, and can be measured throughout the cardiac cycle, thereby enabling the evaluation of LA reservoir function (in systole) and conduit and contractile function (in diastole) **(2).**

Strain and strain rate imaging of the LA

Strain and strain-rate imaging have several advantages over conventional

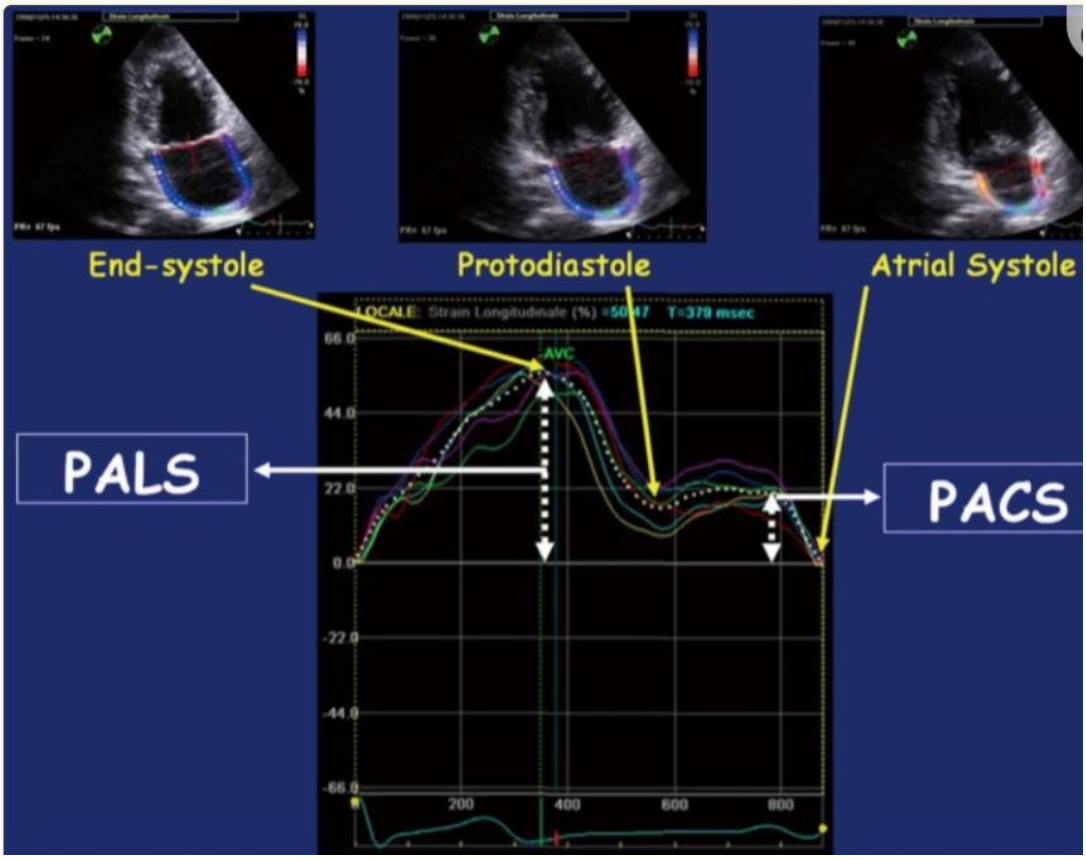
echocardiography in evaluation of LA function. Firstly, strain imaging is not evaluated relative to the transducer position, thus allowing discrimination between active and passive myocardial tissue movement (Strain parameters are relatively independent of tethering effects and is less load dependent compared to traditional parameters of LA function. Additionally, strain and strain rate parameters permit evaluation of phasic atrial function throughout the cardiac cycle. There are as yet no validated strain algorithms that have been developed exclusively for evaluation of LA function. However, several studies have utilised strain software that was developed for the left ventricle, with adjustments to the width of the 'region of interest' (ROI) to evaluate LA strain **(3).**

LA strain measurements can be obtained by tissue Doppler imaging (TDI), two dimensional (2D) speckle tracking echocardiography (STE) and velocity vector imaging (VVI). For the latter two techniques, longitudinal strain and strain rate curves are generated for each of six atrial segments, obtained from the apical four and two chamber views. Heterogeneous segmental deformation of the LA has also been observed, with higher values noted in the regions adjacent to the mitral annulus**(1).**



Apical four and two chamber six LA segments. LA, left atrial.

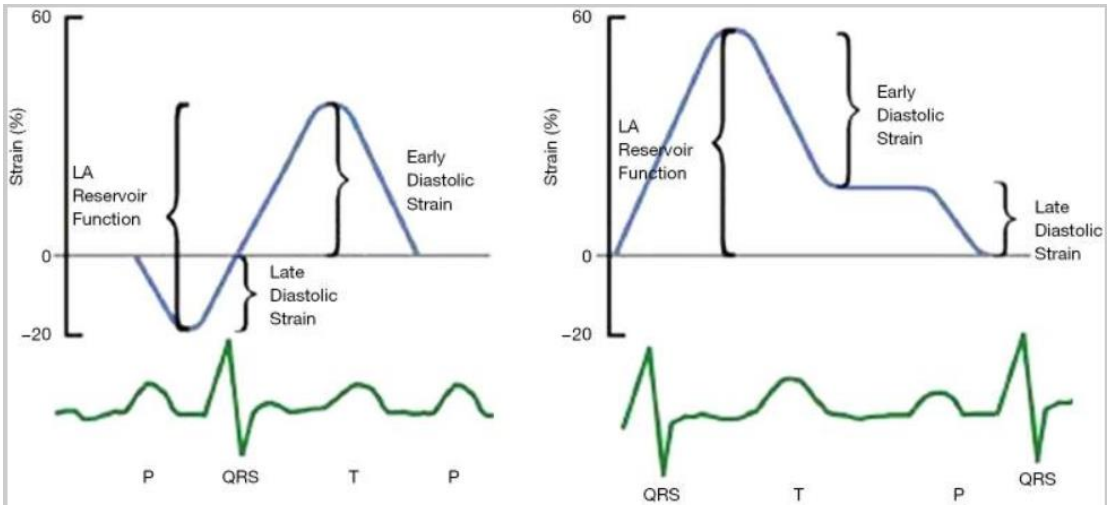
In the reservoir phase, as the LA fills and stretches, there is positive atrial strain that reaches its peak in systole at the end of LA filling, prior to opening of the mitral valve. Following this, passive LA emptying ensues with opening of the mitral valve resulting in decreased atrial strain with negative deflection of the strain curve up to a plateau period which is analogous to diastasis. A second deflection in the strain curve is then observed corresponding to atrial systole. Peak atrial longitudinal strain (PALS) or LA systolic strain is measured at the end of the reservoir phase. Peak atrial contraction strain (PACS) or late diastolic strain, is measured following the P wave and corresponds to active atrial contraction.



Peak atrial longitudinal strain (PALS) and peak atrial contraction strain (PACS).

LA strain curves have two patterns that differ based on the time in the cardiac cycle from which the software processing begins i.e., either at the onset of the P wave (atrial cycle/diastolic gating) or the onset of the QRS complex (ventricular cycle/systolic gating).If the strain processing begins at onset of QRS, ventricular end diastole is the zero reference and peak positive longitudinal strain corresponds to atrial reservoir function, strain during early diastole reflects atrial conduit function and strain during late diastole corresponds to atrial contractile function. Conversely, if software processing

begins at onset of P wave, atrial end diastole becomes the zero reference and the first negative peak strain represents the atrial contractile function, positive peak strain corresponds to conduit function, and their sum (strain total) represents reservoir function. Strain rate in ventricular systole (S sr), early diastole (E sr) and late diastole (A sr) correspond to reservoir, conduit, and booster pump functions in both methods **(4).**



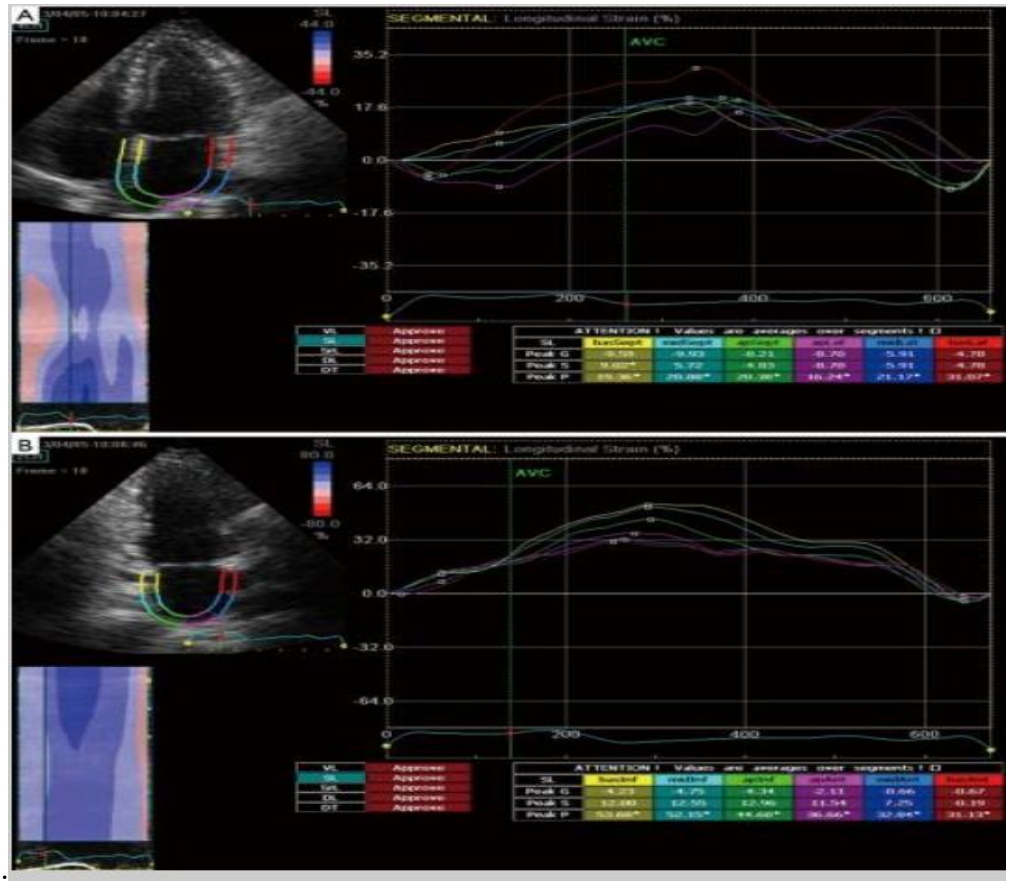
Strain trace based on choice of electrocardiographic gating; electrocardiographic P wave used on the left and QRS complex used on the right. Modified from Hoit *et al*. Left panel: P wave (atrial end diastole) used as zero reference point whereby first negative peak strain represents the atrial contractile function, positive peak strain corresponds to conduit function, and their sum (strain total) represents reservoir function. Right panel: QRS complex (ventricular end diastole) used as zero reference point whereby peak positive longitudinal strain corresponds to atrial reservoir function, strain during early diastole reflects atrial conduit function and strain during late diastole corresponds to atrial contractile function. LA, left atrial.

LA strain by 2D STE

STE is a newer echocardiographic technique for strain and strain rate analyses that tracks ‘speckles’ or natural acoustic markers in the 2D ultrasound image. The geometric shift of each speckle position is traced throughout the cardiac cycle **(5).**

STE strain is increasingly applied in the study of LA mechanics. Apical four and two chamber view images of the LA are obtained using conventional 2 dimensional echocardiography, at relatively high frame rates (60–80 fps). The LA endocardium is traced in both four and two chamber views and the ROI adjusted to the thinner wall of the atrium. In regions of discontinuities of the LA wall, such as areas corresponding to pulmonary veins and LA appendage, extrapolation of the LA endocardial and epicardial surfaces at the junction of these

structures are performed to obtain the ROI. The ROI is divided into six segments and the total of 12 segments is analysed with the software generating the individual segmental longitudinal strain curves together with global strain in each view **(5).**



2D strain by speckle tracking echocardiography demonstrating segmental and global LA strain from the apical (A) four and (B) two chamber views. LA, left atria

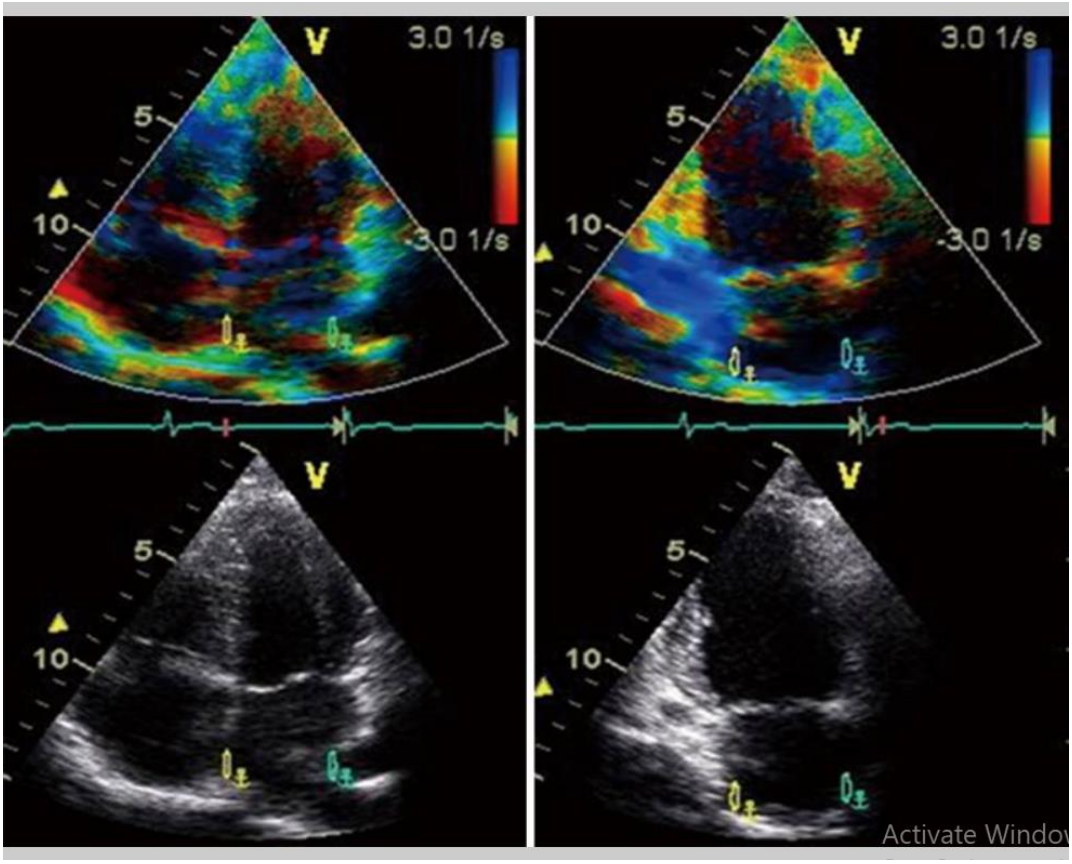
The feasibility and reproducibility of STE for the study of LA mechanics have been validated in several studies, and can be obtained in ~90% of cases. The major limitation is the necessity for adequate 2 dimensional image quality and acquisition at a relatively high frame rate. Though its utility is presently still limited to research settings **(6).**

LA strain by TDI

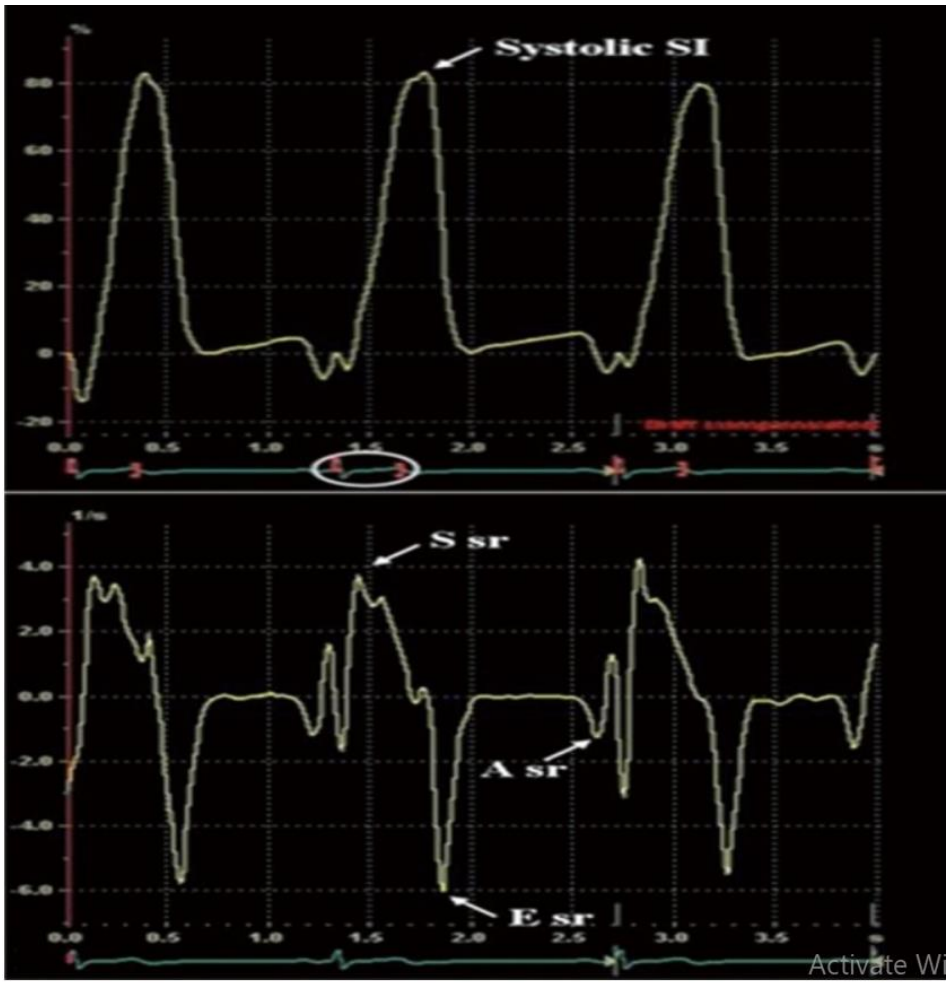
TDI depicts myocardial motion (measured as tissue velocity) at specific locations in the heart. Integration of velocity over time yields displacement or the absolute distance moved by that point.

Tissue-Doppler LA strain and strain rate are measured offline from colour tissue Doppler images of the atria obtained in the apical four and two chamber views, at high

frame rates (>100 fps). A narrow sample volume (9 mm × 1 mm) is selected due to the thin atrial walls, as compared with the sample volume used for LV strain measurements (9 mm × 9 mm). The sample volume is placed superiorly in each of the four LA walls; septal and lateral walls in the apical four chamber view and the inferior and anterior walls in the apical two chamber view. The sample volume is then tracked frame by frame, within this position in the LA wall, to prevent sampling of blood pool. The superior location in the LA walls is selected to avoid interference from mitral annular motion. Peak LA systolic strain was measured by adjusting the electrocardiogram gating to the start of the QRS complex (systolic gating). Atrial strain rate was measured in S sr, E sr and A sr.



Peak systolic strain measured by ECG gating to the start of the QRS complex (systolic gating).



Atrial strain rate measured in systole (S sr), early (E sr) and late diastole (A sr).

From a physiological precept, healthy ageing is associated with alterations in LV systolic and diastolic strain, with corresponding changes in atrial strain. Doppler LA strain parameters demonstrate age related changes earlier than corresponding volumetric measurements of phasic LA function **(7).**

Tissue Doppler assessment of atrial strain has been utilised in a variety of clinical settings to quantitate atrial function, remodelling and changes in phasic atrial function. Evaluations have included patients with hypertension, hypertrophic cardiomyopathy, Fabry disease, atrial septal defects, valvular stenosis and AF **(8).**

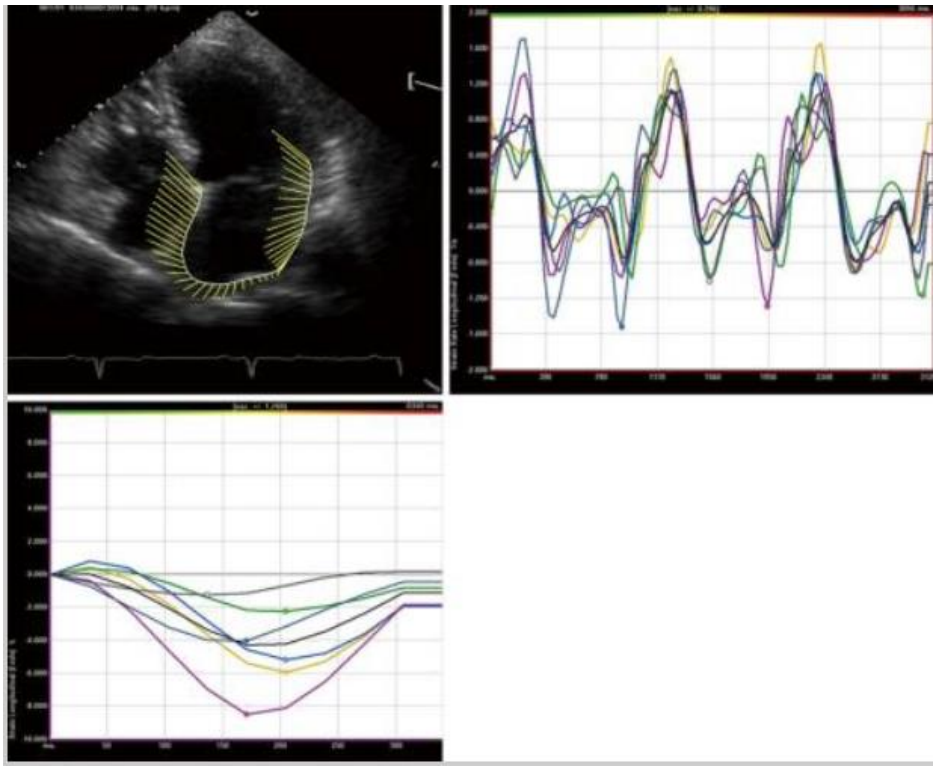
TDI LA strain also has demonstrated prognostic value. Decreased LA systolic strain has been associated with increased LV end-diastolic pressure.and is thus, a predictor of diastolic HF. LA TDI strain has also been shown to be an important predictor of maintenance of SR following both cardioversion and ablation for AF. In the only outcome based study using LA TDI strain, total TDI atrial strain in patients with hypertrophic cardiomyopathy was the strongest predictor of 12-month outcomes**(9).**

More recently TDI LA strain has been used to demonstrate reduced reservoir and conduit phasic function with preserved active contractile function in patients with metabolic syndrome. The use of tissue Doppler techniques in this cohort may have been of particular importance in the setting of potential suboptimal 2D image quality**(10).**

LA strain by VVI

VVI is a novel echocardiographic method that combines speckle tracking and endocardial border detection. Similar to 2D STE strain imaging, VVI is angle independent but has additional advantages of simpler and faster tracking/processing times compared to conventional STE with the use of a continuously self-updating software and requires only a single frame tracing of the endocardial border **(11).**

With VVI analysis, 2D images of apical four and two chamber views are obtained with recommended frame rates between 70–100 Hz. The endocardium of the LA is manually traced in the four and two chamber views and velocity vectors are generated in cine loop format. The ROI is delineated and tracked. The displacement of LA endocardial pixels of the ROI and the velocity of deformation in every frame with the elongation or shortening of myocardium throughout the cardiac cycle, are the strain and SR measures which are calculated automatically. Special reference settings are applied, including valve annulus, chamber borders and tissue motion. **(12)**



Velocity vector imaging.

VVI has been shown to be feasible and less time consuming in assessing LA

volumes and function. In a study by Valocik *et al.* retrospectively assessing 100 transthoracic echocardiograms, LA volumes derived from VVI time volume curves had a good correlation with conventional LA volume assessment. A moderate level of correlation was noted with respect to LAEF. VVI led to a 62% reduction in measurement time in comparison to conventional 2D assessment. These findings were corroborated by Motoki *et al.* in a separate study involving 127 patients with AF. Measurement of LA strain and SR by VVI and 2D STE was noted to be feasible in a large proportion of patients with comparable strain and strain rate measurements using the two techniques **(11).**

LA strain assessed by VVI has shown clinical utility in patients with HF. Esmaeilzadeh *et al.* demonstrated that LA strain by VVI was significantly lower in patients with HFrEF compared to healthy subjects in a study involving 35 patients with LVEF <35% in SR. On multivariable analysis of diastolic parameters, a significant inverse relationship was identified between pulmonary arterial pressure and LA strain suggesting that systolic pulmonary artery pressure in HFrEF may be related to LA contractile dysfunction **(13).**

In diabetic patients, LA strain by VVI was useful in characterising diastolic function. In a study involving 121 patients with type 2 diabetes mellitus, Jarnert *et al.* demonstrated that. LA strain by VVI was impaired in type 2 diabetes mellitus patients with mild or moderate LV diastolic dysfunction compared to those without diastolic dysfunction **(11).**

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