Strain Mechanics

Presented By
Lara Williams, BS, ACS, RCCS, RDCS, RVT, RDMS, FASE

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Disclosures

Employed by Siemens Healthineers
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Strain Mechanics

- Cardiac Function
- Strain Fundamentals
  - Speckle Tracking
  - Types of Strain
- Clinical Impact of Strain
- Strain Analysis
- Pathology Strain Patterns
- Strain outside of the LV

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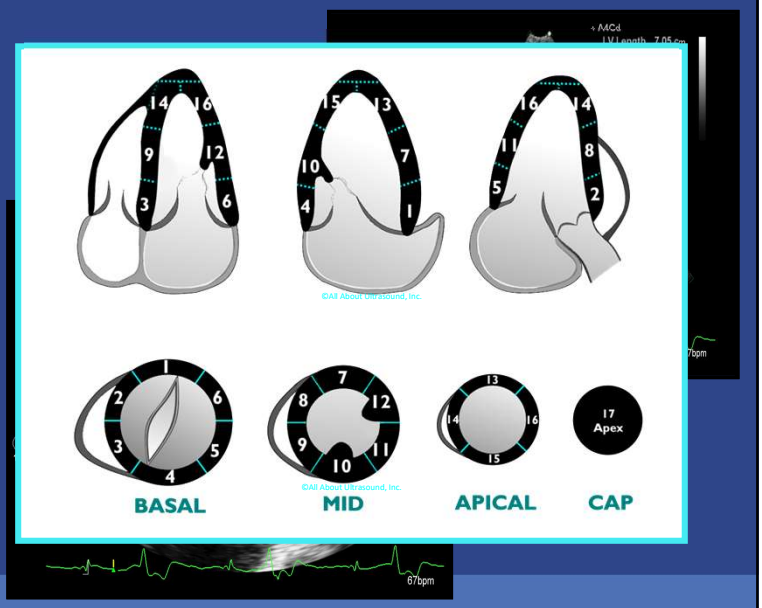
Cardiac Function

- Global Function
  - Ejection Fraction (EF%)
- Regional Function
  - Myocardial Thickening
  - Wall Motion Abnormalities



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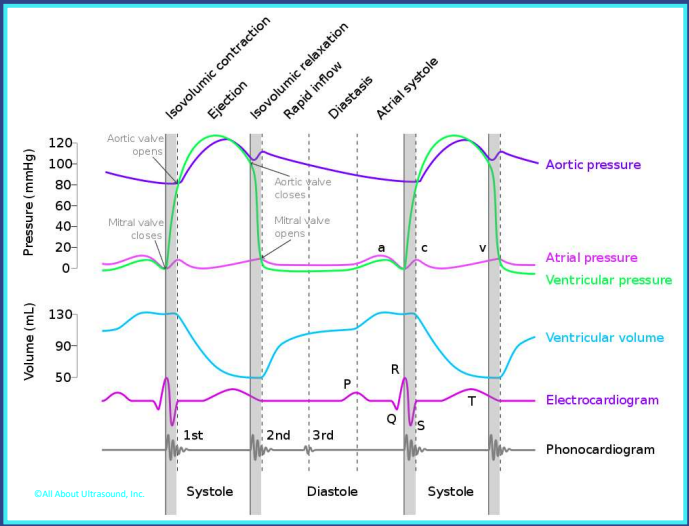
Cardiac Function

Systolic function is seen in the steep rise of LV pressure and rapid fall in LV volume during ejection.
Diastolic function is reflected in how quickly LV pressure falls in relaxation and how efficiently it fills during early diastole.



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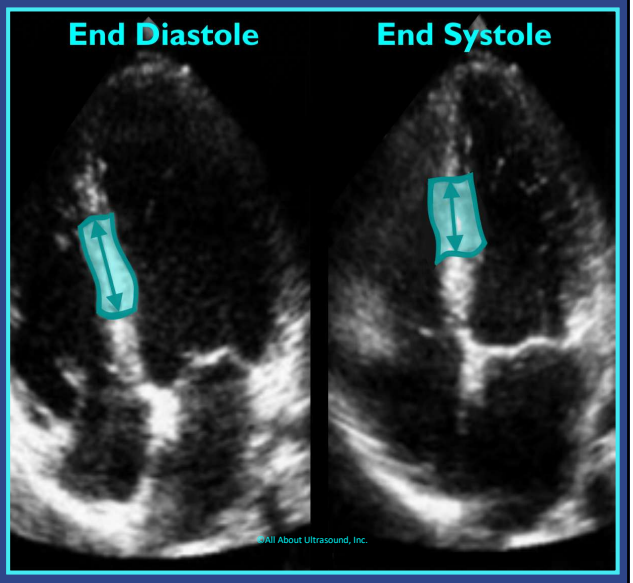
Strain Fundamentals

- Measures the tissue stiffness and degree of distortion or deformation with shortening during systole
- Strain rate and strain deformity imaging is helpful in echocardiography for determining the stiffness of the ventricular walls and function



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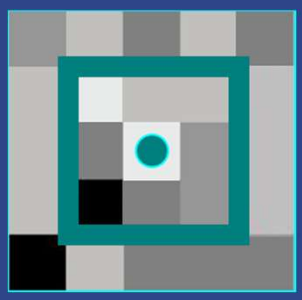
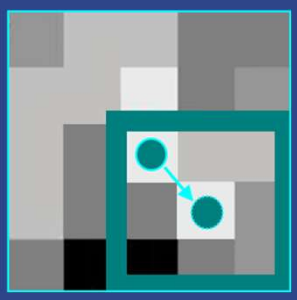
Strain Fundamentals

Speckle Tracking Technology

- Speckle is caused by interference of ultrasound waves/energy from randomly distributed scattered echoes
- Speckle Tracking uses technology to follow patterns in the ultrasound image





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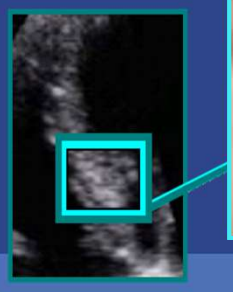
Strain Fundamentals

Speckle Tracking Technology

- Speckle Tracking uses technology to follow patterns in the image.
- Speckle Tracking can be used to calculate velocity, motion, deformation (deformation rate) by using pattern matching technology to determine myocardial distortion and deformation



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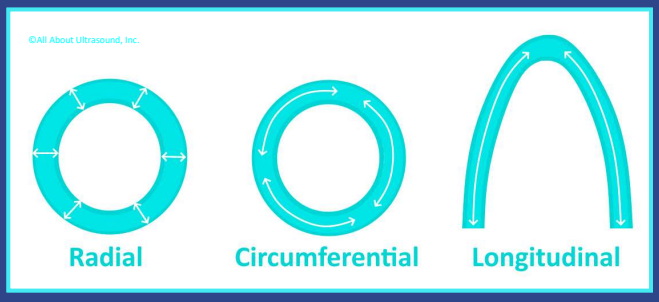
Strain Fundamentals

In echocardiography, the term "strain" is used to describe local shortening, thickening and lengthening of the myocardium as a measure of regional and global function.



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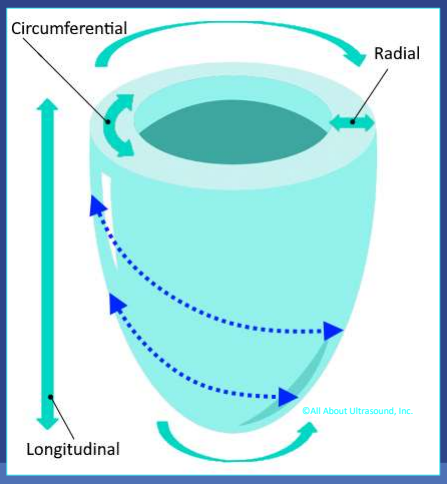

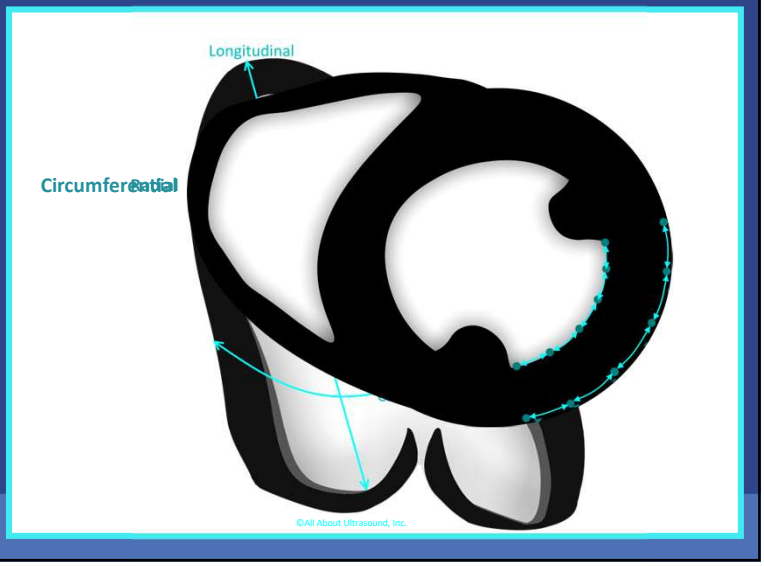

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Strain Fundamentals

Rotation occurs around the long axis of the LV

- Basal rotation in a clockwise direction (negative value)
- Apical rotation in an anticlockwise direction (positive value), when viewed from the apex during systole
- From rotation values, twist and torsion are calculated

A Unifying Framework for Understanding Heart Failure? Response to "Left Ventricular Torsion by Two-Dimensional Speckle Tracking Echocardiography in Patients With Diastolic Dysfunction and Normal Ejection Fraction" by Park SJ et al.; Borg, Alexander N. et al. Journal of the American Society of Echocardiography, Volume 22, Issue 3, 318 - 320

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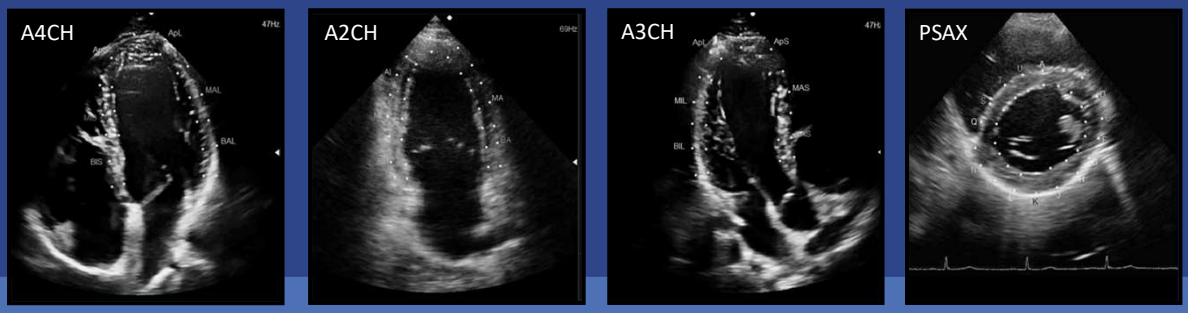
Strain Fundamentals

Imaging parameters of quality LV Strain imaging

- NO or little heart rate variability from view to view
- NO changes in image depth from view to view
- No axis deviation/foreshortening
- Good ECG waveform (Tall R waves)
- Frame Rate of 40-90Hz



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Strain Fundamentals

Additional parameters & analysis:

- Left Ventricular Ejection Fraction (LVEF), Left Ventricular Volume, and Cardiac Output
- Displacement: distance that a certain feature, such as a speckle, has moved between two consecutive frames (cm)
- Myocardial Velocity: reflects displacement per unit of time, or how fast the location of a feature changes (cm/s)
- Cardiac Strain: describes myocardial deformation, or the fractional change in length of a myocardial segment (%). Algorithms exist to calculate cardiac strain in the ventricles and atria (LV, RV, LA, or RA)
- Strain Rate: is the rate of change in strain and is expressed as 1/sec or sec-1

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Strain Fundamentals

Strain

$$\text{Strain} = \frac{L_I - L_0}{L_0} \times 100$$

L_I = Length at given point in time
L_0 = Baseline length

(Lagrangian)

Difference between Strain Rate and Strain

Strain Rate

$$\text{Strain Rate} = \frac{d\varepsilon}{dt}$$

ε = strain (deformation, in %)
t = time (in seconds)

derivative of strain with respect to time

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Strain Fundamentals

Global Longitudinal Strain Values

- **Normal: -17% or more negative**
- **Borderline: -15% to -17%**
- **Abnormal: -15% or more positive**

Varies by vendor but in general (-)17%

Table 5 Effect of vendor age and gender on GLS

Vendor	Age group (y) 0–19	20–29	30–39	40–49	50–59	≥60	P
V1							
Overall	−22.1 ± 2.4	−21.2 ± 1.9	−21.1 ± 2.1	−21.4 ± 2.0	−21.0 ± 2.2	−20.3 ± 1.9	.0218
Male	−21.7 ± 3.1	−20.9 ± 1.9	−20.6 ± 1.9	−20.9 ± 1.8	−21.0 ± 1.9	−19.7 ± 1.4	.1982
Female	−22.4 ± 1.6	−22.3 ± 1.6	−22.8 ± 1.8	−22.6 ± 2.1	−23.3 ± 1.9	−20.9 ± 2.1	.0348
P (male vs female)	.4292	.0316	<.0001	.0178	.0029	.1381	
V2							
Overall	−19.9 ± 2.5	−19.0 ± 2.1	−19.5 ± 2.2	−18.2 ± 2.5	−17.6 ± 2.5	−16.7 ± 2.1	<.0001
Male	−19.4 ± 2.7	−18.8 ± 2.0	−19.1 ± 2.3	−17.9 ± 2.8	−16.9 ± 2.3	−15.8 ± 1.4	.0019
Female	−20.5 ± 2.2	−20.6 ± 2.3	−20.2 ± 2.0	−19.3 ± 0.9	−20.4 ± 1.5	−17.3 ± 2.3	.0002
P (male vs female)	.1349	.0248	.1083	.4316	.0294	.0928	
V3							
Overall	−21.4 ± 1.7	−20.2 ± 2.1	−20.4 ± 2.3	−19.4 ± 2.2	−18.5 ± 2.6	−17.8 ± 2.8	<.0001
Male	−21.6 ± 2.0	−20.2 ± 2.0	−20.4 ± 2.2	−19.8 ± 2.3	−18.7 ± 2.6	−16.3 ± 3.1	<.0001
Female	−21.2 ± 1.5	−20.2 ± 2.4	−20.4 ± 2.8	−18.7 ± 1.8	−18.3 ± 2.8	−18.6 ± 2.3	.0141
P (male vs female)	.6076	.9787	.9201	.1415	.7374	.0668	

V1, Vivid 7 or Vivid E9 (GE Healthcare); *V2*, iE33 (Philips Medical Systems); *V3*, Artida or Aplio (Toshiba Medical Systems).

Head-to-Head Comparison of Global Longitudinal Strain Measurements among Nine Different Vendors
Farsalinos, Konstantinos E. et al.
Journal of the American Society of Echocardiography, Volume 28, Issue 10, 1171 - 1181.e2

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Strain Mechanics

- Cardiac Function
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  - Speckle Tracking
  - Types of Strain
- Clinical Impact of Strain
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- Strain outside of the LV

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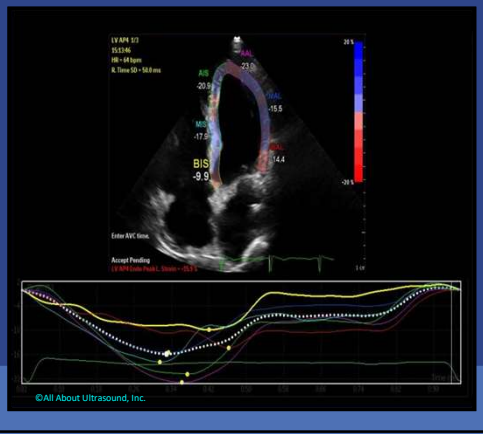
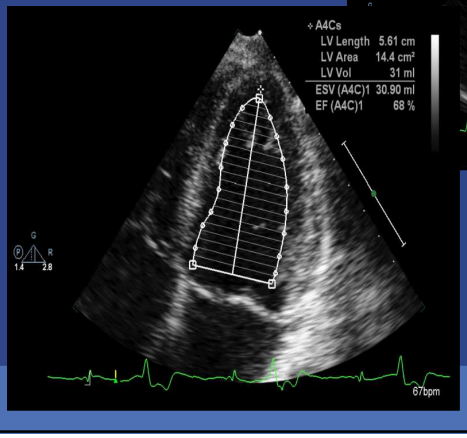
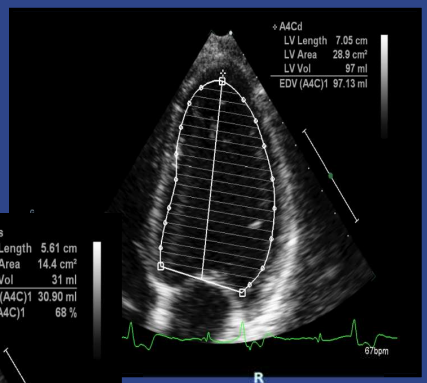
Clinical Impact of Strain

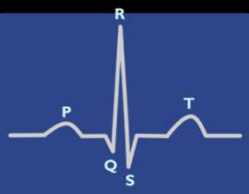
Why Strain?

- **Ejection fraction limitations**
- **Subclinical myocardial dysfunction**
- **Less load dependent**









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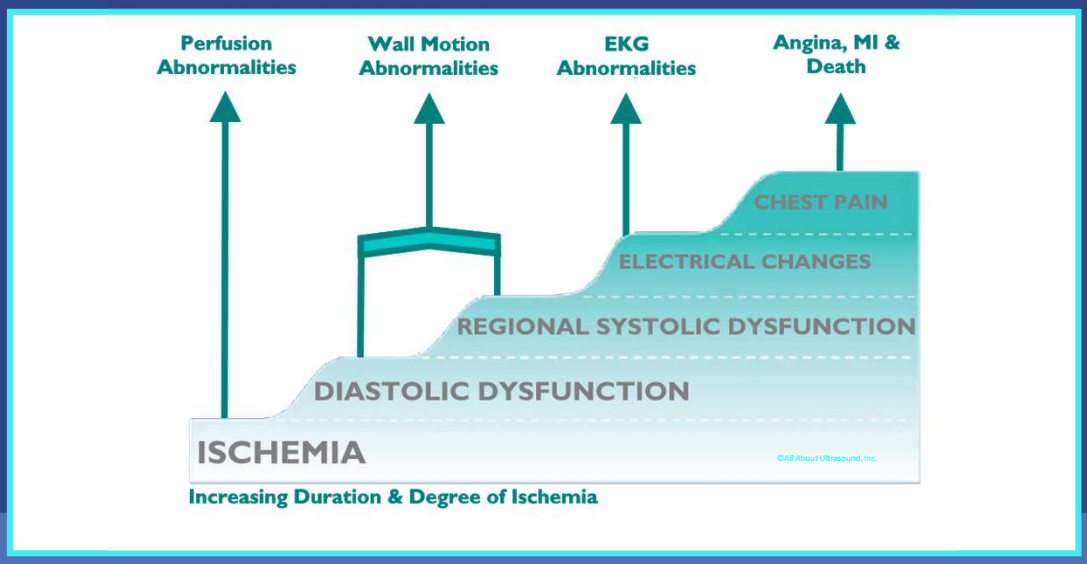
Ischemia Cascade



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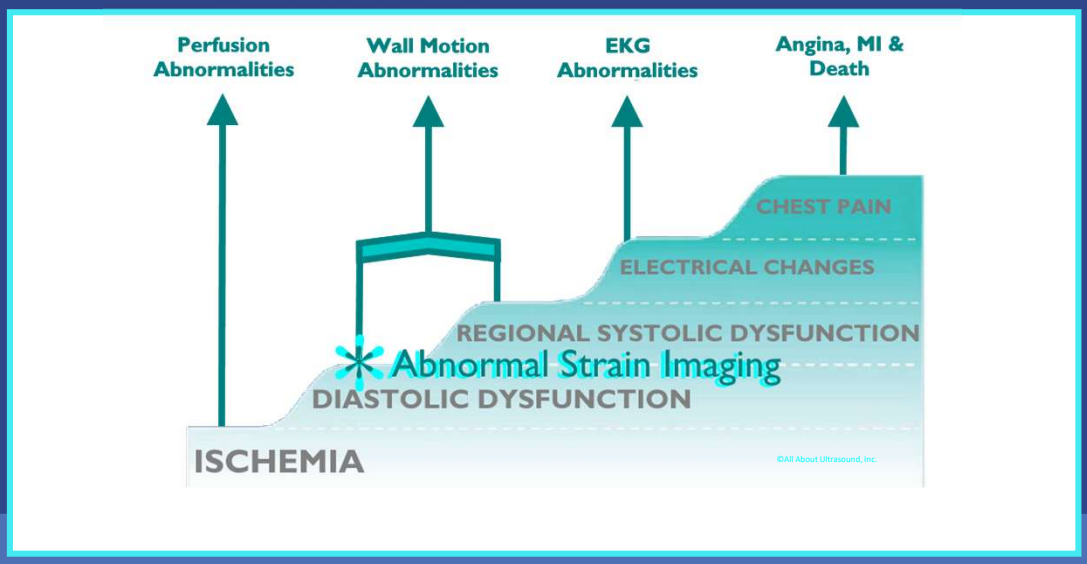
Ischemia Cascade



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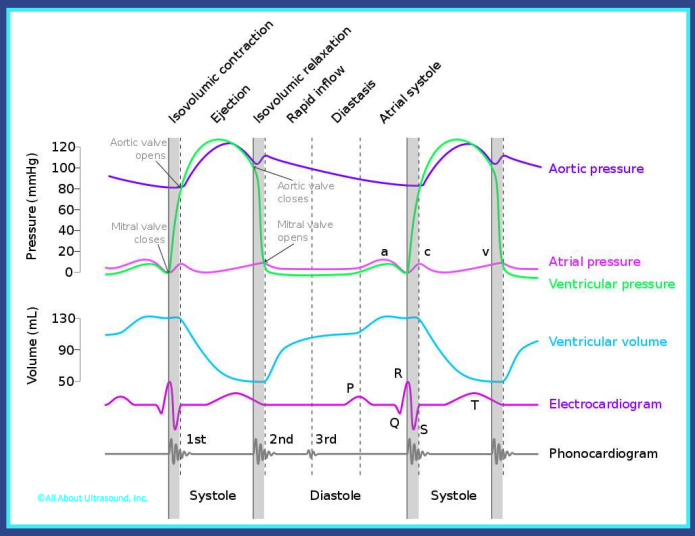
Clinical Impact of Strain

Strain Deformation Imaging

- Ischemia Detection: Delayed peak strain beyond aortic valve closure suggests post-systolic shortening—a sign of regional ischemia.
- Dyssynchrony Assessment: In a healthy ventricle, all segmental strain curves reach peak just before aortic valve closure; in dyssynchrony, peaks scatter across systole.
- Diastolic Function: Strain recovery slopes during early filling can mirror diastolic relaxation seen on the Wiggers diagram volume curve



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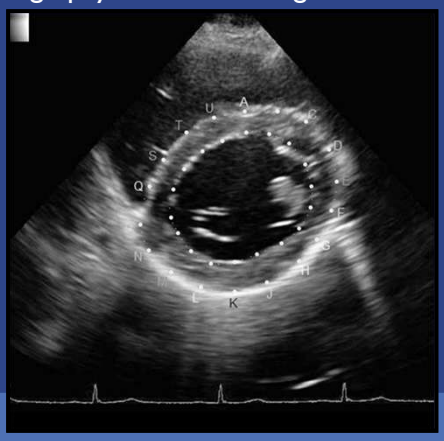
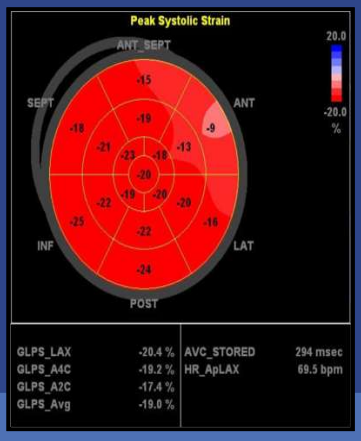
Clinical Impact of Strain

Strain Deformation Imaging

- In cardiac imaging, strain is primarily evaluated in relation to the deformation and stiffness of the myocardial fibers
- Helpful in echocardiography for determining the stiffness of the ventricular walls and function





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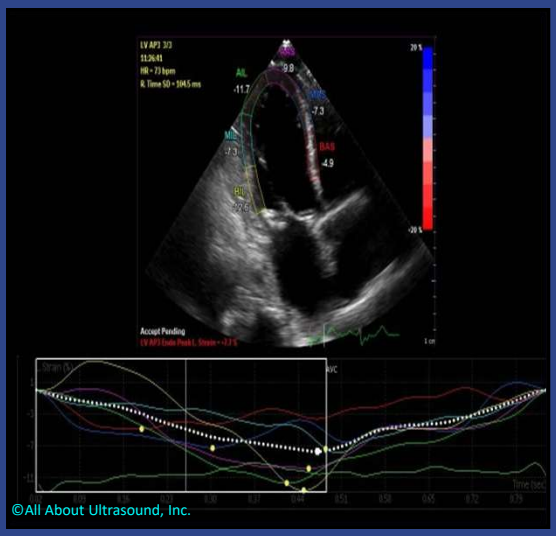
Clinical Impact of Strain

- LV global longitudinal diastolic strain measurements during the isovolumic relaxation period and during early diastole.
- The timing of peak untwisting rate can be of value in diagnosing patients with diastolic dysfunction and normal LV volumes and EF.



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Clinical Impact of Strain

Cardio-Oncology & Cardiotoxicity Diagnosis via Strain

- Changes in strain precede declines in left ventricular ejection fraction
- 10-15% early reduction in strain, the most useful parameter for prediction of cardiotoxicity.
- A relative decline in global longitudinal strain >15% is defined as indicative of subclinical left ventricular dysfunction and should prompt cardiology consultation

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Strain Mechanics

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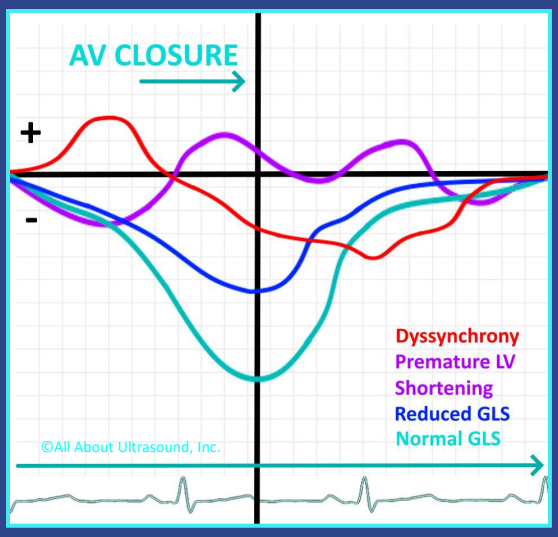
Strain Analysis

Standard **longitudinal strain curve** plots:

- **X-axis:** Time (one full cardiac cycle from end-diastole to the next end-diastole)
- **Y-axis:** Strain percentage (% change in length)
- **Zero line:** Represents baseline length at end-diastole.



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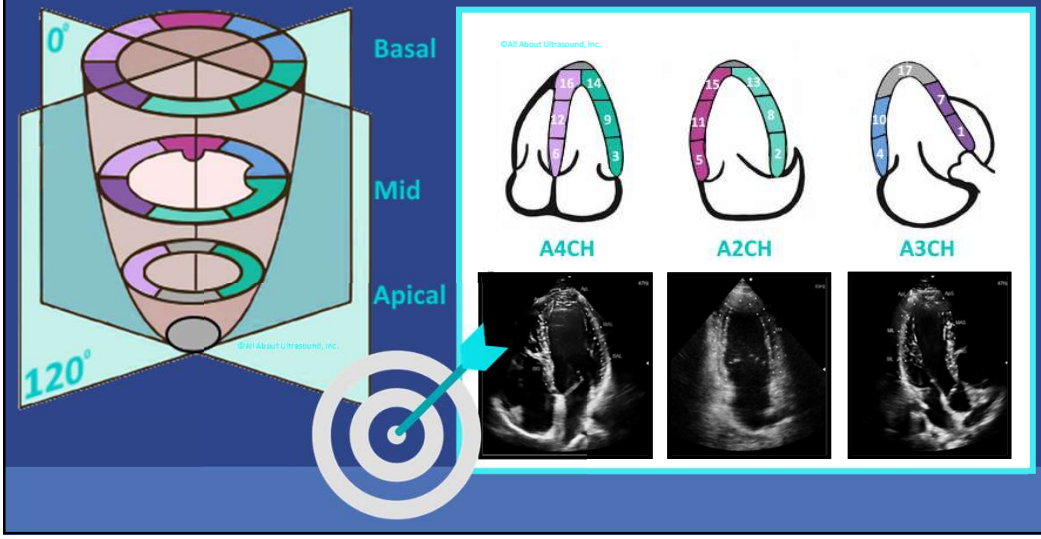
Strain Analysis

Bull's Eye View

The bull's-eye view is a comprehensive visualization of the entire LV based on A4C, A2C and A3C views.



1. Basal Anteroseptal
2. Basal Anterior
3. Basal Anterolateral
4. Basal Inferolateral
5. Basal Inferior
6. Basal Inferoseptal
7. Mid Anteroseptal
8. Mid Anterior
9. Mid Anterolateral
10. Mid Inferolateral
11. Mid Inferior
12. Mid Inferoseptal
13. Apical Anterior
14. Apical Lateral
15. Apical Inferior
16. Apical Septal
17. Apical Cap

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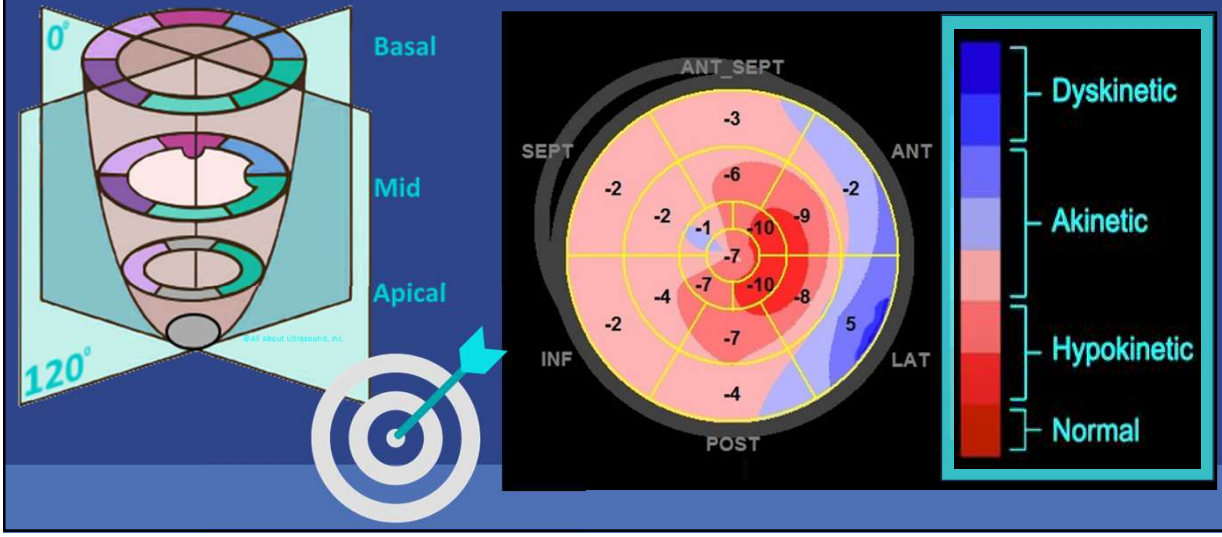
Strain Analysis

Bull's Eye View

The bull's-eye view is a comprehensive visualization of the entire LV based on A4C, A2C and A3C views.



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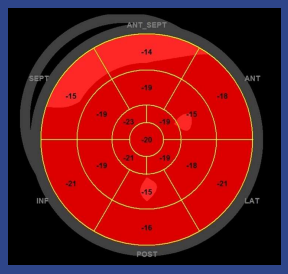
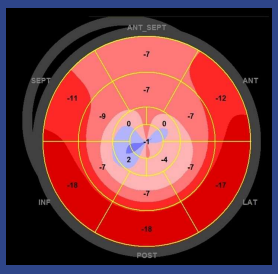
Pathology Diagnosis • Strain Echocardiography

Pathology Diagnosis via Strain

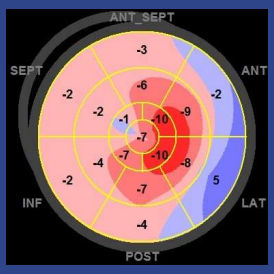
Hypertrophic Cardiomyopathy



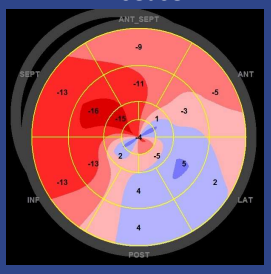
Apical Cardiomyopathy



Amyloidosis



Fabry Disease



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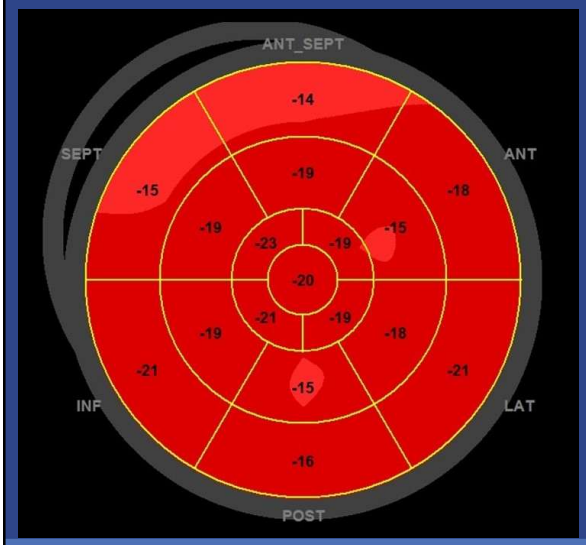
Pathology Diagnosis • Strain Echocardiography

Hypertrophic Cardiomyopathy



Strain Findings in Hypertrophic Cardiomyopathy	
Septal Strain	Markedly Reduced
Apical Strain	Relatively Preserved
GLS Value	Mildly Reduced (-14 to – 17%)
Visual BE Pattern	Basal septal hypokinesis on polar map
Prognostic Use	Reflects fibrosis (may predict arrhythmias)

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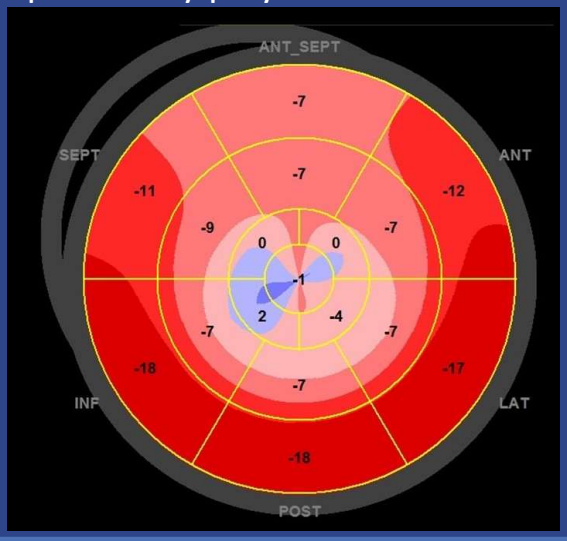
Pathology Diagnosis • Strain Echocardiography

Apical Cardiomyopathy



Strain Findings in Hypertrophic Cardiomyopathy	
Septal Strain	Markedly Reduced
Apical Strain	Relatively Preserved
GLS Value	Mildly Reduced (-14 to – 16%)
Visual BE Pattern	Light colored apex, darker base
Prognostic Use	Fibrosis correlation and functional mapping

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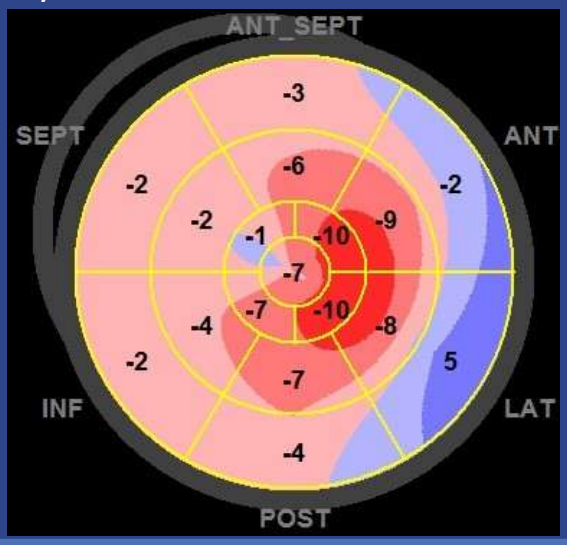
Pathology Diagnosis • Strain Echocardiography

Amyloidosis



Strain Findings in Hypertrophic Cardiomyopathy	
Septal Strain	Severely Reduced
Apical Strain	Relatively Preserved
GLS Value	Significantly Reduced (< -14 %)
Visual BE Pattern	Cherry on top pattern due to apical sparing
Prognostic Use	Distinguish from other LVH etiologies

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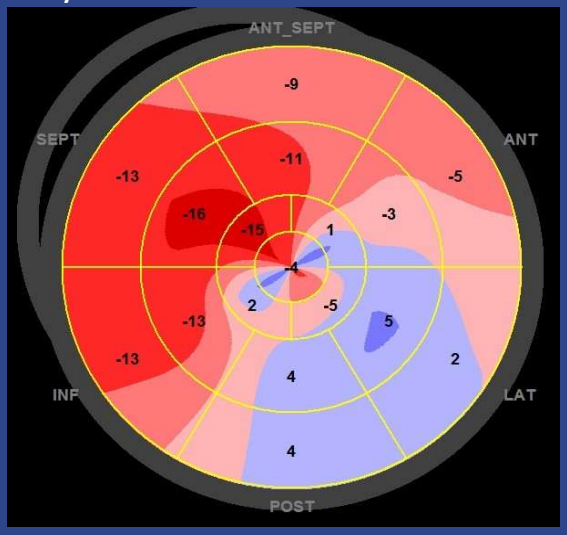
Pathology Diagnosis • Strain Echocardiography

Fabry Disease



Strain Findings in Hypertrophic Cardiomyopathy	
Septal Strain	Focally Reduced
Apical Strain	Relatively Preserved
GLS Value	May be normal or mildly reduced (-16 to – 19%)
Visual BE Pattern	Asymmetric, localized strain defects
Prognostic Use	Early sign of cardiac involvement

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Strain Mechanics

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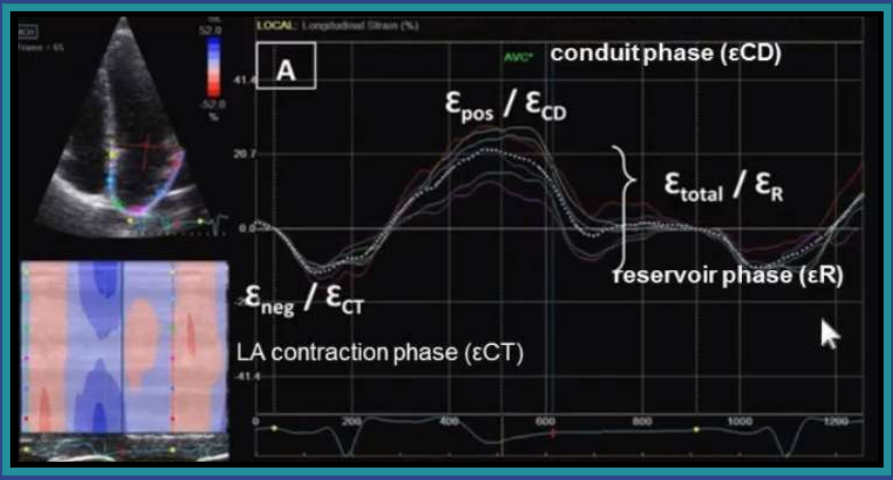
Strain Echocardiography • LA Strain



Vieira MJ, Teixeira R, Gonçalves L, Gersh BJ. Left atrial mechanics: echocardiographic assessment and clinical implications. J Am Soc Echocardiogr. 2014 May;27(5):463-78. doi: 10.1016/j.echo.2014.01.021. Epub 2014 Mar 20. PMID: 24656882

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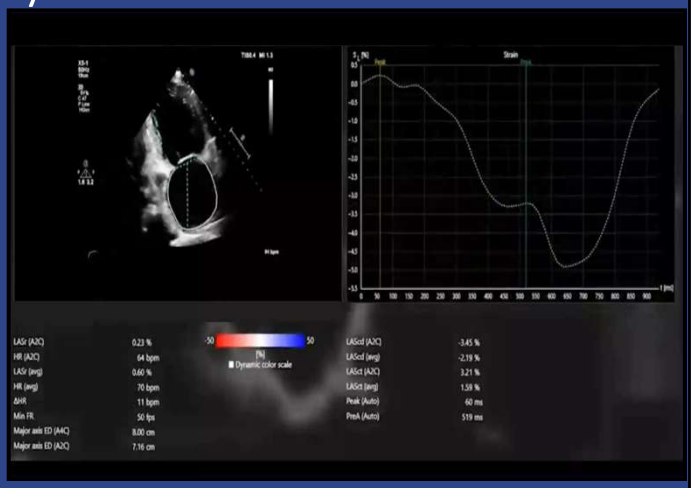
Strain Echocardiography • LA Strain

- LA reservoir strain(LARS) is utilized as an advanced diastolic function assessment parameter
- Normal values are typically >35% (vendor dependent)
- An inverse correlation is present between LARS and mean wedge pressure.



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Strain Echocardiography • RV Strain

- RV GLS is calculated by the average of the 3 segments of the RV free wall.
- RV GLS has prognostic value in conditions like pulmonary embolism and heart failure with preserved ejection fraction (HFpEF).

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Thank you!