Innovations in Cardiac Imaging: the rising importance of LA Strain

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Take Home Messages
• Left Atrial (LA) Strain is an early marker of diastolic dysfunction and can show changes prior to structural/volumetric changes. • It is particularly useful in patients with heart failure and preserved ejection fraction and atrial fibrillation. • LA strain has prognostic value and can predict adverse outcomes. • Incorporation of LA strain should be routinely done as an adjunct to other markers of diastolic dysfunction.

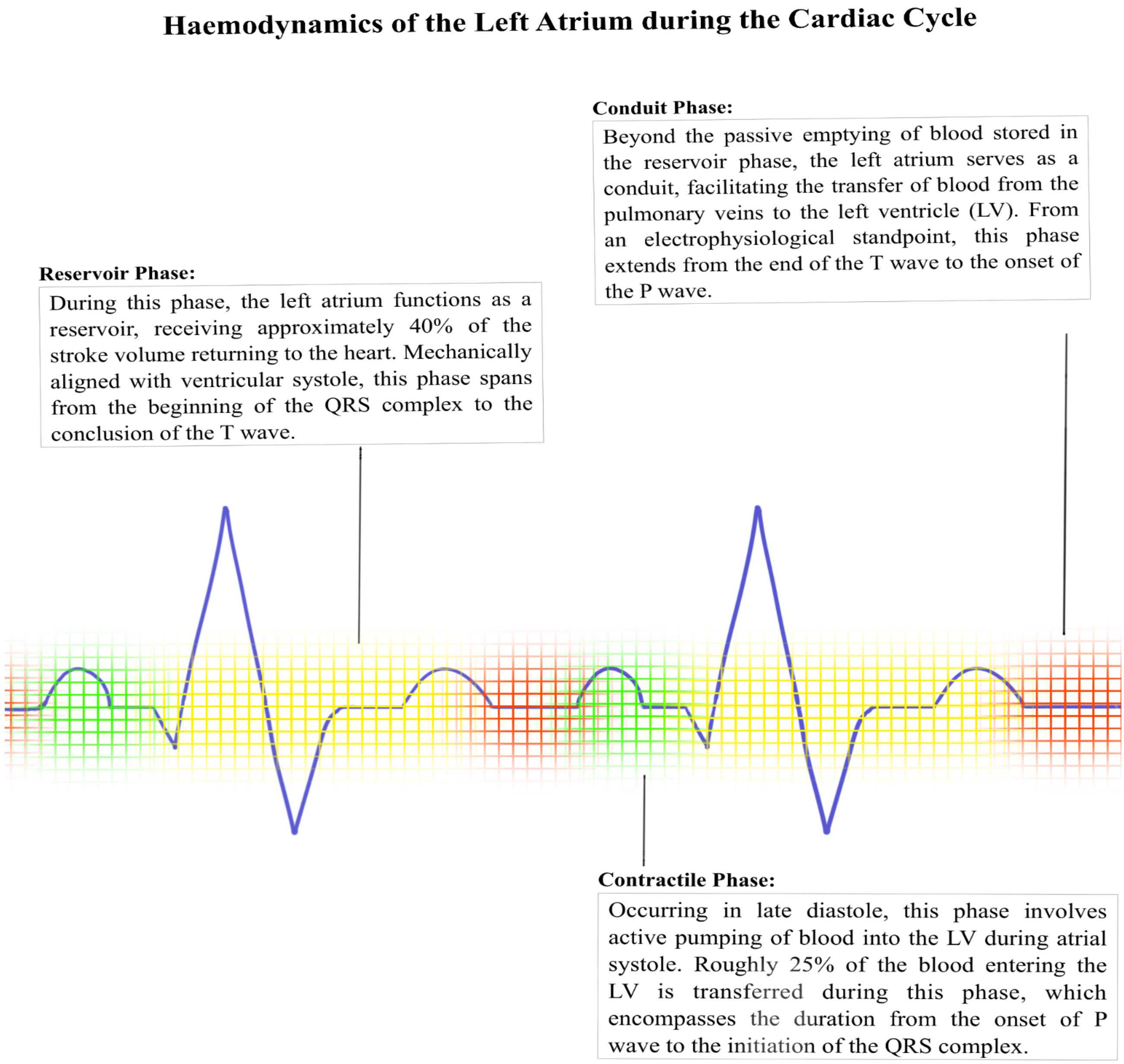

Figure 1. Haemodynamics of the Left Atrium during the cardiac cycle. Created by Dr A Khalil for British Cardiovascular Society.

Strain has become an integral part of cardiac imaging. It is a quantification of deformation, essentially presented as a percentage to illustrate alterations in length relative to initial length. Left atrial (LA) strain mirrors the intricate interplay among left atrial myocardial contractility, compliance, the size of the left atrium and prevailing loading conditions.

Table 1. Measuring LA Strain	
Anatomical Considerations	In grasping the intricacies of left atrial anatomy, it's crucial to note that unlike the LV, the LA lacks a uniform contour with interruptions posed by the presence of pulmonary veins and atrial appendage. When assessing LA strain, the process entails measuring the myocardial length change along a line connecting the lateral mitral annular ring to the medial mitral annular ring, tracing the left atrial contour. We solely assess the global deformation of the left atrium i.e. global longitudinal strain without delving into the regional strain analysis due to these anatomical discontinuities. Moreover, due to thinness of the atrial wall, there is no necessity for a distinct differentiation of the various myocardial layers, a principle commonly employed in the assessment of LV strain. When measuring LA strain, the region of interest stays slender, and the endocardial border is treated as a uniform entity.
Gating considerations	In the context of left atrial assessment using 2D speckle tracking, it is possible to employ two gating approaches: one from the onset of atrial systole (referred to as P-to-P gating) and the other from ventricular systole (referred to as R-to-R gating). However, when dealing with patients experiencing atrial fibrillation, the use of P-to-P gating becomes impractical and therefore R-to-R gating is preferred.

Technique	For image acquisition, one can opt for a monoplane approach with the apical 4-chamber view or a biplane technique incorporating the apical 2-chamber view. Obtaining 3-5 beats of an unmagnified, high frame rate optimised LA view is paramount and the software algorithms can calculate the rest.
Modalities commonly employed to evaluate LA strain	• 2D Speckle Tracking (discussed here) • Tissue Doppler Imaging • Velocity Vector Imaging • 3D Speckle Tracking

Types of LA strain

Left atrial strain is assessed at three specific points during cardiac cycle: the baseline (representing the deformation at end-diastole), the conclusion of the reservoir phase and the commencement of atrial contraction. Three distinct calculations can be derived from these measurements (**Figure. 2/Figure. 3**):

- ***Reservoir Strain (LASr):*** It is determined by calculating the variance between end-systolic and baseline values, resulting in a positive value that signifies left atrial enlargement during this phase.
- ***Conduit Strain (LAScd):*** Calculated as the difference between peak and pre-contraction point value, this measurement correlates with passive emptying of the LA. A negative value is seen indicating a reduction in left atrial size during this conduit phase.
- ***Contractile Strain (LASct):*** Measured between pre-contraction and baseline points, this calculation aligns with active emptying of the left atrium. Like conduit strain, a negative value signifies a further reduction in left atrial deformation during the atrial systole.

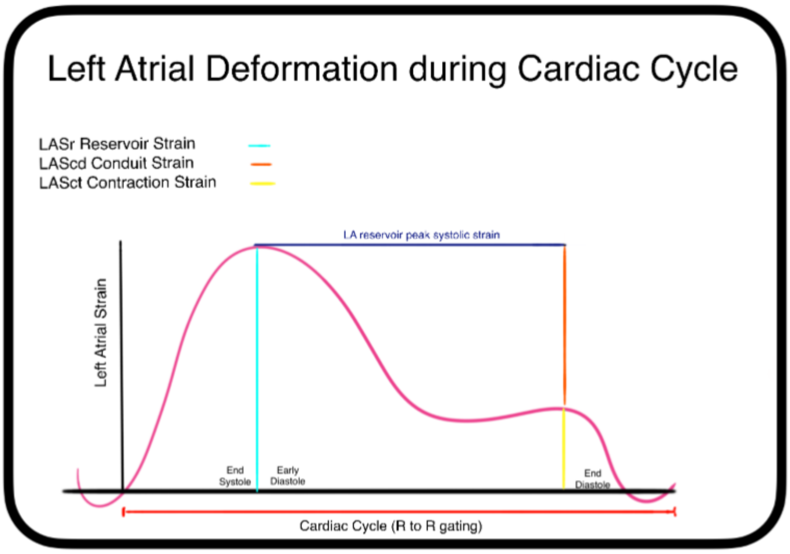

Figure 2. This figure demonstrates LA deformation/strain during Cardiac Cycle. Created by Dr A Khalil for British Cardiovascular Society. (Metanalysis by Pathan et al. provides standard reference range for LASr as 39%, LAScd as 23 % and LASct as 17%.) (1)

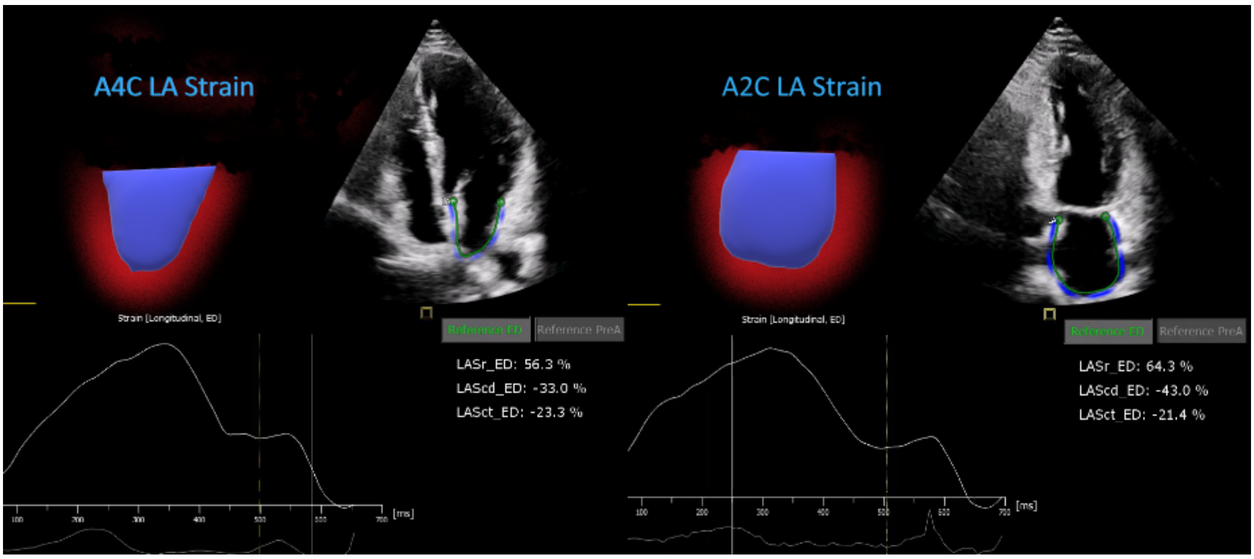

Figure 3. This figure demonstrates LA deformation in a healthy individual (Apical 4 chamber (A4C) and Apical 2 chamber(A2C)). For British Cardiovascular Society.

Clinical Significance of LA strain

Considerable advancements have been made in understanding the relationship between LA strain and various cardiovascular parameters.

Wakami et al. discovered that higher left ventricular end-diastolic pressure (LVEDP) correlated with lower peak longitudinal strain in the left atrial wall. Patients with <30% peak LA strain had elevated LVEDP, while those with 45% or more typically had normal pressures. (2) Kurt et al. found that LASr had a stronger correlation with LVEDP and NTproBNP than LASct. A reservoir strain of ≤31.2% could predict LVEDP ≥ 16 mmHg with 88.2% sensitivity and 92% specificity. (3) These studies highlight LASr's role in predicting elevated LVEDP and distinguishing between cardiac and non-cardiac causes of dyspnoea.

It is worth noting that E/E' has limitations in its use and may not be reliable in cases of concurrent bundle branch block or mitral valve disease. In patients with preserved left ventricular ejection fraction, LA strain showed a stronger correlation with LVEDP than E/E'. (4) Among various LA strain components, LASr demonstrated superior diagnostic accuracy in predicting LVEDP compared to LAScd or LASct. (4) This emphasises LASr's usefulness, particularly in patients with minimal symptoms where traditional measures struggle to differentiate diastology.

Phasic LA strain parameters alter earlier than volumetric LA changes, suggesting they could serve as early markers for detecting diastolic dysfunction. (5) Similarly, Mondillo et al. demonstrated early LASr reduction in hypertensive and diabetic populations despite normal LA volume. (6) This can potentially aid in early detection of individuals at risk for cardiomyopathies.

Singh et al. found that LASr effectively differentiated between various grades of diastolic dysfunction. A strain greater than 35% indicated normal diastolic function, while a strain below 19% identified restrictive filling physiology. (7) In situations where other measurements of diastolic function lack reliability, this could be highly useful.

Venkateshvaran et al. showed that using LASr instead of TR peak velocity when assessing diastology through standard echocardiographic parameters correlated better with invasive measurements of pulmonary capillary wedge pressures. (8) This is particularly valuable in patients with pre-capillary and idiopathic pulmonary hypertension where TR velocities may be misleading.

In individuals with atrial fibrillation (AF), LA strain not only helps in assessing diastolic function but can also predict disease burden. Specifically, LA global strain below 30.9% corresponds to a fourfold increase in the likelihood of paroxysmal AF progressing to persistent AF when followed up over a median duration of 26 months. On the other hand, elevated indexed left atrial volume indicates a twofold increased risk. (9) Employing this can result in effective stratification of patients when exploring diverse treatment alternatives.

Moreover, in a study by Yang et al., LA strain and LA strain rate emerged as prognostic indicators for adverse outcomes in asymptomatic individuals with severe mitral regurgitation and preserved left ventricular ejection fraction. (10) This implies that functional LA changes may precede LV changes and can potentially have utility in deciding timing of valvular intervention.

Whilst most research has focused on acquired cardiac diseases, recent data shows that LASr below 18% outperforms other measures like indexed left atrial volume, E/E', and TR velocity in identifying elevated LVEDP in patients with coarctation of the aorta. (11) This discovery holds the potential to assist in patient stratification before invasive diagnostic procedures, and upon validation, may pave the way for evaluating other congenital heart disease with a comparable approach.

Table 2. Challenges with 2D LA Strain	
Image resolution	The reliability of speckle tracking for the left atrial myocardium diminishes when there is poor image resolution; leading to the loss of contour detection between the darker atrium and the lighter left atrial myocardium.
Reproducibility	Individual variations in image acquisition for the LA focused apical views can result in variations in the acquired values of LA strain.
Concurrent mitral regurgitation	The LA strain exhibits a biphasic pattern in mitral regurgitation (MR). Initially, it increases in mild MR as the LA enlarges. However, as MR becomes moderate or severe, LA strain gradually decreases. Even though the left atrial volume increases significantly in severe MR, the deformation of the left atrium decreases due to remodelling processes.

Conclusion

The integration of strain analysis into modern cardiac imaging has provided valuable insights into functional aspects of the left atrium. The diverse applications of left atrial strain ranging from predicting elevated LVEDP and detecting diastolic dysfunction to its potential role in predicting prognosis and outcomes, underscore its significance. The evolving landscape of strain analysis in cardiac imaging opens avenues for improved risk stratification and early diagnosis, potentially transforming the way we approach and manage cardiovascular conditions.

Disclosures

Nil

References

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