Review Article

My Approach to Atrial Strain by Cardiac Magnetic Resonanc

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Abstract

Assessment of left atrial strain (LAS) using cardiac magnetic resonance (CMR) is gaining interest in cardiology as a novel parameter, as it quantifies the left atrium's (LA) deformation throughout the cardiac cycle. Traditionally, LA function was inferred from left ventricular ejection fraction and LA volume. However, recent studies emphasize the prognostic significance of directly analyzing atrial function, particularly in atrial fibrillation (AF), heart failure, and arterial hypertension. CMR provides a thorough evaluation of cardiac anatomy and function, enabling precise and reproducible measurement of atrial tissue deformation.

Introduction

In recent years, assessing the performance of the left atrium (LA) has become increasingly crucial for diagnosing and prognosing various diseases.[1] Traditionally, evaluations were limited to morphological analyses of diameters and volumes, along with echocardiography using speckle tracking.[2] However, there is a growing emphasis on assessing the degree of deformation of the LA using cardiac magnetic resonance (CMR), which correlates well with echocardiographic data and provides prognostic information in different clinical scenarios.[3, 4]

Left atrial strain (LAS), specifically, refers to the ability of the LA walls to stretch and shorten, indicating atrial pump function, which is a key indicator for adequate ventricular filling and, consequently, overall cardiac function. The assessment of LAS is recommended for patients requiring evaluation of diastolic dysfunction and those with cardiac amyloidosis, atrial fibrillation (AF), arterial hypertension, and heart failure, among other comorbidities.[5,6] The best-known technique for CMR assessment is feature tracking imaging (FTI), which will be detailed further on in this article.

Keywords

Left Atrium; Right Atrium; Cardiac Magnetic Resonance Imaging; Stran Imaging

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My Approach

In order to evaluate LAS, 2D steady-state free procession (SSFP) cine resonance images must be acquired in the longitudinal axes. The longitudinal axis is used as a quantitative parameter for the degree of atrial deformation. There are two different methods for analyzing left atrial longitudinal strain (LALS), as described in the literature:

a. **12-segment** analysis: 4 and 2 chambers (most used);
b. **15-segment** analysis: 4, 2 and 3 chambers.

One of the software options available for analysis is CVI42® (Circle Cardiovascular Imaging Inc., Calgary, AB, Canada, Version 5.13.5), and it has been used in this article. In this analysis, cine resonance images are imported into the software, and the contours of the LA's endocardium and epicardium are manually delineated in selected longitudinal axes (Figure 1). The software automates contour propagation, with the possibility of manual adjustments for tracing correction. Special attention should be given to excluding the LA appendage and pulmonary veins during contour delineation. In the three-chamber view, the aortic root should be excluded from the analysis (Figure 2). After tracing and adjusting, the software automatically calculates the LALS, LA radial strain (Figure 3), and the strain rate. These metrics indicate the magnitude and rate of LA deformation, respectively.

The LALS graphic images allow for the analysis of three aspects of LA deformation: reservoir function (total deformation), booster pump function (active deformation), and conduit function (passive deformation). These functions correspond to various stages of the cardiac cycle where the LA acts as a reservoir, receiving blood from the pulmonary veins; a conduit, transporting blood to the left ventricle (LV) due to pressure differences caused by the opening of the mitral valve; and a booster pump, aiding atrial systole at the end of LV diastole.[7]

Additionally, it is recommended to evaluate the LA function, which can be automated using the same software by calculating the ejection fraction in biplanar mode in four chambers. For calculation purposes, it is necessary to trace the atrial contours from which the values will be extracted: maximum LA volume at the end of ventricular systole and minimum LA volume. Based on this information, the software will provide atrial ejection fraction values.

The same software also evaluates the right atrium strain by performing the contour analysis in the longitudinal plane in four chambers. The software automatically provides longitudinal and radial strain values (Figure 4).

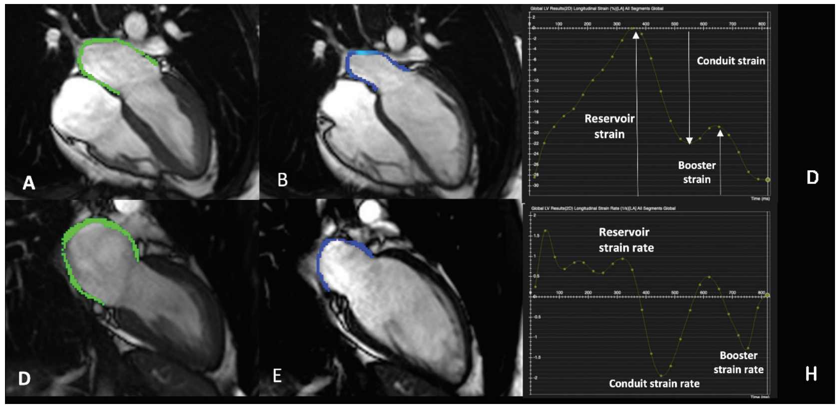

Figure 1 – *LA longitudinal strain analysis by FTI. (A;B) four-chamber view, (A) diastole and (B) systole. (C) graphical analysis of the longitudinal strain of the four-chamber plane. (D;E) two-chamber view, (D) diastole and (E) systole. (F) graphical analysis of the longitudinal strain rate.*

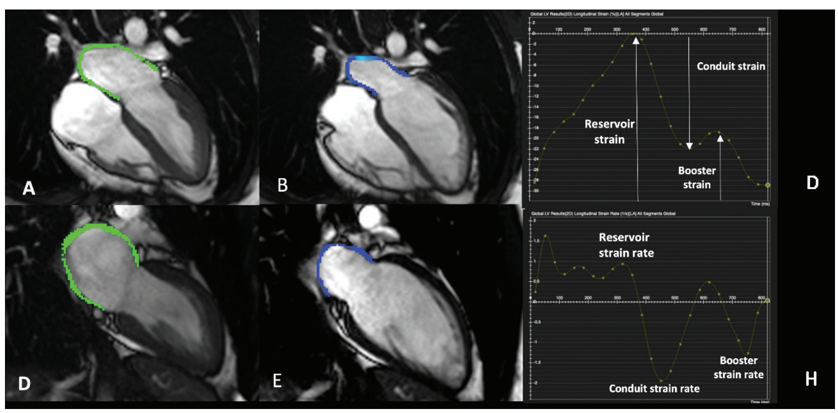

Figure 2 – *Longitudinal strain analysis of the LA in a three-chamber view by FTI. (A) diastole and (B) systole. (C) graphical analysis of the longitudinal strain of the three-chamber plane. (D) graphical analysis of the longitudinal strain rate of the three-chamber plane.*

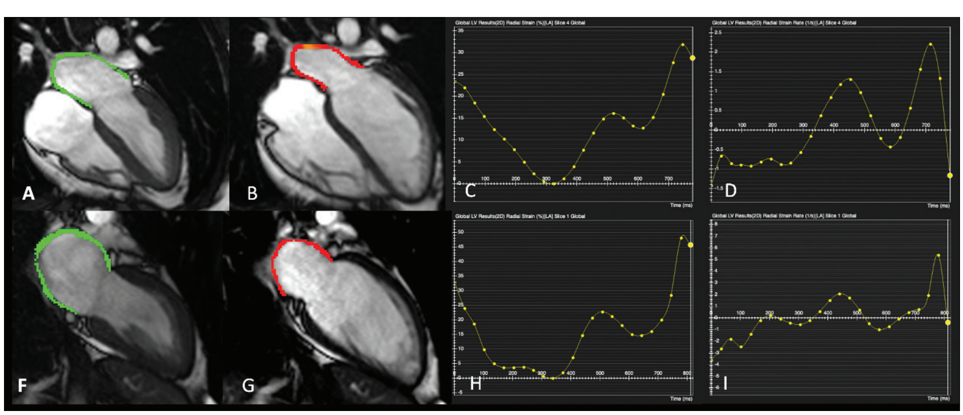

Figure 3 – *LA radial strain analysis by FTI. (A;B) four-chamber view, (A) diastole and (B) systole. (C) graphical analysis of the radial strain of the four-chamber plane, and (D) graphical analysis of the radial strain rate of the four-chamber plane. (F;G) two-chamber view, (F) diastole and (G) systole. (H) graphical analysis of the radial strain of the two-chamber plane, and (I) graphical analysis of the radial strain rate of the two-chamber plane.*

Analysis and Interpretation

Interpreting LA performance requires consideration of both anatomical and functional variables. However, caution is advised in the quantitative analysis of these parameters due to limited data in the literature regarding corresponding values across different modalities and software used for this purpose.[4]

A study evaluated 43 patients and 11 volunteers who underwent CMR and echocardiography to compare LAS values using different post-processing software (Medis and CVI by CMR), and the averages found were:[4]

- Reservoir function: CMR – Medis 34.7% ± 11.9%; CMR – CVI 43.8 ± 16.7%; echocardiography: 35.0± 10.5%;
- Booster-pump function: CMR – Medis 14.4± 5.0%; CMR – CVI: 17.7± 5.3%; echocardiography: 15.3± 4.5%
- Conduit Function: CMR – Medis 20.3± 8.8%; CMR – CVI: 26.1± 13.3%; echocardiography: 19.7± 8.1%.

This study showed a good correlation between the different CMR and echocardiography, as well as between the different software analyzed by CMR.[4] However, due to the variations between them, we still recommend that sequential assessments of the same patient be carried out using the same modality and software.

A study with 114 healthy volunteers, using the CVI with feature tracking technique to quantify normal values of LA strain, showed mean reservoir function values of 39.13 ± 9.27%, conduit function of 25.15 ± 8.34%, and contractile function of 13.99 ± 4.11%. This study found no significant differences when comparing both genders, but it did observe reduced values of the conduit and booster pump components with advanced age.[8]

Studies on different diseases show:

Heart failure: Patients with cardiac insufficiency and preserved left ventricular ejection fraction showed a significant reduction in LALS during early and late diastolic filling. These results indicate changes in the subendocardial fibers, since these fibers are arranged mainly in the longitudinal axis in the anatomy of the LA. The reduction in LALS and change in the minimum indexed volume of the LA are shown to be independent predictive factors for the onset of heart failure.[9] A recently published study evaluated LALS in patients with cardiac insufficiency with reduced ejection fraction (HFrEF), both ischemic and non-ischemic, and without AF. It showed that patients had reduced LALS rates. Reservoir function, ejection fraction and extent of late enhancement were independent predictors of major adverse cardiovascular events.[6] Reservoir and conduit functions were shown to be independent outcome predictors in patients with dilated cardiomyopathy, even after adjustment for clinical, laboratory and CMR variables (including late enhancement).[6, 10]

Hypertrophic cardiomyopathy: Patients diagnosed with hypertrophic cardiomyopathy underwent evaluation with CMR, echocardiography, and cardiopulmonary testing, and reservoir and conduit function were significantly higher in patients who achieved more than 80% of their maximum oxygen consumption (VO2 max). Reservoir, conduit and booster pump functions were significantly associated with the occurrence of AF in these patients ($P<0.05$).[11]

Cardiac Amyloidosis: Patients with cardiac amyloidosis exhibit lower LA strain values compared to those of healthy individuals or patients with hypertrophic cardiomyopathy. LA longitudinal strain (LALS) values did not differ between amyloidosis subtypes.[12] In a recent publication, Tan et al. observed that in patients with light chain amyloidosis, impairment of atrial reservoir function assessed by CMR is an independent and additional factor for all-cause mortality, even when compared to other classic CMR findings (such as late enhancement).[5]

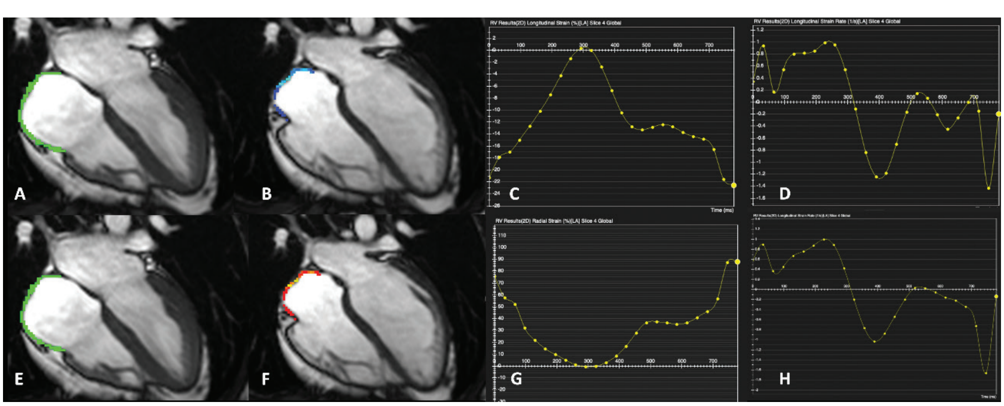

Figure 4 – *Radial and longitudinal strain analyses of the right atrium FTI. (A;B) longitudinal strain in the four-chamber plane, (A) diastole and (B) systole. (C) graphical analysis of the longitudinal strain of the four-chamber plane, and (D) graphical analysis of the longitudinal strain rate of the four-chamber plane. (E;F) radial strain in the four-chamber plane, (E) diastole and (F) systole. (G) graphical analysis of the radial strain of the four-chamber plane, and (H) graphical analysis of the radial strain rate of the four-chamber plane.*

Atrial fibrillation: Assessment of the LA in patients with AF is crucial, with recurrence being classically related to increased LA volumes. Benjamin et al. evaluated a total of 80 patients who underwent AF ablation, of whom 26% had recurrence after ablation. In this population, the reservoir function assessed by CMR was one of the independent predictors of recurrence.[13] Patients with AF or diastolic dysfunction often exhibit reduced LAS, and feature-tracking cardiac magnetic resonance (FT-CMR) analysis has enabled the differentiation of patients with early-stage diastolic dysfunction before the onset of reduced atrial and ventricular ejection fractions from those with advanced-stage dysfunction or AF, serving as an early marker in these patients.[14]

Coronary artery disease: Initial patient studies evaluated the role of LA strain in those with coronary disease. Nayyar et al. studied patients diagnosed with acute coronary syndrome who underwent CMR an average of 4 days after the event and observed that reservoir function and booster pump function were associated with worse clinical outcomes. There was a significant increase in major cardiovascular events in those patients with reservoir function values lower than 19.2% and booster-pump function lower than 9.7%.[15]

Arterial hypertension: Compared to healthy volunteers, patients with arterial hypertension, with or without left ventricular hypertrophy (LVH), had significantly reduced both the LA reservoir and conduit functions. However, the booster pump function, an auxiliary function of the LA, remained preserved in patients without LVH, which may suggest an intermediate stage between the group with LVH and the controls.[16]

The assessment of LA strain has also been conducted in other dysfunctions, such as myocarditis, diabetes mellitus, and obstructive sleep apnea. Still, there is limited data in the literature regarding these populations. Similarly, the evaluation of right atrial strain, despite being a potentially valuable tool for providing diagnostic and prognostic information, especially in the pediatric population, still requires further validation studies, as most of the available data in the literature come from observational studies with a small number of patients.

Conclusion

Assessing LA function with CMR is a promising approach that can provide prognostic insights in patients with heart failure, AF, hypertrophic cardiomyopathy, arterial hypertension, and cardiac amyloidosis. The relevance of this technique is growing, but further validation studies are necessary to establish its routine clinical application. The limited availability of software for analysis remains a barrier that needs to be addressed for more widespread adoption.

Author Contributions

Conception and design of the research: Costa IBSS; writing of the manuscript: Costa IBSS, Fonseca RA; critical revision of the manuscript for intellectual content: Rochitte CE.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

This study is not associated with any thesis or dissertation work.

Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

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