Regional LV function. Speckle tracking or TVI

(– or both)?

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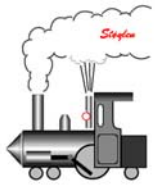
http://folk.ntnu.no/stoylen/lectures
http://folk.ntnu.no/stoylen/strainrate

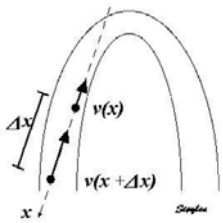
Tissue Doppler:

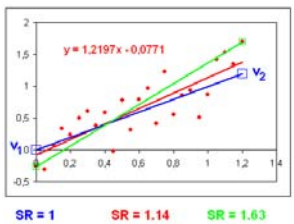


The Doppler effect: $f_D = f_0 \frac{v}{c}$

For reflected ultrasound: $f_D \approx 2f_0 \frac{v}{c}\cos(\alpha)$

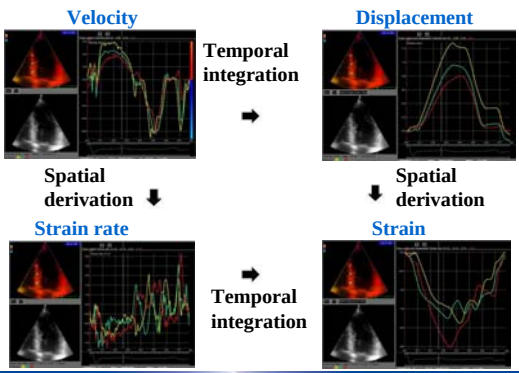
Strain rate – velocity gradient:





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

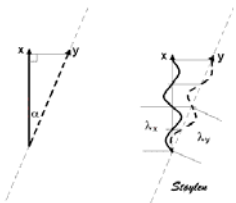
One dataset, four modalities:



Limitations of tissue Doppler

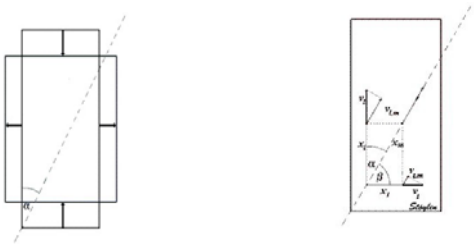
- Angle dependent
  - tracks only in the direction of the ultrasound beam
- Lateral resolution causes distortions
- Noise
- Reverberations and drop outs

Angle dependency:



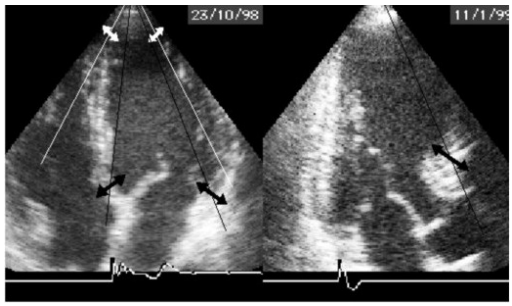
$$f_D = 2 f_0 \frac{v}{c}\cos(\alpha)$$

Angle dependency in deformation:

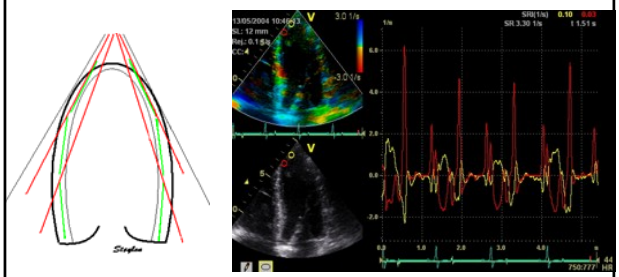


$$SR_m = SR_l \cos^2(\alpha) + SR_t \sin^2(\alpha)$$

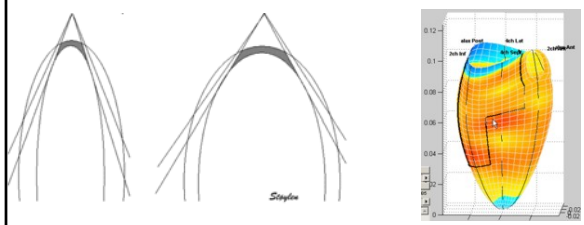
The angle problem:



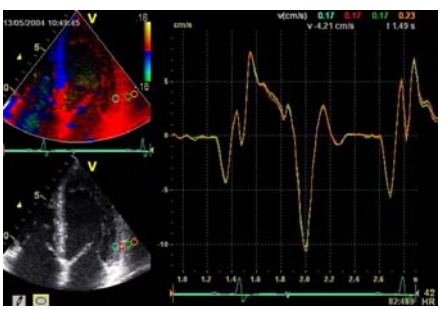
Alignment with the wall:



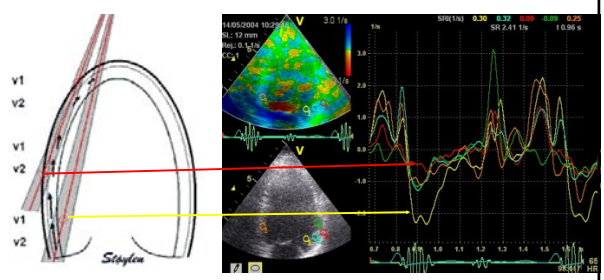
Exclusion in the apex:



Lateral resolution:



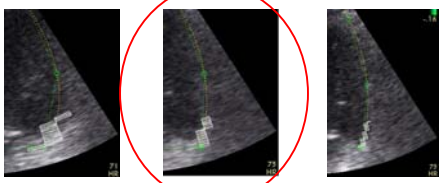
Lateral resolution:



$$SR = \frac{v_1 - v_2}{L}$$

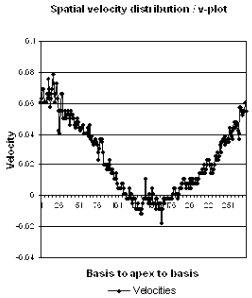
Frame rate is inversely related to line density (number of lines).

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

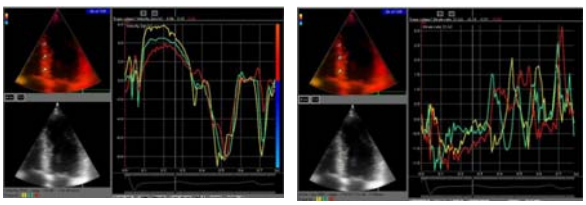


E. Sagberg 2006

Random noise:



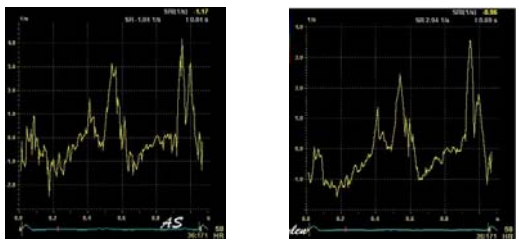
Random noise:



Velocity Strain rate

Noise = the sum of uncertainities of two velocities
Signal = the difference between two velocities
Strain rate has less favorable signal / noise ratio

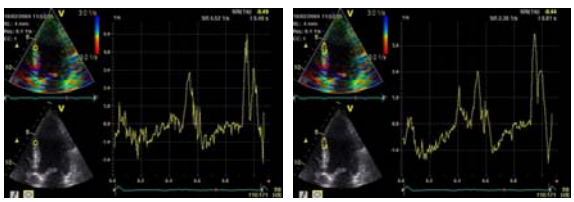
Strain length- improved signal / noise ratio



Offset 4 mm 14 mm

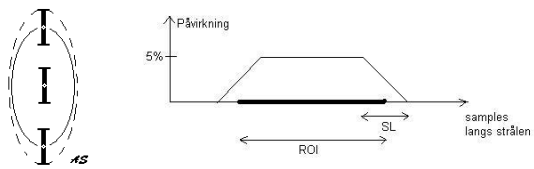
Increased offset: Larger difference between v(x) and v(Δx)
– reduced axial resolution

Spatial averaging



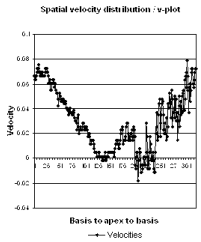
Offset 4 mm, no temporal smoothing
ROI 6x6 mm ROI 12x6 mm

Spatial averaging



Spatial averaging reduces axial and lateral resolution
Axial resolution = Strain length + ROI length

Spatial averaging

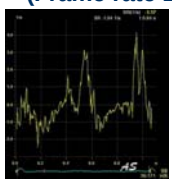


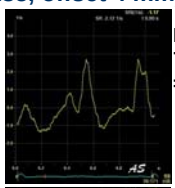
Increases risk of incorporating non-random noise

Temporal smoothing

(Frame rate 185, offset 4 mm)

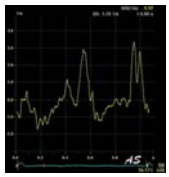
No smoothing

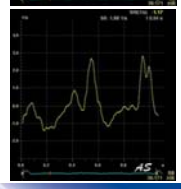




Flat smoothing 7 samples = 35 ms

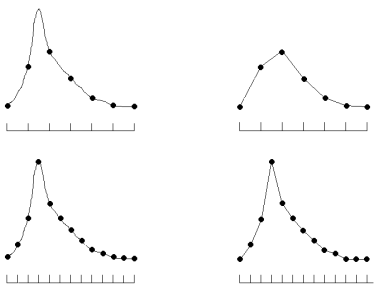
Gaussian smoothing 40 ms



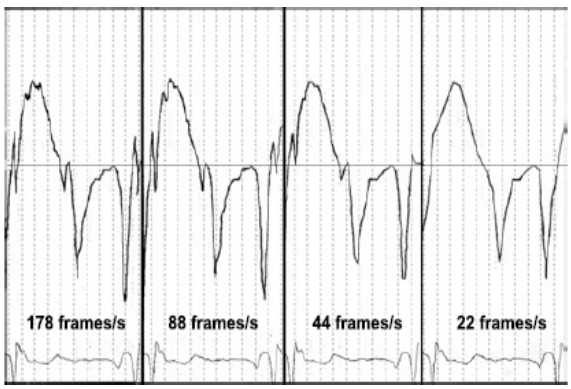


Gaussian smoothing 80 ms

Frame rate:

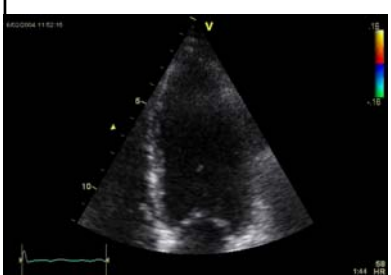


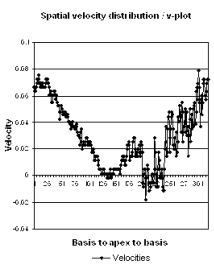
Low frame rate results in undersampling



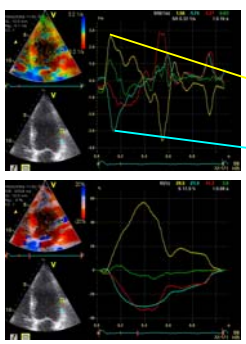
Lind, EJE 2002

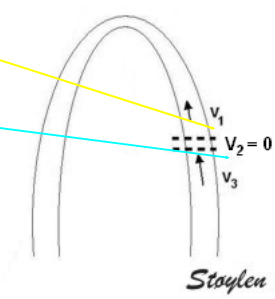
Reverberations:



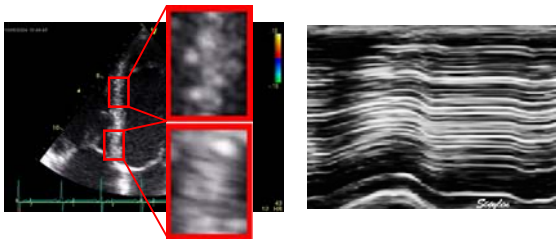


Reverberations:

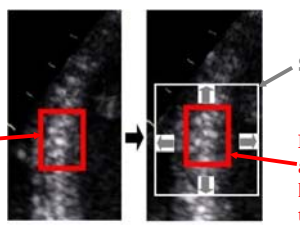




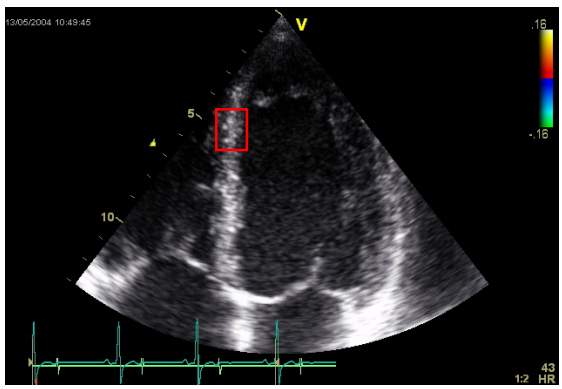
Speckle tracking?



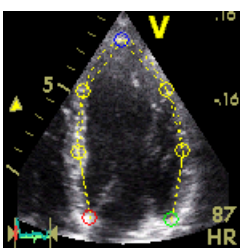
Tracking

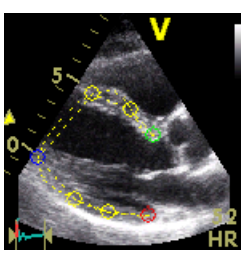


- Sum of absolute differences:
  - SAD = Σ(K – Kt) = Σ([K (x,y) – Kt(x-t,y-u)])
- Cross correlation:
  - R = Σ([K (x,y) × Kt(x-t,y-u)])



Resulting in:

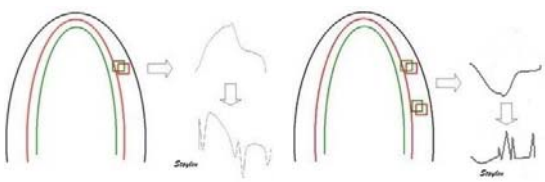




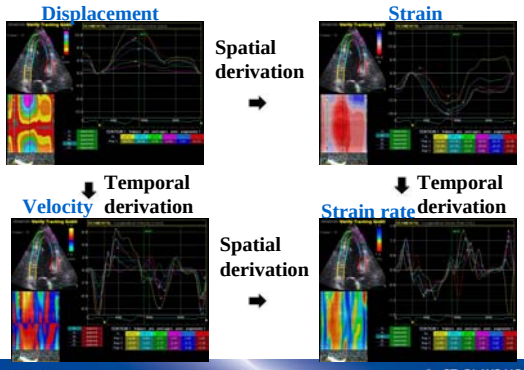
Angle independent tracking (?)

Tracking:

- **Motion:**
  - Displacement
  - Velocity
- **Deformation:**
  - Strain
  - Strain rate



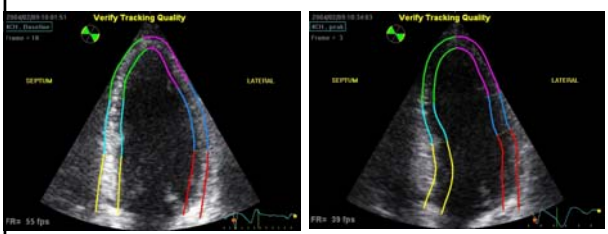
One dataset, four modalities:



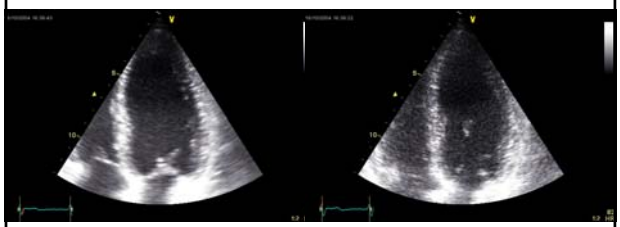
Limitations of speckle tracking

- Frame rate sensitive
  - Too big change from frame to frame – poor tracking
- Heart rate sensitive
  - More motion from frame to frame – equivalent to lower frame rate relative to HR
- Less noisy, due to lower frame rate and smoothing
- Sensitive for reverberations and drop outs
- Lateral tracking dependent on line density

Heart rate:



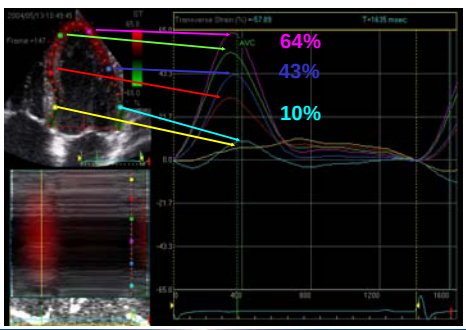
Line density:



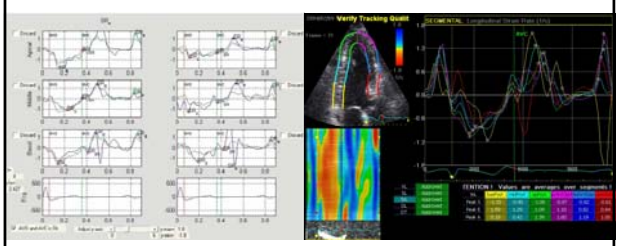
- Frame rate 112
- Frame rate 34

- Transverse tracking poor with low lateral resolution
- ⇒ Tracking mostly along the ultrasound beam
- ⇒ Angle dependent tracking

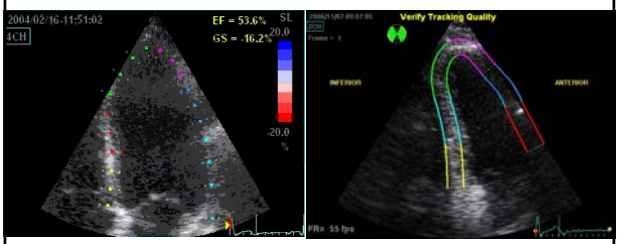
Lateral resolution – transmural strain:



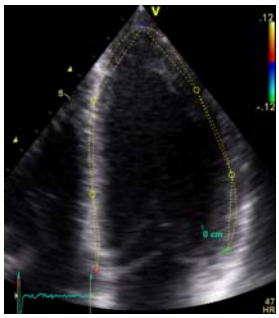
Noise:



Drop outs and reverberations:

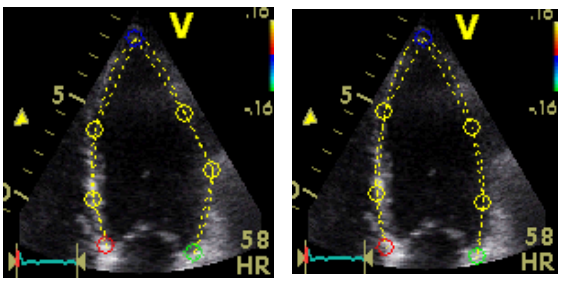


Segmental speckle tracking:



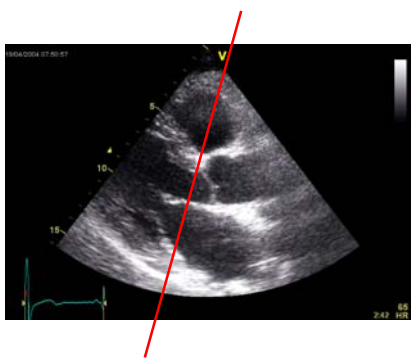
- Basic and robust
  - Uses large kernels
  - Low spatial resolution (segments – equivalent to a strain length of 3 cm)
  - No extra smoothing necessary

Reverberations

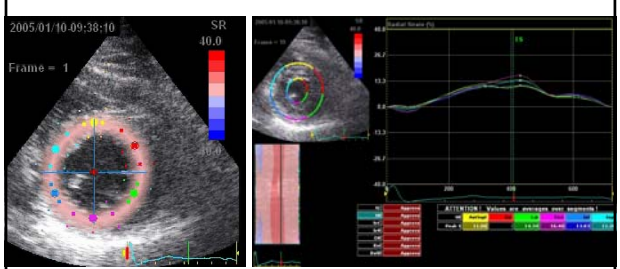


Tracking

- Tissue Doppler
  - Tracks along the ultrasound beam
  - Calculates the position in the next frame by velocity
- Sensitive to direction of motion in the plane
- Speckle tracking
  - Tracks along the line of motion
  - Calculates the kernel most similar to previous frame
- Sensitive to out of plane motion
  - Large out of plane motion: does not track material objects

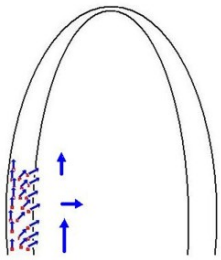


Transmural strain

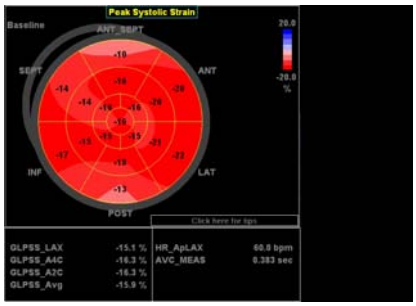


2D strain:

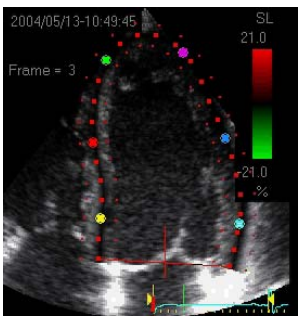
- Manufacturer specific application, not a basic method
  - User friendly interface
  - Deformation in two dimensions simultaneously (?)
  - Tracking of more kernels
  - Stable speckles (akoustic tagging) (stability criteria?)
  - Smothing



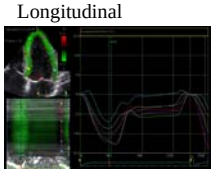
Attractive user interface



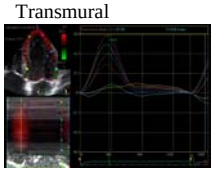
2D strain



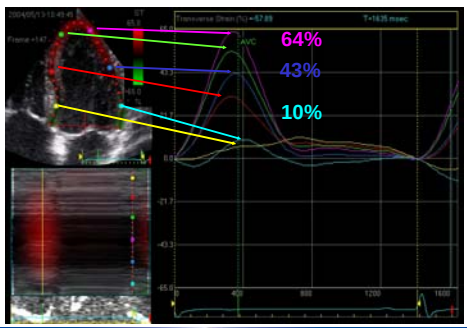
Longitudinal



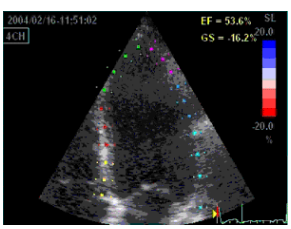
Transmural

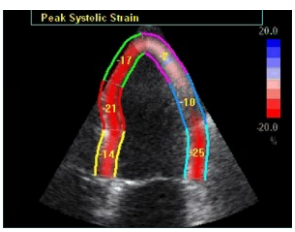


Lateral resolution – transmural strain:



Smoothing





Example: Inferior infarct

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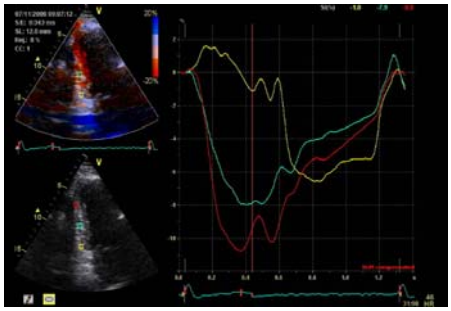
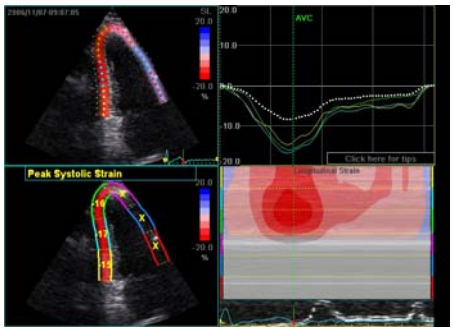


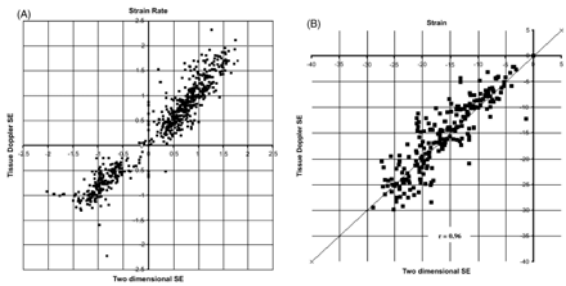
Example: Inferior infarct



Strain values were not zero in completely non-viable segments. This may be due to measurement artefacts related to tethering from adjacent segments. These artefacts are likely to have affected in particular segments with low myocardial deformation. However, in spite of these artefacts, a distinction of hyperenhancement categories was still possible.

Becker et. Al EJE nov 2006

Validation – DTI:



R = 0,94

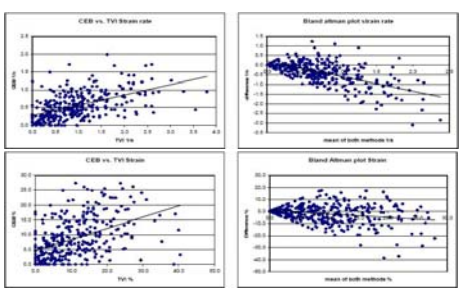
R= 0,96

Modesto 2006

Validation – DTI:

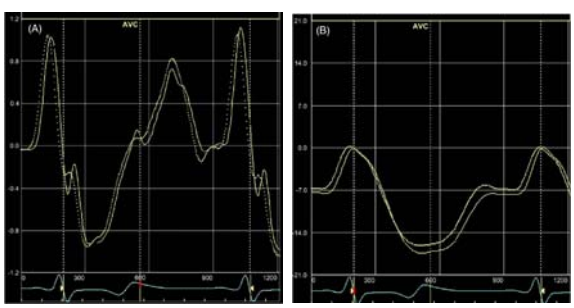
R = 0.53

R= 0.47



Støylen 2004: www.folk.ntnu.no/stoylen/strainrate

Smoothing and automation



Modesto 2006

Validation – MR tagging:

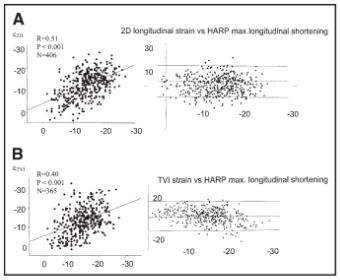
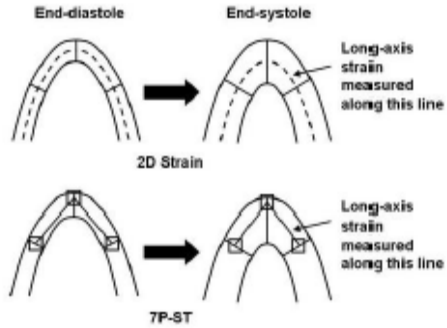
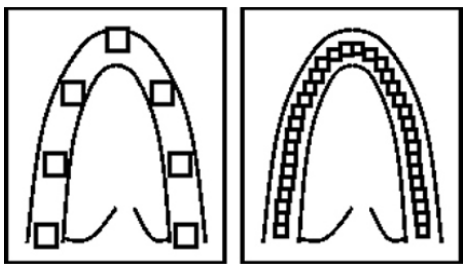


Figure 1. Correlation and Bland-Altman limits of agreement for longitudinal strain. *(A)* ε_{2D} versus HARP MRI and *(B)* ε_{TVI} versus HARP MRI.

Cho et al 2006

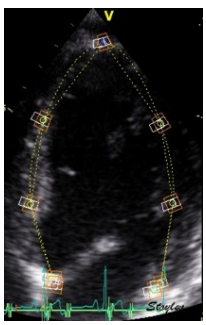


Speckle tracking vs. 2Ds



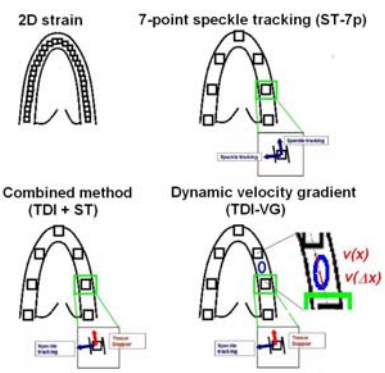
Amundsen 05

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)

Methods:

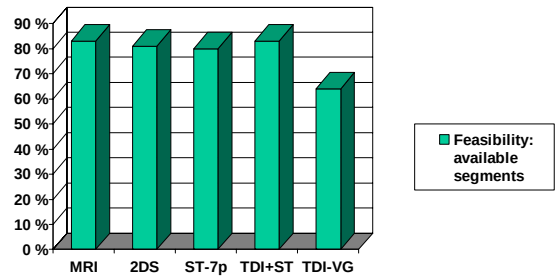


Comparative study

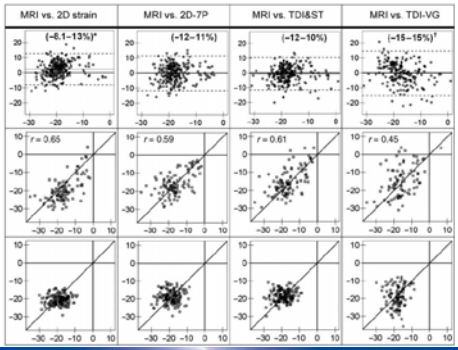
- 21 subjects 10 with MI, 11 normals
- Echo and MRI within 24h
- Segments excluded on basis of visual tracking, VG also on basis of angle
- 3T MR, tagging
- Harmonic phase analysis

 Amundsen B et al, EJE 2008

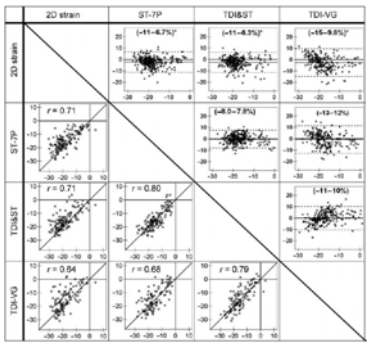
Results



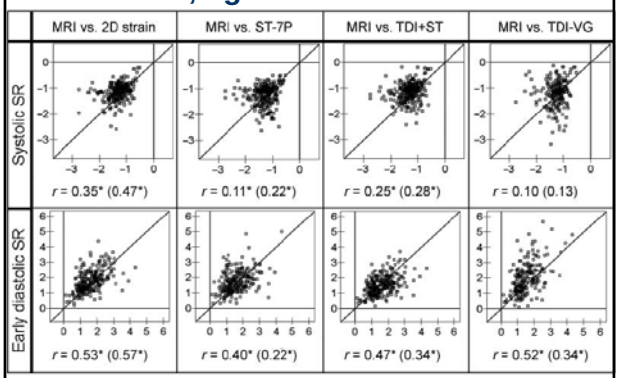
Systolic strain; agreement with MRI



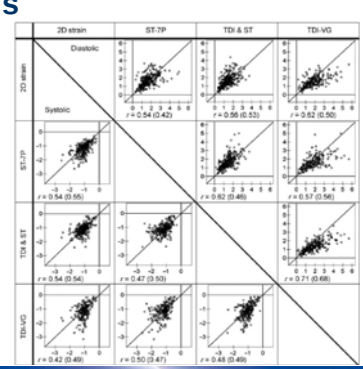
Systolic strain; agreement between echo methods:



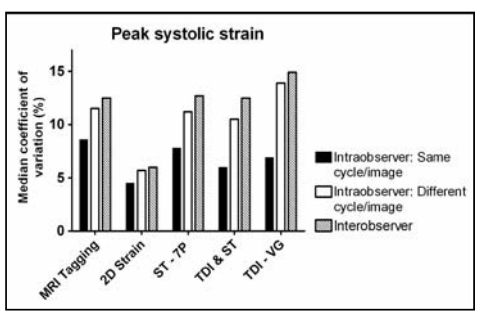
Strain rate; agreement with MRI



Strain rate; agreement between echo metods



Reproducibility (Strain):



Strain rate vs. speckle tracking:

- Angle sensitive
- Tracks motion
- High frame rate suitable for high velocities
- Moderately smoothing dependent and fairly high spatial resolution

- Less angle sensitive
- Tracks apparent material objects
- Low frame rate
- Highly smoothing dependent (2DS) or low spatial resolution(7P-ST)

How?

- Level?
- Angle?
- Quality based?
  - Tracking evaluation
  - Comparison
- Weighted?