

## Vevsdoppler og speckle tracking i praktisk bruk

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NTNU

<http://folk.ntnu.no/stoylen/lectures/#student>  
<http://folk.ntnu.no/stoylen/strainrate>  
<http://folk.ntnu.no/stoylen/strainrate/Ultrasound>  
<http://folk.ntnu.no/stoylen/strainrate/Howto/Pitfalls.html>

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## What's "in" in echo research?

- 1960s: M-mode 1-dimensional:
  - Valvular motion, wall motion (Function)
- 1970s:
  - 2D: Morphology, regional function (qualitative), Volumes, EF
  - Doppler: Cardiac output, valvular function, diastolic function (filling)
- 1980s: Colour Doppler:
  - Valvular insufficiencies (Semi quantitative) LV filling
- 1990s: Tissue Doppler
  - Systolic funktion: AV-plane motion and velocity
  - Diastolic funktion: AV-plane velocity
  - Regional funktion: Strain / strain rate
- 2000: Speckle tracking
  - Regional funktion: Strain / strain rate
- Now: 3D ekkokardiografi:
  - Volumes, EF

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## Vevsdoppler og speckle tracking

- Analyseverktøy
- Hva kan det brukes til?
- Hvordan skal det brukes?
- Feilkilder

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## Vevsdoppler:



- Global funksjon
  - Systolisk
  - Diastolisk
- Regional funksjon = deformasjonsavbildning
  - Systolisk
- Deformasjonsavbildning også speckle tracking
  - Samme prinsipp




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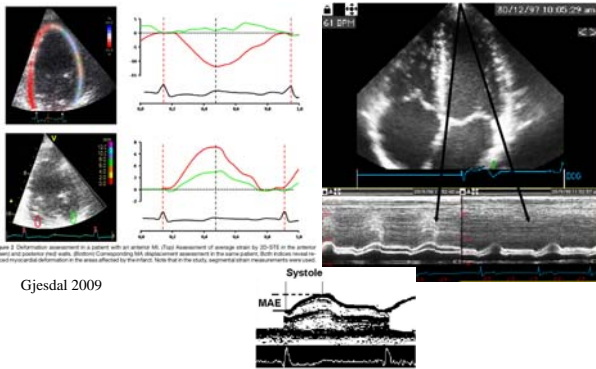
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## Annulus displacement / global strain:



Gjesdal 2009

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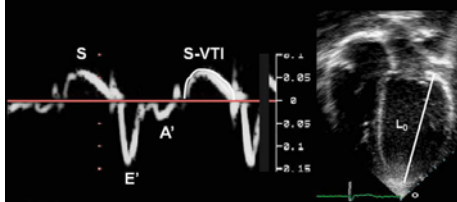
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## Global strain

$D_x = \text{longitudinal displacement index} = D / L_0$

$D = \text{displacement} = \text{S wave VTI}$

$L_0 = \text{distance from annulus to apex at end diastole}$



Roberson 2009

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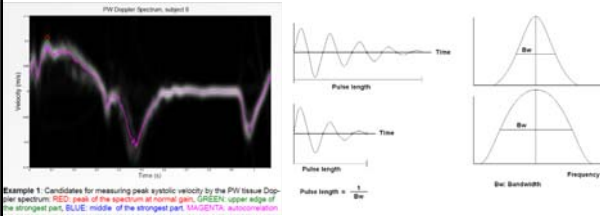
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## Bredden på spekteret:




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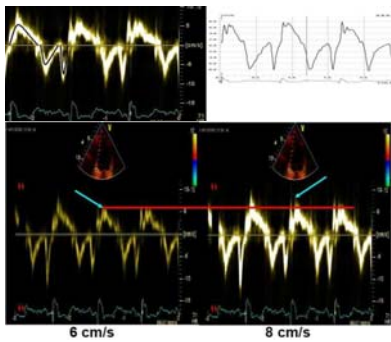
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## Pitfalls:




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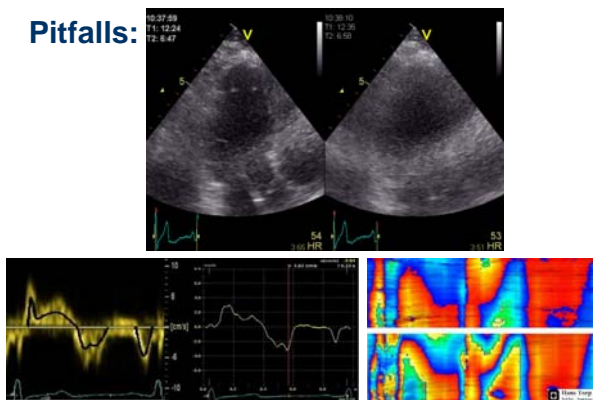
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## Pitfalls:




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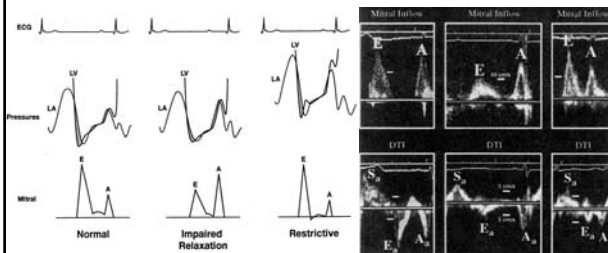
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## Normalverdier fra HUNT3

	Left ventricle (mean of 4 walls)				Right ventricle (free wall)		
	S' (pwTDI)	S' (cTDI)	e' (pwTDI)	a' (pwTDI)	S' (pwTDI)	e' (pwTDI)	a' (pwTDI)
<i>females</i>							
Feasibility N (%)	652 (98%)	657 (99%)	652 (98%)	652 (98%)	648 (98%)	648 (98%)	648 (98%)
<40 years, mean (SD), cm/s	8.9 (1.1)	7.2 (1.0)	14.6 (2.3)	8.8 (1.9)	13.0 (1.8)	14.7 (2.9)	12.4 (3.5)
40-60 years, mean (SD), cm/s	8.1 (1.2)	6.5 (1.0)	11.8 (2.4)	10.0 (1.8)	12.4 (1.9)	13.1 (2.9)	15.0 (3.5)
>60 years, mean (SD), cm/s	7.2 (1.2)	5.7 (1.1)	8.2 (2.0)	10.6 (1.9)	11.8 (2.0)	11.0 (2.3)	16.1 (3.1)
All, mean (SD), cm/s	8.2 (1.3)	6.6 (1.1)	11.8 (3.2)	9.7 (2.0)	12.5 (1.9)	13.3 (3.0)	14.4 (3.7)
<i>males</i>							
Feasibility N (%)	590 (98%)	601 (99%)	590 (98%)	590 (98%)	586 (97%)	586 (97%)	586 (97%)
<40 years, mean (SD), cm/s	9.4 (1.4)	7.6 (1.2)	14.1 (2.7)	9.1 (1.7)	13.2 (2.0)	14.5 (2.9)	12.3 (3.5)
40-60 years, mean (SD), cm/s	8.6 (1.3)	6.9 (1.3)	10.7 (2.5)	10.4 (1.6)	12.8 (2.2)	12.5 (3.2)	14.3 (3.7)
>60 years, mean (SD), cm/s	8.0 (1.3)	6.4 (1.2)	8.2 (1.9)	11.1 (1.6)	12.5 (2.3)	11.0 (3.0)	15.8 (4.2)
All, mean (SD), cm/s	8.6 (1.4)	6.9 (1.3)	10.8 (3.0)	10.3 (1.7)	12.8 (2.2)	12.5 (3.3)	14.2 (3.9)

Dalen 2010

## Fylningstrykk og mitralflow



## E/e'

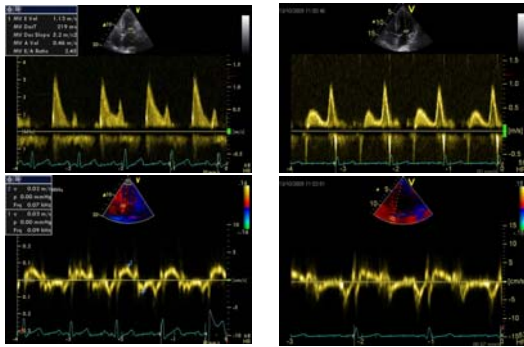
- Normalt fylningstrykk:  $E/e' < 8$
- Forhøyet fylningstrykk:  $E/e' > 15$

Table 5 E/e': Mean (SD) by age, wall and method.

Age	pwTDI			All	pwTDI	cTDI
	<40 years	40-59 years	≥60 years			
N	327	651	263	1241	100	100
Mean	5.6 (1.3)	6.5 (1.7)	8.2 (2.6)	6.6 (2.1)	6.9 (2.3)	9.1 (3.4)

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## Pulset vevsdoppler



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## Regional funksjon – deformasjons-avbildning - strain og strain rate

- Både Speckle tracking og TDI
  - Forskjellig prinsipp
  - Forskjellig akvisisjon
  - Forskjellig prosessering
  - Forskjellige fordeler og ulemper

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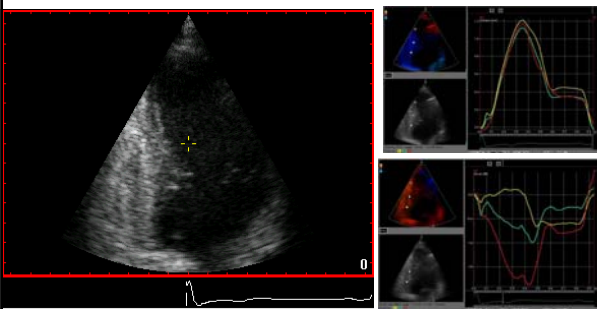
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## Motion vs. deformation:



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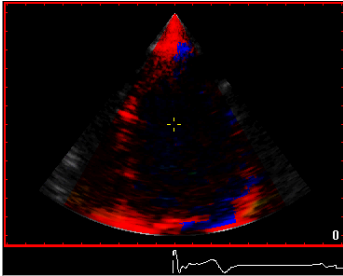
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## Vevsdoppler



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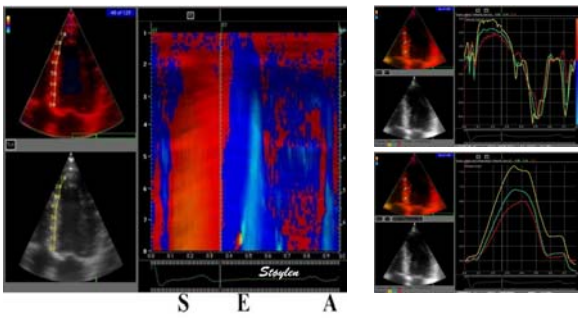
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## Normal, kurvet M-mode



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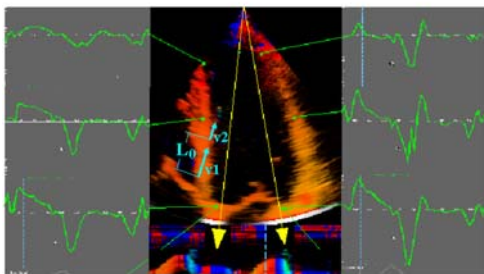
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## Strain rate:



$$SR = v_1 - v_2 / L_0$$

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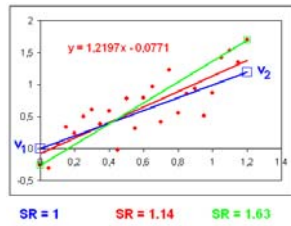
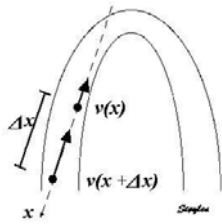
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## Strain rate – velocity gradient:



$$SR = \frac{v(x) - v(x + \Delta x)}{\Delta x}$$

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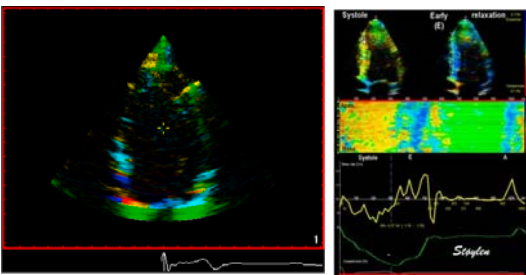
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## Strain rate




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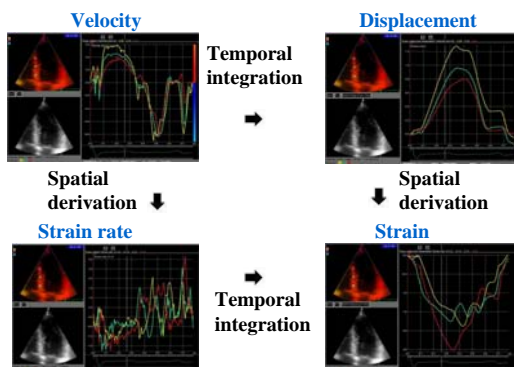
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## One dataset, four modalities:




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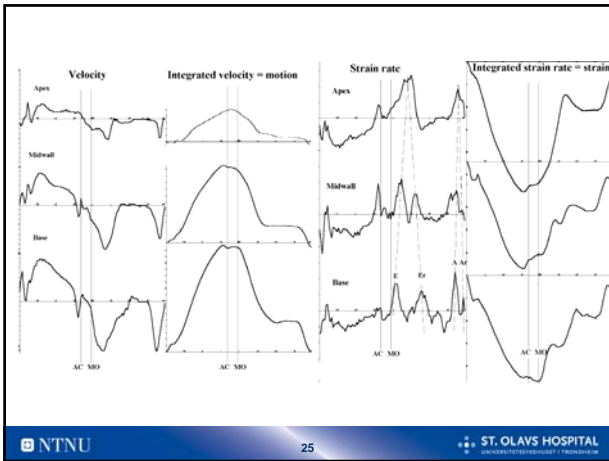
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### Metoder:

- TDI: Kommerielle analysepakker (EchoPAC)
  - Glatting kun lokal
  - Kan varieres
- Speckle tracking: Kommerielle analysepakker (AFI, VVI)
  - Komplekse glattealgoritmer
  - Globale tilpasninger
- GCmat: Kan variere metode. Ikke glatting, men lav tids- og romoppløsning
  - Speckle tracking
  - Komb Speckle tracking / TDI
  - TDI
    - Stasjonær
    - Dynamisk

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### Normalverdier

**Table 2 Segmental longitudinal systolic strain (S<sub>lv</sub>) and strain rate (SR<sub>lv</sub>)**

	Inferoseptum	Anterolateral	Inferior	Anterior	Inferolateral	Anteroseptum	Mean
<b>Apical</b>							
S <sub>lv</sub> (%), mean (SD)	-17.8 (3.9)	-14.6 (4.0)	-17.6 (4.3)	-14.3 (4.7)	-15.5 (4.3)	-16.1 (3.9)	-16.4 (4.3) <sup>1,2</sup>
SR <sub>lv</sub> (s <sup>-1</sup> ), mean (SD)	-1.08 (0.24)	-1.03 (0.29)	-1.08 (0.23)	-0.98 (0.30)	-1.06 (0.28)	-0.95 (0.26)	-1.04 (0.26) <sup>3</sup>
<b>Mid-ventricular</b>							
S <sub>lv</sub> (%), mean (SD)	-17.9 (3.5)	-16.4 (3.5)	-17.3 (3.7)	-17.4 (3.6)	-17.0 (3.8)	-17.1 (3.5)	-17.3 (3.6) <sup>1,3</sup>
SR <sub>lv</sub> (s <sup>-1</sup> ), mean (SD)	-1.10 (0.20)	-0.94 (0.22)	-1.08 (0.27)	-1.01 (0.31)	-1.05 (0.29)	-1.05 (0.28)	-1.05 (0.26) <sup>3</sup>
<b>Basal</b>							
S <sub>lv</sub> (%), mean (SD)	-14.6 (3.9)	-19.2 (3.7)	-15.9 (3.9)	-17.7 (4.1)	-17.0 (4.0)	-13.9 (4.5)	-16.2 (4.3) <sup>1,2</sup>
SR <sub>lv</sub> (s <sup>-1</sup> ), mean (SD)	-0.85 (0.21)	-1.22 (0.27)	-0.91 (0.24)	-1.07 (0.24)	-1.10 (0.25)	-0.95 (0.23)	-0.99 (0.27) <sup>1,2</sup>
<b>Mean</b>							
S <sub>lv</sub> (%), mean (SD)	-16.8 (4.0) <sup>4,5</sup>	-16.6 (4.1) <sup>4,5</sup>	-17.0 (4.0) <sup>4,5</sup>	-16.8 (4.3) <sup>6</sup>	-16.5 (4.1) <sup>4,5,6</sup>	-16.0 (4.1) <sup>4,8</sup>	-16.7 (4.1)
SR <sub>lv</sub> (s <sup>-1</sup> ), mean (SD)	-1.01 (0.25) <sup>4,5,6</sup>	-1.05 (0.28) <sup>4,5</sup>	-1.03 (0.26) <sup>4,5</sup>	-1.02 (0.28) <sup>4,5</sup>	-1.07 (0.27) <sup>4,5,6</sup>	-0.99 (0.27) <sup>4,8</sup>	-1.03 (0.27)

Footnotes refer to significant difference between the respective level/wall of the left ventricle (LV) and <sup>1</sup>apical, <sup>2</sup>mid-ventricular, and <sup>3</sup>basal level of LV and <sup>4</sup>inferoseptum, <sup>5</sup>anterolateral, <sup>6</sup>anterior, <sup>7</sup>inferolateral, and <sup>8</sup>anteroseptal myocardial wall. Level of significance P < 0.05 [one-way ANOVA (post hoc Bonferroni)].

Dalen 2010

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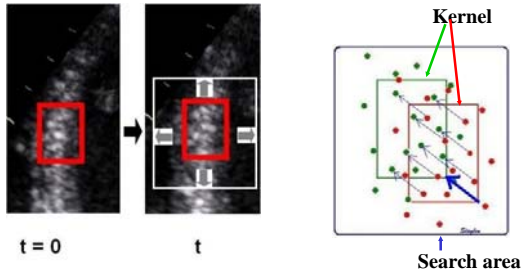
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Thus the kernel can be tracked from one frame to the next:



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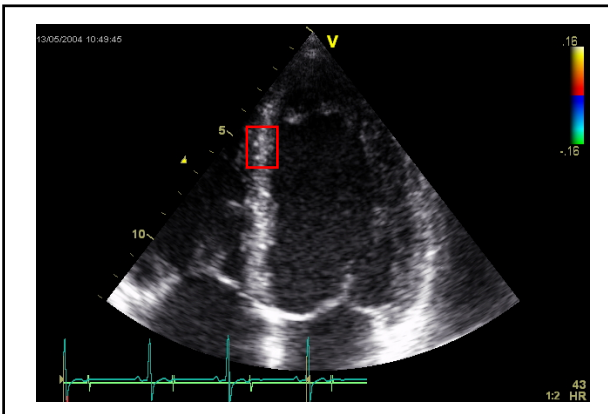
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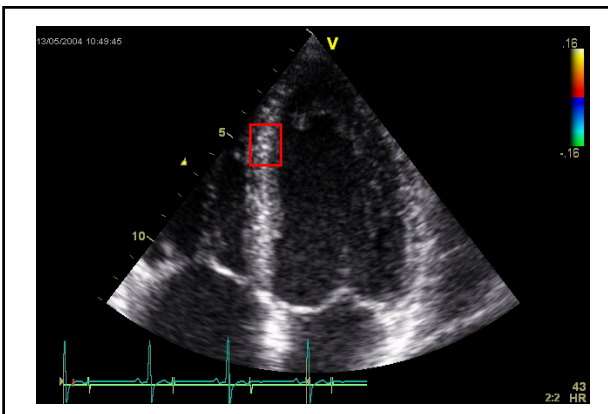
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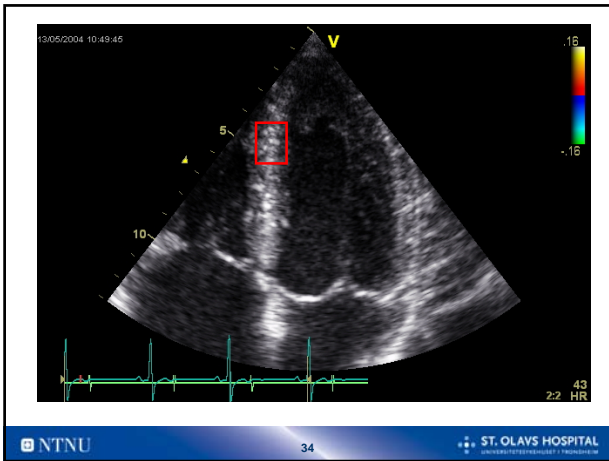
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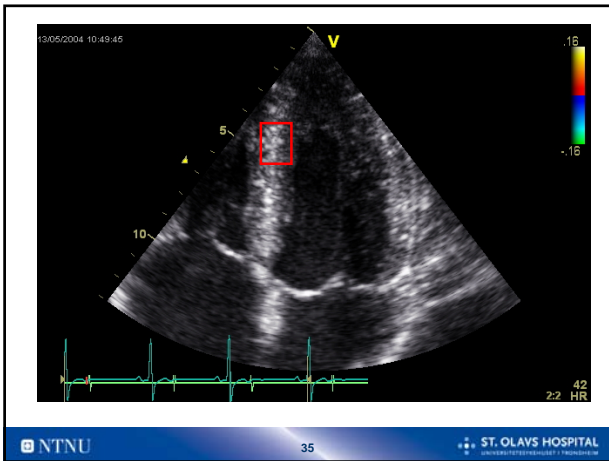
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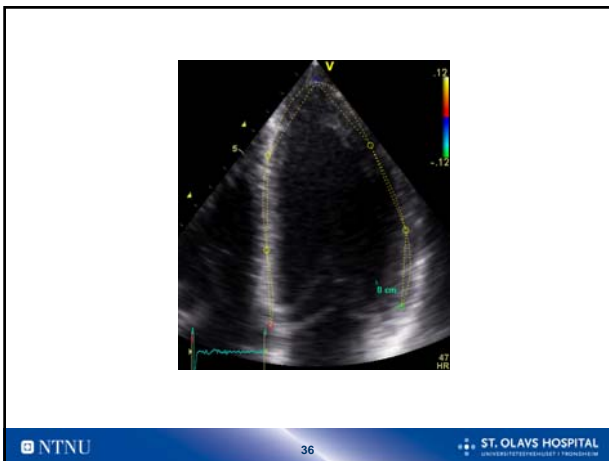
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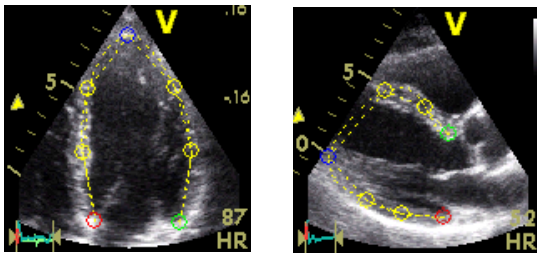
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### Resulting in:



Angle independent tracking

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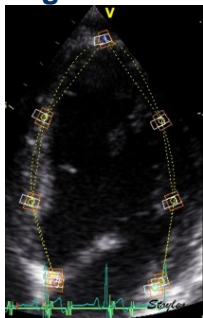
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### Integrated analysis:



- Longitudinal: Tissue Doppler
- Transverse: Speckle tracking
- Allows for faster tracking
- Longitudinal data with high frame rate
- Angle independent even with tissue Doppler (segment length)
- Can be applied without tissue Doppler
- Can use segment tracking as base for longitudinal velocity gradient (mid segment ROI)

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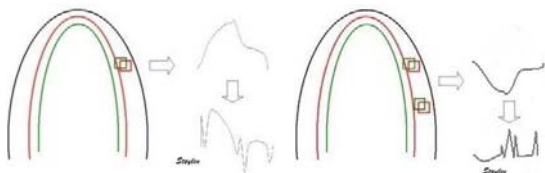
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### Tracking:

- Motion:
  - Displacement
  - Velocity

- Deformation:
  - Strain
  - Strain rate



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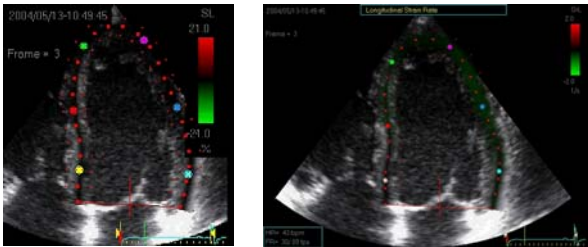
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## 2D strain



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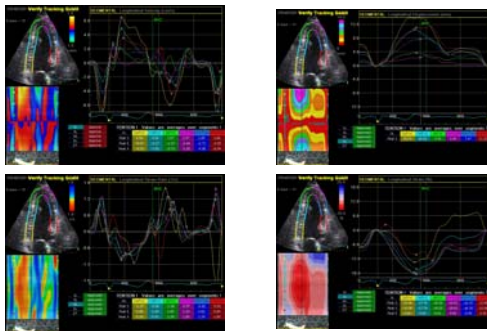
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## One dataset, four modalities:



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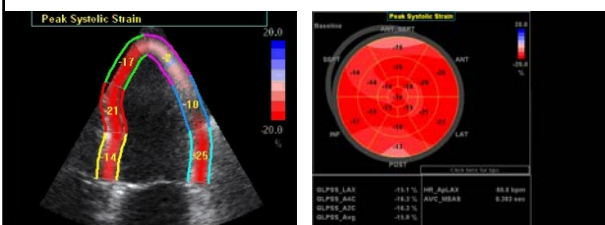
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## Peak strain, automatically detected



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Frame rate is inversely related to line density (number of lines).

- Frame rate
  - Ca 150
  - Ca 105
  - Ca 90
- Number of lines in sector
  - 16
  - 32
  - 64



E. Sagberg  
2006

NTNU

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ST. OLAVS HOSPITAL

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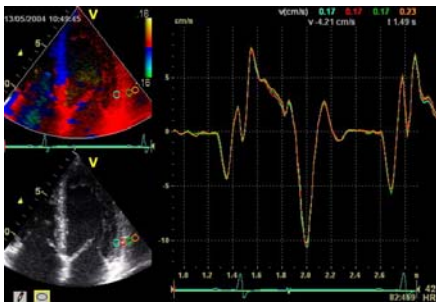
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Lateral resolution:



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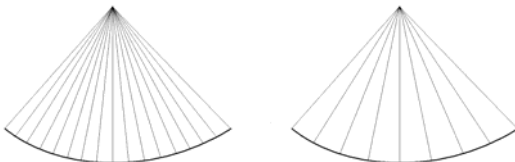
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Increase frame rate: reduces line density



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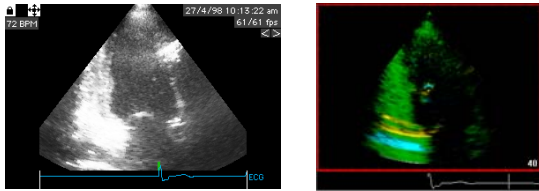
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## Nedreveggsinfarkt



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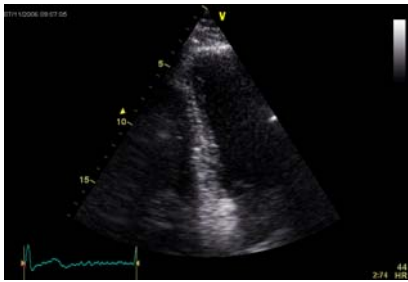
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## Example: inferior infarct:



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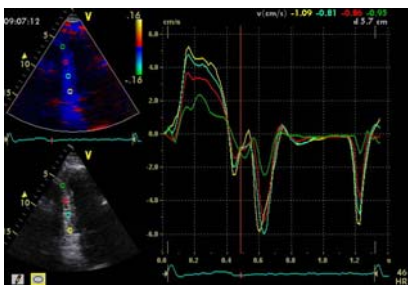
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## 1: Assess velocity curves



Normal distribution?

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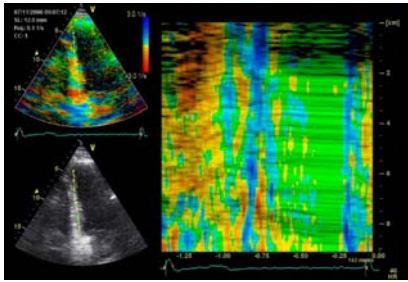
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## 2: Assess Curved M-mode



Extent of pathology

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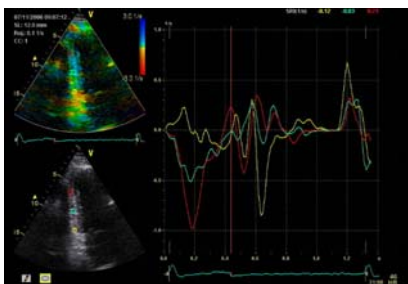
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## 3: Assess both strain rate



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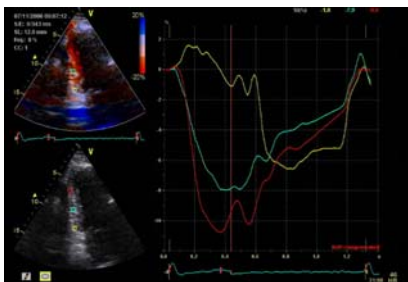
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## 3: And strain



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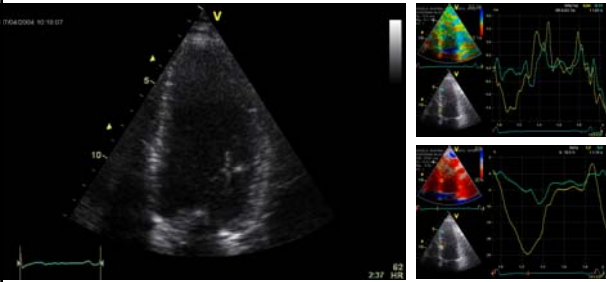
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### Initial echo



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### Coronary angiography:



Before After  
PCI with stent delivery

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### Echocardiography after one week:



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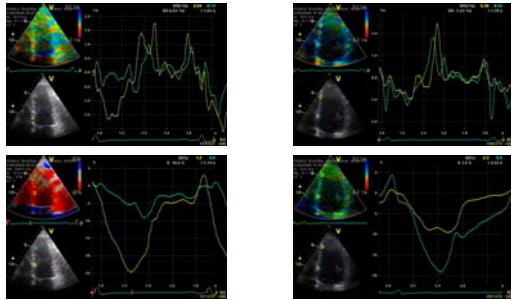
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## Tissue Doppler:



NTNU Day 1

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Day 7 ST. OLAVS HOSPITAL

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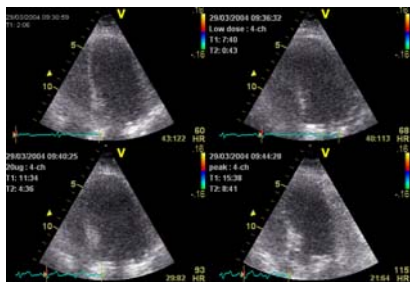
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## Stress echo



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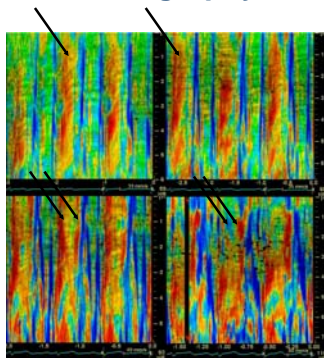
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## Stress echocardiography

Baseline  
HR 60

20  $\mu$ g  
HR 93



10  $\mu$ g  
HR 68

Peak dose  
HR 115

NTNU

60

ST. OLAVS HOSPITAL

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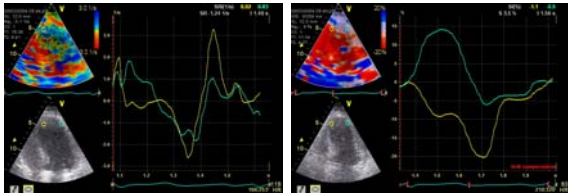
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### Peak stress:



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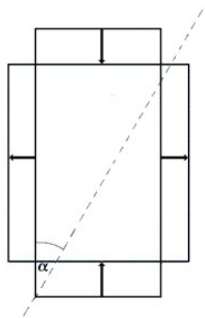
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### The angle problem:



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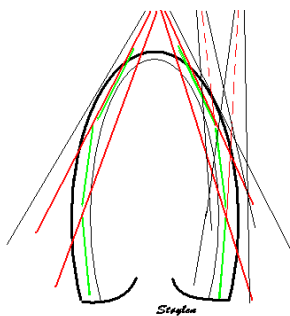
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### Alignment with the wall:



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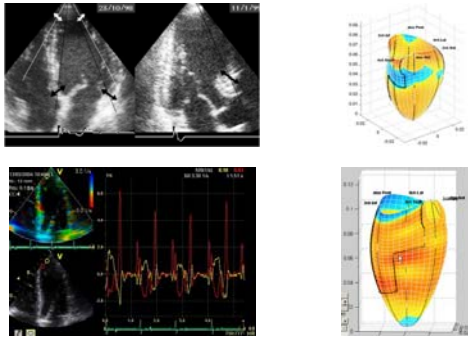
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### The angle problem:



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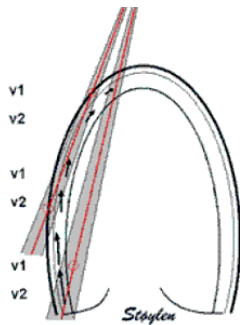
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### Lateral resolution:



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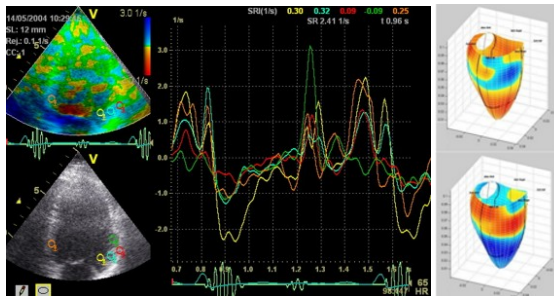
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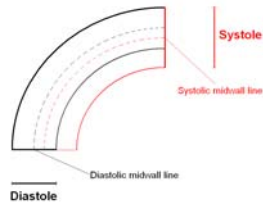
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## Strain is curvature dependent

- Longitudinal shortening is curvature dependent
- Part of midwall shortening is due to wall thickening if wall is curved
  - Depends on wall thickness
  - Wall thickening
  - Wall curvature




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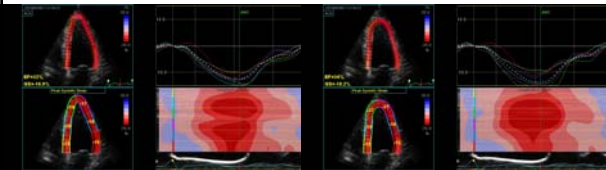
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## Strain is curvature dependent




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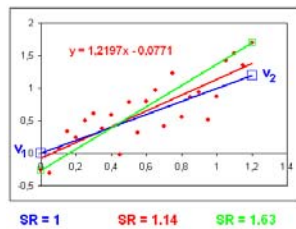
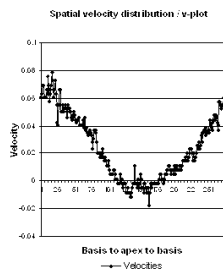
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## Random noise:




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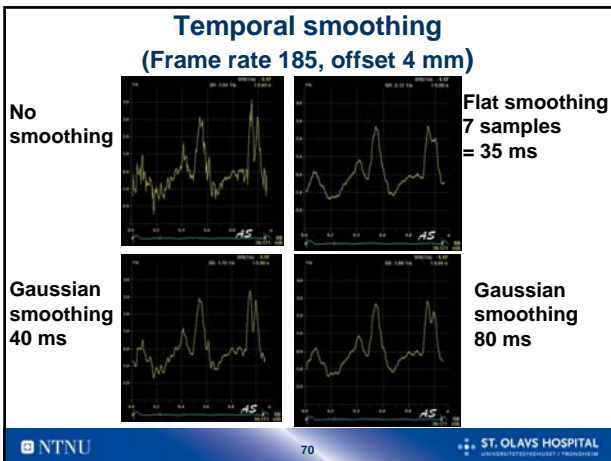
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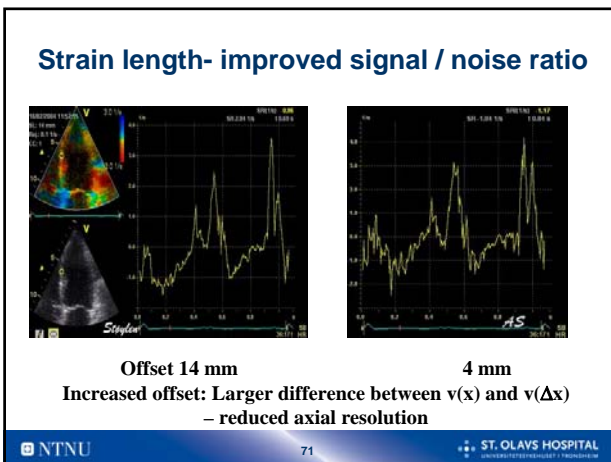
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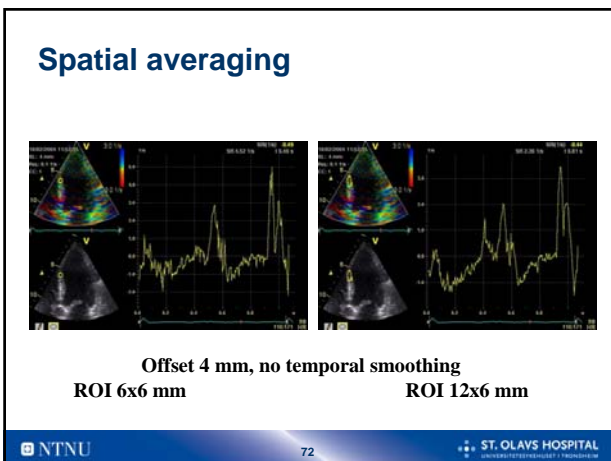
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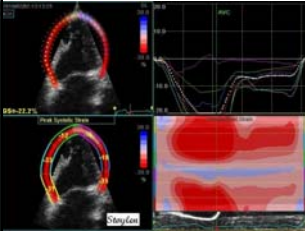
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## Smoothing



- Much of the information is from AV-plane motion
- Information is global, not regional
- Sensitivity may be an issue

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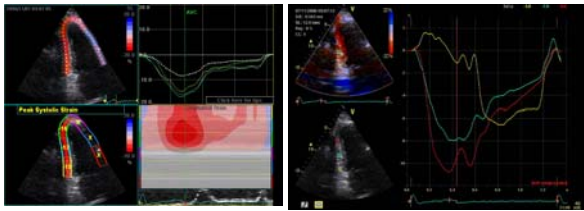
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## Inferior infarct:



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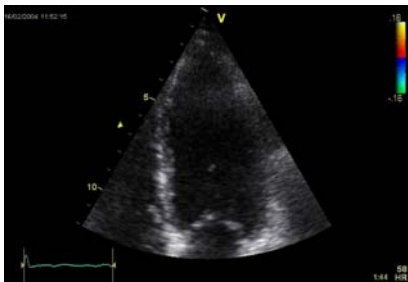
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## Reverberations:



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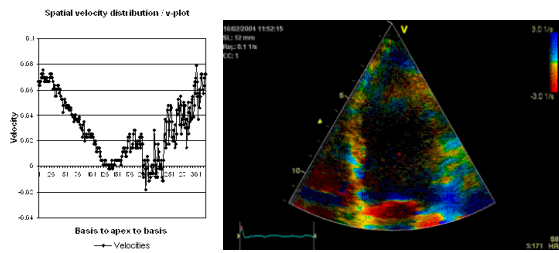
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## Reverberations:




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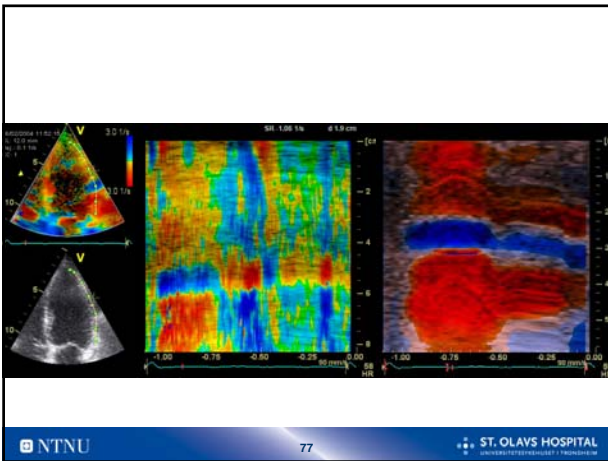
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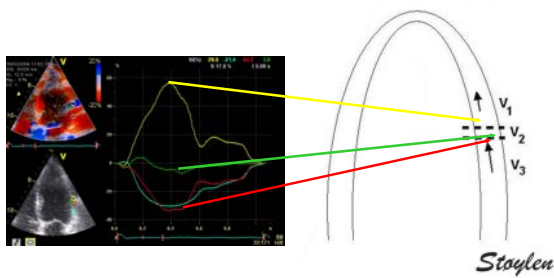
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## Reverberation artefact:




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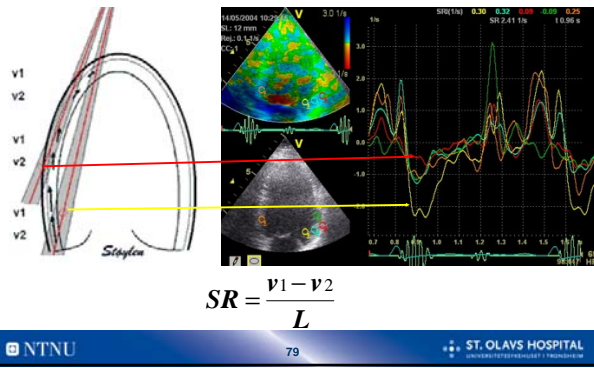
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### Lateral resolution:




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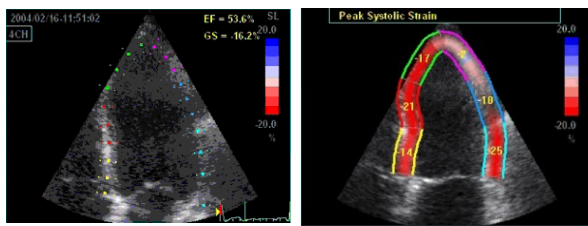
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### Smoothing:



The smoothing gives an interdependence of measurements

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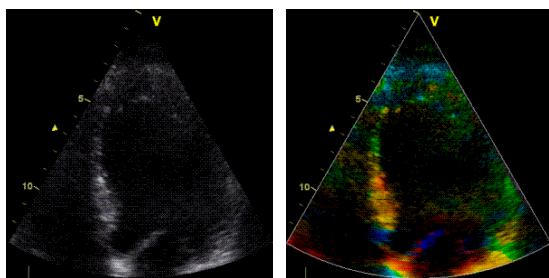
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### Shadowy reverberations




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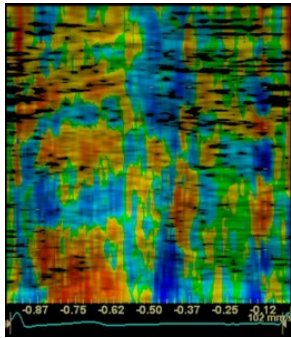
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## Shadowy reverberations



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