Principles of Strain Imaging

Echocardiography: Basics

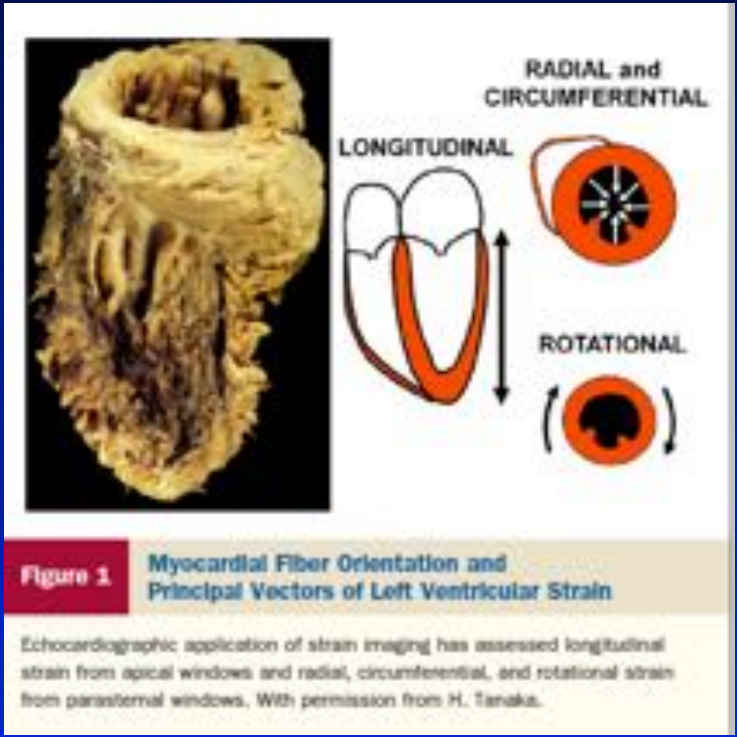


Figure 1 Myocardial Fiber Orientation and Principal Vectors of Left Ventricular Strain

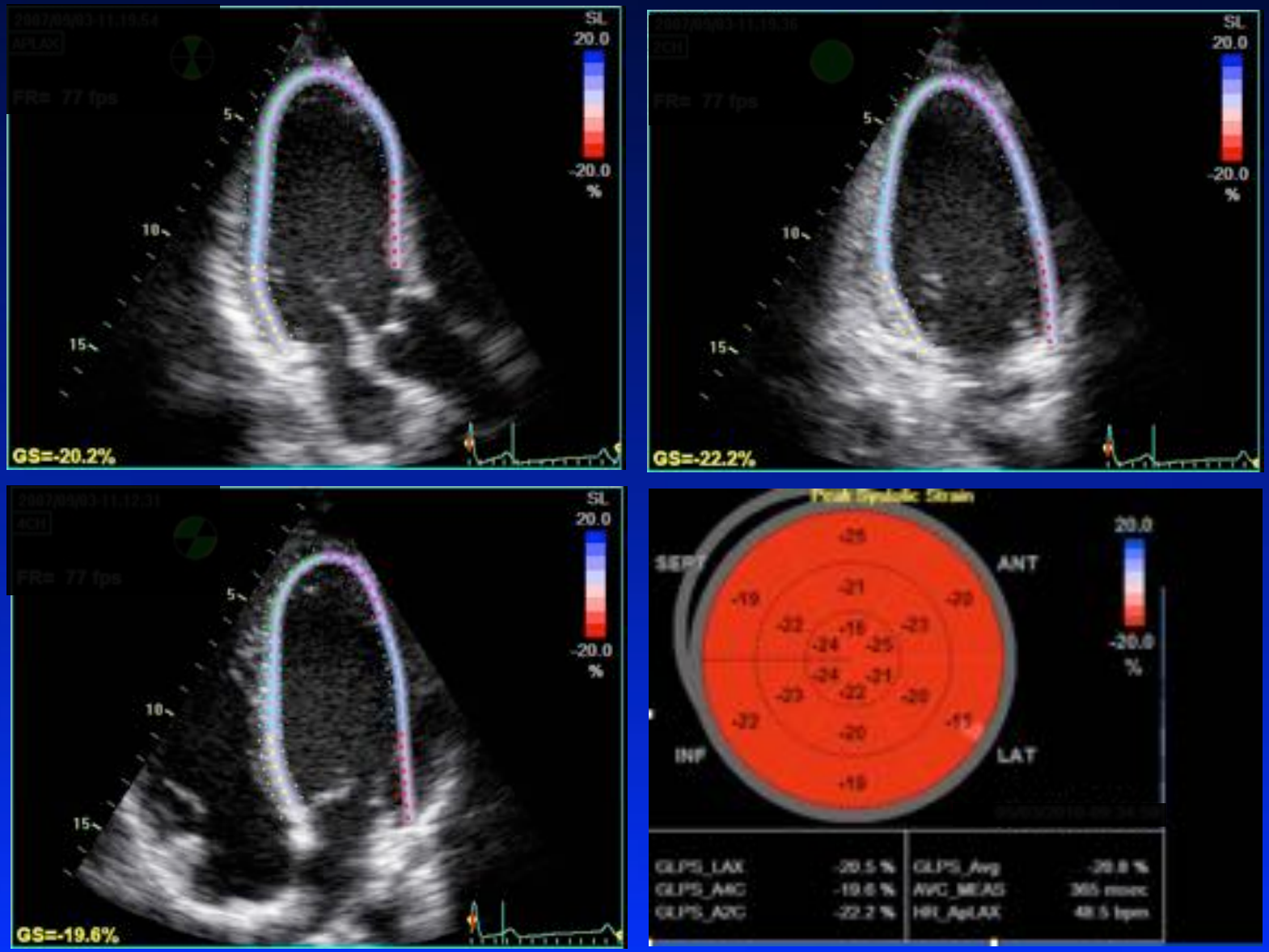
Echocardiographic application of strain imaging has assessed longitudinal strain from apical windows and radial, circumferential, and rotational strain from parasternal windows. With permission from H. Tanaka.

- Radial, circumferential, and longitudinal strains are measured using tissue Doppler or more commonly by 2D speckle tracking
- LV global longitudinal strain (GLS) used in diagnosis and prognosis
- Although normal values for GLS vary based on gender, age, and system used, -20% is normal value

Gorscan J et al. Echocardiographic assessment of myocardial strain. *J Am Coll Cardiol.* 2011; 58: 1401-13.
Collier P et al. A test in context: myocardial strain measured by speckle tracking. *J Am Coll Cardiol*. 2017.

Principles of Strain Imaging

Global longitudinal strain (GLS): -20% is normal value



Clinical applications

Strain imaging: Cardiac amyloidosis

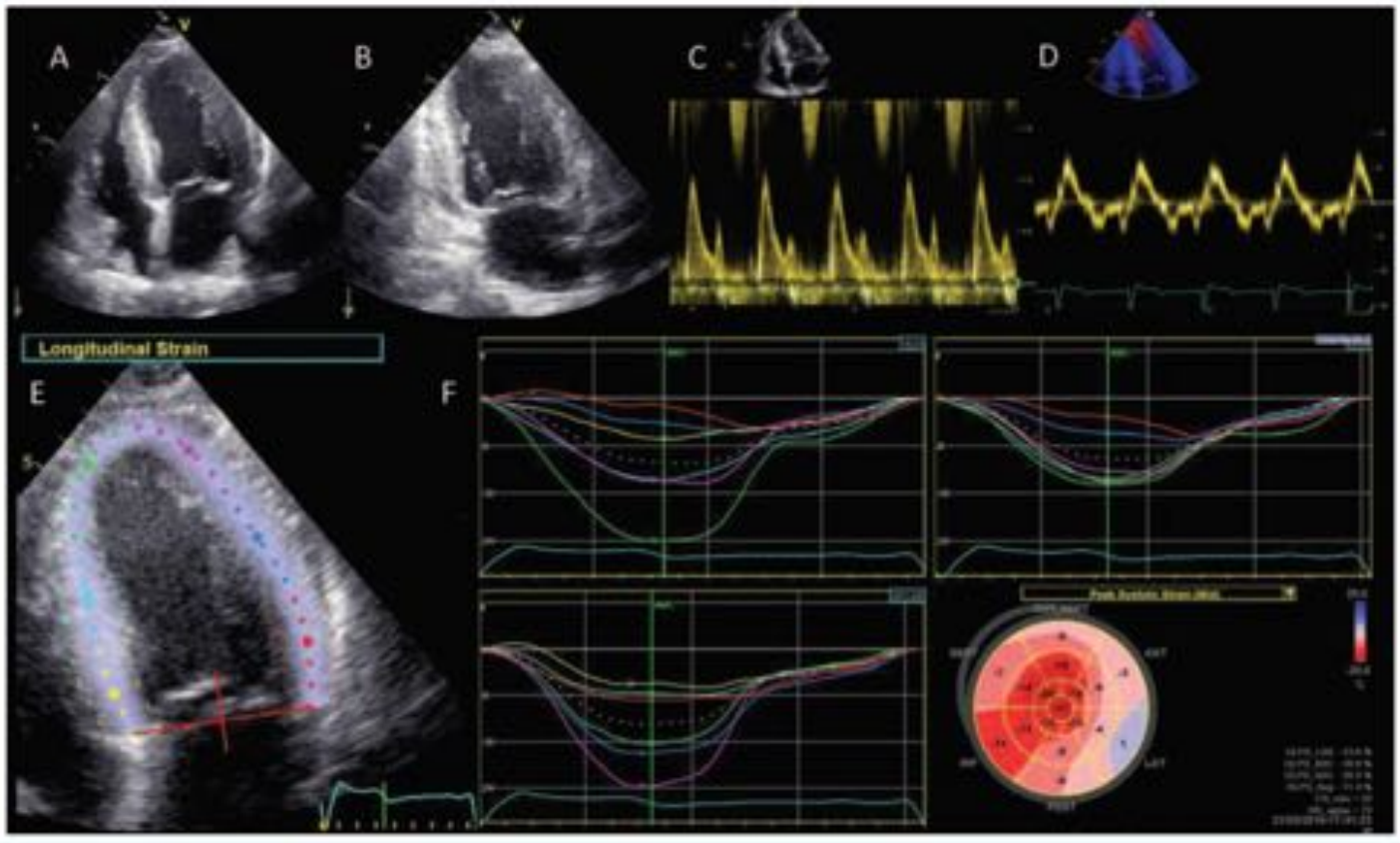


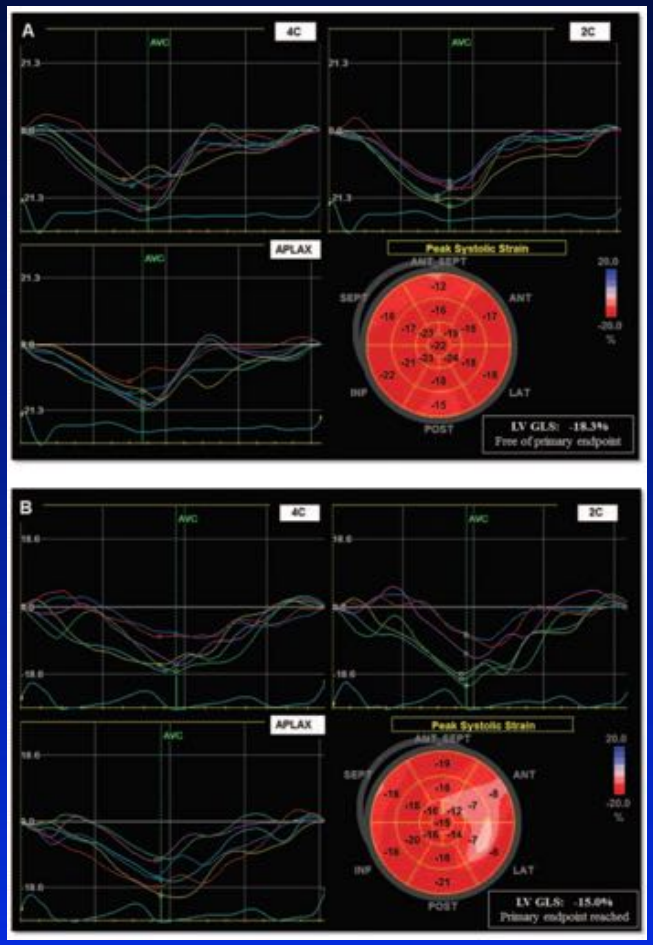
Figure 3 Left ventricular global longitudinal strain (GLS) in cardiac amyloidosis. Example of a patient (male, 65 years) with cardiac amyloidosis. Please note the concentric LV hypertrophy on the apical four-chamber (*A*) and two-chamber (*B*) views, as well as hypertrophy of the interatrial septum and right ventricular free wall. The calculated LVEF is 66%. On the pulsed wave Doppler of the mitral inflow (*C*), the E/A ratio is 2.42, whereas on pulsed wave tissue Doppler imaging (*D*) the E' is 4 cm/s, resulting in an E/E' of 23. (*E* and *F*) Impairment of LV GLS (−11.4%) derived from speckle tracking echocardiography, and the bull's eye plot shows the typical preserved longitudinal strain of the apical segments.

Buss SJ et al. Longitudinal left ventricular function for prediction of survival in systemic light-chain amyloidosis. *J Am Coll Cardiol* 2012; 60: 1067-76.

Clinical applications

Strain imaging: Cardiac sarcoidosis

- 100 patients (55±13 years; 48% male) with biopsy proven sarcoid demonstrated impaired LV GLS as compared to controls (-17.3 vs. -20.0%, p<0.001)
- LV GLS independently associated with cardiac device implantation and all-cause mortality
- Patient A with LV GLS of -18.3% and cardiac sarcoid with no symptoms at 8 year follow-up; Patient B with LV GLS of -15.0% requiring PPM at 1 year follow-up due to complete heart block



Joyce E et al. Subclinical left ventricular dysfunction by echocardiography speckle-tracking strain analysis relates to outcome in sarcoidosis. *Eur J Heart Fail* 2015; 17: 51-62.

Clinical applications

Strain imaging: Hypertrophic cardiomyopathy

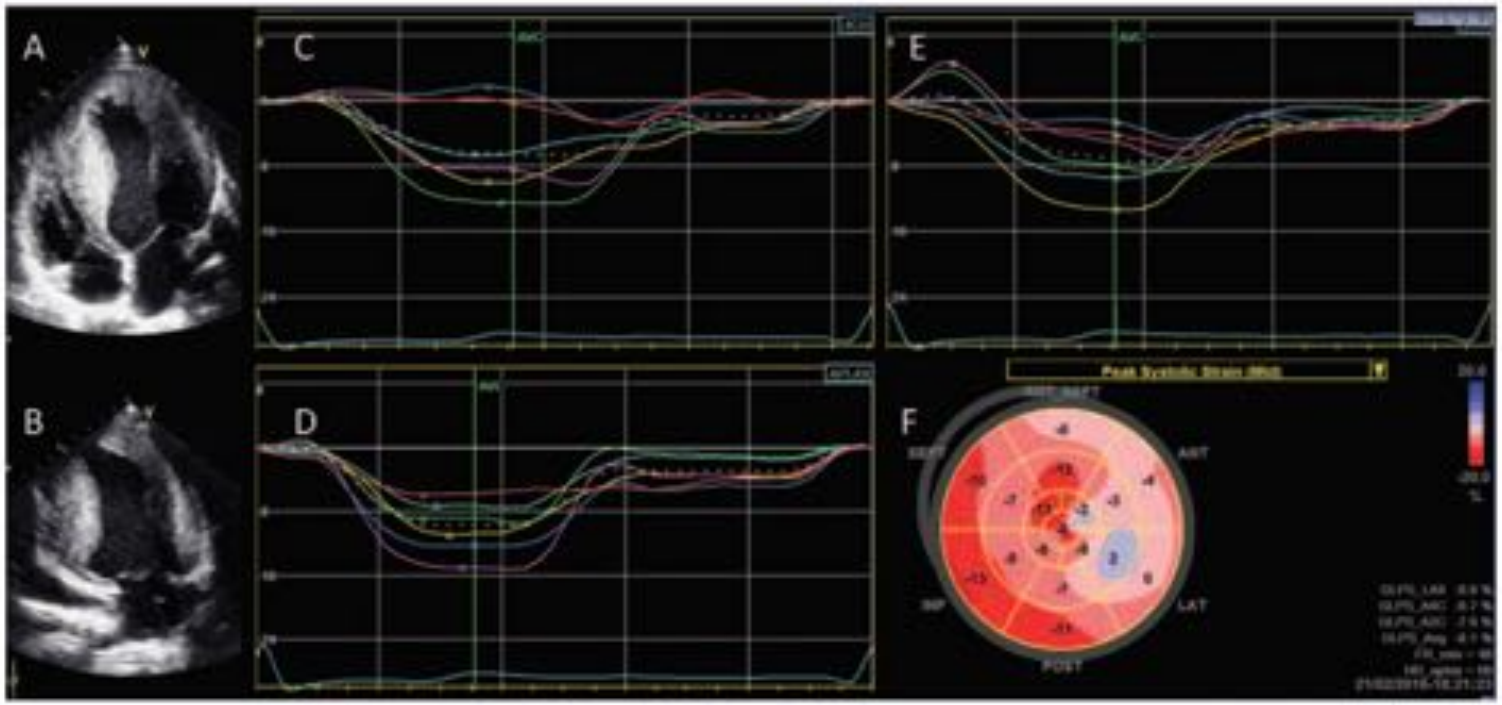


Figure 4 Left ventricular global longitudinal strain (GLS) in hypertrophic cardiomyopathy. Example of a patient (male, 21 years) with genotype-positive hypertrophic cardiomyopathy. Calculated LVEF from the apical four-chamber (*A*) and two-chamber (*B*) views is 65%. However, LV GLS is significantly impaired (−8.1%). The strain curves derived from the apical four-, three-, and two-chamber views are presented in C, D, and E, respectively. The impaired LV GLS is shown in the bull's eye plot (*F*).

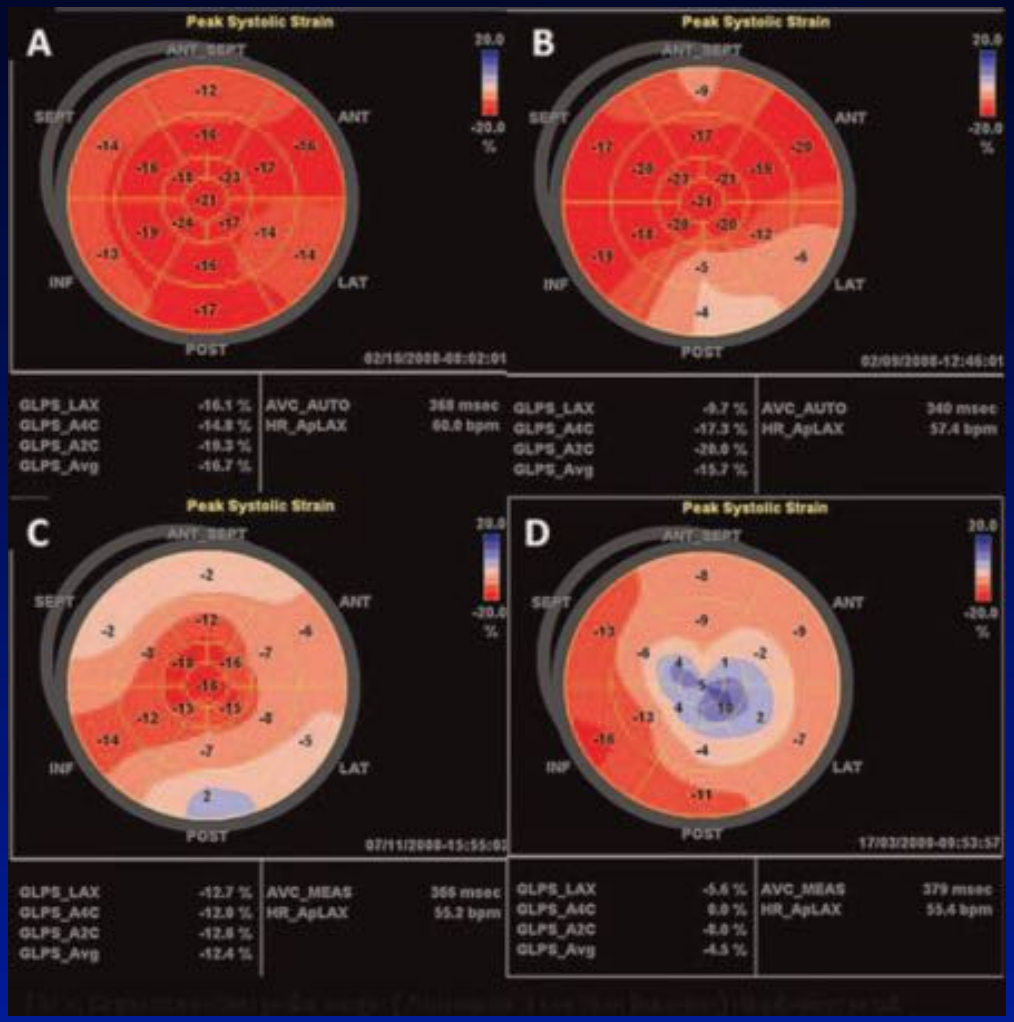
Tops LF et al. Myocardial strain to detect subtle left ventricular systolic dysfunction. *Eur J Heart Failure* 2016.

HCM vs. Hypertensive LVH vs. Athlete

Strain imaging: LV GLS

Athlete

Hypertension



HCM

Apical HCM

Afonso L et al. Two-dimensional strain profile in patients with physiological and pathological hypertrophy and preserved LV systolic function. *BMJ Open.* 2012.

Clinical applications

Strain imaging: Aortic stenosis

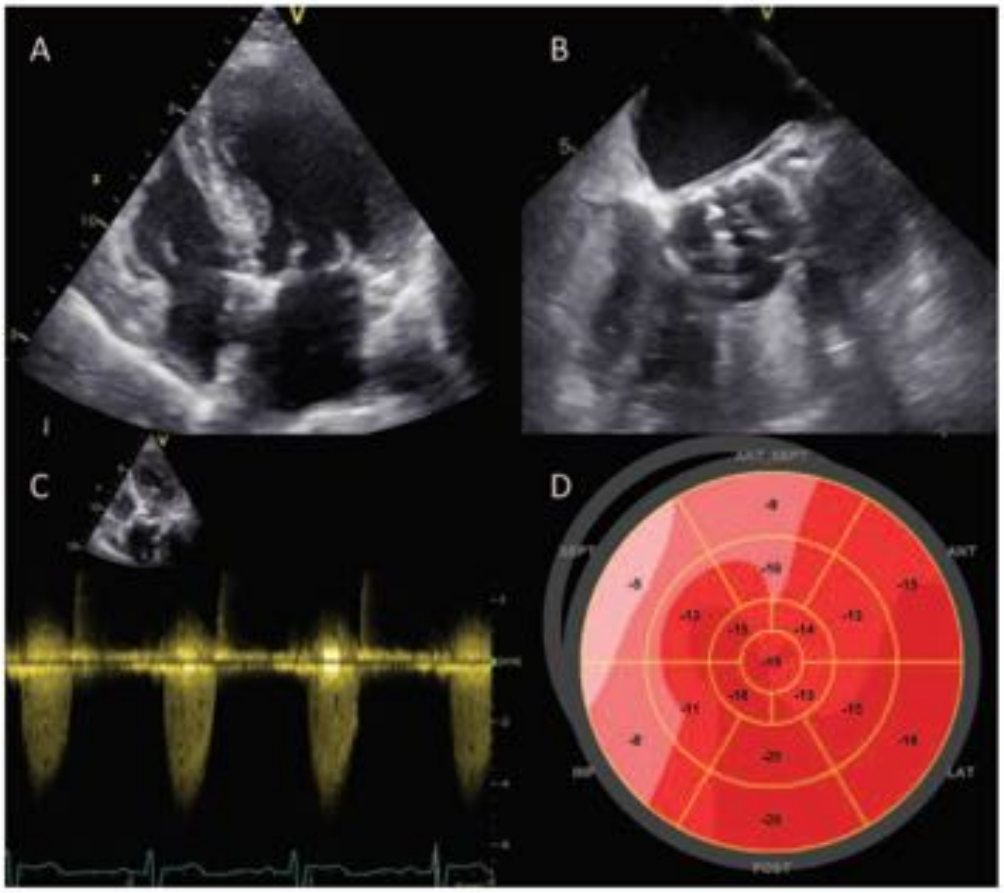


Figure 2 Left ventricular global longitudinal strain (GLS) in valvular heart disease. Example of a patient (female, 83 years) with asymptomatic severe aortic stenosis. (*A*) Concentric hypertrophy of the left ventricle. The calculated LVEF is 62%. The short-axis view (*B*) shows a calcified aortic valve, and continuous wave Doppler of the aortic valve (*C*) shows a mean pressure gradient over the aortic valve of 56 mmHg. The calculated aortic valve area is 0.9 cm^2. Despite preserved LVEF, LV GLS is impaired: the bull's eye plot in (*D*) shows an LV GLS of −13.2%, with the septal segments being most affected.

Ng AC et al. Alterations in multidirectional myocardial functions in patients with AS and preserved EF: a 2D speckle tracking analysis. *Eur Heart J* 2011; 32: 1542-50.

Clinical applications

Strain imaging: Cardio-Oncology

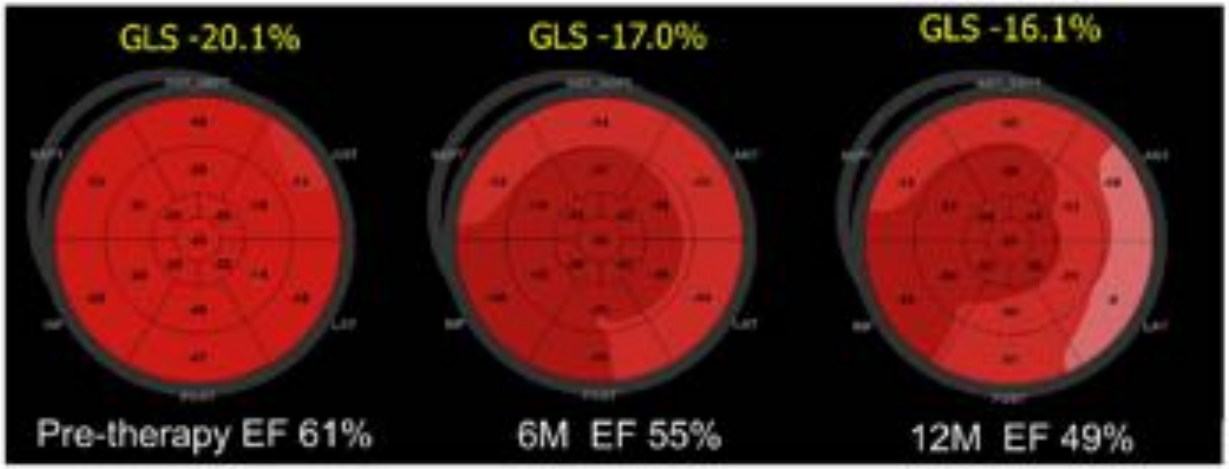


Figure 4 **The Utility of Early Strain Changes to Predict Subsequent Cardiotoxicity**

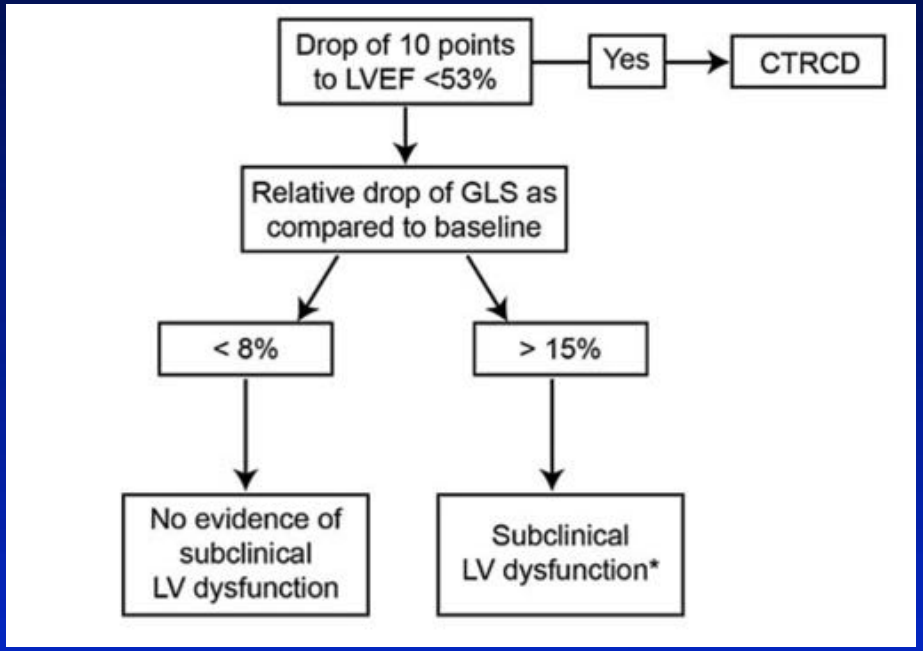
The images demonstrate a "bull's eye" plot of strain values for each of the 17 myocardial segments. A patient receiving cytotoxic chemotherapy had normal baseline strain and left ventricular (LV) ejection fraction (EF) **(left)**. Six months into therapy, the LVEF dropped by 6% but did not meet criteria for cardiotoxicity. However, the peak systolic global longitudinal strain (GLS) fell by 15.4% (a significant change based on the literature). Then, by 12 months there was a clinically significant fall in LVEF meeting the criteria for cardiotoxicity. See Online Videos 1, 2, and 3 for 4-chamber movie images demonstrating the changes in function. LVEF was calculated using the Biplane Simpson's method. 6M = 6 months; 12M = 12 months.

Thavendiranathan P et al. Use of myocardial strain imaging by echocardiography for the early detection of cardiotoxicity in patients during and after cancer chemotherapy. *J Am Coll Cardiol* 2014; 63: 2751-68.

Clinical applications

Strain imaging: Cardio-Oncology

- Although strain can be measured using TDI or 2D STE, the latter using same vendor-specific ultrasound machine is favoured due to lack of angle dependency
- LV GLS is optimal parameter of deformation for early detection of sub-clinical LV systolic dysfunction
- >15% early reduction in LV GLS by STE during chemotherapy was most useful parameter for prediction of cardiotoxicity



Plana JC. Expert consensus for multimodality imaging evaluation of adult patients during and after cancer therapy. Eur Heart J 2014; 15: 1063-93.

Take Home Message

- Strain imaging: more sensitive than LVEF to assess LV systolic dysfunction and to detect early changes in myocardial performance
- Restrictive cardiomyopathy: GLS values are reduced despite normal LVEF predicting adverse cardiovascular outcomes
- Hypertrophic cardiomyopathy: GLS may help differentiate from LVH due to hypertension or athlete heart
- Valvular heart disease: GLS values are reduced in symptomatic patients with AS/AI and may predict need for future surgical intervention
- Cardio-Oncology: >15% early reduction in LV GLS during chemotherapy is most useful parameter for prediction of cardiotoxicity