Straining to see the future

Emerging applications of Strain Imaging

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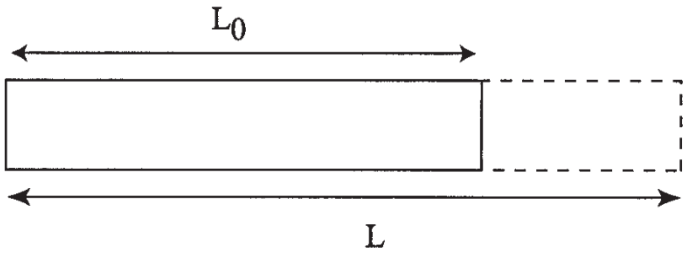
Emerging Applications of Strain Imaging

1. The What
2. The How
3. The Who,When and Why

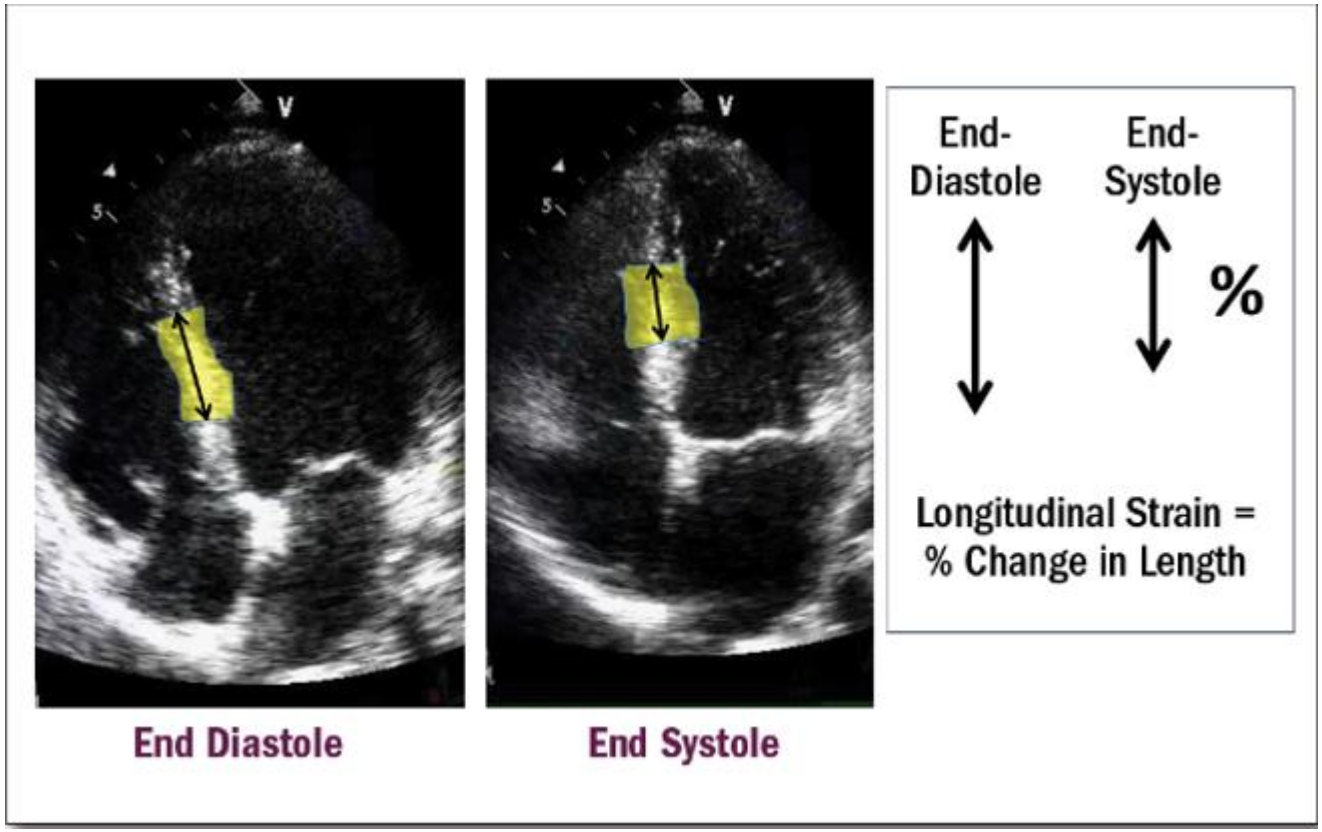
The Mechanical Engineering Principle of Strain (Deformation)



$$\varepsilon = \frac{L - L_0}{L_0}$$

1) A unitless percentage of change.
2) If it shortens, ε will be negative; if lengthens, ε will be positive.

Myocardial shortening in a region of interest



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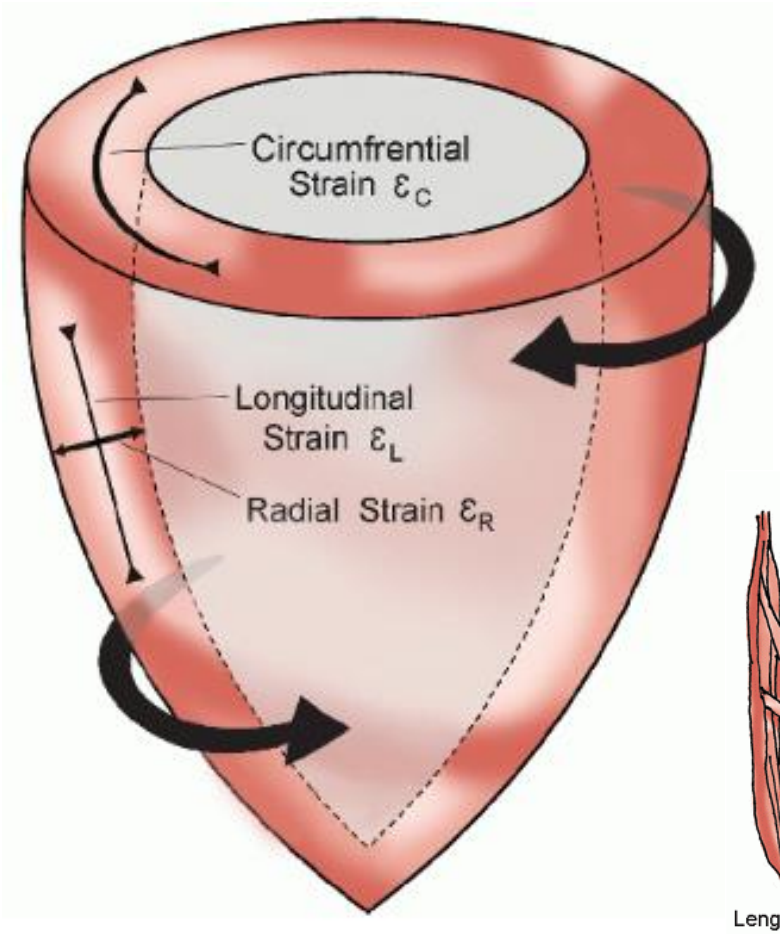

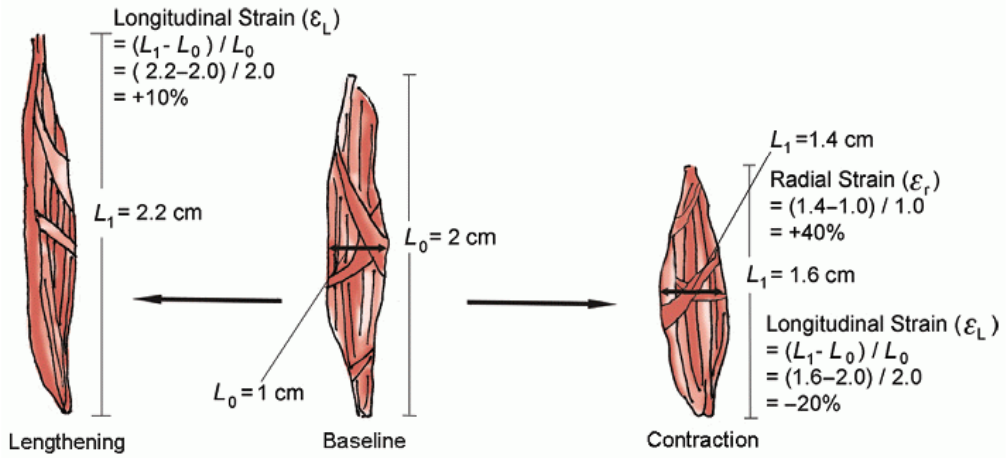

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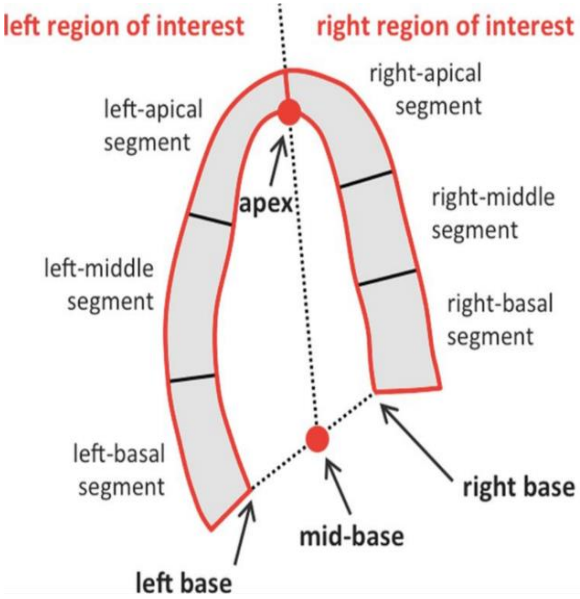
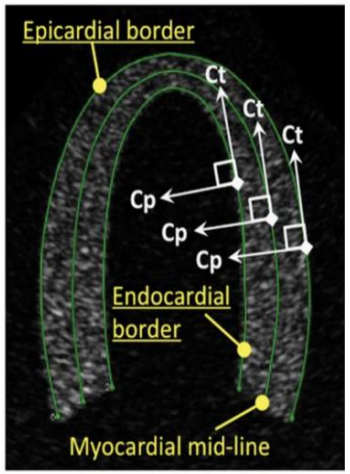
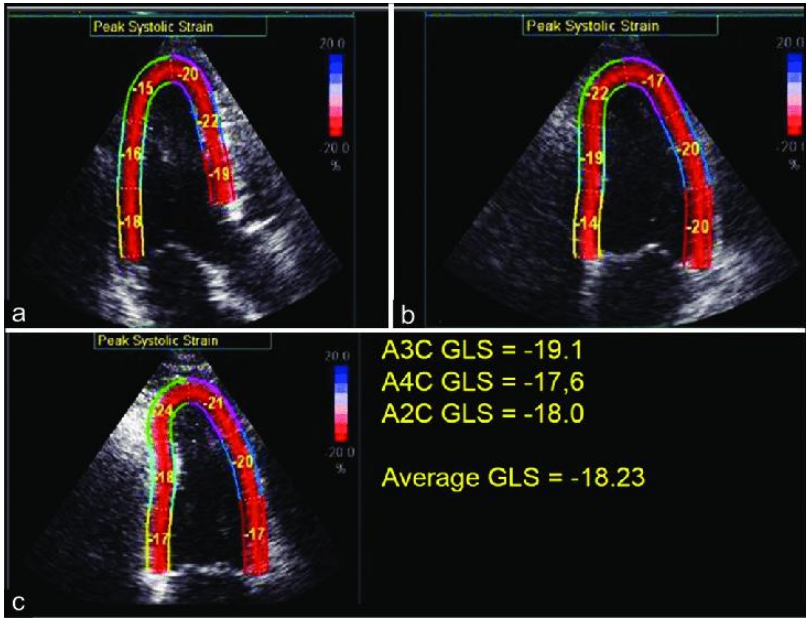




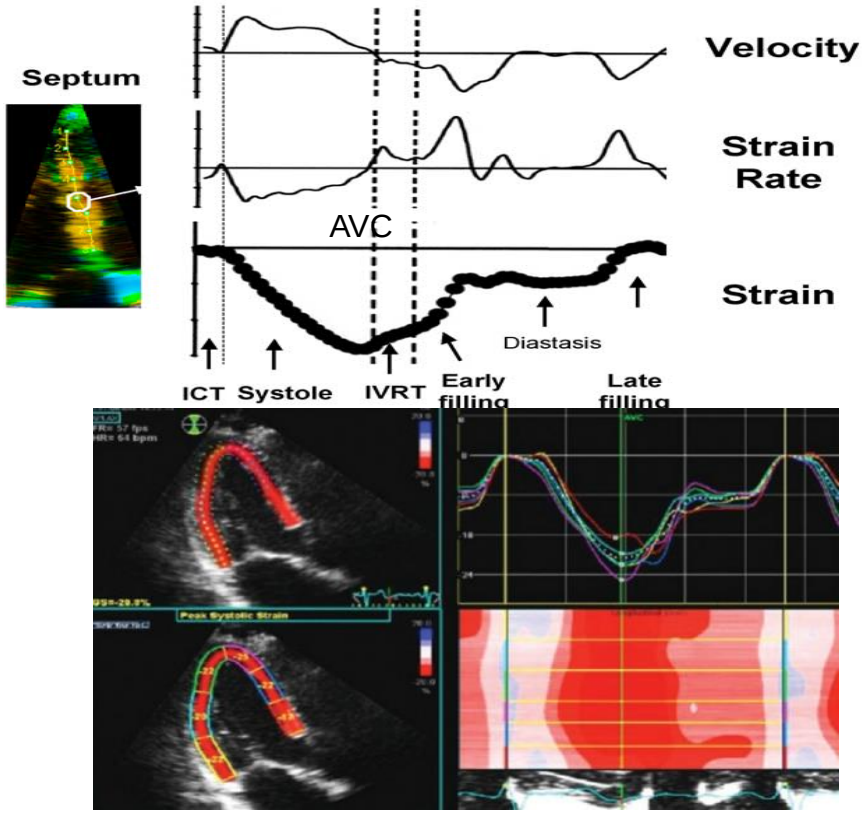


From: Definitions for a common standard for 2D speckle tracking echocardiography: consensus document of the EACVI/ASE/Industry Task Force to standardize deformation imaging

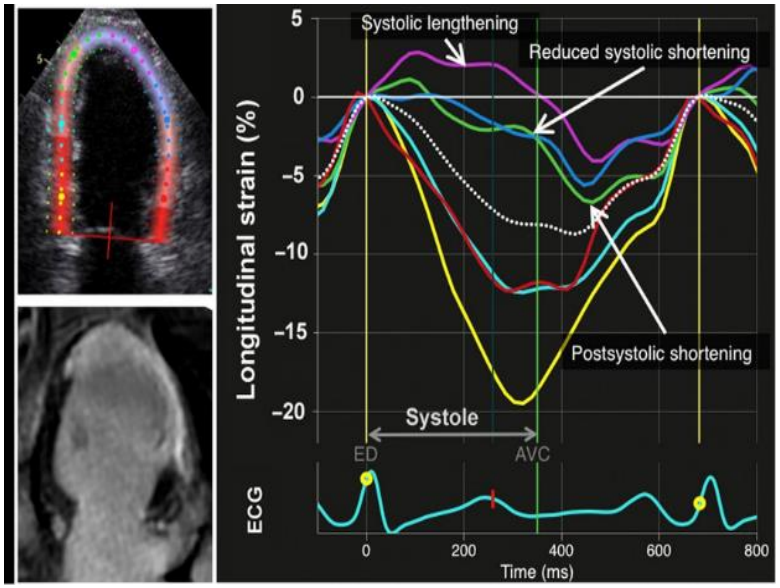
Eur Heart J Cardiovasc Imaging | Published on behalf of the European Society of Cardiology.

Relationship Between Timing and Strain
Normal and Abnormal Strain Curves

Normal Curve



Abnormal Curve



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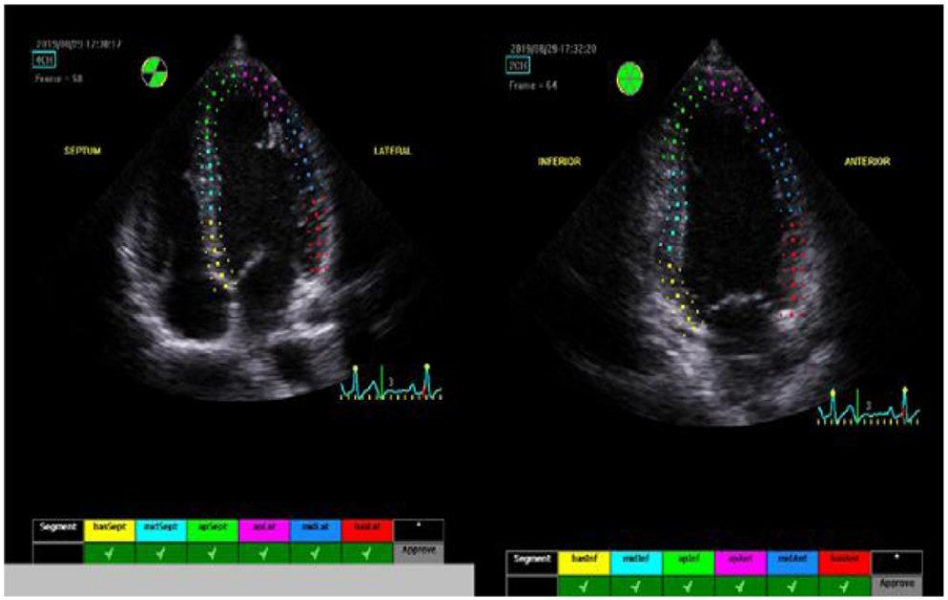
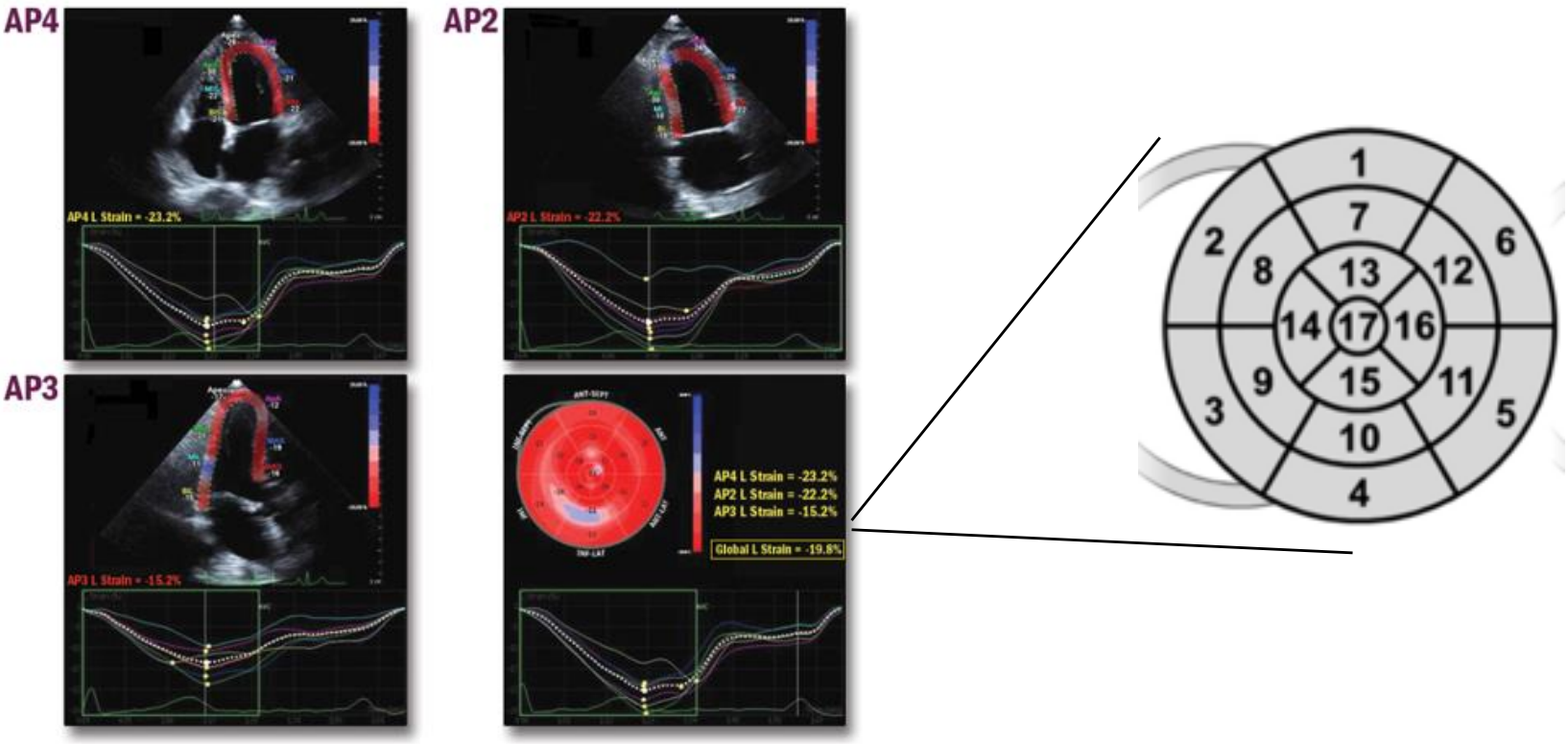
Strain- Technical

- Clear endocardial and epicardial definition is required to ensure adequate segmental tracking throughout the cardiac cycle.
- Use automated tracking where possible to maintain reproducible results.
- Automated tracking should also be combined with a visual assessment of tracking in each view across the whole ROI, including the endocardial and epicardial border
- If more than two segments in any one view are not adequately tracked, the calculation of GLS should be avoided.

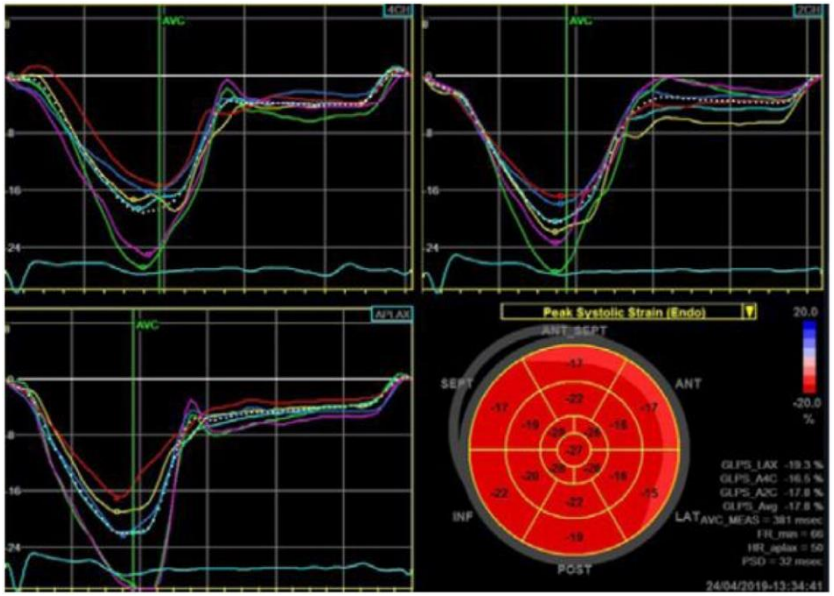


2D Strain Display

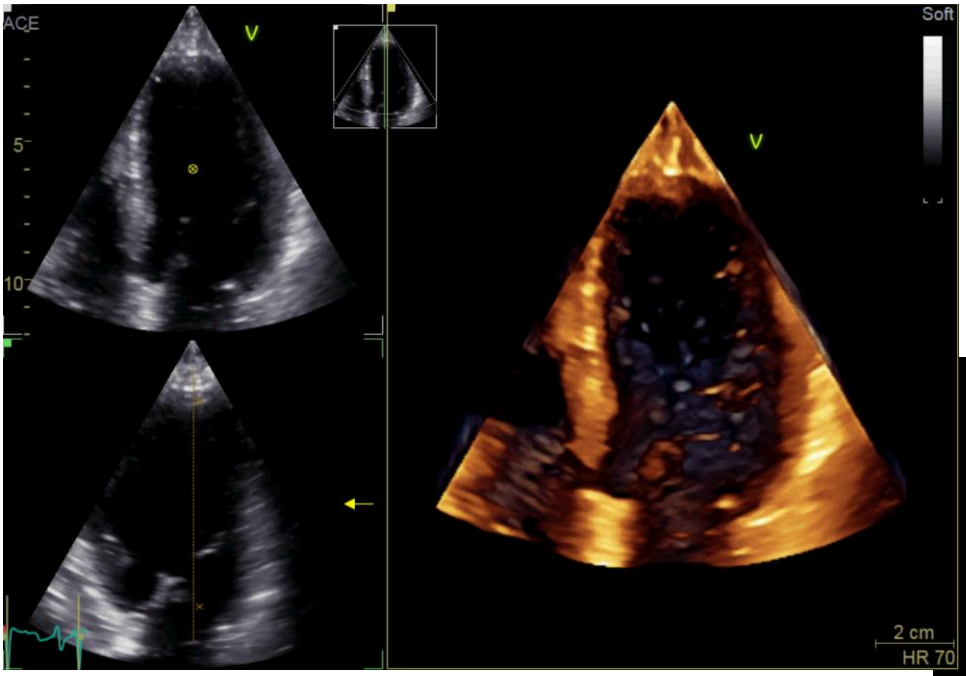


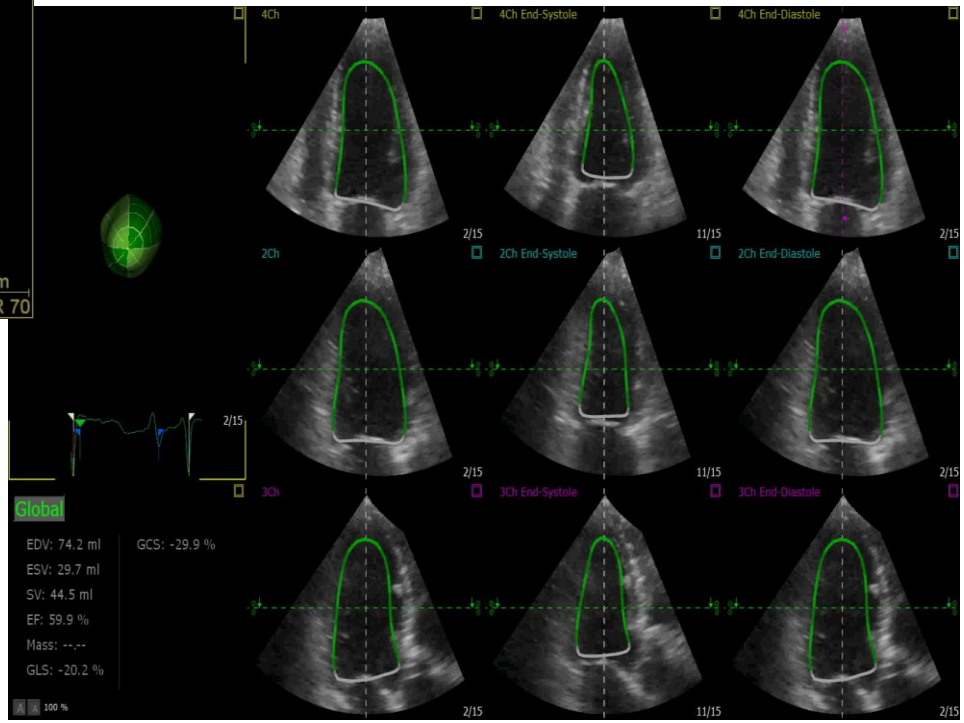
2D Strain- Technical

- Optimal ECG signal with minimal heart rate variability should be present across the three cardiac cycles.
- Heart rate variability will limit the calculation of GLS values, which can be problematic in patients with atrial fibrillation.
- High-quality image acquisition, maintaining a frame rate of 40 to 90 frames/s at a normal heart rate is key.



3D Global Longitudinal Strain Acquisition and Processing





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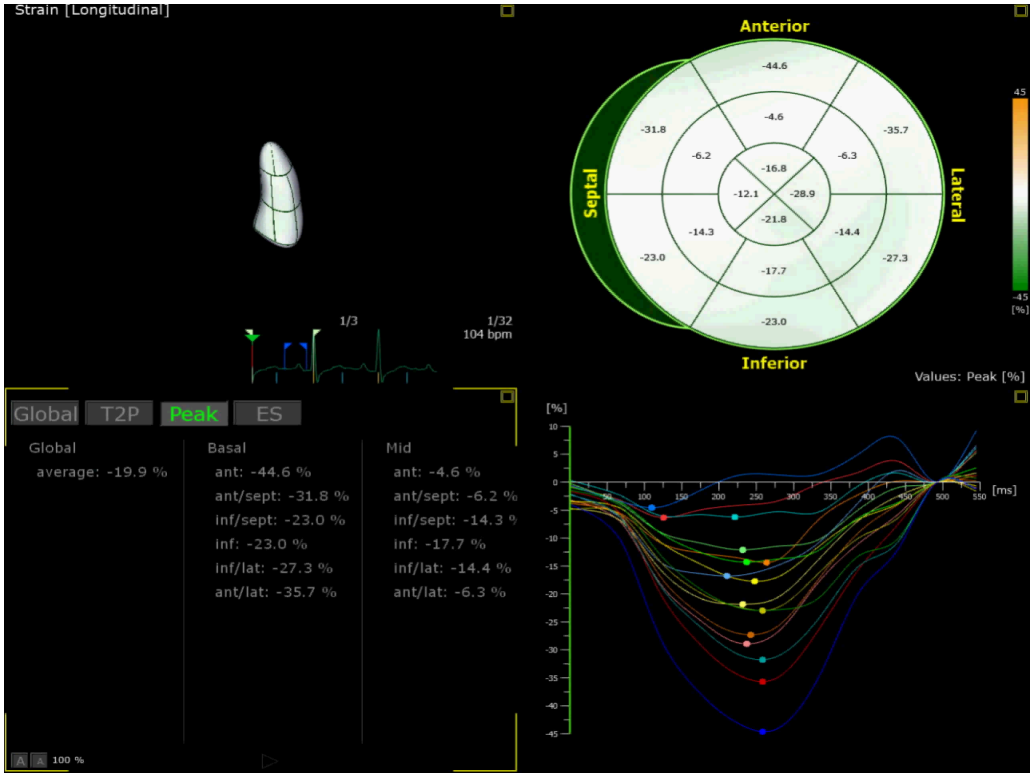
3D Global Longitudinal Strain Processing



- More representative volumes
- More reproducible
- Needs specialized training and quality control

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What's wrong with this picture?

Timing of AVC

Avoid LVOT

Avoid the atrium

ROI

Foreshortened images

Tracking well

What's wrong with this picture?

Timing of AVC

LVOT involved

Atrium involved

ROI not optimal

Foreshortened images

Not tracking well

What's wrong with this picture?

Timing of AVC

Avoid LVOT

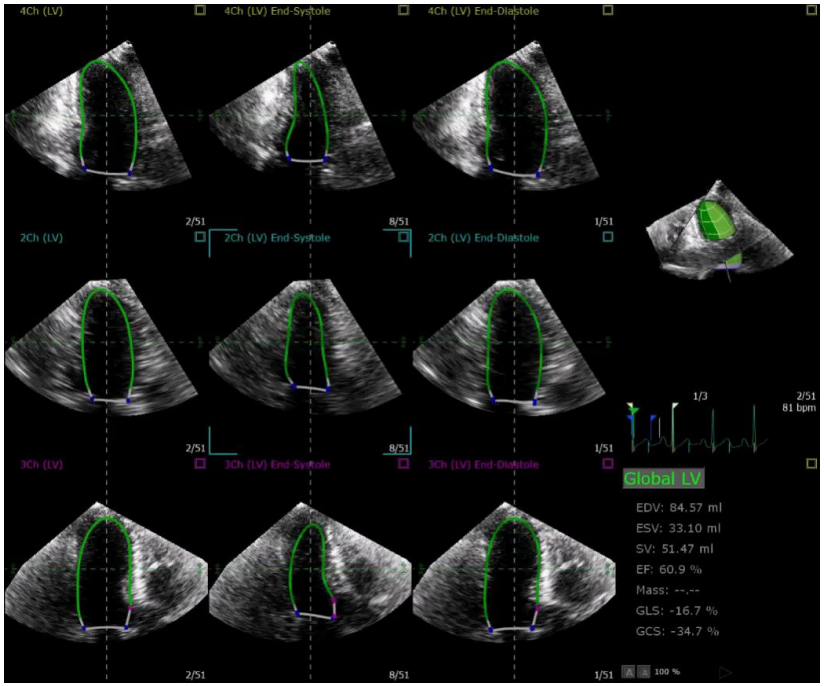
Avoid the atrium

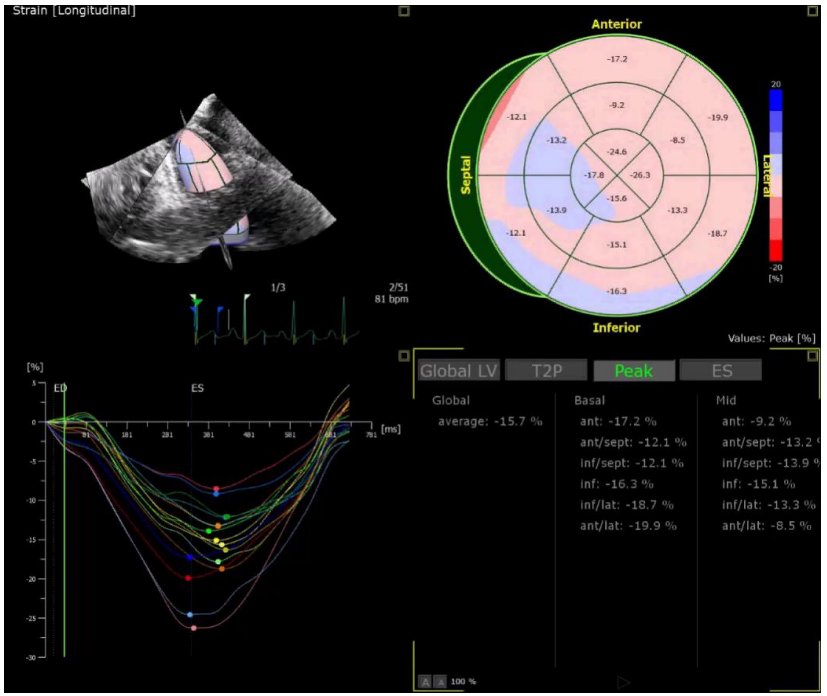
ROI too small

Foreshortened images

Not tracking well

What's wrong with this picture? (LVEF normal)





Whats wrong with this picture?

Timing of AVC

Avoid LVOT

Avoid the atrium

ROI wrong

Foreshortened images

Not tracking well

Whats wrong with this picture?

Timing of AVC

Avoid LVOT

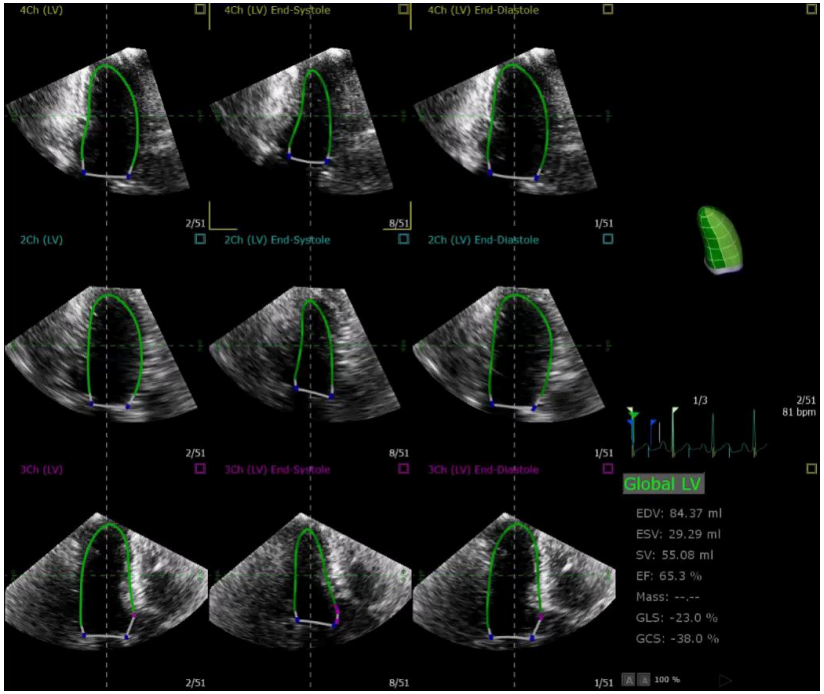
Avoid the atrium

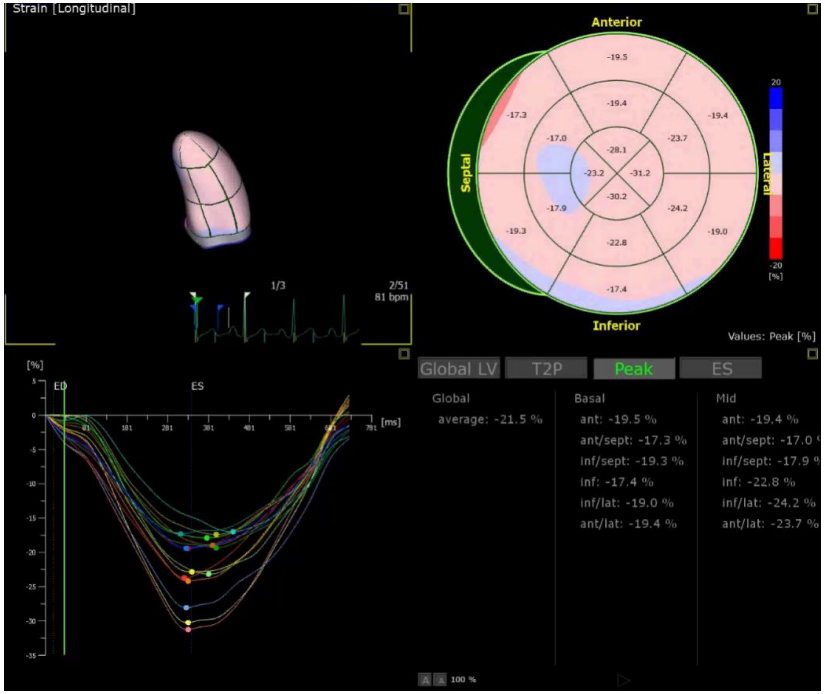
ROI to Wide

Foreshortened images

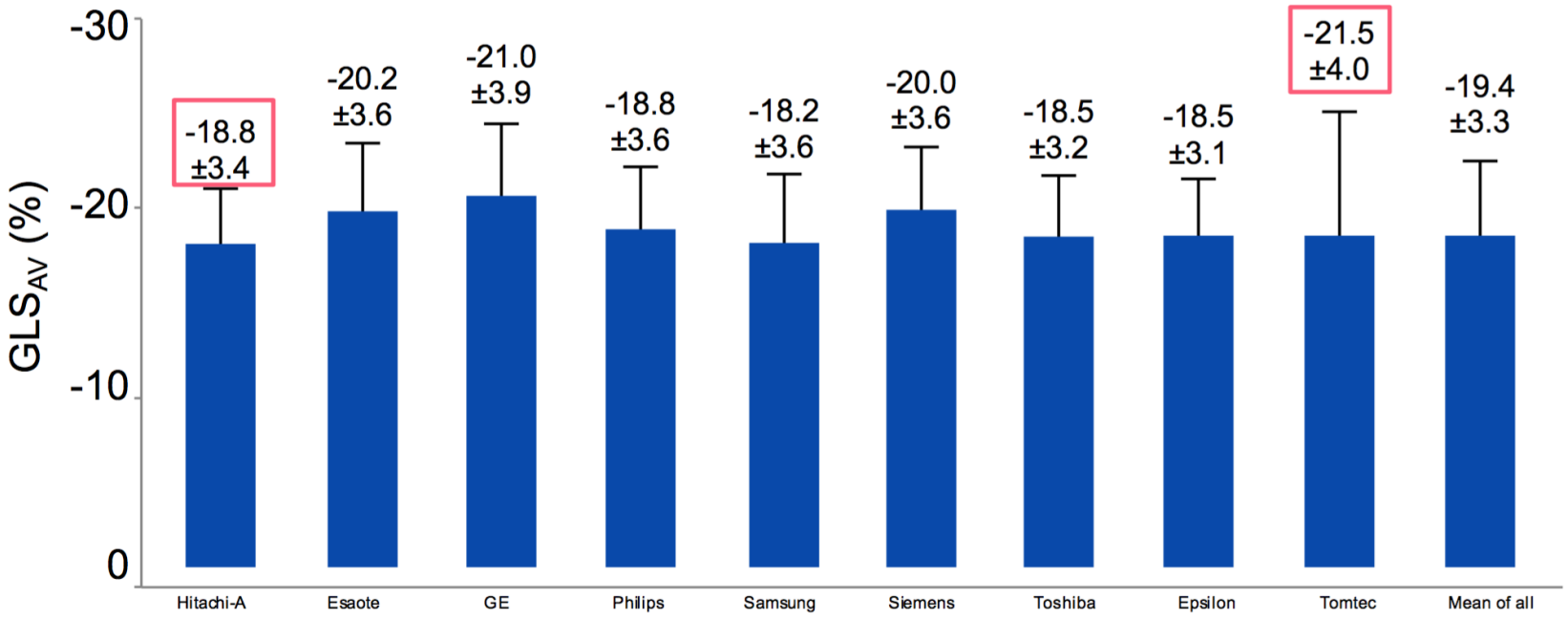
Not tracking well

GLS went from (-)15.7% to (-)21.5%





Global Longitudinal Strain Among Various Vendors



Farsalinos et al: J Am Soc Echocardiogr 28:1171, 2015

Try to use same company and same software version for serial studies

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Recommendations for Cardiac Chamber

Global Longitudinal Peak Systolic Strain (GLS)
"in the range of -20%"

M ...o
are: Roberto M. Lang, MD, FASE, et al

- "Optimize image quality, maximize frame rate and minimize foreshortening".
- "When regional tracking is suboptimal in more than two myocardial segments in a single view the calculation of GLS should be avoided".

assembled by the American Society of Echocardiography and the European Association of Cardiovascular Imaging. This document provides updated normal values for all four cardiac chambers, including three-dimensional echocardiography and myocardial deformation, when possible, on the basis of considerably larger numbers of normal subjects, compiled from multiple databases. In addition, this document attempts to eliminate several minor discrepancies that existed between previously published guidelines. (J Am Soc Echocardiogr 2015;28:1-39.)

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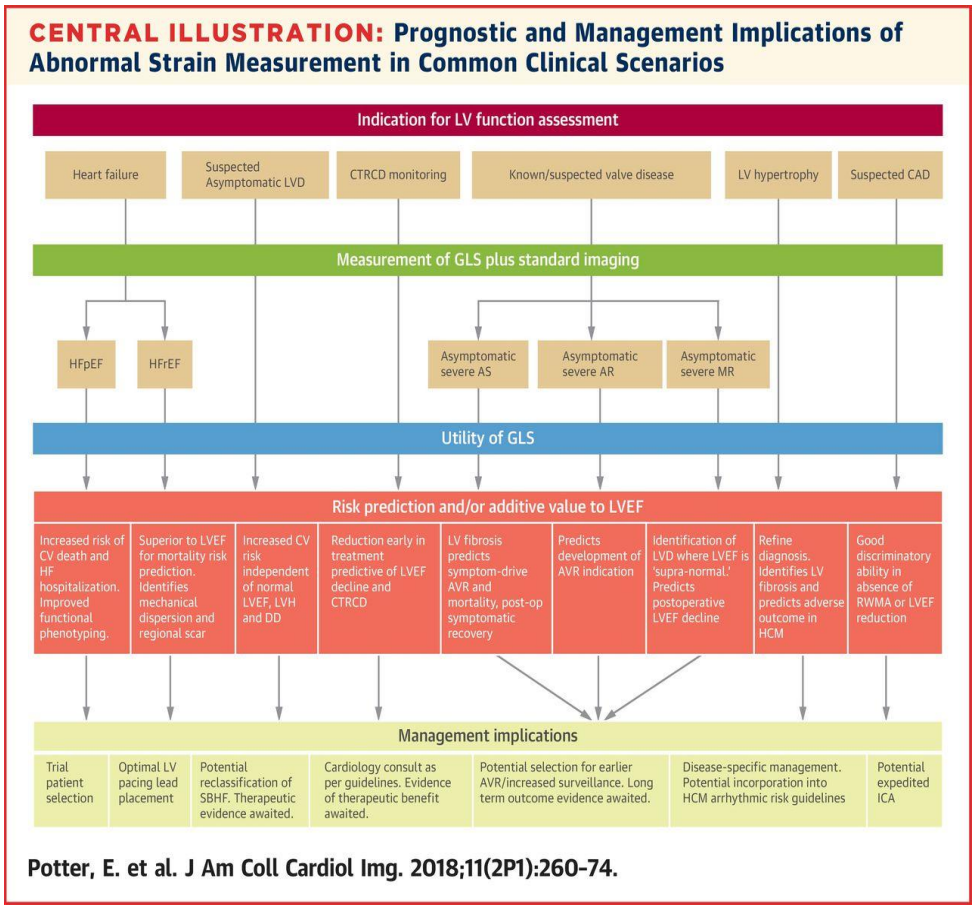
Current/Emerging Applications: strain imaging



- Hypertrophic cardiomyopathy
- Dilated cardiomyopathy
- Restrictive Cardiomyopathy
- Cancer therapy induced cardiomyopathy
- Heart transplant recipients and cardiac function
- Left ventricular dyssynchrony
- Diastolic dysfunction (LA strain)
- Valvular disease

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Clinical Applications of Strain Imaging

Hypertrophic cardiomyopathy

Dilated cardiomyopathy

Coronary Artery Disease

Restrictive Cardiomyopathy

Cancer therapy induced cardiomyopathy

Heart transplant recipients and cardiac function

Left ventricular dyssynchrony

RV affecting disease (PE, PHTN)

Diastolic dysfunction (LA strain)

Valve disease

Clinical Applications of Strain Imaging

Hypertrophic cardiomyopathy

Dilated cardiomyopathy

Coronary artery disease

Infiltrative Cardiomyopathy (Amyloid)

Cancer therapy induced cardiomyopathy

Heart transplant recipients and cardiac function

Left ventricular dysynchrony

RV affecting disease (PE, PHTN)

Diastolic dysfunction (LA strain)

Valve disease

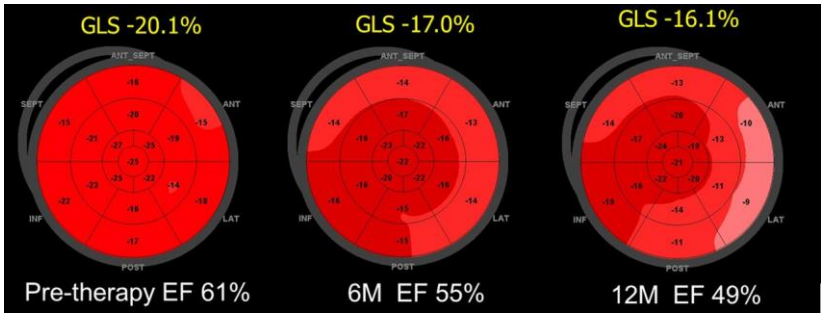
Strain and Chemotherapy Related Cardiotoxicity (CTRCT) monitoring

- Defining CTRCT purely by LVEF or symptomatic heart failure yields a reported rate of 1%-5% of CIMP in cancer survivors. When definition is expanded to include other markers of myocardial dysfunction Including strain- 37.5%.
- CTRCT portends a worse prognosis, so careful monitoring is crucial.
- CTRCT can also interrupt therapy or treatments, reducing overall survival in patients with cancer.
- Early recognition of CIMP and initiation of cardioprotective therapies improve the chances of LV function recovery.

Technique	Currently available diagnostic criteria	Advantages	Major limitations
Echocardiography: **–3D-based LVEF** **–2D Simpson's LVEF** **–GLS**	• LVEF: >10 percentage points decrease to a value below the LLN suggests cardiotoxicity. • GLS: >15% relative percentage reduction from baseline may suggest risk of cardiotoxicity.	• Wide availability. • Lack of radiation. • Assessment of haemo-dynamics and other cardiac structures.	• Inter-observer variability. • Image quality. • GLS: inter-vendor variability, technical requirements.
Nuclear cardiac imaging (MUGA)	• >10 percentage points decrease in LVEF with a value <50% identifies patients with cardiotoxicity.	• Reproducibility.	• Cumulative radiation exposure. • Limited structural and functional information on other cardiac structures.
Cardiac magnetic resonance	• Typically used if other techniques are non-diagnostic or to confirm the presence of LV dysfunction if LVEF is borderlines.	• Accuracy, reproducibility. • Detection of diffuse myocardial fibrosis using T1/T2 mapping and ECVF evaluation.	• Limited availability. • Patient's adaptation (claustrophobia, breath hold, long acquisition times).

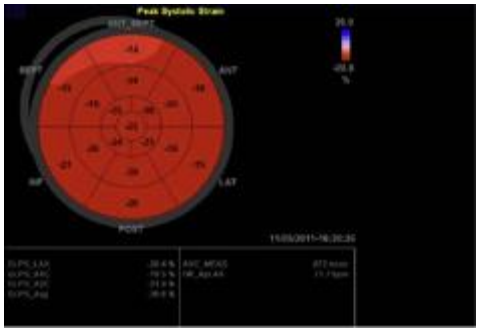
Zamorano JL, et al: 2016 ESC Position Paper on cancer treatments and cardiovascular toxicity developed under the auspices of the ESC Committee for Practice Guidelines: The Task Force for cancer treatments and cardiovascular toxicity of the European Society of Cardiology (ESC). Eur Heart J 37:2768-2801, 2016
2.Plana JC, et al: Expert consensus for multimodality imaging evaluation of adult patients during and after cancer therapy: A report from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. Eur Heart J Cardiovasc Imaging 15:1063-1093, 2014

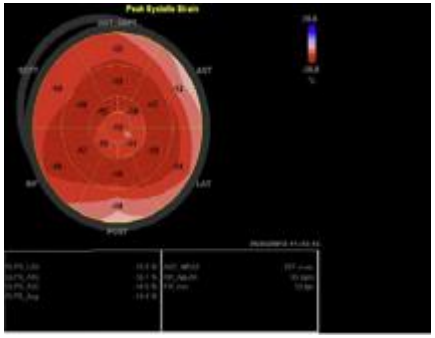
Echo Surveillance CRTCT-

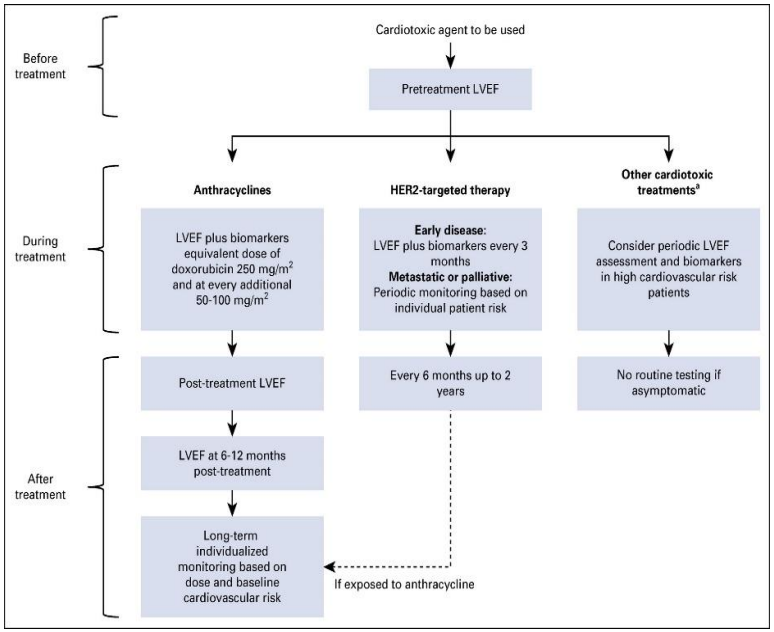


ECHO criteria LV Dysfunction

- LVEF decrease 10% (<50%)
- GLPSS decrease > 15%







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Cardio-oncology

Cardio-oncology patients account for an increasing proportion of echocardiography requests.

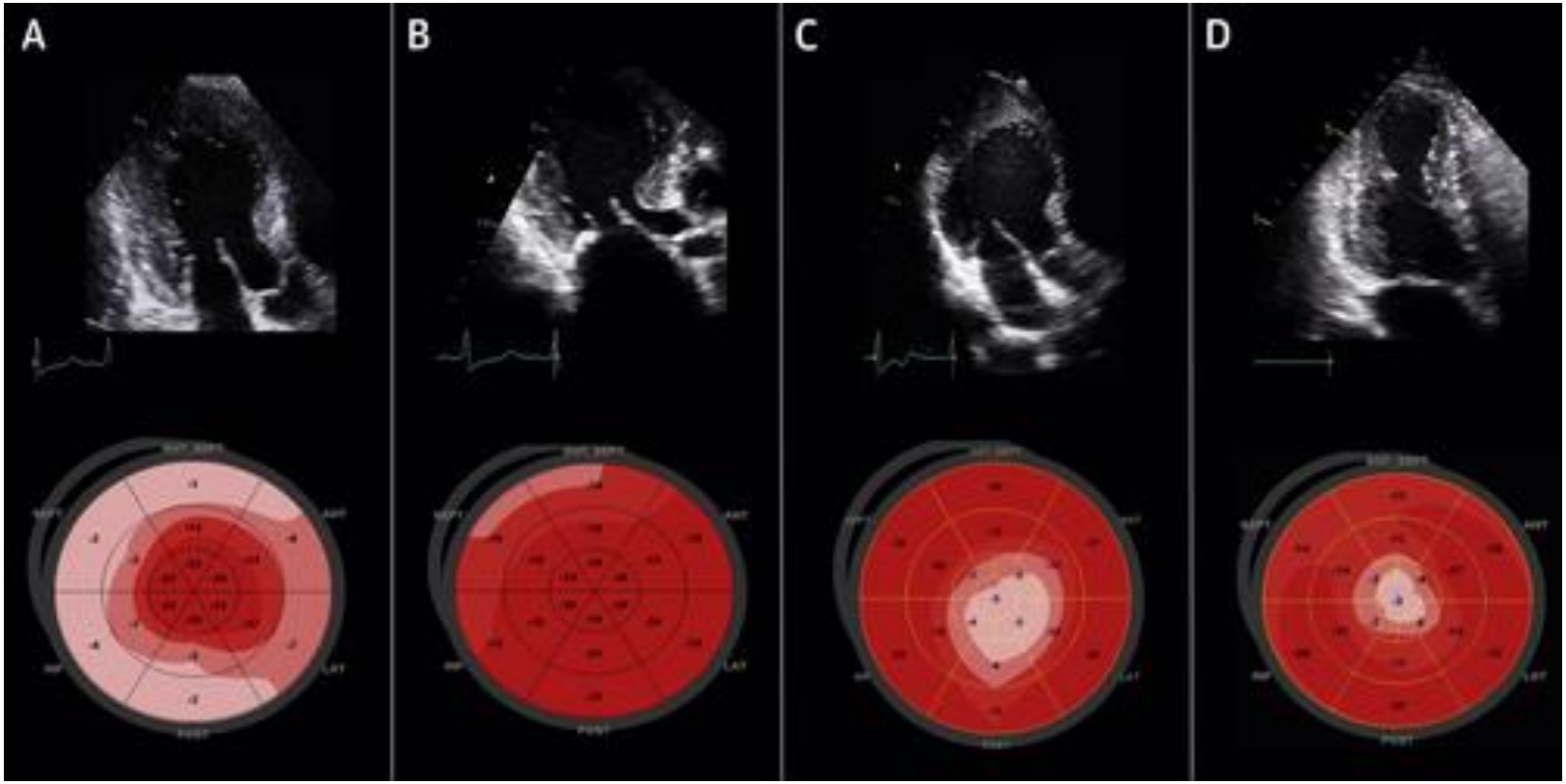
Accurate assessment of LV systolic function (LVEF and GLS) is critical to decision making in this patient group.

2D LVEF, **3D LVEF**, GLS, and RV assessment should be used in the echocardiographic assessment of these patients.

The ability to perform GLS and 3D measurements is heavily technical.

STE measured GLS is the most consistent parameter of future cardiotoxicity (GLS > 15%)

Strain Imaging improves echo diagnostic ability in restrictive cardiomyopathies



Patrick Collier et al. *J Am Coll Cardiol* 2017; 69:1043-1056.

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Amyloid Heart Disease:“Hiding in Plain Sight”

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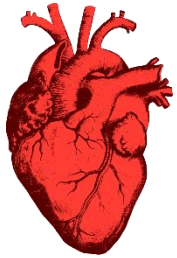
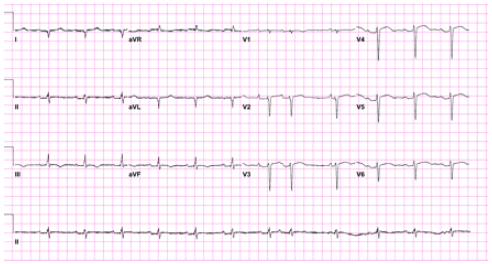
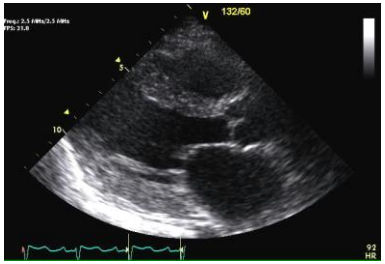
Amyloidosis: Diagnostic Evaluation

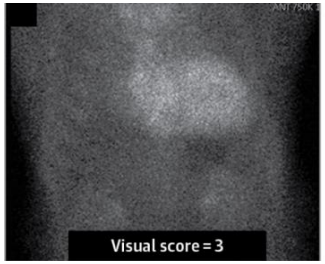




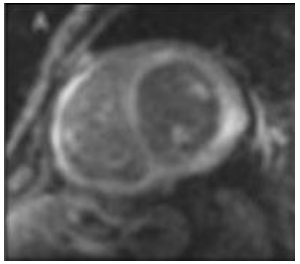
EKG



Echocardiogram

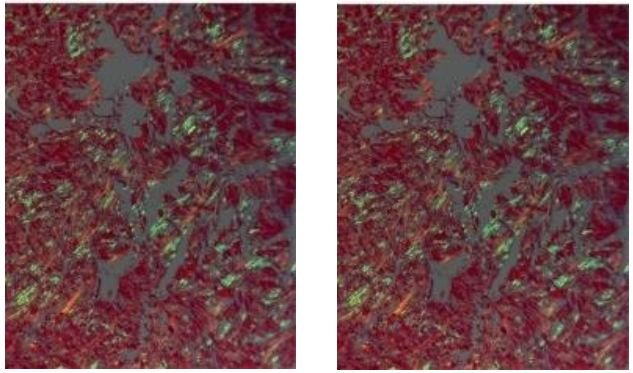


Nuclear Scan

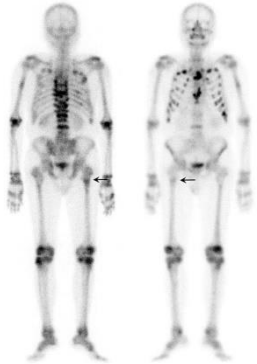


Cardiac MRI

Blood/urine tests: kidney, liver protein



Biopsy: Heart/kidney/marrow

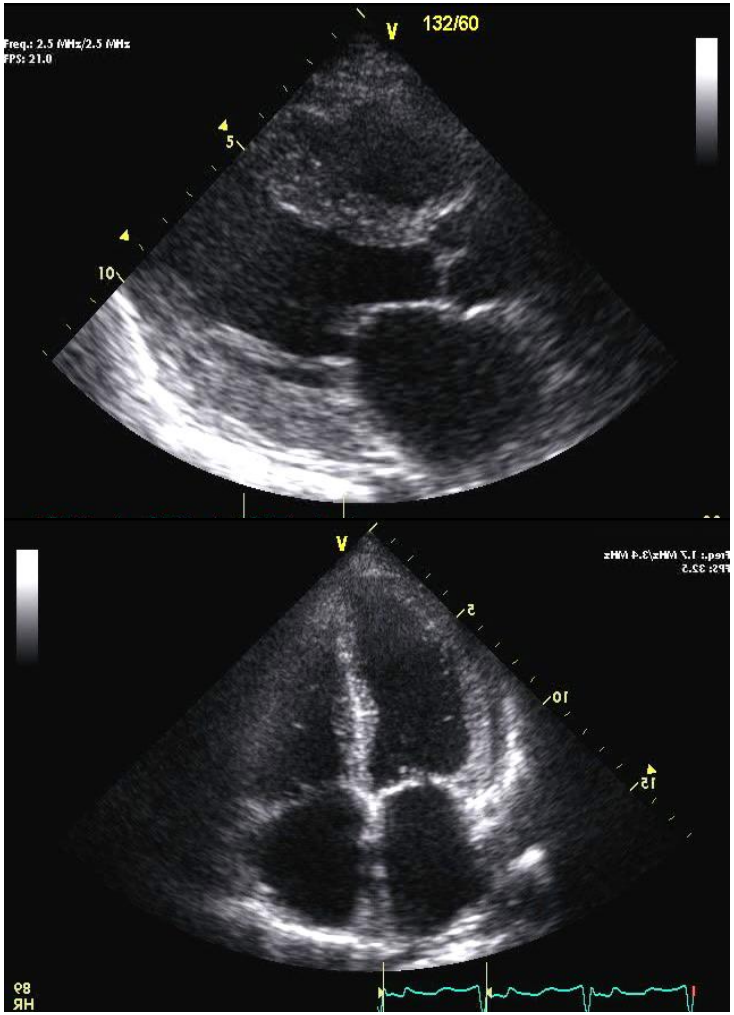


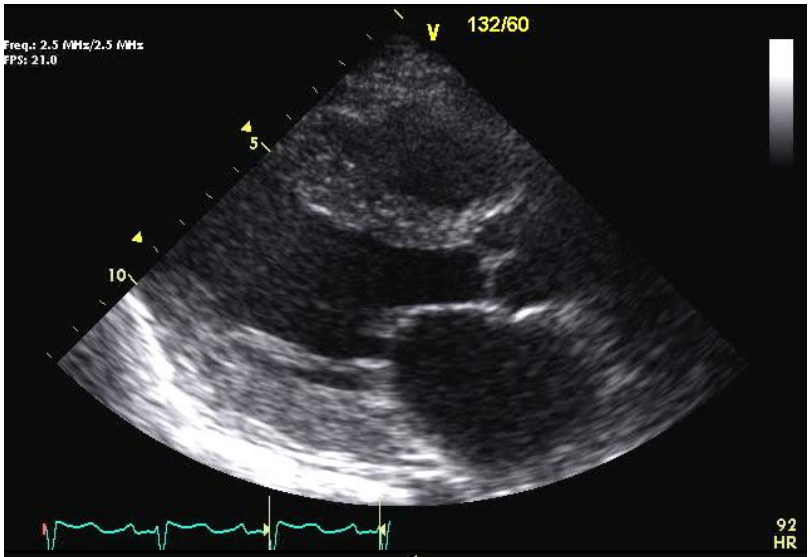
Bone scan

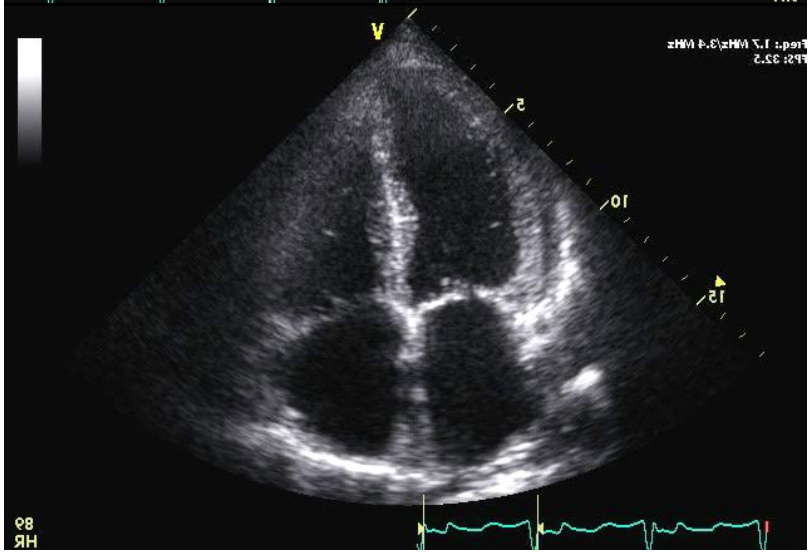
Case 1 –Amyloid patient

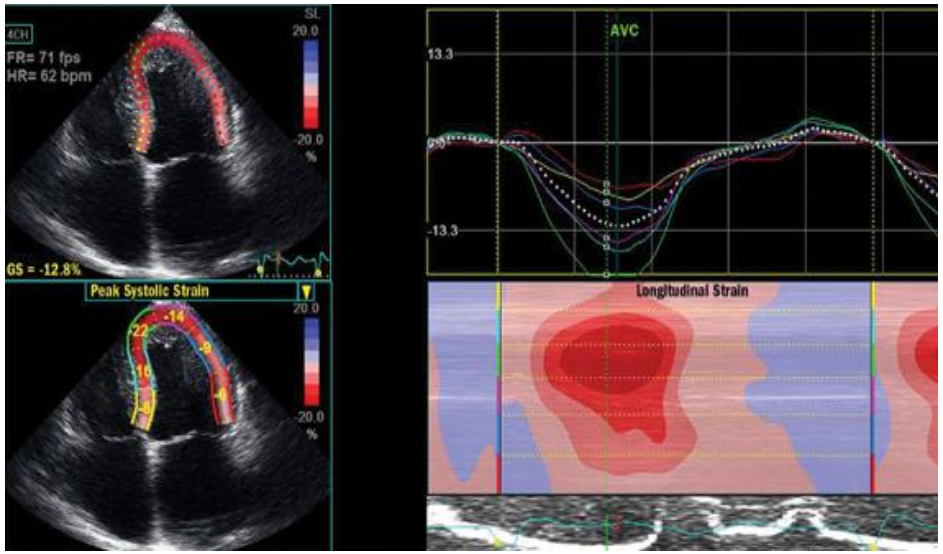
60 yr old woman referred

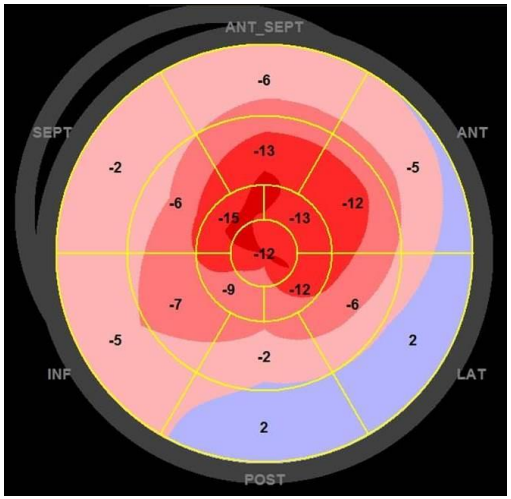
- carpal tunnel release 2 years prior
- monoclonal gammopathy x 2 years
- peripheral neuropathy x 6 months
- Lower extremity edema
- echocardiogram with ↑ wall thickness
- Buccal mucosa biopsy positive for amyloid











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Case 1 – Amyloid evaluation and treatment

Bone Marrow Biopsy positive for amyloid

Assessment/Plan: AL Amyloidosis with Cardiac involvement

- Chemotherapy + stem cell transplant

Significant cardiac involvement predicted a poor prognosis

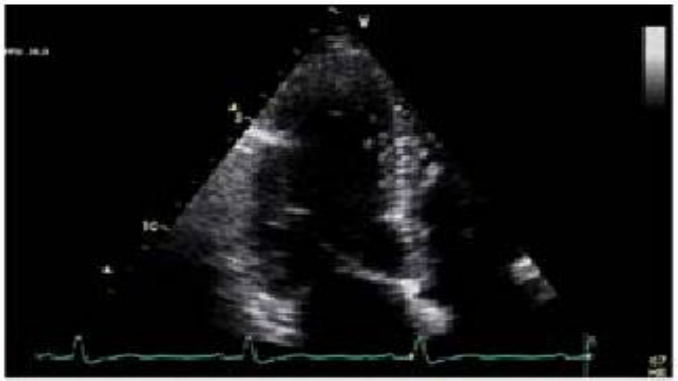
15 days after stem cell transplant

- Cardiac arrest in ICU with defibrillation/CPR
- ICD/pacemaker implanted before hospital discharge

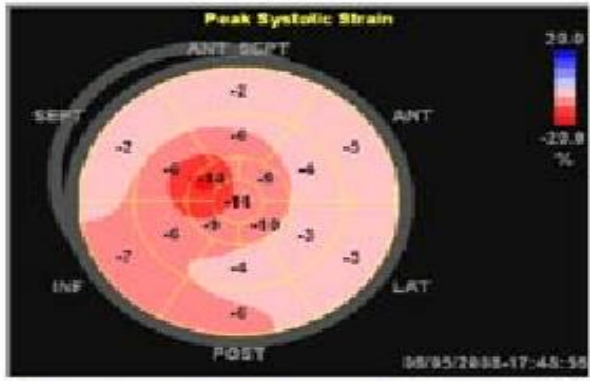
However, no subsequent hospitalizations in > 2 years
Enjoying winters in Arizona

Cardiac Amyloidosis: Incremental Value of Strain

Normal



Late Cardiac Amyloid



Early Cardiac Amyloid

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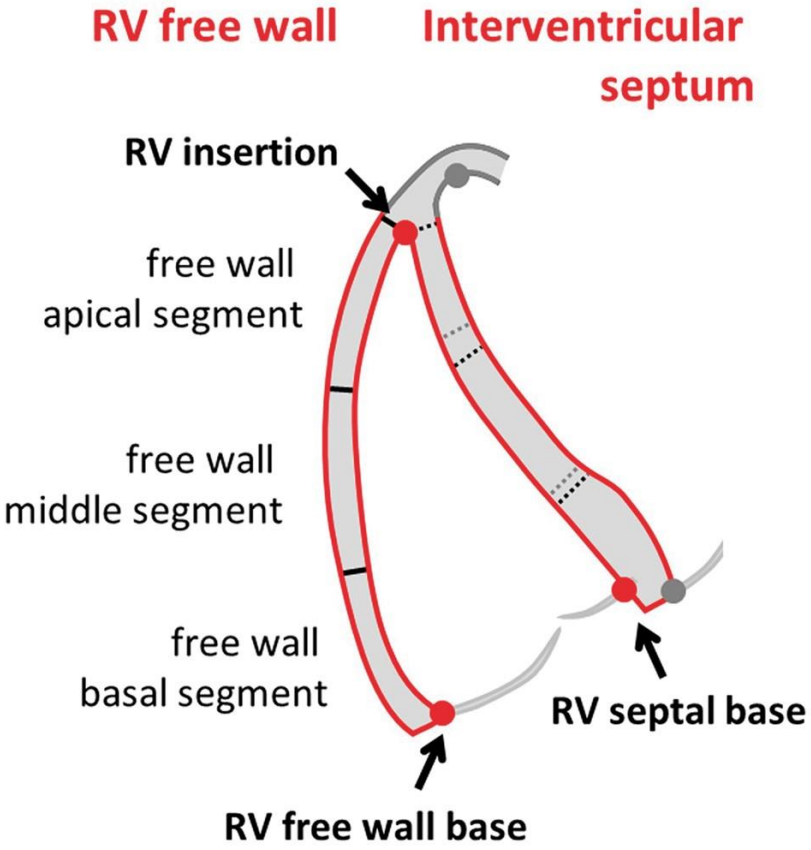
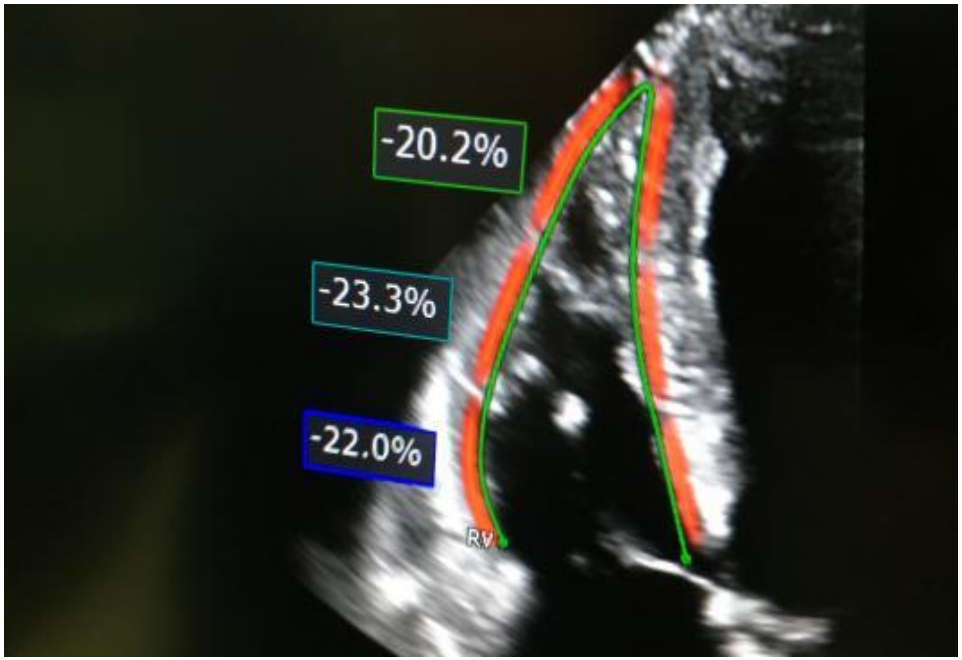
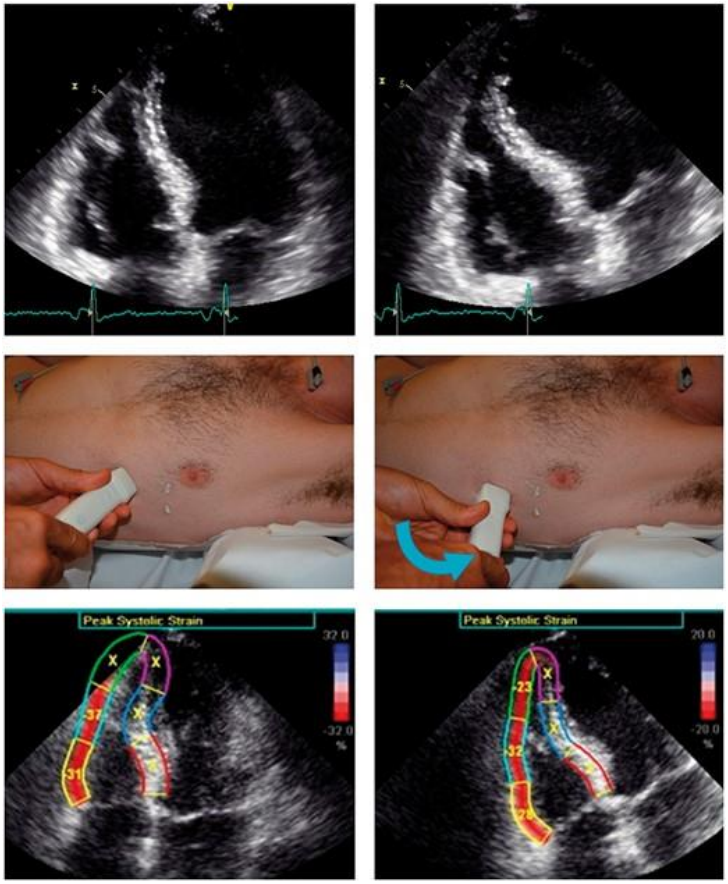
Segmentation of the RV focused free wall

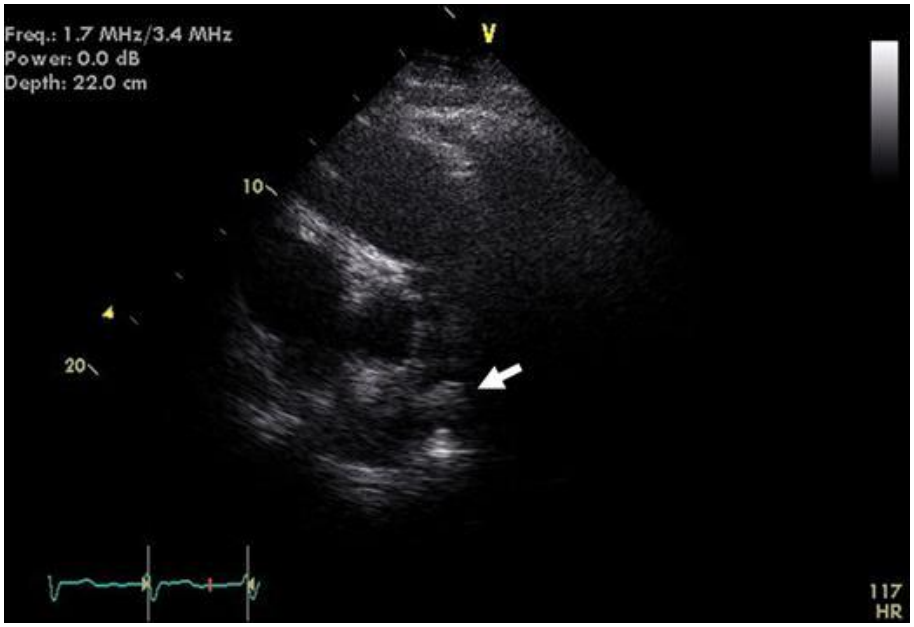


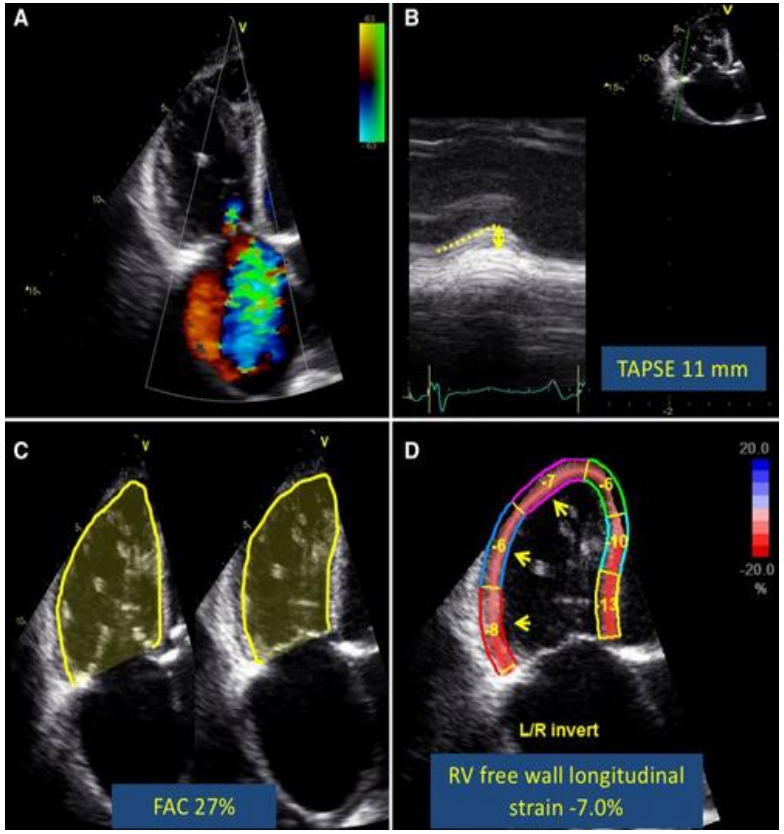


RV focused free wall



Patient with PE- Conservative treatment or to IR





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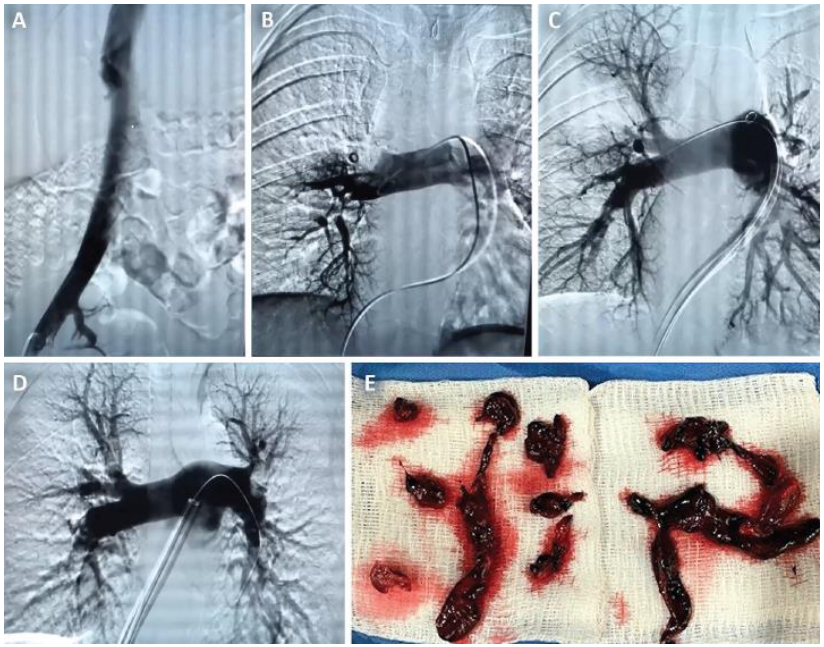
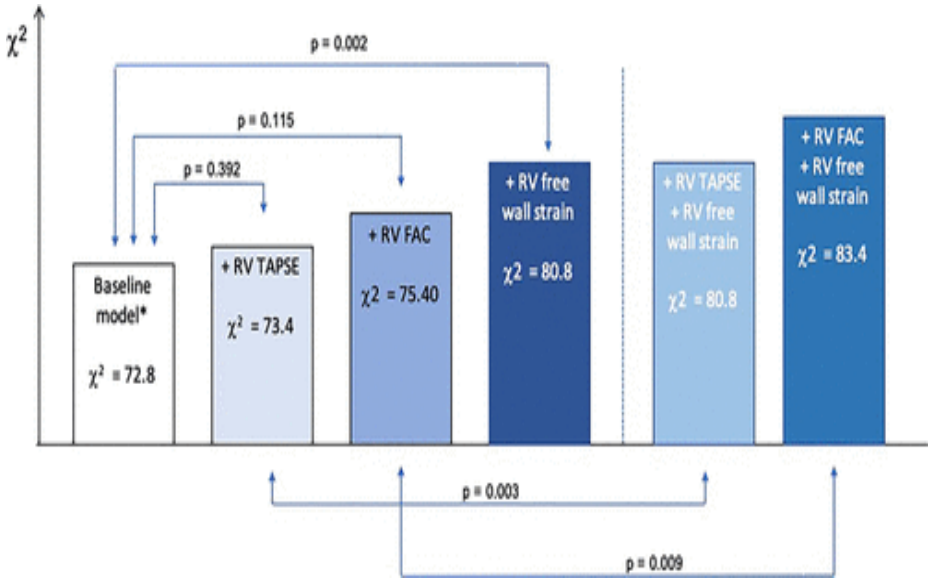
Association between adding RVFW GLS and mortality





Prognostic Implications of Right Ventricular Free Wall Longitudinal Strain in Patients With Significant Functional Tricuspid Regurgitation Circulation: Cardiovascular Imaging. 2019;12:e00866

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Ten echocardiographic findings of right ventricular strain

PERT (Pulmonary Artery Response Team)

We went live with our PERT process in November 2019.

Clinical Decision Pathway (CDP): CT- if PE, then urgent Right Heart Echo with Strain Imaging

Since then, we have seen steady growth in terms of referrals, and currently have had more than 300 PERT activations/year (i.e., approximately four or five per week).

> 90% normalize RV function at 3 months

- increased right ventricle: left ventricle size ratio
- abnormal septal motion
- McConnell's sign
- tricuspid regurgitation
- elevated pulmonary artery systolic pressure decreased tricuspid annular plane systolic excursion
- decreased S’
- pulmonary artery mid-systolic notching,
- **speckle tracking demonstrating decreased right ventricular free wall strain.**

LA strain

The left atrium (LA) plays a fundamental role in the function of the heart (reservoir function) (conduit function) (booster pump function).

LAVI has been shown to have low sensitivity in the early detection of left atrial dysfunction in the setting of LV diastolic dysfunction (DD).

A method assessing the reservoir function of the left atrium is the LA longitudinal strain, an angle-independent parameter derived from speckle-tracking echocardiography.

Particularly in HFpEF entity, recent studies suggest that LA strain has an important clinical and prognostic relevance, underlying the active role of the LA in the pathophysiology of the disease.

In addition, recent studies have suggested that LA strain could be of significant utility in the assessment of DD because this new LA parameter is significantly linked to the severity of DD.

1. Morris DA,. Potential usefulness and clinical relevance of adding left atrial strain to left atrial volume index in the detection of left ventricular diastolic dysfunction. J Am Coll Cardiol Img 2018; 11: 1405–1415
2. Morris DA, Normal values and clinical relevance of left atrial myocardial function analysed by speckle-tracking echocardiography: multicentre study. Eur Heart J Cardiovasc Imaging 2015; 16: 364–372.
3. Freed BH, Shah SJ. Stepping out of the left ventricle's shadow: time to focus on the left atrium in heart failure with preserved ejection fraction. Circ Cardiovasc Imaging 2017; 10.

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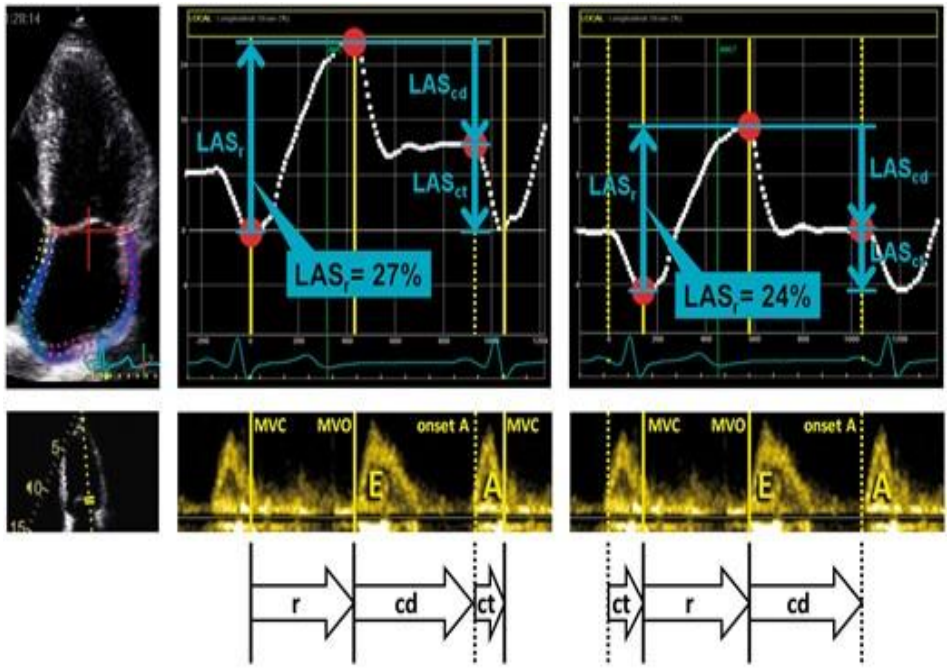
LA Strain measurement

LA strain should be measured using a non-foreshortened apical four-chamber view of the left atrium.

The LA is contoured extrapolating across the pulmonary veins and LA appendage orifice.

Once the ROI has been defined, the user should be always offered a moving display on which can visually check the quality of tracking by comparing the underlying image loop with the superimposed tracking results, along with the actual curves.

A dedicated mode for atrial analysis should be used if available.



European Heart Journal - Cardiovascular Imaging, Volume 19, Issue 6, June 2018, Pages 591–600,

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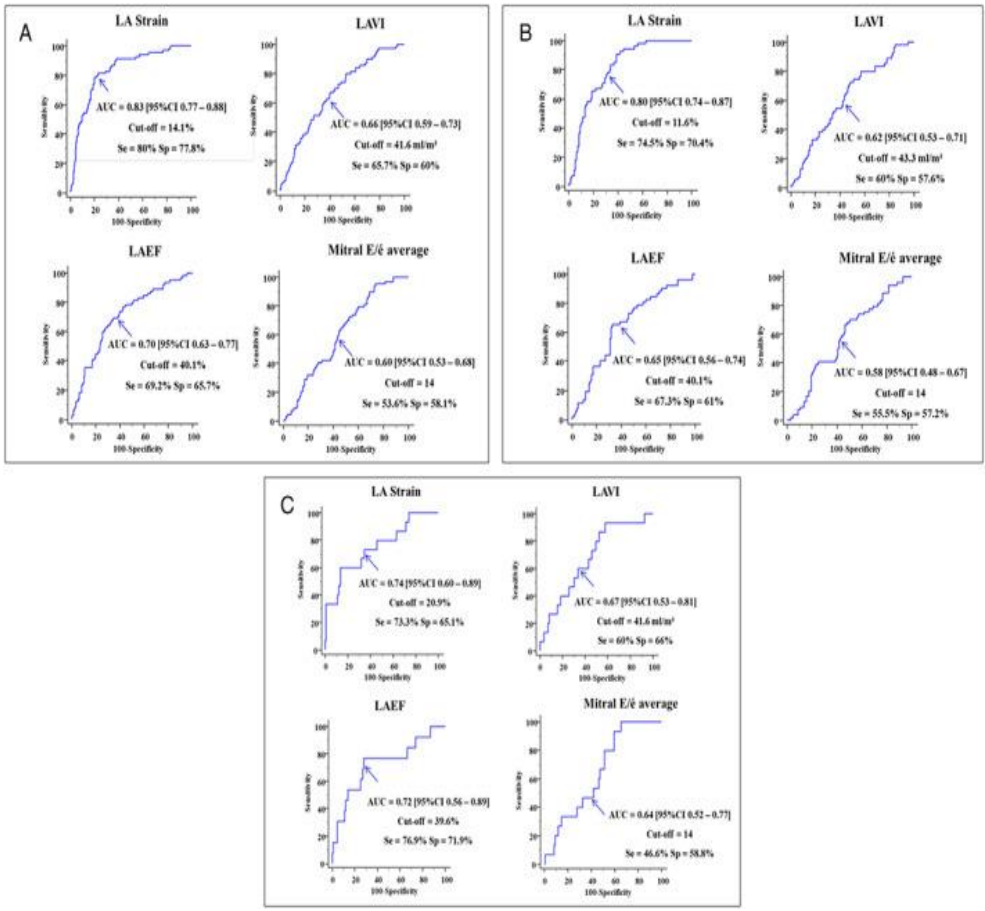
LA Strain and Diastolic Dysfunction

Left atrial strain as sensitive marker of left ventricular diastolic dysfunction in heart failure

The findings of this analysis suggest that LA strain could be a useful parameter in the evaluation of DD in patients with heart failure and sinus rhythm, irrespective of LVEF.



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Technical Summary

Strengths

- Ability to recognize subclinical LV/RV dysfunction
- Reproducible when performed by trained operators
- Growing evidence for standard of care use
- Improved automated software

Limitations

- Heavy dependence on the quality of 2D echo images
- Influenced by loading conditions
- Dependence on lab standardization for reproducibility
- Vendor and software specific

Plana JC, et al. Expert Consensus for multimodality imaging evaluation of adult patients during and after cancer therapy: a report from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr..