MEDICAL FORUM

CARDIAC STRAIN MRI: PRINCIPLE, TECHNIQUE AND CLINICAL APPLICATIONS

Nguyen Ngoc Trang, Nguyen Thi Huyen**

SUMMARY

Cardiac strain MRI is an advanced imaging technique that quantifies myocardial deformation, providing comprehensive insights into cardiac function. The principle behind this method is based on tracking the motion of tissue features. Clinically, cardiac strain MRI is used to detect early signs of myocardial dysfunction and management in various conditions such as ischemic heart disease, cardiomyopathies, chemotherapy-induced cardiotoxicity,… With its ability to provide precise and detailed information about the myocardium, cardiac strain MRI is becoming an essential tool in cardiovascular diagnostics and research.

Keywords: cardiac strain, myocardial strain imaging, cardiac magnetic resonance.

I. INTRODUCTION

Cardiac strain MRI, also known as myocardial strain imaging, is a technique used to assess the deformation of the heart muscle during contraction and relaxation. It provides detailed information about the heart's function and can detect abnormalities that might not be visible with traditional imaging methods [1].

1. **Principle and technique**

The principle of strain cardiac MRI involves measuring the deformation (strain) of the heart muscle during its contraction and relaxation phases [2].

- Myocardial strain: strain refers to the percentage change in length of the heart muscle fibers from their original (relaxed) state to their contracted state. It's a way to quantify how much the heart muscle stretches and contracts.

- Strain directions: can be measured in different directions during contraction (Figure 1) longitudinal, radial and circumferential.

- Mathematical formula: strain is calculated using the formula:

$\varepsilon = L - Lo/Lo$

ε is strain; Lo is the baseline length, and L is the length during systole (contraction).

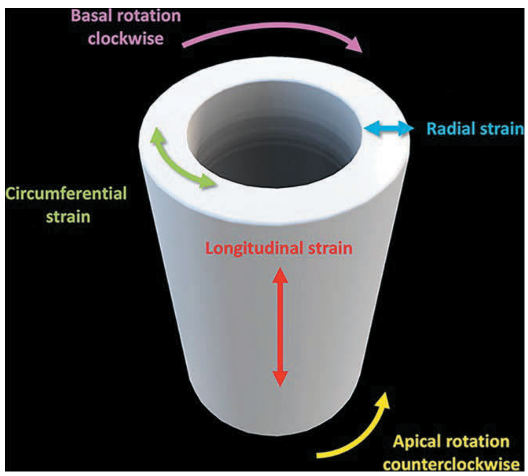


Figure 1. The schematic illustration depicts the different types of myocardial strain [1]

Cardiac MRI uses magnetic resonance imaging to capture detailed images of the heart. Special software algorithms track specific points or segments of the heart muscle throughout the cardiac cycle to measure strain (Figure 2,3):

** Radiology Center, Bach Mai Hospital*

1. Global longitudinal strain: This is a commonly evaluated parameter that measures the shortening of the heart muscle from the base to the apex during contraction. It's considered more sensitive than the traditional left ventricular ejection fraction (LVEF) for assessing systolic function [3].

2. Radial strain: This measures the thickening of the heart wall during contraction.

3. Circumferential strain: This measures the shortening of the heart muscle around the circumference of the heart during contraction.

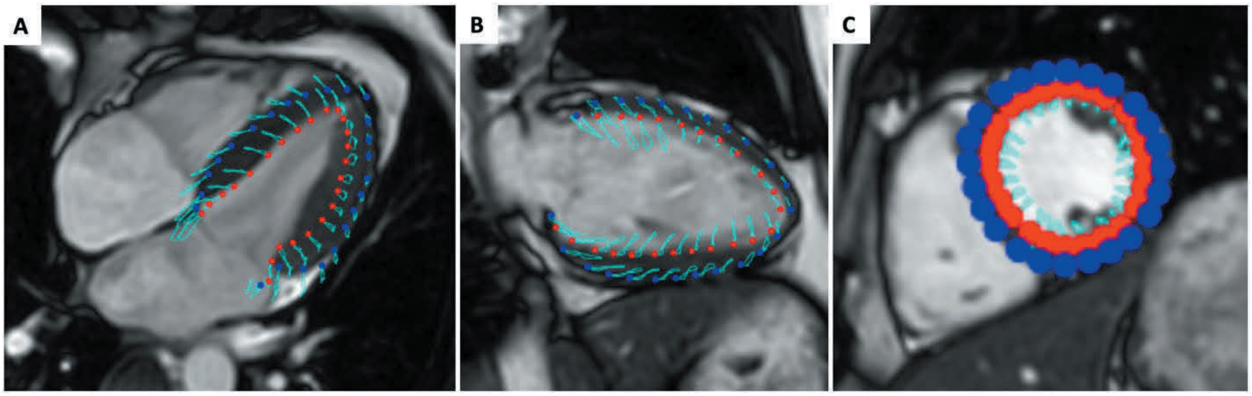


Figure 2. Left ventricular strain analyzed by using feature tracking technique in a four-chamber cine SSFP image (A), two-chamber cine SSFP image (B), and short-axis cine SSFP image (C).

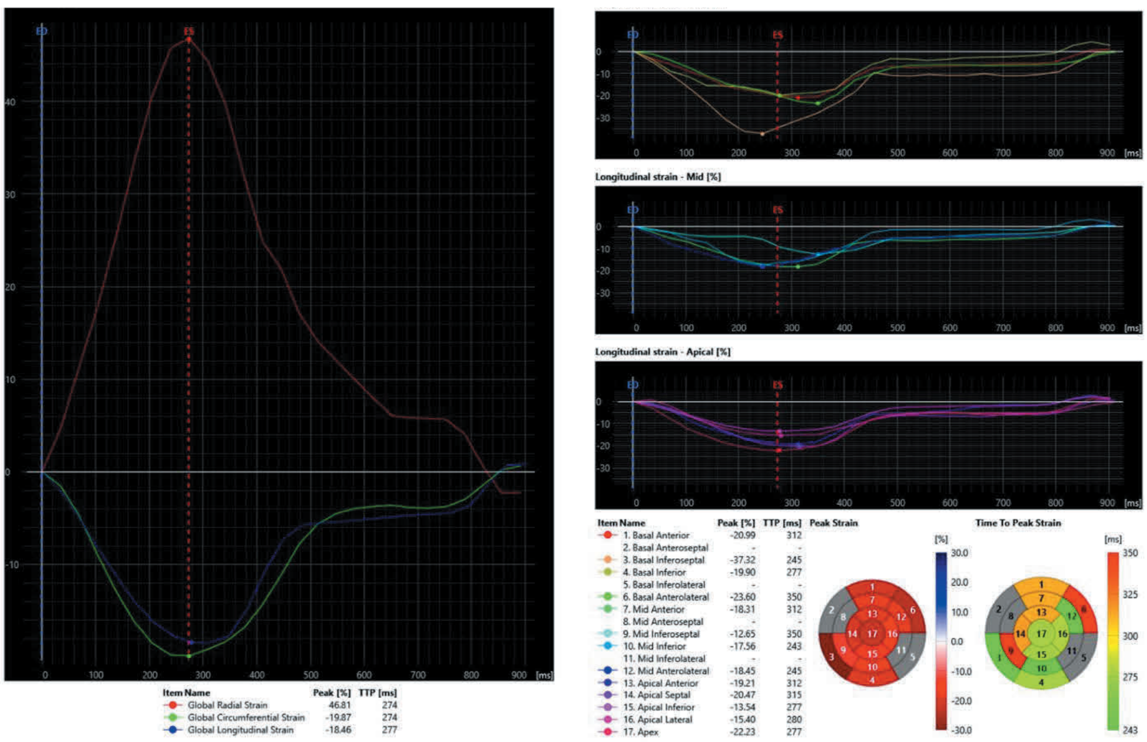
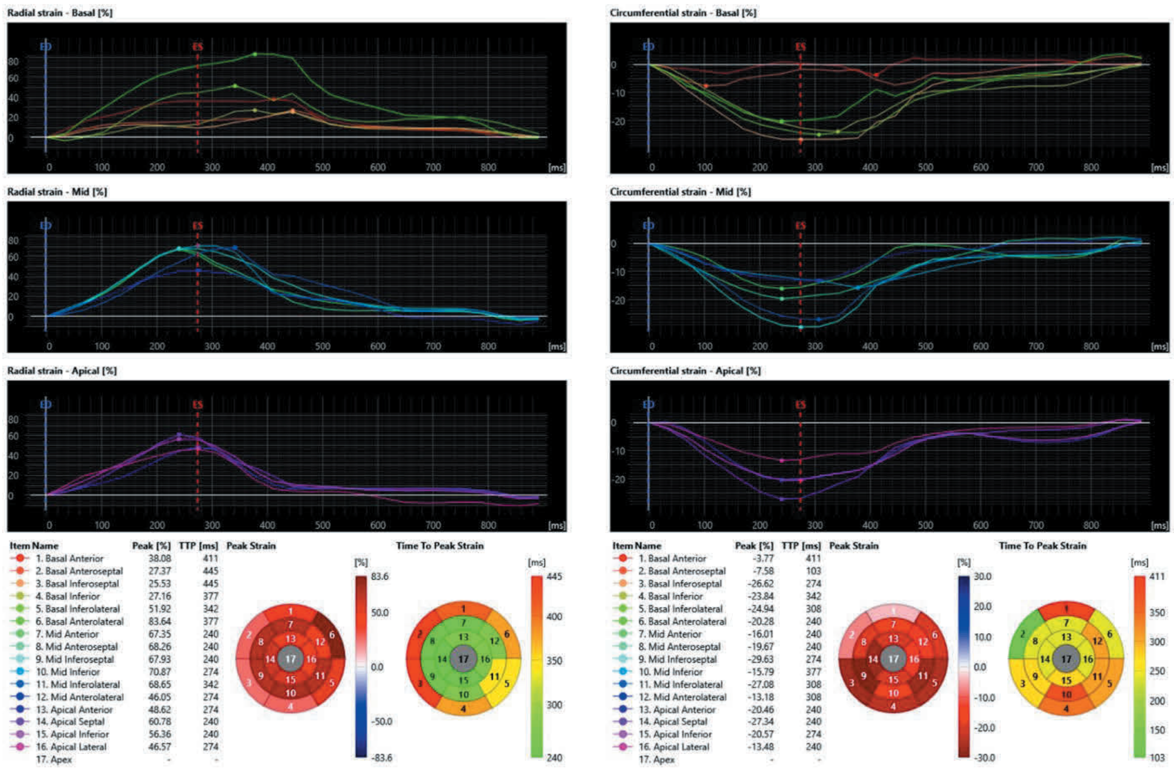


Figure 3. Strain measurements through feature tracking technique can be obtained at various levels, including the whole heart, specific sections (basal, mid, apical), and the 17 American Heart Association segments.



2. Applications

Cardiac strain MRI has a wide range of clinical applications, making it a valuable tool in cardiology. Here are some key areas where it is used:

1. Detection of systolic dysfunction: It can identify systolic dysfunction in patients with preserved or normal LVEF.

2. Cardiomyopathy evaluation: It helps in the evaluation and differentiation of various types of cardiomyopathy, such as hypertrophic cardiomyopathy and dilated cardiomyopathy [4].

3. Athlete's heart differentiation: It aids in distinguishing between athlete's heart and hypertrophic cardiomyopathy.

4. Hypertensive heart disease: It can detect subclinical left ventricular dysfunction in patients with hypertensive heart disease [5].

5. Chemotherapy-induced cardiotoxicity: It is used to monitor and detect early signs of cardiotoxicity in patients undergoing chemotherapy [6].

6. Ischemic heart disease: It provides additional information in cases of ischemic heart disease, helping to assess the extent of myocardial damage.

7. Cardiac dyssynchrony: It can identify patients at risk for arrhythmia and guide lead placement for cardiac resynchronization therapy [7].

8. Acute transplant rejection: It helps in the early detection of acute transplant rejection [8]

Besides MRI, echocardiography can measure strain, but they have different strengths and limitations. Cardiac strain MRI offers several advantages over strain echocardiography, particularly in accuracy, reproducibility, and comprehensive myocardial assessment. Below are the key advantages of cardiac strain MRI compared to strain echocardiography [9].

- Superior spatial resolution: cardiac MRI provides much higher spatial resolution than echocardiography, allowing for more precise delineation of myocardial borders and finer details of myocardial deformation. This is particularly useful for assessing regional strain patterns, especially in complex cases like cardiomyopathies or congenital heart disease.

- 3D strain assessment: cardiac MRI can measure strain in all three dimensions (longitudinal, circumferential, and radial) simultaneously, providing a more comprehensive evaluation of myocardial mechanics. Echocardiography typically focuses on 2D strain, which may miss subtle abnormalities in myocardial deformation.

- No acoustic window limitations: cardiac MRI is not dependent on acoustic windows, making it suitable for patients with poor echocardiographic views (e.g., obese patients or those with lung disease).

- Reproducibility and consistency: cardiac MRI is less operator-dependent than echocardiography, leading to higher reproducibility and consistency in strain measurements. This is particularly important for serial monitoring of patients over time or in research studies where precise measurements are critical.

- Comprehensive myocardial assessment: cardiac MRI can simultaneously assess strain, myocardial perfusion, fibrosis (via late gadolinium enhancement), and tissue characterization (e.g., T1/T2 mapping). It provides a more complete picture of the myocardium, which is especially valuable in conditions like ischemic heart disease, myocarditis, or cardiomyopathies.

- Better for complex cases: cardiac MRI excels in evaluating complex cardiac conditions, such as non-ischemic cardiomyopathies (e.g., hypertrophic cardiomyopathy, amyloidosis), congenital heart disease, subtle myocardial dysfunction (e.g., early-stage heart failure or chemotherapy-induced cardiotoxicity). It offers detailed insights into myocardial mechanics and tissue properties that echocardiography may miss.

In conclusion, myocardial strain MRI offers many advantages, providing detailed and precise information about the myocardium, and is valuable for the early diagnosis and management of various heart diseases.

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Correspondent: Nguyen Thi Huyen. Email: hoamoclanhmu@gmail.com

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