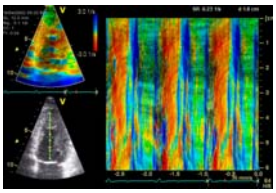
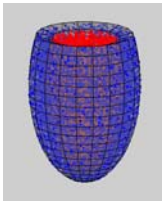
Strain og strain rate
klinisk bruk og praktisk demonstrasjon



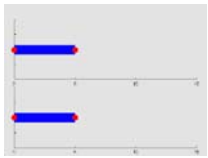
Charlotte Björk Ingul
Lege, Dr. med., Postdoc
Inst. for sirkulasjon og bildediagnostikk, NTNU

Ultrasound for deformation



Global motion
v1 = v2

Deformation
v1 ≠ v2



Strain imaging

⇩

Quantitative analysis off segmental myocardial deformation
(mechanics ~ pathology)

Deformation estimation =

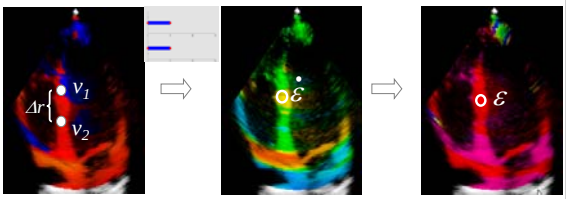
motion estimation
+
post-processing

Courtesy: J. D'Hooge

Strain estimation scheme

The quantitative assessment of *regional* myocardial function remains an important goal in clinical cardiology

Velocities | Strain rate | Strain

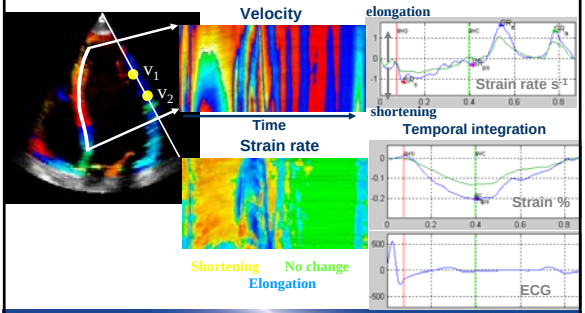


Calculate spatial gradient | Integrate temporally

Courtesy: J. D'Hooge

Myocardial velocity and strain rate/strain

Spatial derivation of velocity



Strain and strain rate

Strain
- -is deformation relative to its original length
- -shortening (compression) in systole is negative strain and lengthening (stretching) in diastole positive strain
- -calculated as the time integral of strain rate, most often using end-diastole as reference, and is a dimensionless quantity

Strain rate
- -means deformation rate and reflects how fast regional myocardial shortening or lengthening occurs
- -calculated from myocardial Doppler velocities (V1 and V2) measured at two locations separated by a distance (L)
- -equals the instantaneous spatial velocity gradient and has units of sec-1: SR = (V2-V1)/L

Regional systolic function

Function	Strain rate s^{-1}	Strain %
Normal	-1,5- -1,0	-20- -15
Hypokinesia	-1,0- 0	-15- 0
Akinesia	0	0
Dyskinesia	+ values	+ values

Peak diastolic strain rate

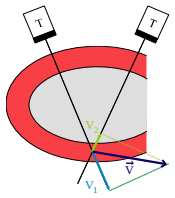
Peak diastolic strain rate E
2,30 s^{-1}

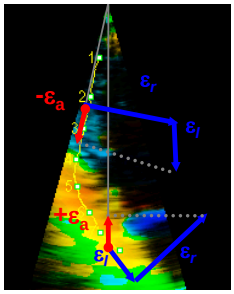
Peak diastolic strain rate A
1,38 s^{-1}

(young, healthy)

Pitfall: angle dependency

Myocardial Velocity Estimate is angle dependent



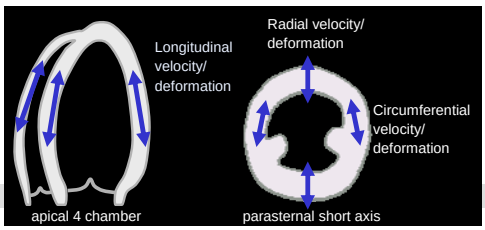


Courtesy: J.U. Voigt

P.L. Castro et al., *Ultrasonics Sci. Instrum.*, 2000 (Effect of angle on SRI values)

Limited strain data

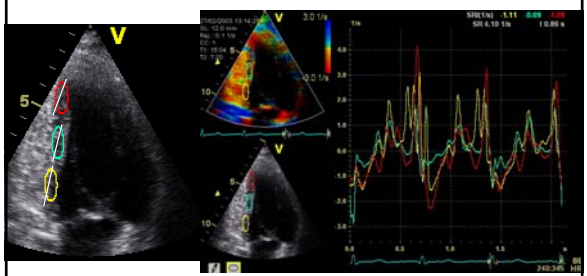
Meaningful data can only be acquired in the following segments:



Courtesy: J. D'Hooge

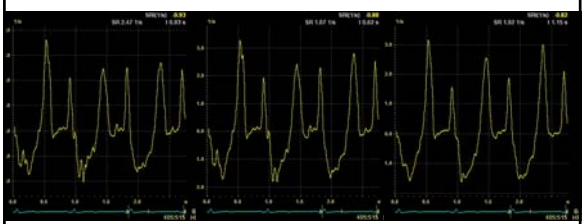
Not all strain components can be assessed for all LV segments

Sector LV, ROI size and position



Half strain length outside ROI, not shown

Strain length

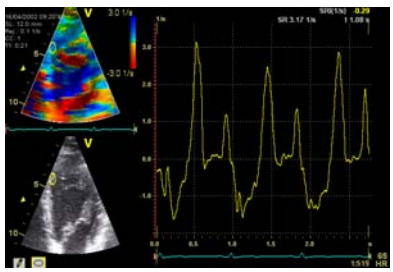


4 mm

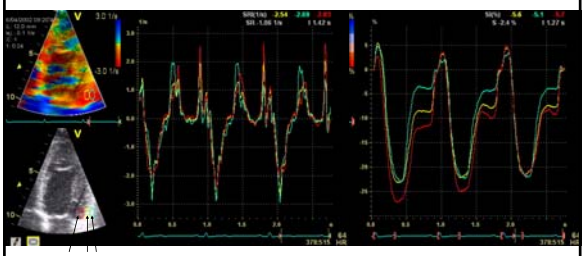
12 mm default

20 mm

Tracking of ROI



Lateral (spatial) resolution

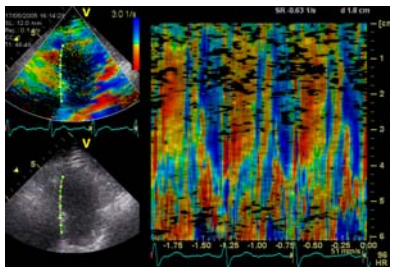


Info from the same beam

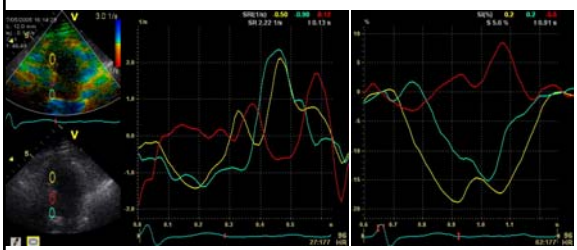
Strain rate

Strain

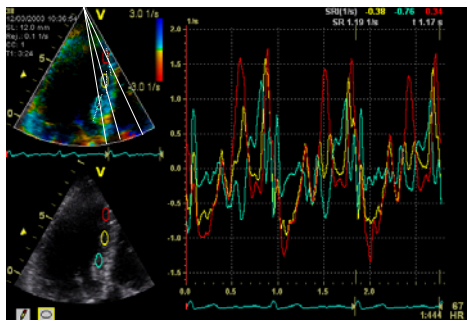
Reverberation



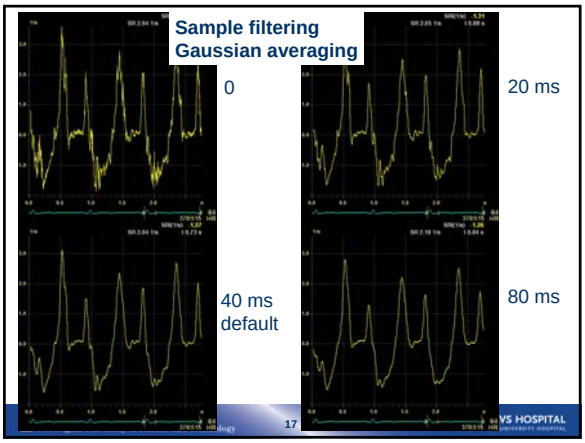
Reverberation



Angle deviation alignment beam, segment



Sample filtering
Gaussian averaging



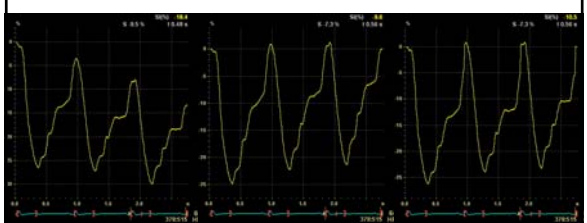
0

20 ms

40 ms
default

80 ms

Drift compensation strain

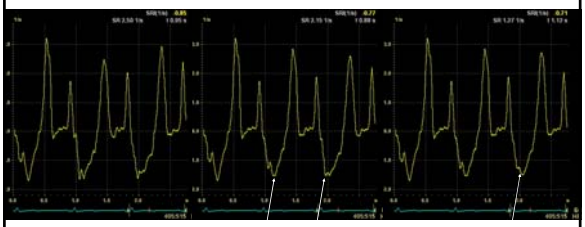


Drift compensation off

Linear compensation

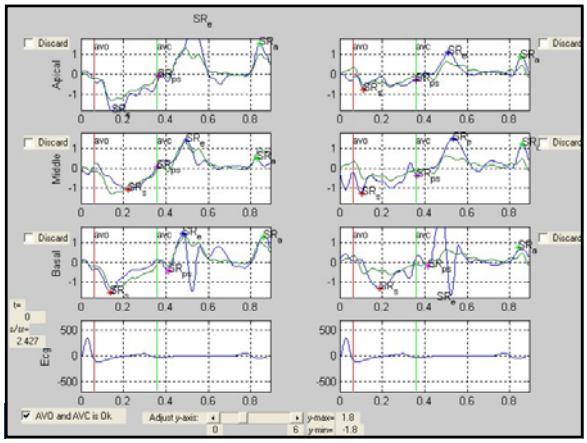
Reset at every cycle

Cine-compound



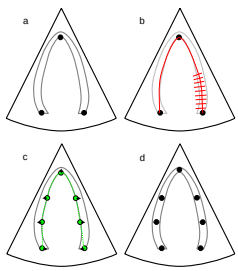
Average of 2 cycles
Cycle 1-2

Average of 3 cycles
Cycle 1-3



Automated analysis of strain and SR

- Landmark detection (a), endocardial detection (b-c) and segment border marker placement are automatic (d)
- After the segment border markers are placed, the locations can be manually adjusted
- Having determined the segment border markers in end-diastole, tracking can be used to find the location of the markers in all frames of the cardiac cycle



SA Aase

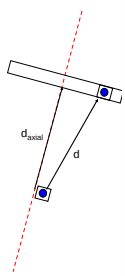
Automated analysis of strain and SR

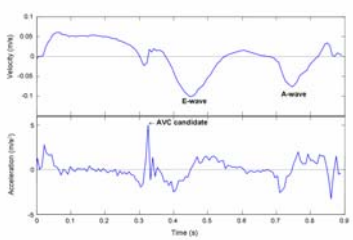
- Feasible, time-saving and more accurate than conventional wall motion scoring
- The automated methods define the region of interest and objective traces are obtained as there is no possibility of searching for a suitable curve.
- Feasibility is lower than for manual analysis
- Increase accuracy compared to wall motion score for dobutamine stress echocardiography and to be a stronger predictor for the prognosis of all cause mortality.

Combination of TDI and speckle tracking

- Axial tracking using TDI
- Lateral tracking using a sum of absolute differences (SAD) speckle tracking algorithm
- TDI tracking of a marker at a given frame consists of calculating the displacement (in axial direction) of that marker from the velocity at that location.
- B-mode intensity based speckle tracking is performed in the lateral direction

Combination of TDI and speckle tracking

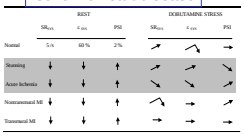




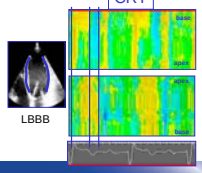
SA Aase

Applications

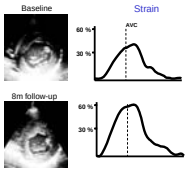
Ischemic heart disease



CRT



Therapy follow-up



- Valve disease
- Hypertension
- Cardiomyopathies

Courtesy: J. D'Hooge

Myocardial infarction sensitivity/specificity

Stoylen A, Heimdal A, Bjornstad K, Torp H, Skjaerpe T. Strain rate imaging by ultrasound in the diagnosis of regional dysfunction of the left ventricle. Echocardiography 1999 May; 16(4):321-9

Stoylen A, Heimdal A Bjornstad K, Wiseth R, Vik-Mo H, Torp H, Angelsen B, Skjærpe T. Strain rate imaging by ultrasound in the diagnosis of coronary artery disease. J Am Soc Echocardiogr 2000 Dec;13(12):1053-64

Voigt JU, Arnold MF, Karlsson M, Hubbert L, Kukulski T, Hatle L, Sutherland GR.Assessment of regional longitudinal myocardial strain rate derived from doppler myocardial imaging indexes in normal and infarcted myocardium.J Am Soc Echocardiogr. 2000 Jun;13(6):588-98

Edvardsen T, Gerber BL, Garot J, Bluemke DA, Lima JA, Smiseth OA. Quantitative assessment of intrinsic regional myocardial deformation by Doppler strain rate echocardiography in humans: validation against three-dimensional tagged magnetic resonance imaging. Circulation. 2002 Jul 2;106(1):50-6

Jamal F, Kukulski T, Sutherland GR, Weidemann F, D'hooge J, Bijnens B, Derumeaux G. Can changes in systolic longitudinal deformation quantify regional myocardial function after an acute infarction? An ultrasonic strain rate and strain study. J Am Soc Echocardiogr. 2002 Jul;15(7):723-30

Mele D, Pasanisi G, Heimdal A, Cittanti C, Guardigli G, Levine RA, Sutherland G, Ferrari R. Improved recognition of dysfunctioning myocardial segments by longitudinal strain rate versus velocity in patients with myocardial infarction.J Am Soc Echocardiogr. 2004 Apr;17(4):313-21

Myocardial infarction- recovery

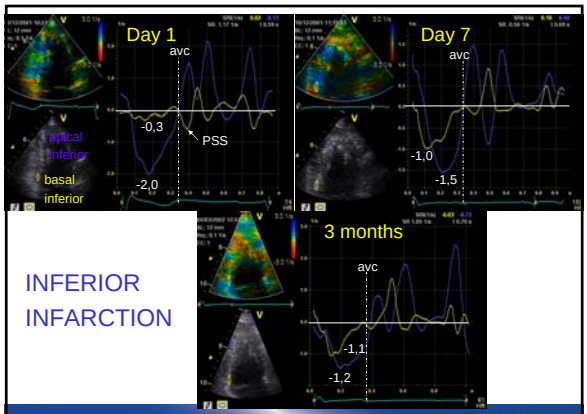
Strain rate imaging can quantify early contractility improvement due to stunning recovery after AMI

Peak systolic strain rate (SRs) in infarcted segments increased significantly from day 1 to 7, but not after day 7

Postsystolic shortening disappeared mainly between 7 days and 3 months, probably due to fibrosis and reduced elasticity

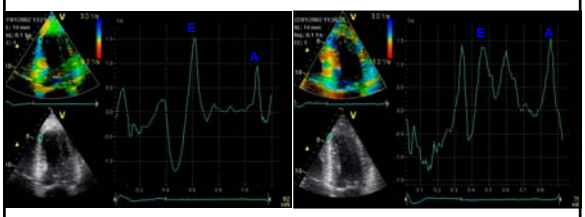
Diastolic function is relatively less reduced in the acute phase than systolic, but with no subsequent recovery

Ingul CB, Stoylen A, Slordahl SA,
J Am Soc Echocardiogr. 2005;18(5):401-10



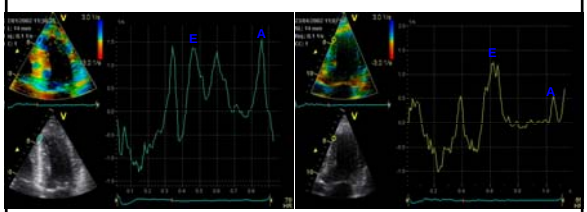
Apical infarction

Day 1 *Strain Rate* *Day 7*



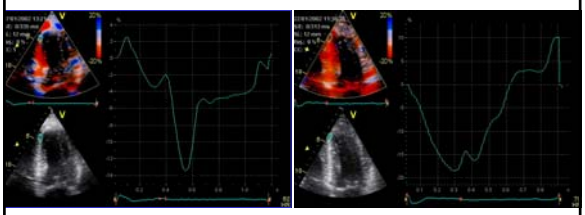
Apical infarction

Day 7 *Strain Rate* *3 Months*



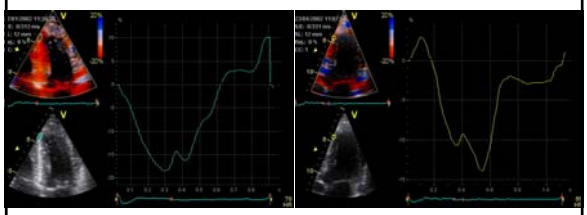
Apical infarction

Day 1 Strain Day 7



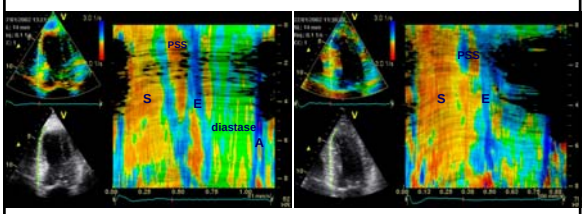
Apical infarction

Day 7 Strain 3 Months



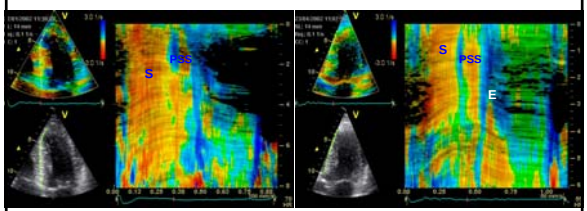
Apical infarction

Day 1 CAMM Day 7



Apical infarction

Day 7 CAMM 3 Months



SRI during dobutamine stressecho

Do we need SRI for interpretation of DSE

- The cardiac cycle is a complex motion
- Need to be an expert to interpret DSE by conventional WM
- So yes we need quantitative measurements as an adjunctive to WM
- Need to be an expert in SRI to be used in DSE?
- Basic understanding necessary because of pitfalls

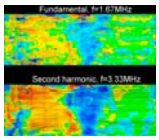
How to obtain good data

Before scanning optimize the following settings

- PRF
- Image- adjust sector width and depth, to cover only the left ventricle, frame rate above 100 for systole (higher for if IVC, diastole)
- Velocity, minimum 16 cm/s (aliasing)
- Protocol, 3 cineloops
- Second harmonic strain rate

During scanning

- Apical views optimize for best alignment, remember angle deviation, keep walls aligned with ultrasound beam
- Don't move probe during scanning



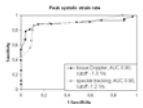
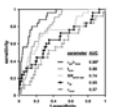
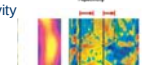
H.Torp

Pitfalls in SRI interpretation

- Low frame rate
  - May miss peaks
  - Averaging not possible
- Probe movement during scanning
  - Prevents cine compound *(average of 2-3 cardiac cycles)*
- Misaligned areas
  - To measure in a misaligned area you will pick up the wrong strain rate component
- Artifacts
  - Misinterpretation if not recognized
  - Reverberations common! Use CAMM to reveal them, change of color to opposite

Optimal parameter for stress induced ischemia, clinical studies

- Bjork Ingul Bjork Ingul et al European Heart Journal 2005; Vol.26(Abstract Supplement):230;
  SR_s, increased sensitivity compared to WMS (87 vs. 75%), AUC 0.90 (cut-off -1.3 s^{-1}) (n=197)
- Hanekom (European Heart Journal 2005;Vol.26 (Abstract Supplement):210);
  SR_s may improve specificity of DSE, AUC 0.78 (cut-off -0.95 s^{-1}) (n=207)
- Voigt (Circulation 2005);
  PSS strain index optimal parameter, AUC 0.90 (cutoff 35%, sens 82%, spec 85%)
  semi-quantitative by CAMM (strain rate) increased sensitivity (86 vs. 81%) and specificity (98 vs.82%)(n=44)

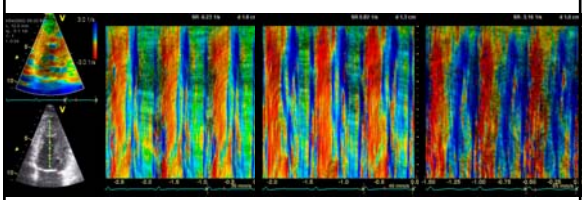
Strain rate and strain normal values

	Rest	Peak
Strain rate s^{-1}	-1.4 (0.4)	-2.6 (0.7)
Strain %	-18.4 (6.8)	-18.2 (8.4)

- 110 patients a normal response to DSE
- age >70, SBP >160, HR <140, use of beta-blocker therapy had significantly lower SRs However, beta-blockade was the only independent predictor of SRs
- a different normal range (-2.4 ± 0.7 s^{-1}) should be considered for patients on beta-blockers.

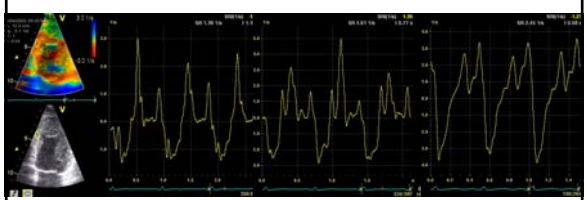
European Heart Journal 2005;Vol.26(Abstract Supplement):210

Normal response to DSE by SR CAMM



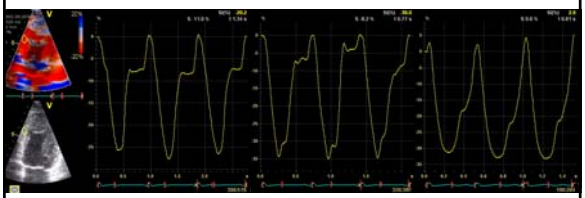
Baseline HR 64 Low-dose HR 87 Peak HR 110

Normal response to DSE by SR traces



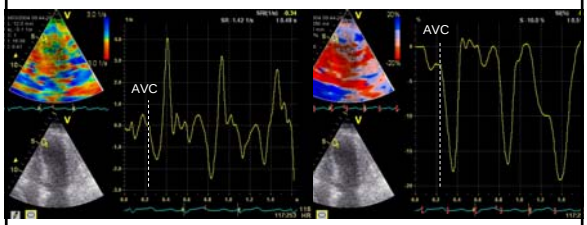
Baseline SR -1.2 s^{-1} Low-dose SR -2.5 s^{-1} Peak SR -3.5 s^{-1}

Normal response to DSE by strain traces



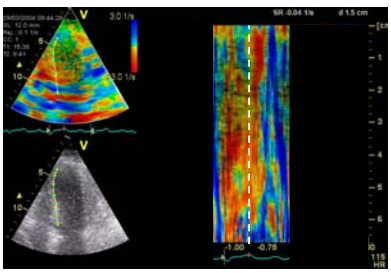
Baseline strain 26% Low-dose strain 35% Peak strain 32%

Apical ischemia, traces at peak



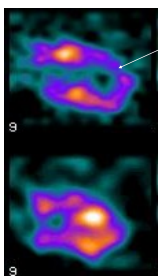
Strain rate Strain

CAMM SR septum

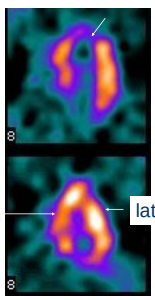


Vertical longaxis

Horisontal longaxis



stress
Tc-tetrofosmin myocardial perfusion scintigraphy reveals an apical perfusion defect



rest septum

2 ch

Støylen/Dahle

4 ch

Conclusion

- Use SRI in addition to WM, never without!
- Always CAMM (SR) of all walls in the three apical views
- Strain rate and strain traces where your WM is suspicious
- Clinical studies have shown SRI (SR_s, CAMM,PSI)
  - Increased sensitivity (ischemia)
  - Increased specificity (ischemia)
  - Increased sensitivity (viability)
  - Incremental value on prognostic information on mortality to WM