

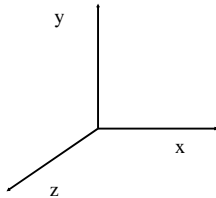
# Bruk av vevsdoppler og strain rate imaging:

Asbjørn Støylen, Dr. Med  
ISB  
DMF  
NTNU

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

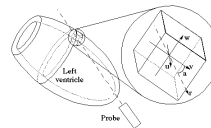
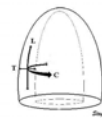
- Innstillinger for opptak
- tolkning av kurver
- Post prosessering, problemer og fallgruber
- Klinisk anvendelse
  - Dokumentert
  - Ikke dokumentert

## Koordinater



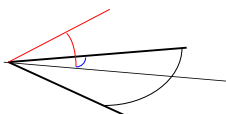
- x, (Horizontal)
- y, (Vertikal)
- Z (Lateral)

## Koordinater

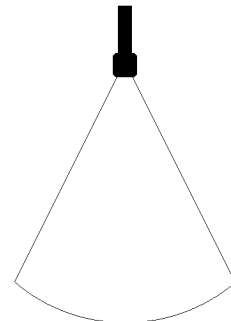


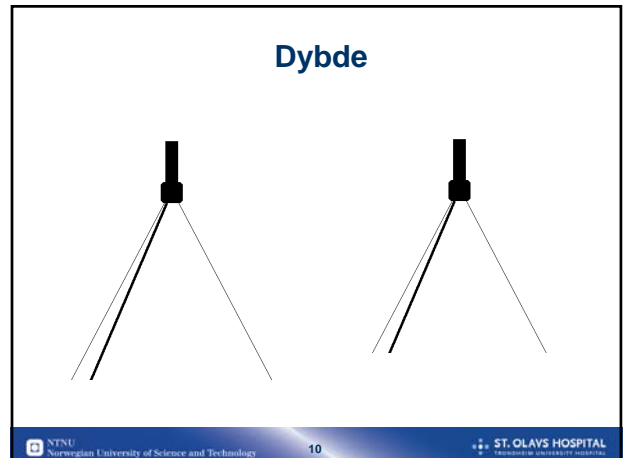
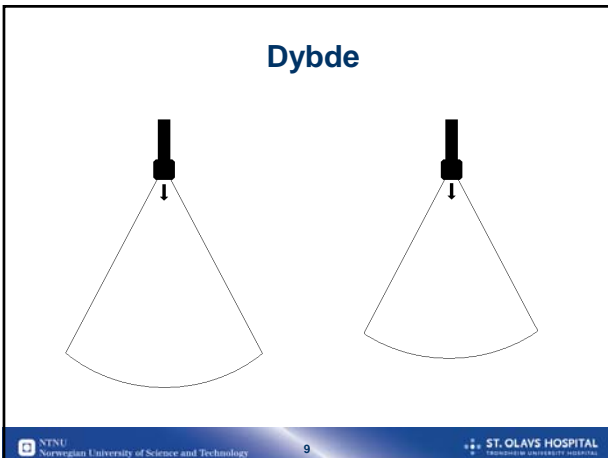
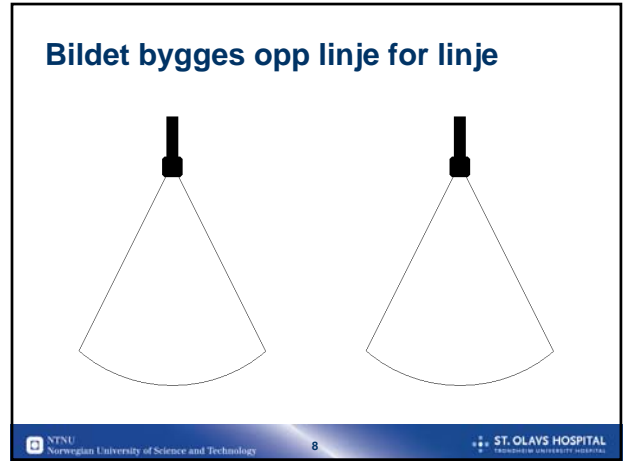
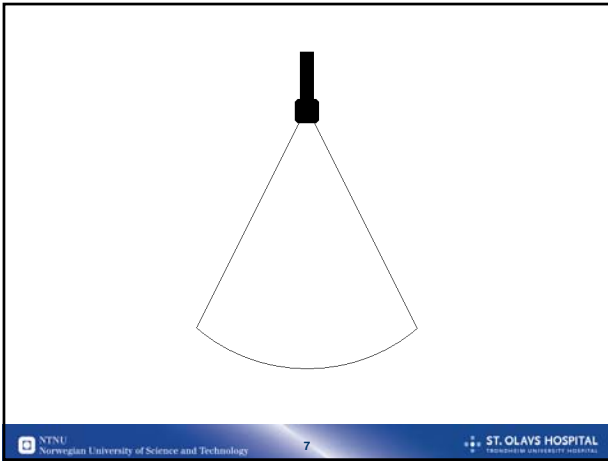
- Longitudinell,
- Circumferensiell,
- Transmural (transversell, radiell)

## Koordinater



- Axial (Avstand, radiell)
- Lateral, transversell
- Elevasjon





### Dybde

- Mindre dybde gir høyere frame rate
- Bruk kun den dybde som er nødvendig

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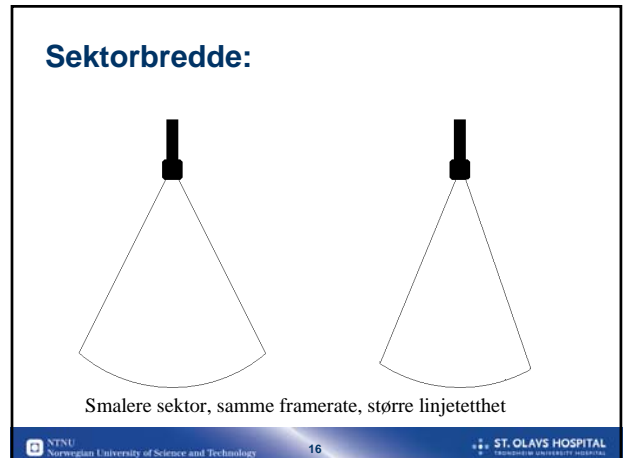
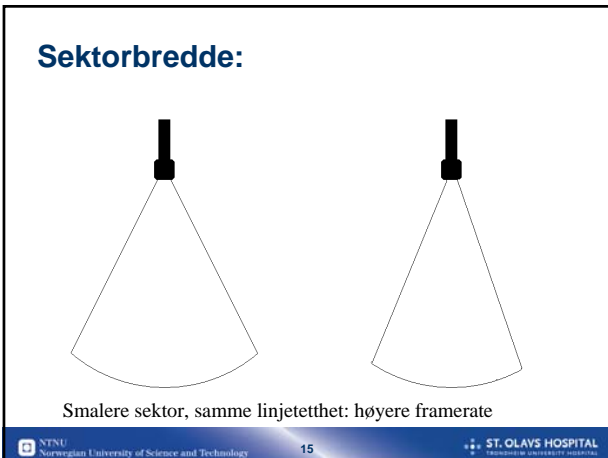
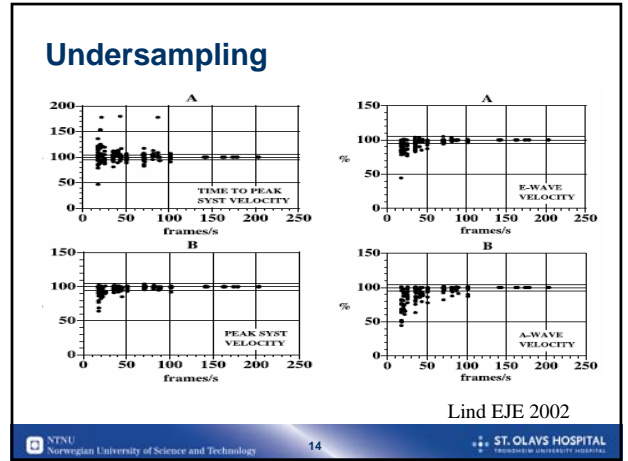
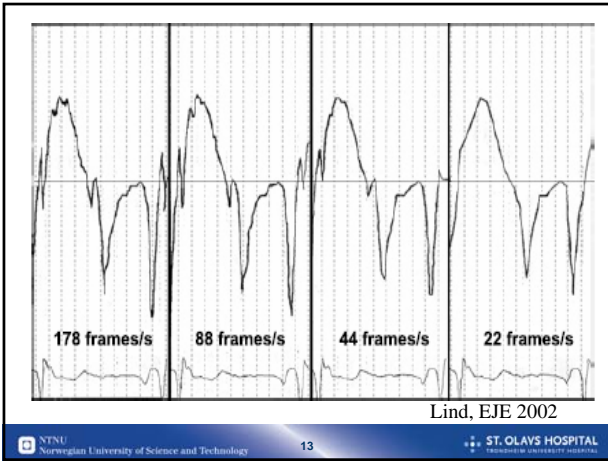
NTNU Norwegian University of Science and Technology ST. OLAVS HOSPITAL

### Betydningen av høy frame rate i TVI:

For lav frame rate gir undersampling

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- ### Presettinger for TVI opptak:
- Ikke mer dybde enn nødvendig
  - Ikke bredere sektor enn nødvendig
    - Best resultat ved å se på en vegg, men
      - Lengre akvisisjonstid for en full undersøkelse
      - Ikke mulig å sammenligne vegger
  - Juster frame rate til ønsket nivå
    - "TVI visible" for å justere TVI frame rate
    - økning i frame rate oppnås ved reduksjon i antall linjer
    - Oftest tre nivåer
- NTNU Norwegian University of Science and Technology 18 ST. OLAVS HOSPITAL

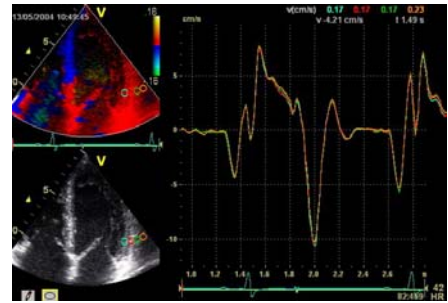
Frame rate vs. linjetetthet avhenger av sektor bredde og dybde.  
Oftest tre nivåer

- Frame rate
  - Ca 90
  - **Ca 105**
  - Ca 150
- Antall linjer i sektor
  - 16
  - **32**
  - 64

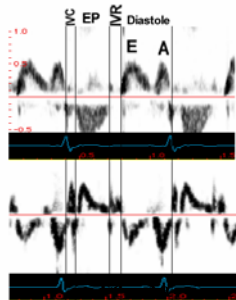


Bilder:  
E. Sagberg  
2006

Lateral oppløsning:



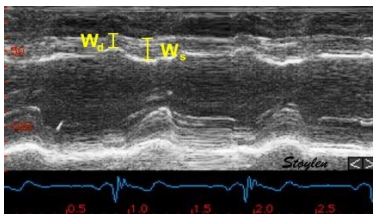
Vevsdoppler og flow:



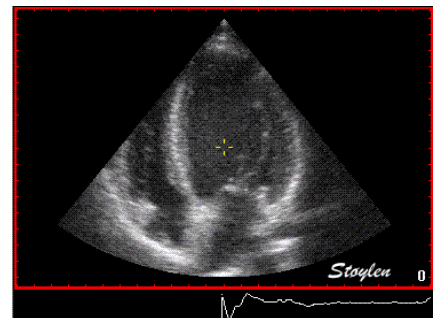
Strain:

$$\epsilon = (L - L_0)/L_0$$

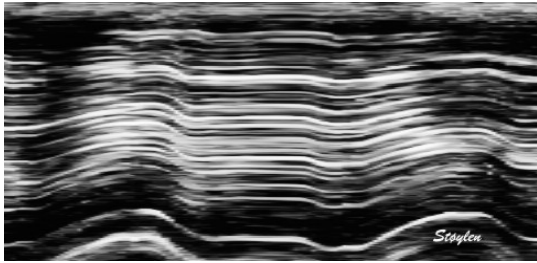
Veggfortykning:



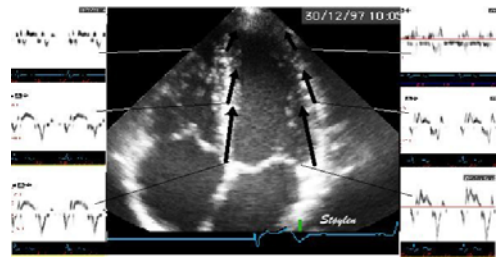
$$WT = \frac{W_d - W_s}{W_d} = \frac{\Delta W}{W_d}$$



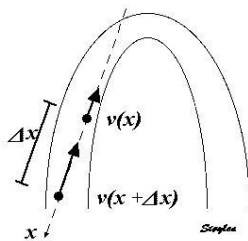
## Longitudinell strain:



## Longitudinelle hastigheter:

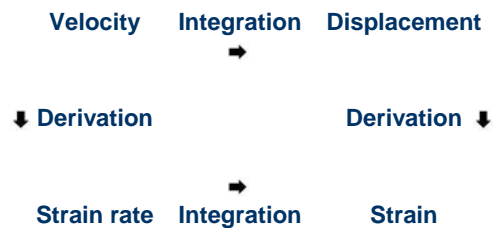


## Strain rate

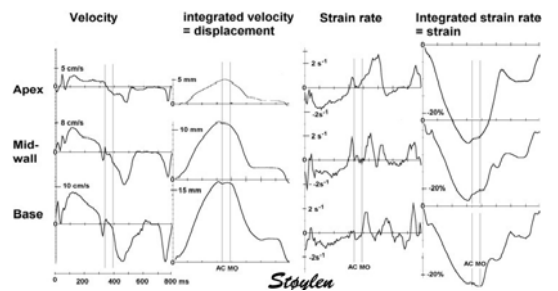


$\Delta(x)$ : Offset eller strain lengde

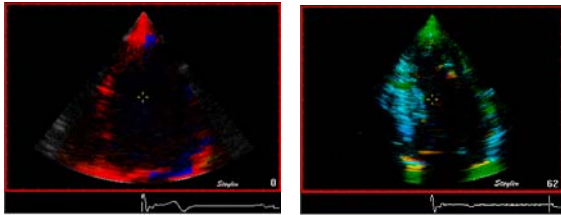
$$SR = \frac{v(x) - v(x + \Delta x)}{\Delta x} = \frac{\Delta v}{\Delta x}$$



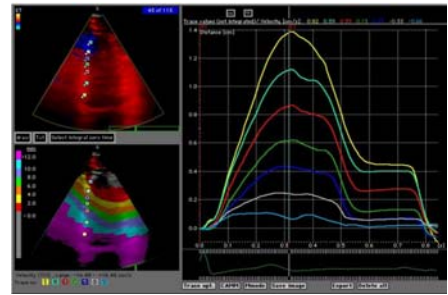
## Samme strain, forskjellig strain rate



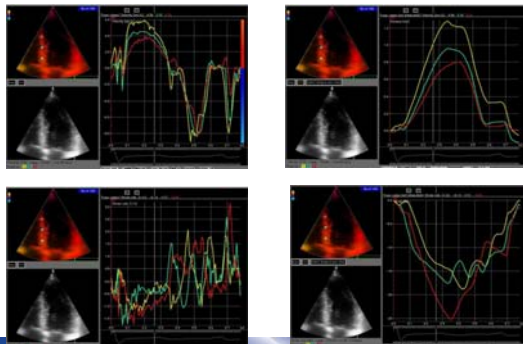
## Normal:



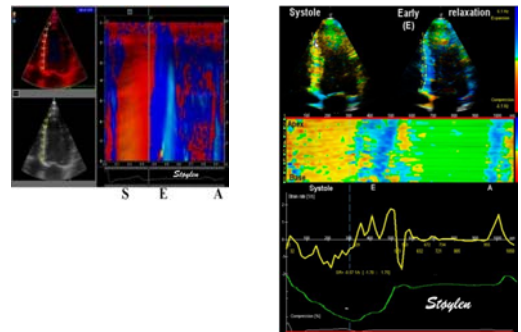
## Displacement (tissue tracking)



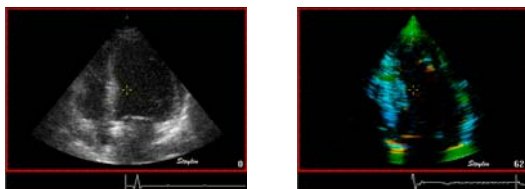
## Normal:



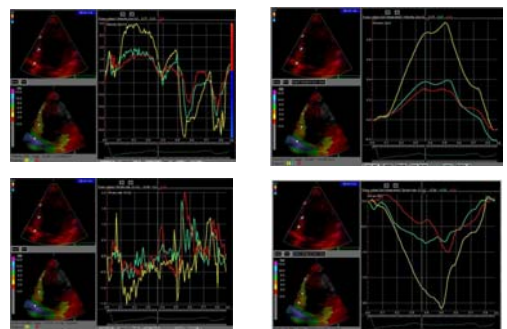
## Normal, kurvet M-mode



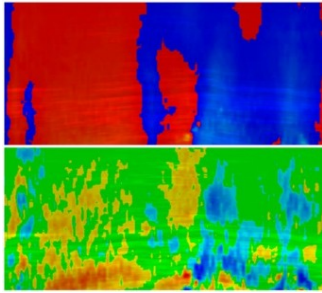
## Fremreveggsinfarkt:



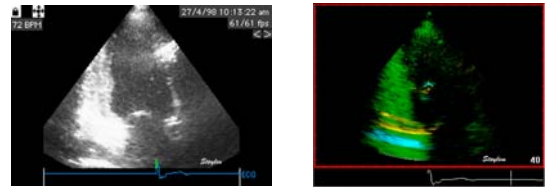
## Fremreveggsinfarkt:



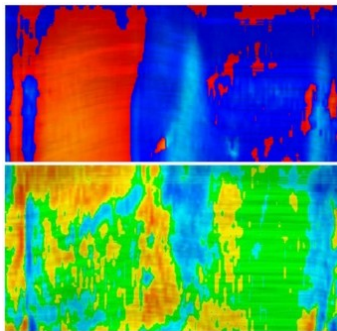
## Fremreveggsinfarkt:



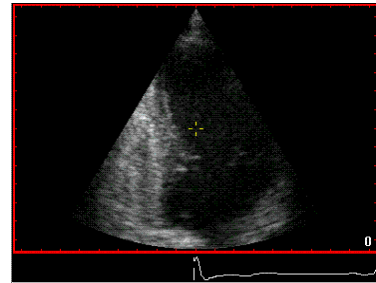
## Nedreveggsinfarkt



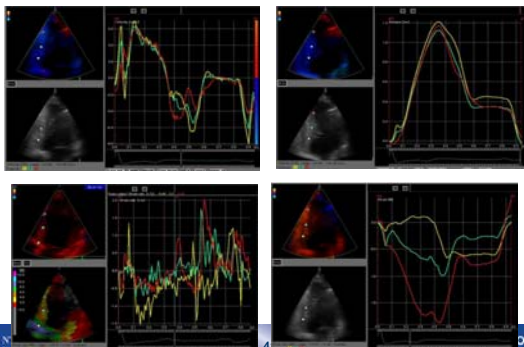
## Nedreveggsinfarkt



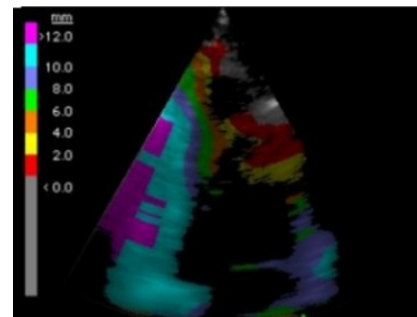
## Nedreveggsinfarkt



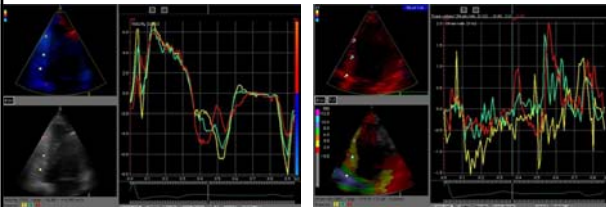
## Nedreveggsinfarkt



## Nedreveggsinfarkt



## Tilfeldig støy

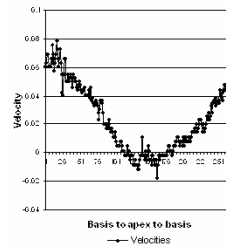


Velocity

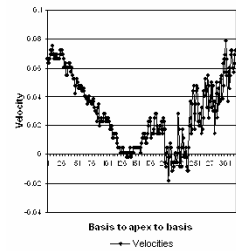
Strain rate

## Hastighetsprofiler

Spatial velocity distribution : v-plot

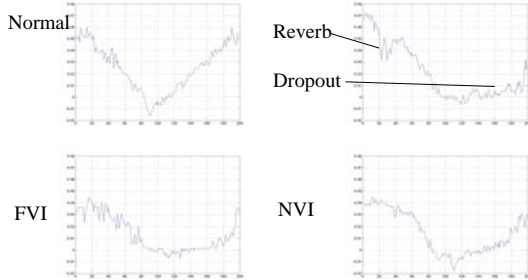


Spatial velocity distribution : v-plot



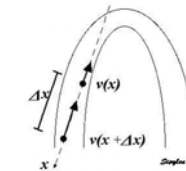
Bilde: E. Sagberg

## Hastighetsprofiler



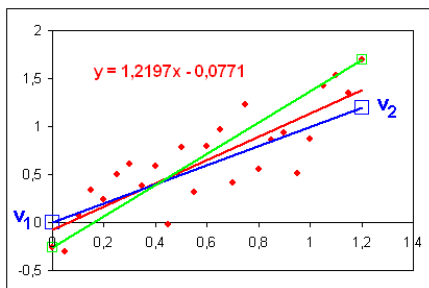
Bilde: E. Sagberg

## Strain rate



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

- Signalet er differansen mellom hastighetene
- Støyen er summen av støy fra de to hastighetene
- ): Dårligere signal – støyforhold enn hastigheter



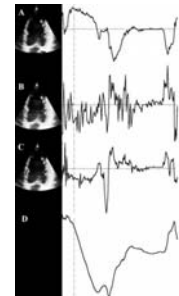
SR = 1

SR = 1.14

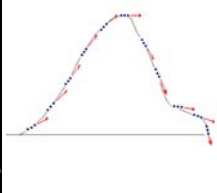
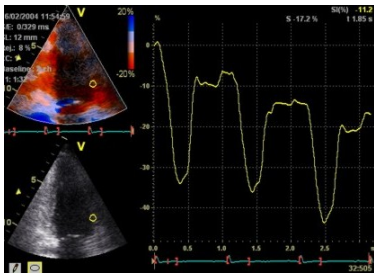
SR = 1.63

## Strain lengde

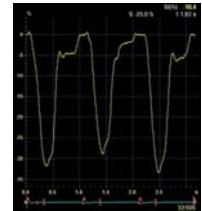
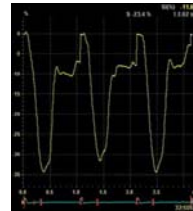
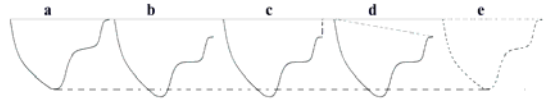
- Hastighet
- Strain rate, offset 5 mm
- Strain rate offset 15 mm
- Integrert strain



## Drift (Strain)



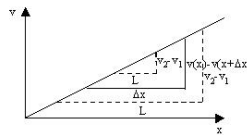
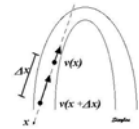
## Drift



## Driftkompensasjon:

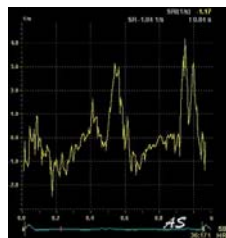
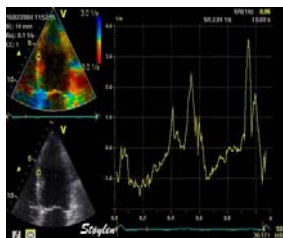
- Ta opp flere sykler
- Se om det er systematisk drift
- Ikke kompenser drift i en syklus som ikke er systematisk

## Strain rate



- Støyen er summen av støy fra de to hastighetene
- Lengre strainlengde gir større differanse
- ): Bedre signal - støyforhold

## Strain lengde

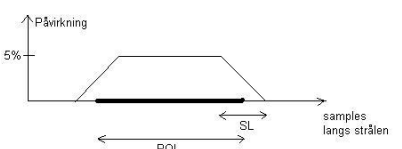
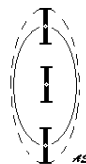


Offset 14 mm

4 mm

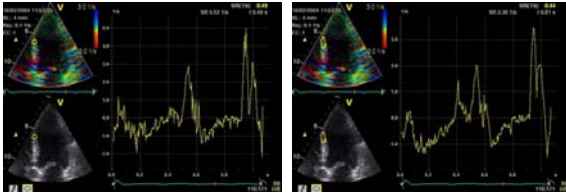
Økt offset – lavere axial oppløsning

## Romlig midling



Romlig midling reduserer axial og transversell midling  
Axial oppløsning = Strain lengde + ROI lengde

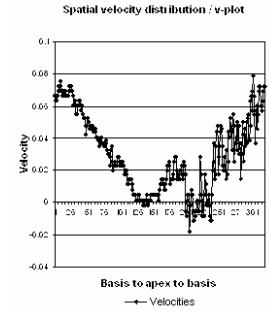
## Romlig midling



Offset 4 mm, ingen tidsmidling  
ROI 6x6 mm                      ROI 12x6 mm

## Romlig midling og økt strain lengde

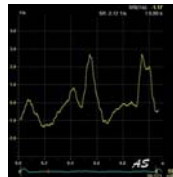
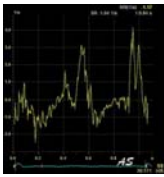
- Økt sjans for inkorporering av artefakter som strekker seg over et område, som f. eks reverberasjoner eller drop outs
- Høyere romlig oppløsning gir mulighet for mer romlig midling



Bilde: E. Sagberg

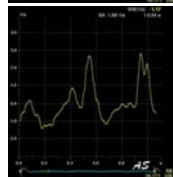
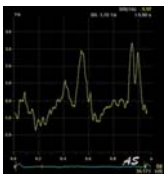
## Tidsmidling (Frame rate 185, offset 4 mm)

Ingen midling



Flat midling  
7 samples =  
35 ms

Gaussisk midling  
40 ms



Gaussisk  
midling  
80 ms

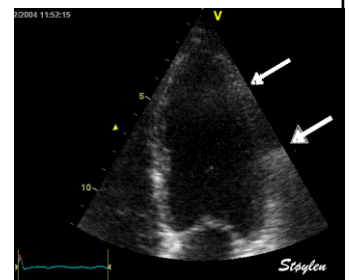
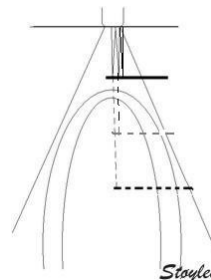
## Tidsmidling

- Både på hastigheter og strain rate gir Gaussisk midling best effekt
  - Bare tilgjengelig på Strain rate
- All tidsmidling gir tap av tidsoppløsning
  - Redusert effektiv frame rate
  - Undersampling
- Høyere frame rate gir mulighet for mer tidsmidling

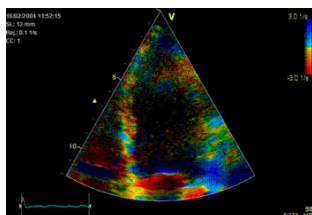
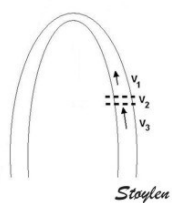
## Midling

- Data er midlet allerede før scankonvertering. Default: middels lateral, ingen axial midling. Midling før konvertering til hastigheter er mest effektiv.
- Bruk en kombinasjon av romlig midling og tidsmidling i forhold til den frame rate som er satt.
- Ved middels frame rate (og linjetetthet) brukes minst romlig midling

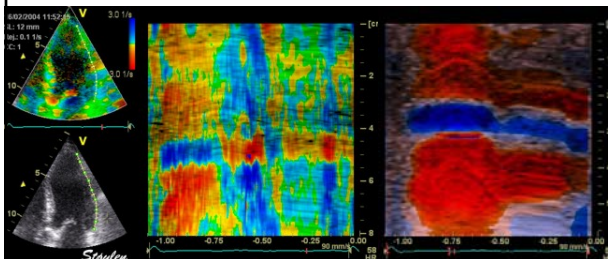
## Reverberasjoner:



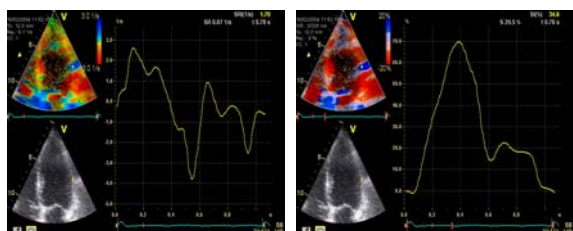
## Reverberasjoner



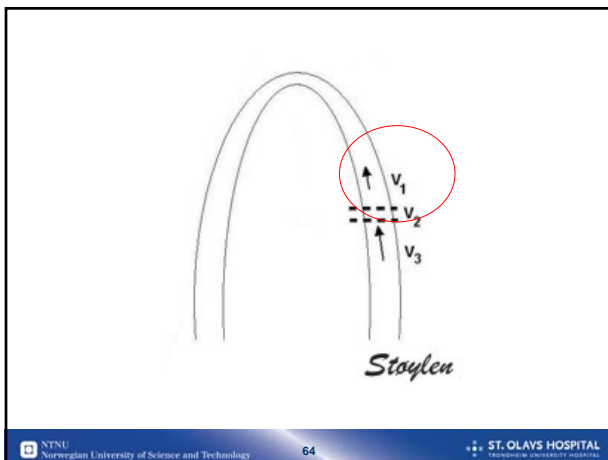
## Reverberasjoner



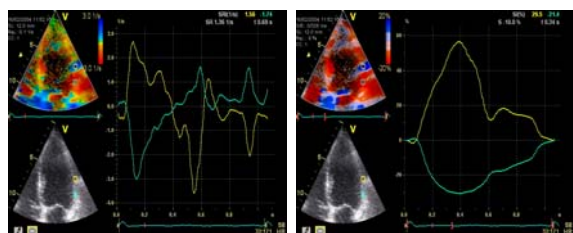
## Reverberation artefact:



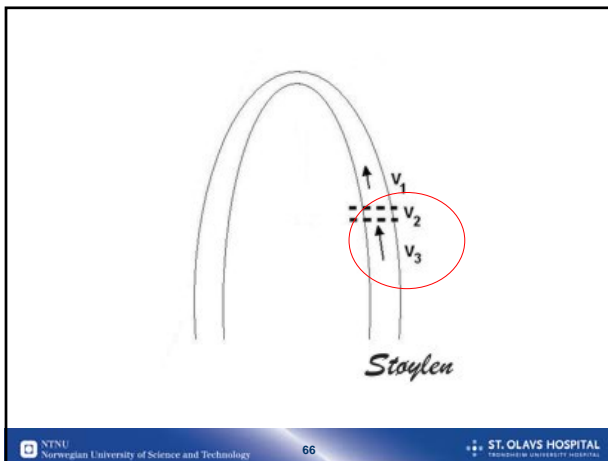
Inverted strain rate curves v1 - 0



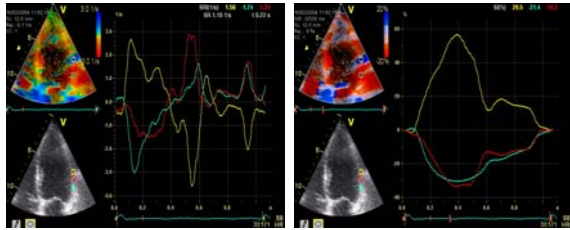
## Reverberation artefact:



Apparent hyperkinesia 0 - v3

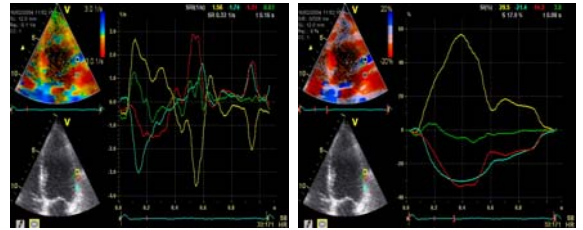


## Reverberation artefact:



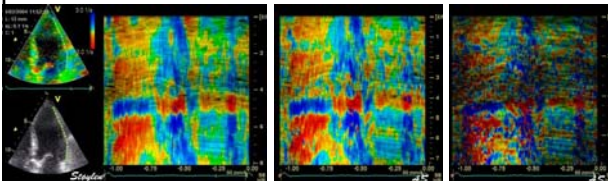
Apparent normal strain rate

## Reverberation artefact:



Apparent initial dyskinesia

## Strain lengde



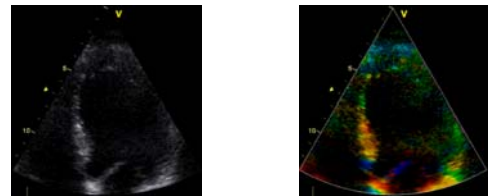
12 mm,

8 mm,

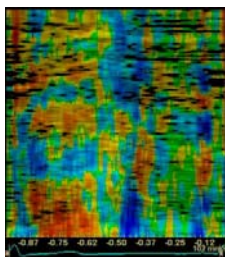
4 mm

Reverberasjoner dessuten sterkt følsom for romlig midling

## Skjggeaktige reverberasjoner

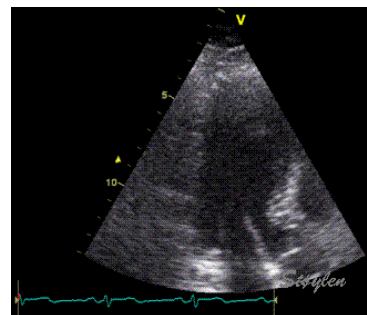


## Identifiseres med kurvet M-mode

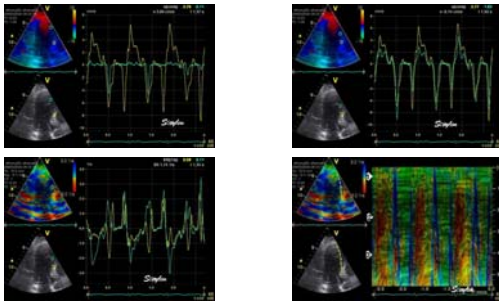


- Ikke direkte samsvar mellom gråtone og vevsdoppler kvalitet
- Områder med mye reverberasjoner må forkastes, ikke prøv å trekke ut informasjon av lavkvalitetsdata

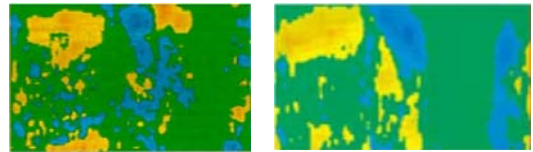
## Dropouts



## Dropouts



## Dropouts

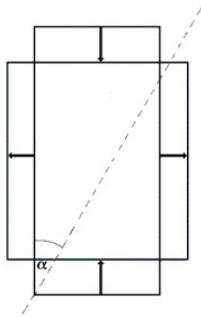


Dropout  
Ingen A-bølge

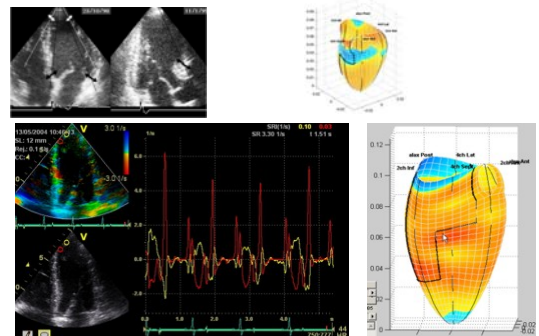
Infarkt  
Post systolisk forkortn  
Intakt A-bølge

Vevssignal til stede?

## Vinkelproblemet:



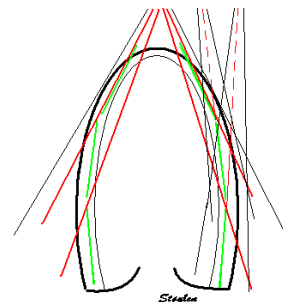
## Vinkelproblemet:



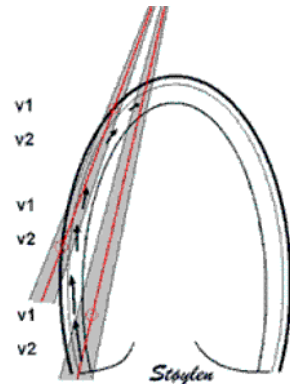
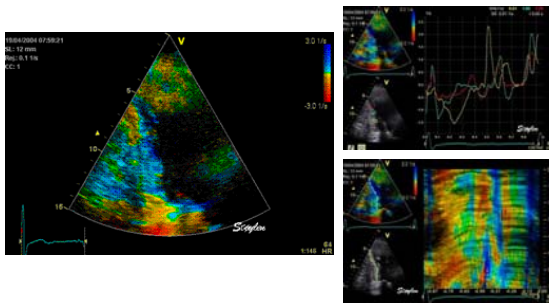
## Apical sone



## Vinkelproblemet:

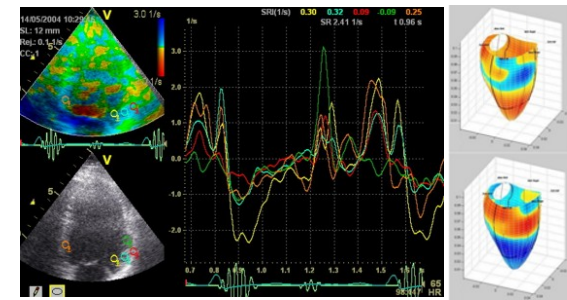


## Vinkelartefaktet i nedre vegg



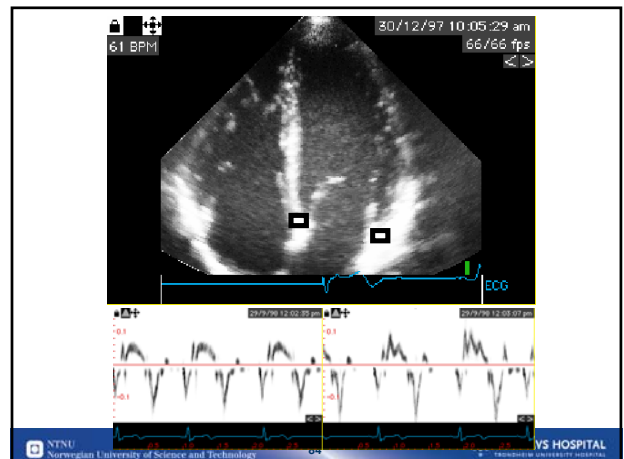
## Hvordan tilnærme seg vevsdoppler?

- Evaluer billedkvalitet mht dropouts og reverberasjoner på gråtone
- Ta alltid pulsete klaffepan hastigheter
- Sammenlign med klaffepan hastigheter fra farge
- Se på hastighetskurvene mot apex (jevnt fall, neppe regional dyskinesi)
- Se på strain rate, kurvet M-mode etter tilstedeværelse av reverberasjoner, ikke analysér områder med dårlige data
- Kvalitativ vurdering av kurvet M-mode mer robust enn kurveanalyse
- Ved unormale kurver, sjekk mot kurvet M-mode, om fenomenet har en viss utstrekning



## Klinisk bruk:

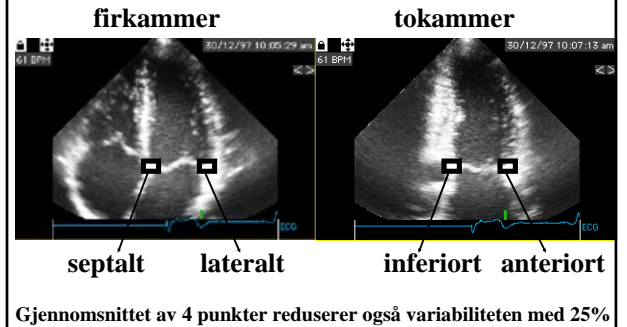
- Hastigheter: Global funksjon
- Strain/Strain rate: Regional funksjon
- Strain/Strain rate: Systolisk funksjon
- Velocities: Diastolisk funksjon



## Normalverdier:

- Gulati et al 1996:
  - Peak velocity korelerer med EF:  $R = 0.86$  (Støylen et al 2003:  $R = 0.66$ )
  - Peak velocity  $> 5,4$  cm/s tilsvarer EF  $> 50\%$
- Vinereanu et al 2001:
  - Peak velocity  $> 9$  differensierer mellom normal og patologisk hypertrofi (men alle med normal EF)
  - Normalverdi  $> 8$

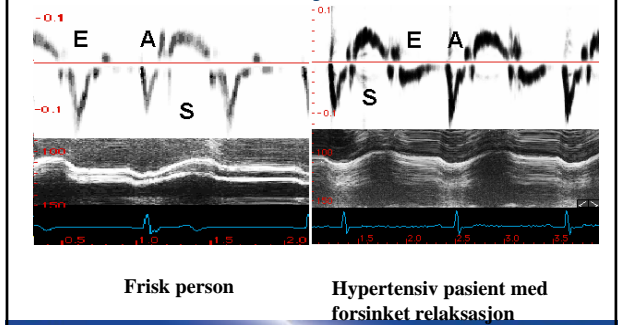
## Normalverdiene gjelder gjennomsnitt av 4 punkter:



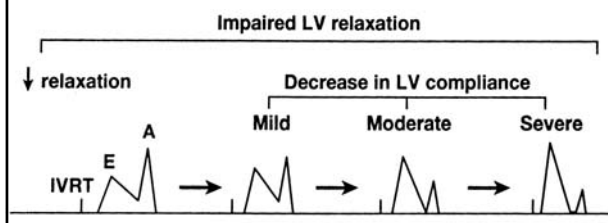
## Klaffeplan vevsdoppler:

- Fordeler:
  - Enkel i bruk
  - Robust – gir data på de fleste
  - Reproduserbar
  - Sensitiv
  - Nærmeste korrelat til kontraktilitet
- Ulemper:
  - Gain-avhengig
  - Fortsatt noe usikkerhet om normalgrense
  - Langaksebevegelse er nedsatt ved
    - Hypertrofi: OBS hypertensjon HCM, ASI
    - Alder

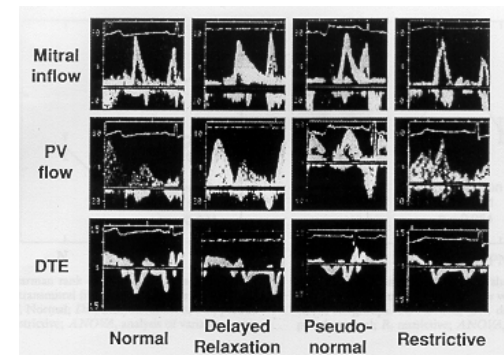
## Diastolisk funksjon VV:



## Mitralflow og økande fylningstrykk



## Diastolisk funksjon:

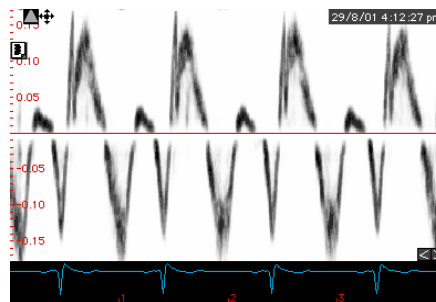


## E-mitral/e-annulus og fylningstrykk

	E/e(lm)	PCWP (mmHg)	Sens. (%)	Spes. (%)
Nagueh 1997 *	>10	>10	91	81
	>10	>15	97	78
Nagueh 1998 **	>10	>12	78	95
	>10	>15	85	93
Sundereswaran 1998 ***	>8	>15	87	81
	Endring >2,5	Øking ≥5	77	75
Nagueh 1999 ****	>10	>15	92	85
Sohn 1999 *****	E/e(septal)			
	>11	>15	75	93

Tabell: Vegsundvåg

## Høyre ventrikkelfunksjon:

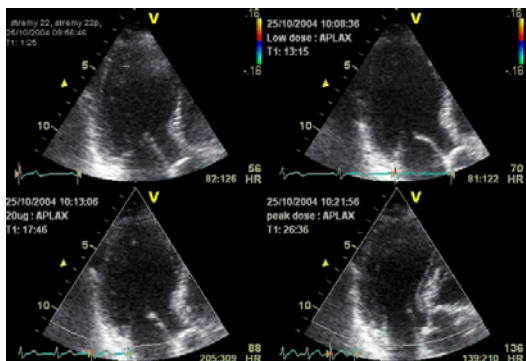
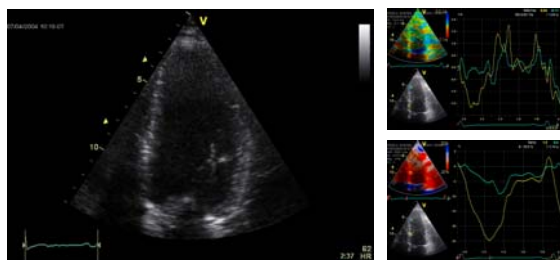


Tabell: Vegsundvåg

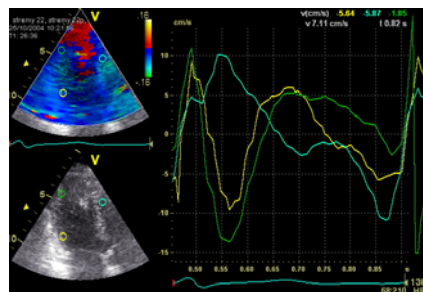
## Systolisk høyre ventrikkelfunksjon

- Peak systolisk hastighet av tricuspidalringen
- Et målepunkt.
- Normalt 15 cm/s = Normal høyre ventrikkelfunksjon patologisk < 10 cm/s (Alam 2000)
- Systolisk pulmonalarterietrykk?
  - Påvisbar IVR (cfr Burstin 1967)

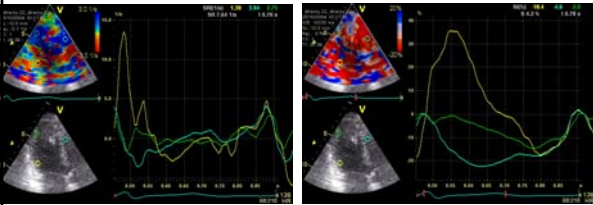
## In case of doubt:



## Confirm finding – velocities:

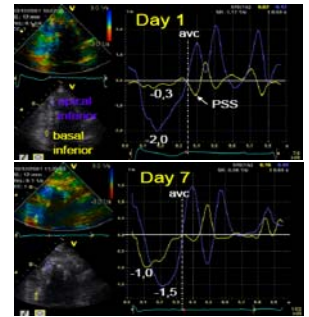


## Additional information – SRI



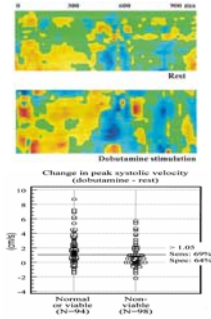
## Myocardial infarction:

- Recovery
  - Ingul et al 2005



## Myocardial infarction:

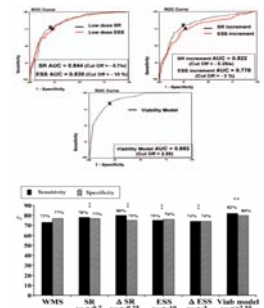
- Recovery
  - Ingul et al 2005
- Viability
  - Hoffmann 2002 (DSE)
  - Hoffmann 2005 (DSE)



Hoffmann R et al, JACC 2002

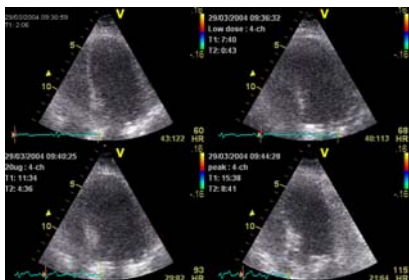
## Myocardial infarction:

- Recovery
  - Ingul et al 2005
- Viability
  - Hoffmann 2002 (DSE)
  - Hoffmann 2005 (DSE)
  - Hanekom 2005

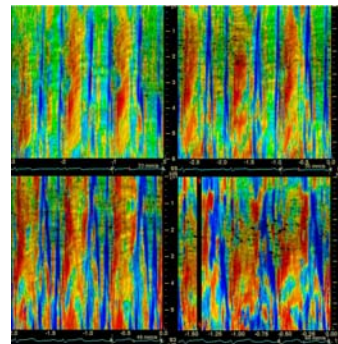


Hanekom et al, Circulation 2005

## Stressekko

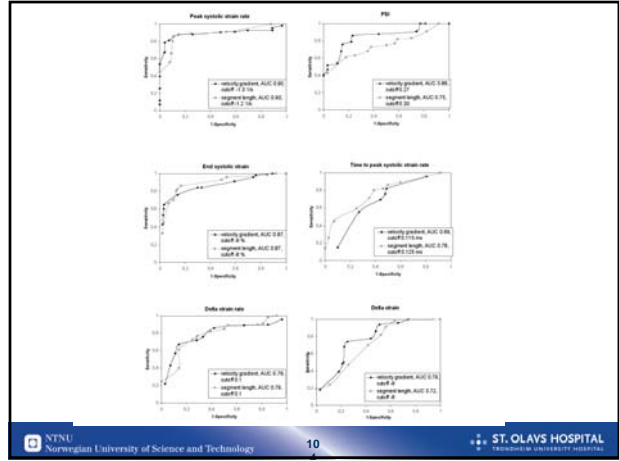


## Stressekko

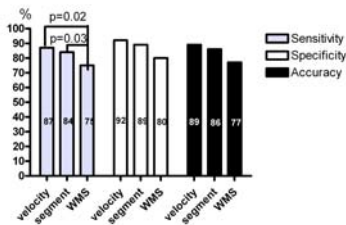


# Stress echocardiography:

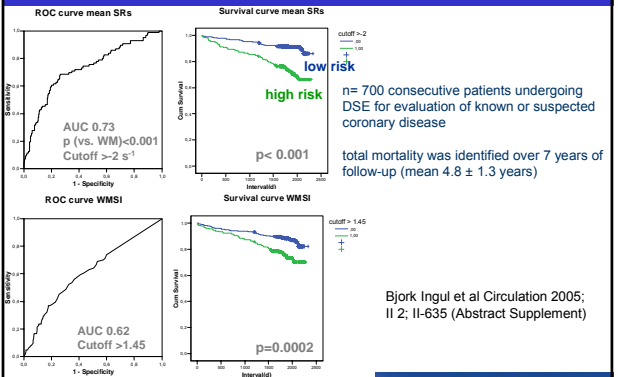
- **Voigt 2003, 2004**
  - 44 pats: Feasibility 85% (traces) to 95% (CAMM)
  - PSI best parameter (AUC 0.9)
  - SRI (CAMM) better than WMS (sens/spec 89/86 vs 82/81%)
- **Ingul 2005; 137 pats:**
  - Automated analysis. Feasibility 80%
  - Sensitivity/specificity vs. angio 81/89%
  - Peak SR significantly better than WMS
- **Hanekom 2005; 170 pats:**
  - Manual analysis. (Feasibility 92%)
  - Both WMS and Peak SR Sens >90%, specificity better with SRI



## 137 patients with angiography SRs vs. WMS



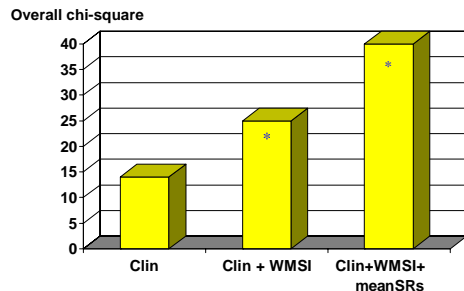
## Prediction of mortality using SRI in DSE



## Prediction of mortality, multivariate analysis of clinical, WM and SR variables

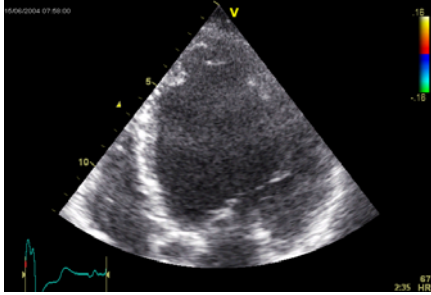
Variable	HR (95% CI)	p-value
Diabetes mellitus	1.69 (1.04-2.72)	0.11
Abnormal test	0.60 (0.28-1.24)	0.16
Number of ischemic segments	0.98 (0.87-1.10)	0.76
Number of scarred segments	0.99 (0.90-1.07)	0.74
WMSI cutoff 1.45	1.35 (0.81-2.26)	0.25
Mean SR <sub>s</sub> (s <sup>-1</sup> ) cutoff -2	3.50 (2.10-5.84)	<0.001

## Incremental value of mean SRs



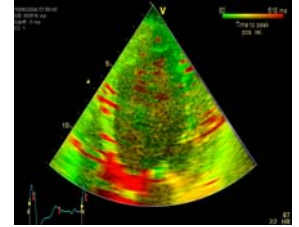
Clin= diabetes mellitus, hypertension, age \* p < 0.001

## CRT:

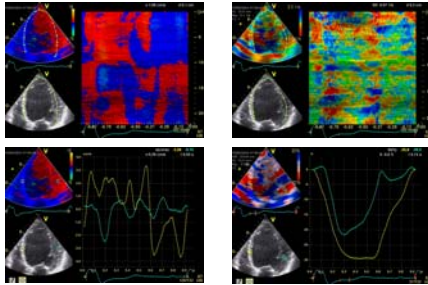


## CRT:

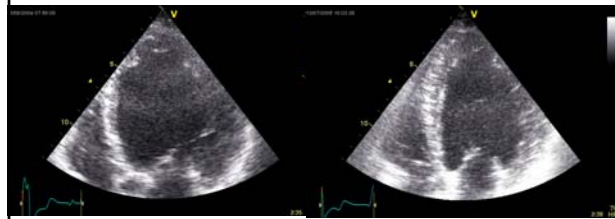
- No definite studies of the value of SRI, as opposed to other imaging methods.
- So far the main point is in diagnosing mechanical asynchrony



## CRT:



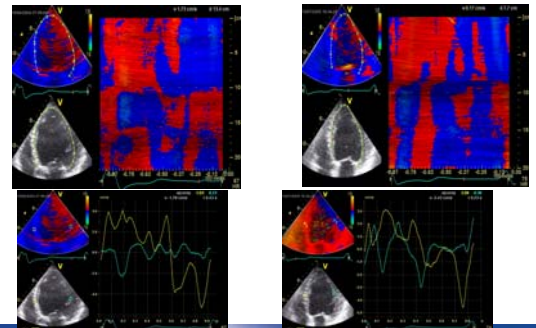
## CRT:



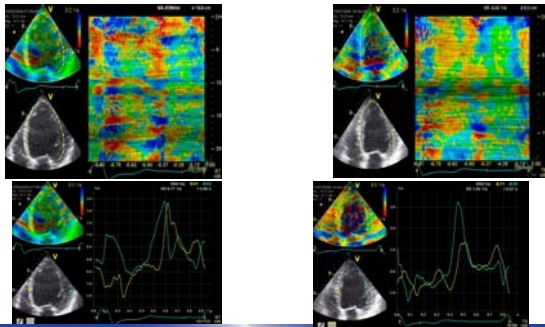
## CRT:

- Sogaard 2002: Tissue tracking
- Breithardt 2003: Strain rate
- Yu 2005: TVI Better than SRI
- Capasio 2005: SRI

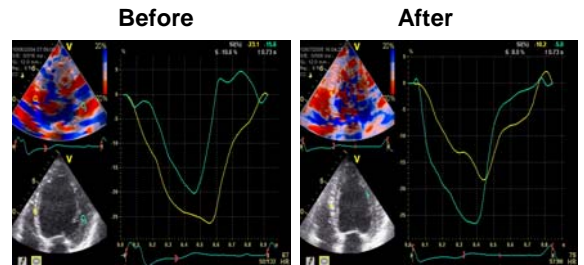
## CRT:



## CRT:



## CRT:



## Conclusions:

- Basically an add-on
  - (except stress echo?)
  - Post infarct: Ischemia/stunning/recovery
  - CRT
  - Right ventricular function
- Parametric imaging most robust
- Clinical studies still few and small
- Future use:
  - Tx reject/vasculopathy
  - Cardiomyopathies
  - Valvular/CHD
  - Reperfusion