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Clinical Applications of Speckle Tracking in Ischemic Heart Disease

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Abstract:

Background: Ischemic heart disease remains a major cause of myocardial dysfunction, and accurate assessment of regional and global left ventricular performance is essential for diagnosis, risk stratification, and therapeutic decision-making. Conventional echocardiographic evaluation based on visual wall-motion analysis and left ventricular ejection fraction is limited by subjectivity, operator dependence, loading conditions, and reduced sensitivity for early or subclinical dysfunction. Speckle tracking echocardiography is a noninvasive, angle-independent technique that tracks natural acoustic markers within the myocardium to quantify myocardial deformation. It enables assessment of longitudinal, circumferential, and radial strain, while global longitudinal strain provides a sensitive measure of overall left ventricular systolic function. In ischemic heart disease, speckle tracking can detect subtle regional abnormalities, identify myocardial ischemia before overt changes in ejection fraction, estimate the extent of ischemic injury, and help differentiate transmural from non-transmural scar. Accordingly, speckle tracking has become an important adjunct to conventional echocardiography, offering more objective and reproducible evaluation of myocardial mechanics and potentially improving diagnosis, prognostic assessment, and follow-up of patients with coronary artery disease.

Keywords: Speckle tracking echocardiography; Ischemic heart disease; Myocardial strain; Global longitudinal strain; Coronary artery disease; Left ventricular function; Myocardial deformation.

Introduction:

Ischemic heart disease encompasses a broad spectrum of clinical conditions resulting from structural or functional abnormalities of the coronary circulation that impair myocardial blood supply. It remains a major contributor to cardiovascular morbidity and mortality and may present as chronic coronary syndrome, acute myocardial infarction, heart failure, or sudden cardiac death. Early recognition of myocardial ischemia and accurate assessment of its effects on left ventricular function are therefore essential for diagnosis, risk stratification, selection of appropriate treatment, and evaluation of prognosis. Noninvasive cardiac imaging has become a central component of this assessment because it provides important information regarding ventricular function, myocardial viability, ischemic burden, and the presence of regional wall-motion abnormalities **(1).**

Left ventricular ejection fraction is traditionally used as the principal echocardiographic measure of systolic function; however, it may remain within the normal range during the early stages of myocardial ischemia and does not adequately characterize regional or subclinical myocardial dysfunction. Myocardial deformation imaging provides a more detailed assessment of myocardial shortening, thickening, and lengthening throughout the cardiac cycle. Among the available techniques, speckle-tracking echocardiography enables angle-independent quantification of regional and global myocardial strain. Global longitudinal strain is the most widely applied parameter and is generally more sensitive than conventional ejection fraction for identifying subtle left ventricular systolic impairment, making it particularly valuable in patients with suspected or established ischemic heart disease **(2).**

The echocardiographic assessment of regional myocardial function plays a critical role in the diagnosis and management of ischemic heart disease and in most laboratories relies on the visual detection of endocardial wall motion abnormalities and assessment of left ventricular (LV) ejection fraction. However, this approach is subjective and operator dependent, demands complete visualization of the endocardium and is subjected to the cardiac loading and heart rate. Thus, there is a need for an objective, comprehensive, noninvasive measurement of myocardial performance and contractility with acceptable interpretative variability (**3**).

Measurements of myocardial strain and strain rate (SR) are newer indices those have the potential to overcome these limitations. Strain and SR represent the magnitude and rate, respectively, of myocardial deformation, which is an energy requiring process that occurs in both systole and diastole. Abnormalities of myocardial deformation are seen early in the development of many pathophysiologic states including ischemia and thus provide a sensitive means for detecting regional myocardial dysfunction **(4)**.

Tissue Doppler also allows indirect computation of myocardial deformation by the use of velocity gradients along the myocardial tissue. This allows an accurate assessment of myocardial deformation and thus enables quantification of myocardial strain and strain rate (SR). These deformation indices are not affected by the tethering phenomenon and are therefore direct indices of myocardial contractility **(5).**

Speckle tracking echocardiography (STE) has emerged as a new noninvasive ultrasound modality for quantifying myocardial mechanics. It evaluates tissue motion by tracking natural acoustic reflection and interference patterns within a defined ultrasound window. This tracking is performed by an image processing algorithm which tracks blocks of 20–40 pixels (Kernels), which contain markers or fingerprints also called Speckles **(6).**

This modality is therefore an angle independent analysis of tissue motion and deformation. Thus STE is inherently evaluates myocardial deformation or strain, as opposed to tissue Doppler strain, which indirectly computes strain from velocity gradients**,** Doppler derived strain is highly dependent on the angle of interrogation and is therefore likely to be reliable only in the apical imaging planes and unpredictable in the parasternal long axis and short axis planes (**7**).

- Longitudinal Strain:

Longitudinal strain represents myocardial deformation directed from the base to the apex. During systole, ventricular myocardial fibers shorten with a translational movement from the base to the apex; the consequent reduction of the distance between single kernels is represented by negative trend curves **(8)**.

Through longitudinal strain analyses in 4-chamber, 2-chamber, and apical long axis views, both regional (relative to each of the17 LV segments) and global strain values (global longitudinal strain) can be obtained. Global longitudinal strain recently has been validated as a quantitative index for global LV function **(9)**.

Coronary Artery Disease:

Possibly the most valuable clinical application of strain measurements is the evaluation of regional dysfunction in patients with CAD. Longitudinal strain can detect the presence of ischemia. Additionally, encouraging data were reported with respect to the ability of strain measurements to predict the extent of the ischemic and to differentiate between transmural and non-transmural scar **(10)**.

Techniques of strain echocardiography.

Although LVEF has been used as a useful echocardiographic parameter in the diagnosis and determination of treatment in many cardiovascular diseases, it has many limitations including load-dependency, inability to discover subclinical LV systolic dysfunction, and insufficiency in the prognostication. Myocardial strain refers to the percentage change in myocardial length and thickness during the cardiac cycle. Myocardial shortening can be calculated as the difference between end-diastolic and end-systolic lengths relative to the end-diastolic length and measured by longitudinal strain (longitudinal shortening) and circumferential strain (CS, circumferential shortening).**(11)**

Myocardial thickening can be assessed by radial strain. These strains reflect distinct aspects of myocardial mechanics and offers insights beyond traditional volumetric indices. Strain can be assessed using several techniques, including tissue Doppler imaging, STE, and feature tracking method, with the availability and implementation of each method varying across ultrasound vendors and software platforms. Among these, STE is currently the most widely used method in clinical practice due to its angle independence, feasibility, and reproducibility.9) STE works by tracking natural acoustic markers, known as "speckles," present within the

myocardium on standard 2D grayscale echocardiographic images. These speckles are followed frame by frame throughout the cardiac cycle to measure myocardial deformation along longitudinal, circumferential, or radial axes. In this review, we focus on strain parameters derived from STE.**(12)**

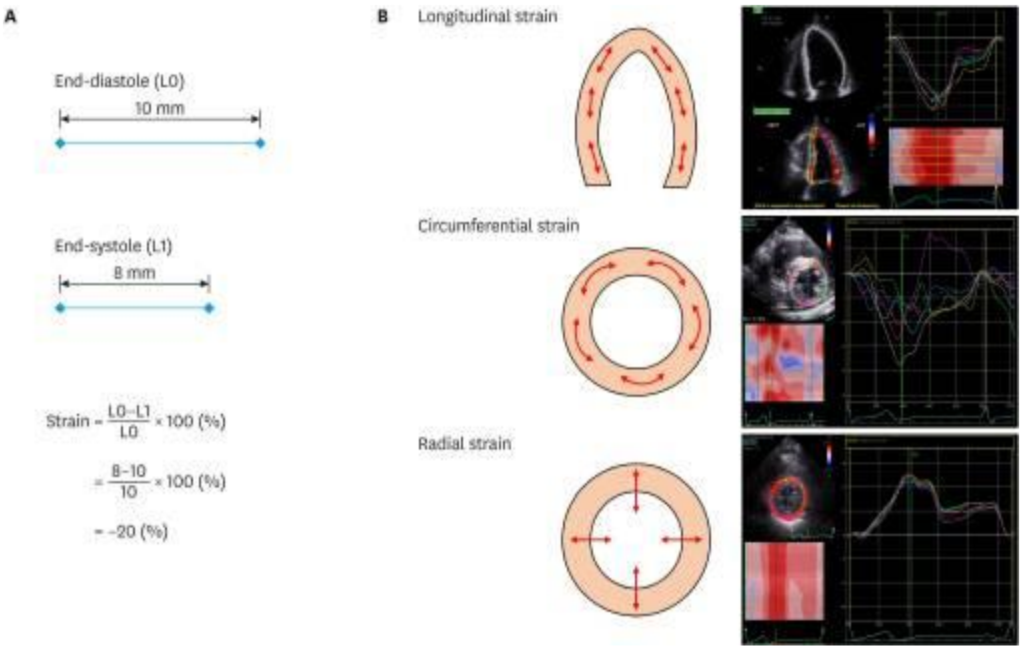

Figure 1. Principles of myocardial strain measurement. Panel (A) Illustrates the concept of strain calculation using the change in myocardial segment length from end-diastole (L0) to end-systole (L1). In this example, longitudinal shortening results in a negative strain value. Panel (B) schematically depicts the three primary types of myocardial strain of the LV: longitudinal strain, representing shortening and lengthening along the long axis of the left ventricle; circumferential strain, representing changes in the circumference of the left ventricle; and radial strain, representing changes in the thickness of the left ventricle. Representative echocardiographic images, color-coded strain maps, and corresponding time-strain curves for each strain type are shown on the right. **(12)**

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