

# Echocardiography strain: why is it used more and more?

Matteo Cameli\*

Division of Cardiology, Department of Medical Biotechnologies, University of Siena, Siena

## KEYWORDS

Speckle tracking echocardiography;  
Left ventricular ejection fraction;  
Left atrial strain

In the last decade, speckle tracking echocardiography (STE) has acquired a fundamental role in the evaluation of the systolic function of the left ventricle, with several advantages over the Doppler method, including angle independence, greater reproducibility, and rapidity of image acquisition. Speckle tracking finds application in various pathologies, ranging from ischaemic heart disease, to cardiomyopathies, to heart failure, both with reduced and preserved ejection fraction (EF), in which the EF is not a reliable prognostic marker and the estimate of left ventricular function by means of 'strain' is of crucial utility. In addition, the strain of the left atrium finds application in many clinical contexts as an early index of diastolic dysfunction and left ventricular filling pressures. Finally, the strain of the right ventricle is of particular prognostic importance in the evaluation of heart failure, particularly in its advanced form, becoming an indispensable index in the evaluation of patients who are candidates for advanced therapeutic strategies. This document aims to describe the various fields of clinical application of STE, with particular emphasis on its diagnostic and prognostic role, so much that it is now integrated into the algorithms for managing multiple pathologies in daily clinical practice.

## Introduction

In echocardiography, the term 'strain' indicates the degree of deformation of the myocardium during the phase of contraction and relaxation. For its measurement, the 'speckle tracking' method is used, which is a non-invasive method, independent of the limits of the Doppler signal. The 'speckles' are acoustic markers generated by the myocardium, which can be followed in their displacement during the cardiac cycle. Negative strain values are indicative of a shortening or compression of the object under examination, while positive values indicate elongation of the same. By averaging the various regional strains, it is possible to calculate the global strain [global longitudinal strain (GLS)], a parameter that can accurately identify the damage of the

subendocardial longitudinal fibres early, for example, after ischaemic insult.<sup>1</sup> Normal reported GLS values, for major echocardiographic systems, are expected to range from 18 to 25% in healthy individuals. This variation can be explained by the variability between software and suppliers, but particularly in the different characteristics of gender and age.

For over 10 years, speckle tracking echocardiography (STE) has been integrated into clinical algorithms for the identification of myocardial damage.<sup>2</sup> It has the advantage, among others, of being angle-independent, as a non-Doppler method, and of being more easily reproducible and faster in acquiring images, compared with other methods for measuring global systolic function (Table 1). Speckle tracking echocardiography finds application in multiple pathologies, with both an early diagnosis role, such as in the context of ischaemic heart disease or cardiomyopathies, and prognostic, such as in chronic heart failure.

\*Corresponding author. Email: [matteo.cameli@unisi.it](mailto:matteo.cameli@unisi.it)

**Table 1 Advantages of speckle tracking echocardiography**

Angle independence, as a non-Doppler method
Direct determination of the strain without the need for temporal integration
Fast image acquisition and reduced time for regional and global quantitative analysis
Semi-automatic quantitative analysis and, therefore, less operator-dependent
Greater reproducibility
Possibility to analyse the myocardial deformation of all cardiac chambers

### Coronary heart disease

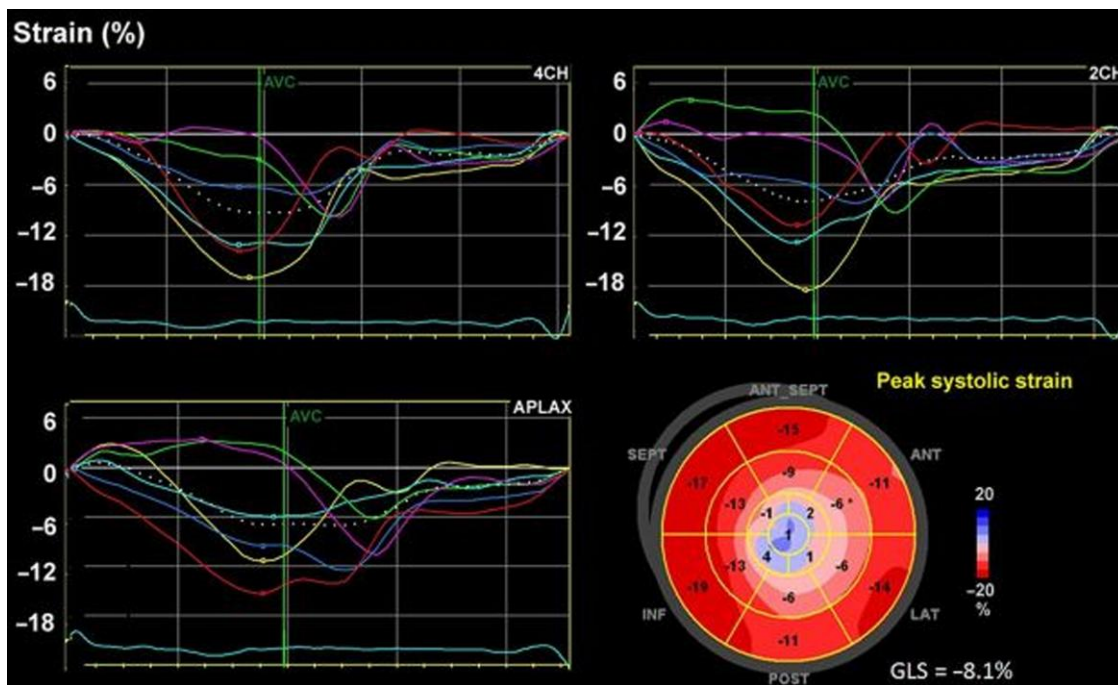
In patients with ischaemic heart disease, ischaemic tissue is well represented in the ‘bull’s eye’, a topographic display of the longitudinal strain values of the 17 segments of the myocardial wall, from a confined area of severe GLS reduction.<sup>2</sup> Elevated sensitivity and specificity values (86 and 73%, respectively) have been reported for left ventricular GLS cut-off values  $>-18.8\%$  in detecting significant coronary stenosis in patients with chest pain and electrocardiographic results and blood tests not indicative of acute coronary syndrome (ACS), providing an additional value to the wall motion score index, a parameter commonly used in clinical practice.<sup>3</sup> In acute settings, GLS is an important predictor of the extension of the infarct area and a predictor of periprocedural complications, when performed after coronary reperfusion<sup>1</sup> (Figure 1). Regional strain may also be

useful in the differential diagnosis between ACS and Takotsubo syndrome; in the latter, in fact, the ‘polar map’ has a typical pattern, with exclusive apical involvement. Also in myocarditis, typically, the areas affected by GLS reduction do not follow the typical coronary topographic localization and typically there is a greater reduction of GLS in the sub-epicardial layer, and this suggests an element of differential diagnosis from the ACS.<sup>3</sup> Speckle tracking echocardiography can also be used to determine the degree of involvement of the left ventricle during inferior wall infarction and in the evaluation of patients treated by percutaneous coronary intervention, identifying increased risk of mortality, reinfarction, and hospitalization for heart failure.<sup>1</sup> The innovative aspect remains the prognostic role of strain in the context of ischaemic heart disease, especially in patients with preserved ejection fraction (EF), being able to identify myocardial dysfunction even before the reduction of EF.

In addition, strain values showed an association with post-ACS events in several studies: a left ventricular GLS  $>-13\%$  measured during hospitalization was a predictor of complication-free survival in a cohort of both ACS with ST-T segment elevation and ACS without ST-T segment elevation.<sup>5</sup> This would also suggest its role in post-acute event risk stratification.

### Heart failure

Echocardiography represents the gold standard in the diagnosis of heart failure. The current era is marked by the emergence of heart failure with preserved EF (HFpEF) as the predominant form of heart failure, in



**Figure 1** Patient with anterior infarction. The global longitudinal strain is altered ( $-8.1\%$ ) and the apical segments appear dyskinetic (blue segments in the bull’s eye), while the other segments appear hypokinetic.<sup>4</sup>

which EF has lost its utility from a prognostic point of view.<sup>6</sup> Although there is an inverse relationship between EF and mortality rate, it regards an EF value of 40–45%, above which EF is not related to mortality. Despite this finding, heart failure patients have a similar 1-year mortality rate regardless of whether they have preserved or reduced EF. Conversely, GLS correlates with mortality, regardless of EF, in heart failure patients with reduced EF (HFrEF). In particular, it adds a significant predictive value for mortality in patients with EF >35%. A meta-analysis of 5721 subjects in 16 studies of various heart diseases confirmed that GLS is a stronger predictor of EF for all-cause mortality, as well as a predictor of hospitalization for heart failure and malignant arrhythmia.<sup>7</sup>

Furthermore, it is very important to remember that STE provides another parameter of great importance in the risk stratification of the patient with heart failure: the strain of the left atrium. In patients with chronic heart failure, in fact, the increase in filling pressures in the left ventricle corresponds to a progressive initial adaptive dilation of the left atrium, to the point where remodelling results in atrial dysfunction. This often coincides with the onset of symptoms typical of heart failure, in arrhythmias, and in the development of pulmonary hypertension with transition to advanced biventricular decompensation, which leads to a decidedly worse prognosis. Peak atrial longitudinal strain (PALS), measured at the end of the atrial reservoir phase, has been shown to be an accurate index of left ventricular filling and to have a strong association with elevated pulmonary capillary pressures in both HFrEF and HFpEF patients.<sup>8</sup>

Atrial strain has also shown an important diagnostic and prognostic role in the study of patients with atrial fibrillation (AF). Kuppahally *et al.*<sup>9</sup> demonstrated an inverse relationship between the degree of atrial fibrosis, the main cause of electrical conduction alterations, demonstrated on cardiac magnetic resonance with late gadolinium enhancement, with atrial strain, especially in patients with permanent AF. Atrial strain was also an important predictor of AF recurrence in the 6 months following electrical or pharmacological cardioversion: the improvement in PALS was found to be greater in patients who maintain sinus rhythm than in patients with AF recurrence.<sup>8</sup>

## Cardiomyopathies

In overt cardiomyopathies, conventional echocardiography is certainly sufficient in the diagnostic definition of the disease. Speckle tracking echocardiography, however, plays an important role in patient prognostic assessment. In fact, in many heart diseases, GLS has a greater predictive value on patient outcome than EF. In hypertrophic ventricles, for example, left ventricular EF has poor sensitivity in assessing systolic dysfunction. This is well known in patients with hypertrophic cardiomyopathy (HCM) in whom the left ventricular EF (LVEF) can be normal or even supernormal when systolic function is markedly reduced. Indeed, hypertrophic ventricles thicken more in absolute terms, which reduces

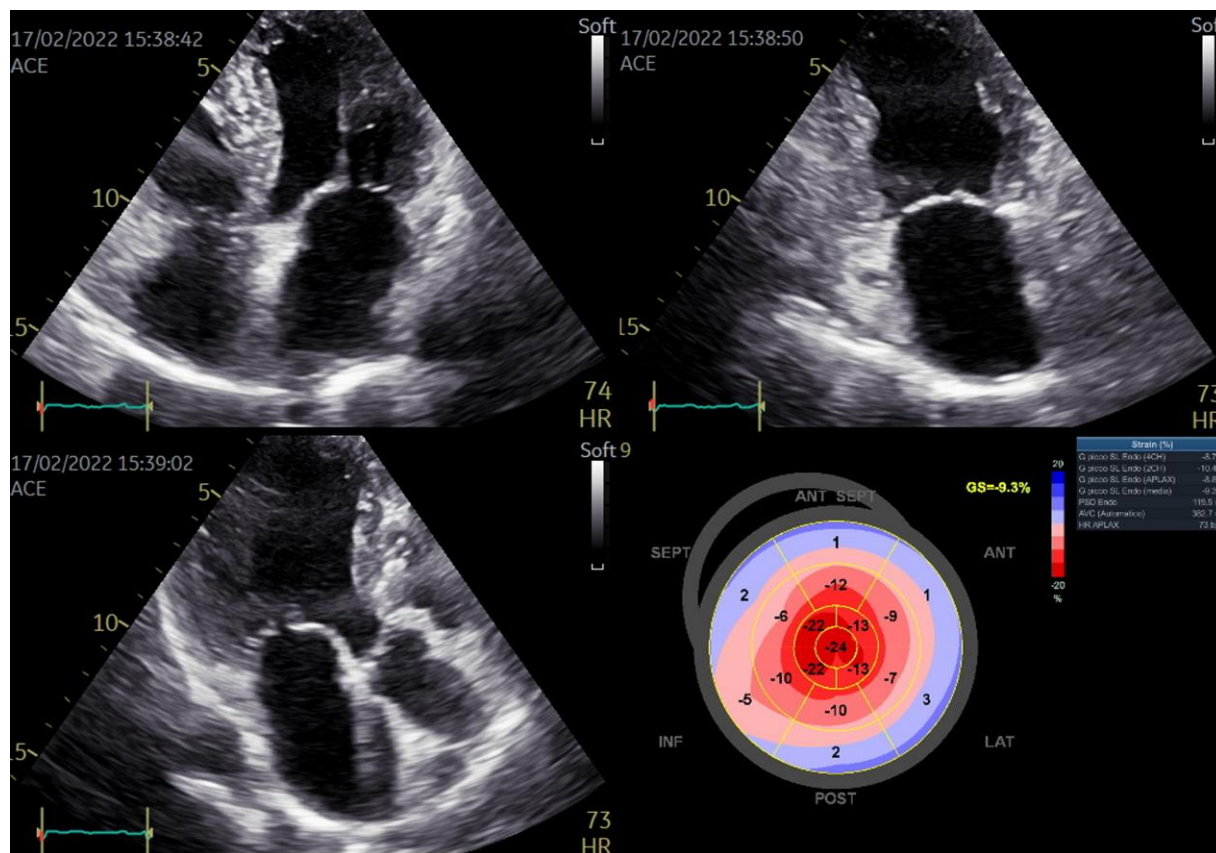
cavity volumes more than ventricles with normal wall thickness. Contrary to LVEF, GLS is reduced in the early stages of the disease, especially at the site of hypertrophy, commonly in the interventricular septum. Current clinical practice guidelines for the management of HCM include STE to evaluate systolic function in early phase of the disease.<sup>4</sup>

In patients suffering from amyloidosis, the strain parameters are significantly reduced, with a typical ‘apical sparing’ pattern, if there is cardiac involvement, compared with those who do not have it. To differentiate cardiac amyloidosis (CA) from other forms of cardiac hypertrophy, it has been proposed by Phelan *et al.* to specifically analyse the relative differences in longitudinal myocardial deformation at the level of the LV apex (relative apical sparing, calculated as the ratio between the mean apical LS and the sum between the mean ventricular and basal LS), which is less affected by deposits of amyloid and therefore maintains a greater function even in the advanced stages of the disease (*Figure 2*), demonstrating how this parameter has high sensitivity and specificity in identifying the same CA as well as prognostic importance. However, its use is still controversial as the absence of a relative apical sparing does not allow the diagnosis of CA to be excluded with certainty.<sup>1</sup>

In various cardiomyopathies, estimation of the function of the right ventricle has a central importance. In recent years, right ventricular longitudinal strain (RVLS) and right ventricular free wall strain using STE have emerged as a method for estimating right ventricular systolic performance, with an important clinical-prognostic role. In the context of arrhythmogenic right ventricular heart disease, currently recognized as arrhythmogenic cardiomyopathy (ACM), the evaluation of the right ventricle is very important, which most often shows involvement already in the early stages of the disease.<sup>10</sup> The utility of RVLS in risk stratification of patients with ACM was demonstrated in a prospective study of 117 event-free ACM mutation patients at baseline, in follow-up for 4.2 years.<sup>10</sup> The RVLS was also used in the evaluation of the right ventricle and arrhythmias in the ‘athlete’s heart’. Lie *et al.* found right ventricular dysfunction by means of RVLS in patients with ventricular arrhythmias and myocardial fibrosis, in comparison with healthy athletes.<sup>11</sup>

## Valvulopathies

The evaluation of valvular defects by STE is carried out in the context of stress echocardiography, as well as in the peri-operative evaluation of patients with valvular heart disease. In asymptomatic patients with severe mitral regurgitation (MR), a small increase in exercise GLS predicts reduced postoperative ventricular function. Global longitudinal strain values > –19.9% also predict long-term left ventricular dysfunction after mitral repair of an organic MR.<sup>1</sup> Also in patients with aortic stenosis and normal left ventricular function, Delgado *et al.* demonstrated a reduction of GLS with improvement after valve repair surgery. Furthermore, Kanellopoulos *et al.*



**Figure 2** Patient suffering from cardiac amyloidosis of the amyloidosis transretina (ATTR) type. Marked cardiac hypertrophy and reduced global longitudinal strain ( $-9.3\%$ ) with typical bull's eye pattern with apical sparing.

compared the GLS of patients with bicuspid aortic valve with that of patients with degenerative valve disease, concluding that patients with aortic bicuspid valve have structural heart disease, regardless of the degree of stenosis, compared with degenerative valve disease. These data highlight the importance of STE in the detection of subclinical left ventricular dysfunction in patients with valvular heart disease.<sup>12</sup> Furthermore, PALS plays an important role in patients with MR as it identifies left atrial dysfunction that follows chronic MR already in asymptomatic patients and has shown a correlation with the degree of atrial fibrosis and remodelling and with long-term survival after valve surgery.<sup>1</sup>

### Heart transplant and ventricular assist devices

Speckle tracking echocardiography is configured as a prognostic tool even in patients with advanced chronic heart failure awaiting the implementation of therapeutic strategies such as heart transplantation or the 'left ventricular assist device' (LVAD). Echocardiography represents an easy-to-implement method to evaluate the potential benefits for this category of patients. Many authors have identified in patients awaiting cardiac transplant, a correlation between the reduction of the

left ventricular GLS and the strain of the free wall of the right ventricle (RVLS) and the increased probability of post-transplant rejection.<sup>13</sup> Even in patients waiting for LVAD implantation—a strategy that is an excellent therapeutic alternative in patients who cannot undergo transplantation—the RVLS free wall plays a fundamental role in the prognostic evaluation, as therapeutic success is strongly influenced by the function of the right ventricle. It has been observed that patients with a higher RVLS free wall before LVAD implantation more often show an improvement in deformation and therefore in the global systolic function of the post-implantation right ventricle.<sup>14</sup> These data suggest a fundamental role of the RVLS free wall as an echocardiographic parameter to be evaluated in the prognostic prediction of the patient undergoing therapy with LVAD.

### Limitations

Despite the multiple advantages of STE, compared with traditional methods of evaluating the function of the left ventricle, it has some limitations, including the need to have images of satisfactory quality in order to have reliable assessments. Furthermore, the lack of pathology standardized cut-offs of normality makes its objective evaluation difficult in clinical practice but leaves room for new research.

## Conclusions

Speckle tracking echocardiography is an advanced echocardiographic analysis technique that allows the study of longitudinal, radial, and circumferential myocardial deformation, overcoming most of the limitations of techniques based on the Doppler signal. It is now easily accessible to every clinical operator in centres from the first to the third level equipped with the latest generation echocardiographers, with the advantage, compared with other cardiac imaging methods, of being faster and above all usable even in conditions of poor patient mobility. Scientific evidence supports its role in the diagnostic-therapeutic and prognostic process of many heart diseases. It is also an ever-expanding method: preliminary studies have already demonstrated its applicability in the field of 3D echocardiography.

**Conflict of interest:** None declared.

## References

1. Cameli M, Mondillo S, Galderisi M *et al.* L'ecocardiografia speckle: roadmap per la misurazione e l'utilizzo clinico. *G Ital Cardiol* 2017; **18**:253-269.
2. Pastore MC, De Carli G, Mandoli GE *et al.* The prognostic role of speckle tracking echocardiography in clinical practice: evidence and reference values from the literature. *Heart Fail Rev* 2021; **26**: 1371-1381.
3. Pastore MC, Mandoli GE, Contorni F *et al.* Speckle tracking echocardiography: early predictor of diagnosis and prognosis in coronary artery disease. *Biomed Res Int* 2021; **2021**:6685378.
4. Smiseth OA, Torp H, Opdahl A, Haugaa KH *et al.* Myocardial strain imaging: how useful is it in clinical decision making? *Eur Heart J* 2016; **37**:1196-1207.
5. Choi SW, Park JH, Sun BJ *et al.* Impaired two-dimensional global longitudinal strain of left ventricle predicts adverse long-term clinical outcomes in patients with acute myocardial infarction. *Int J Cardiol* 2015; **196**:165-167.
6. Senni M, Tribouilloy CM, Rodeheffer RJ *et al.* Congestive heart failure in the community: a study of all incident cases in Olmsted County, Minnesota, in 1991. *Circulation* 1998; **98**:2282-2289.
7. Oikonomou EK, Kokkinidis DG, Kampaktis PN *et al.* Assessment of prognostic value of left ventricular global longitudinal strain for early prediction of chemotherapy-induced cardiotoxicity: a systematic review and meta-analysis. *JAMA Cardiol* 2019; **4**:1007-1018.
8. Pastore MC, Mandoli GE, Santoro C *et al.* Left atrial strain in cardiovascular diseases: an overview of clinical applications. *Cardiologia Hungarica* 2021; **51**:11-17.
9. Kuppahally SS, Akoum N, Burgon NS *et al.* Left atrial strain and strain rate in patients with paroxysmal and persistent atrial fibrillation: relationship to left atrial structural remodeling detected by delayed-enhancement MRI. *Circ Cardiovasc Imaging* 2010; **3**:231-239.
10. Leren IS, Saberniak J, Haland TF *et al.* Combination of ECG and echocardiography for identification of arrhythmic events in early ARVC. *JACC Cardiovasc Imaging* 2017; **10**:503-513.
11. Muraru D, Haugaa K, Donal E *et al.* Right ventricular longitudinal strain in the clinical routine: a state-of-the-art review. *Eur Heart J Cardiovasc Imaging* 2022; **23**:898-912.
12. Malik V, Subramaniam A, Kapoor PM *et al.* Strain and strain rate: an emerging technology in the perioperative period. *Ann Card Anaesth* 2016; **19**:112-121.
13. Mingo-Santos S, Moñivas-Palomero V, Garcia-Lunar I *et al.* Usefulness of two-dimensional strain parameters to diagnose acute rejection after heart transplantation. *J Am Soc Echocardiogr* 2015; **28**:1149-1156.
14. Pastore MC, Mandoli GE, Aboumarie HS *et al.*; Working Group of Echocardiography of the Italian Society of Cardiology. Basic and advanced echocardiography in advanced heart failure: an overview. *Heart Fail Rev* 2020; **25**:937-948.