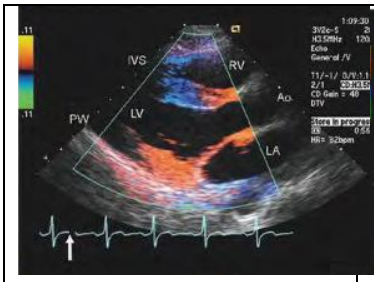
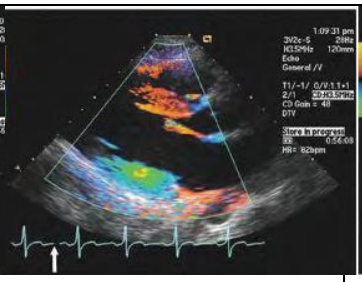
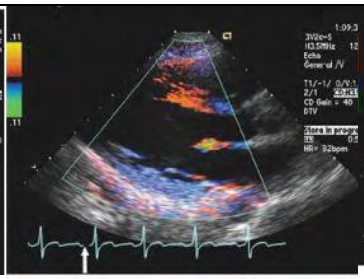
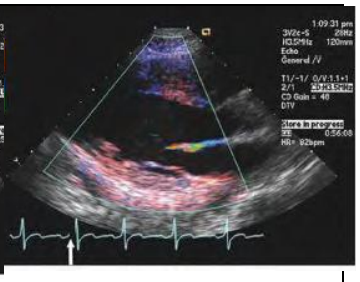
Tissue Doppler, Strain & Speckle Tracking

Tissue Doppler Imaging- is a **pulsed Doppler technique** that uses low pass filter to record the low-velocity/high-amplitude myocardial motion and remove the high-velocity/low-amplitude blood flow signals. TDI can play a significant role in the assessment of (1) LV function (systolic and diastolic), (2) myocardial ischaemia (segmental LV function), (3) distinguishing between constrictive pericarditis and restrictive cardiomyopathy, and (4) ventricular dyssynchrony for cardiac resynchronization therapy. The resulting signals can be displayed as colour Doppler images or as spectral PW Doppler traces.

Colour tissue Doppler - can appreciate the phasic change in colour coincident with myocardial contraction. In a parasternal long-axis view, because the anterior septum and posterior walls are moving together, they are colour encoded in opposite colours for normal motion.

			
At the end of mechanical systole: red colorization of the anterior moving posterior wall and blue colorization of the anterior septum indicating appropriate posterior motion.	In early diastole immediately after opening of the MV: red colorization of the anterior septum as it expands anteriorly and the bright green of the colorization of the posterior wall as it moves briskly in the opposite direction.	Immediately after onset of atrial systole revealing further active appropriate motion anteriorly of the ventricular septum and posterior motion of the posterior wall encoded in red and blue, respectively	At end-diastole when there is minimal motion, as manifest by the fainter colour signals.

Colour tissue Doppler M-mode- has shown some utility in describing the timing of wall motion abnormalities. In this modality, the change is tissue velocity is manifest by colour signals. For example, in the presence of a LBBB, clear alternation in blue-red colorization of the septum is seen due to multiphasic septal motion.

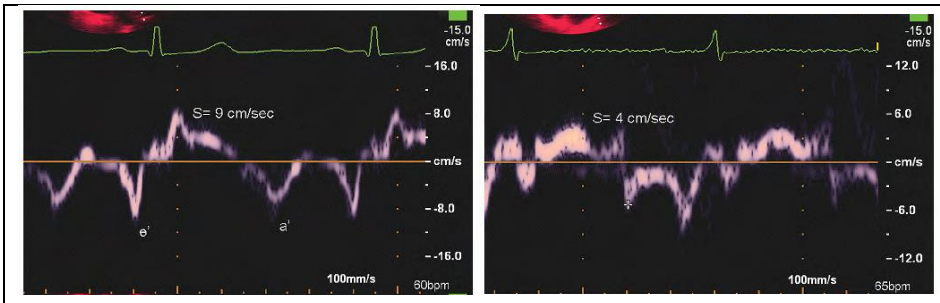
Spectral tissue Doppler (also called Myocardial Velocity Imaging, MVI) - provides quantitative information regarding tissue velocity. Adjust the colour scale to avoid aliasing and use small sector angle (i.e. small box size) to increase the frame rate (optimal > 115 fps). Adjust sample position, sample size, wall filter, and sweep speed. High-quality ECG required for optimal timings all apply for myocardial PW and colour Doppler analyses *(as for blood pool Doppler)*. Mitral annular velocity has three peaks in the longitudinal orientation (apical views):

- **A positive systolic peak s′** that reflects the movement of the base towards the apex in systole (a marker of global left ventricular systolic function in a uniformly contracting ventricle)
- **Two negative diastolic peaks: early e′ and late a′** that reflect the movement of the base away from the apex (play a major role in assessment of diastolic function).

The most useful velocity measurement is the peak velocity in early diastole (e′). The e′ velocity primarily depends on left ventricular relaxation and is relatively independent of preload. It is recommended that e′ and E/e′ be reported as the average of the septal and lateral values. The ratio of E/e' correlates well with LAP/ LVEPD/ PCWP and is normally < 8 at the septum and < 10 at the lateral wall, and > 15 indicates CCF.

Additionally, isovolumic contraction and relaxation periods can also be identified by TDI; however, isovolumic periods are best measured with conventional PW Doppler as myocardial movement does not necessarily correlate with valve opening and closure.

TDI measures tissue velocity in relation to the transducer rather than to adjacent myocardium; therefore it is limited by its inability to differentiate active myocardial contraction from the translational motion of the heart in the chest during the cardiac cycle and the tethering effects of adjacent myocardium.

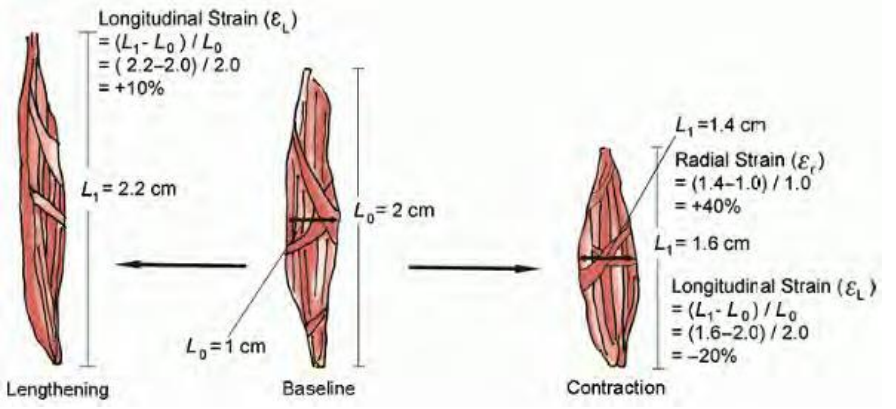


Doppler tissue imaging of the lateral annulus performed in two patients. The top panel was recorded in a patient with normal systolic function and an ejection fraction of 60%. Notice the S wave of 9 cm/sec. Also noted are the diastolic e′ and a′ velocities. The lower panel was recorded in a patient with a dilated cardiomyopathy and ejection fraction of 27%. Notice the annular systolic velocity of 4 cm/sec consistent with reduced global function.

Strain & Strain rate - allow evaluation of a myocardial region with reference to an adjacent myocardial segment rather than to a fixed transducer position. Initially strain and strain rate imaging became possible using tissue Doppler. More recently myocardial deformation imaging also become possible with myocardial speckle tracking using 2D echocardiography.

As scarred segments of myocardium can be tethered and moved along with adjacent viable myocardium, measuring velocity with tissue Doppler is not as accurate an assessment of regional function as strain rate imaging, because the latter measures actual deformation of myocardium that therefore represents actively contracting myocardium only.

Strain (deformation)- represents the change in length between two points and may be calculated in any of three orthogonal planes, representing longitudinal, circumferential, and radial contraction. Strain & strain rates can be displayed as spectral curves or a curved M-mode image.



Demonstration (strain) in a myocardial segment assuming a baseline longitudinal length 2 cm (L_0) and baseline radial length 1 cm (L_0).

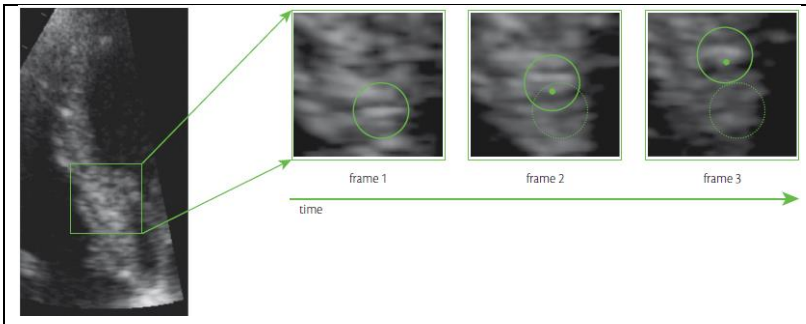
Systole (to the right)→ decreased longitudinal length (due to contraction of the myocardium) and increased radial length (due thickening of the myocardium) → negative longitudinal strain (εL) and positive radial strain (εR)

Diastole (to the left) → increased longitudinal length (due to relaxation of the myocardium) → positive longitudinal strain (εL)

Strain rate (rate of deformation)- represents the change in velocity between two adjacent points. Strain rate imaging is superior to TDI in evaluation of regional function as it measures actual deformation of myocardium that represents actively contracting myocardium only; whereas measuring tissue velocity by TDI is not accurate in differentiating actively contracting myocardium from a scarred segment that is tethered to adjacent viable myocardium and moves along with it.

Speckle tracking- with speckle tracking, the actual location of a discrete myocardial segment is calculated (rather than the velocity of an area of interest located in a fixed point in space). As such, the primary calculation is of tissue displacement, and if two points are simultaneously compared for their location, the primary parameter derived is strain rather than strain rate. With speckle tracking, strain rate can be derived from the original data by calculating the change in location over time (velocity) for two adjacent points. Speckle tracking is:

- Doppler independent (calculated using 2-D)
- Angle independent
- Grey scale (standard views)
- Monitor strain in two rather than one dimension
- Minimal user input
- Assessment of rotation: derived from circumferential strain at different levels in the heart (no fixed sample volume)



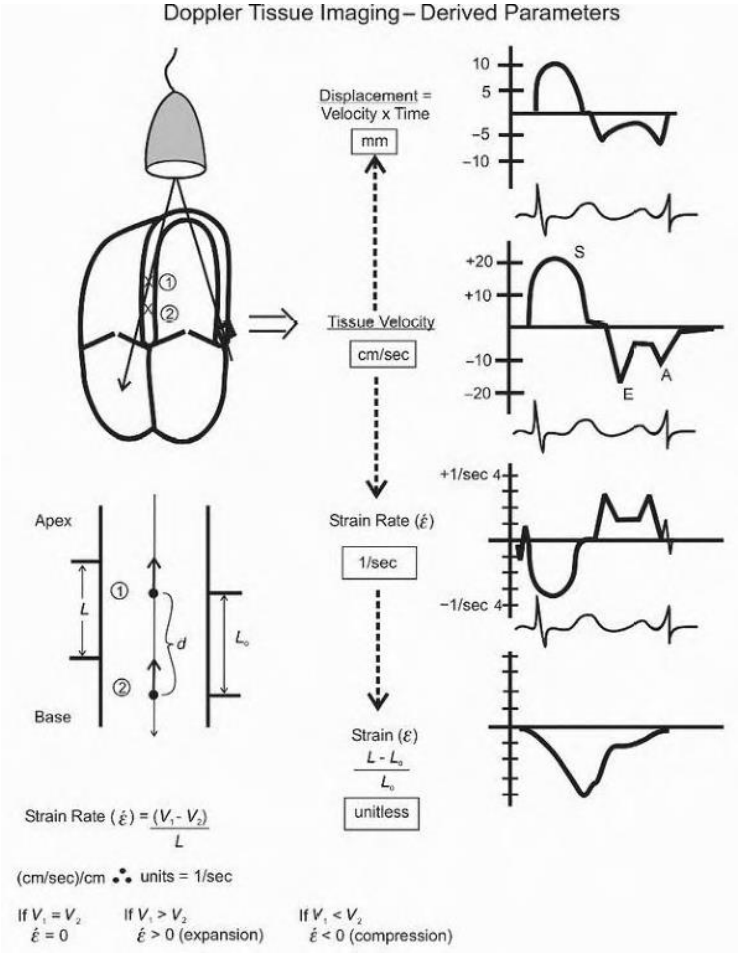
In speckle tracking, complex image analysis software identifies features of the image (i.e. bright speckles, as indicated by the green dot) and follows them over time from frame to frame. Analysing the displacement of several speckles over time allows to calculate motion, velocity, strain, and strain rate. Adjust frame rates since specific analysis software often requires specific frame rate settings (optimal 50–90 fps)

Optimization of speckle tracking—2D strain (rate) imaging:

1. Optimize gain settings and focus position
2. Centre the region of interest
3. Adjust depth and region of interest size for optimal spatial resolution (MV annulus at the bottom of the image for LV regional function analysis)
4. Adjust frame rates since specific analysis software often requires specific frame rate settings (optimal 50–90 fps). We have to find a trade-off between high frame rate and good lateral resolution. **Remember**: optimal frame rate for MVI is 115 fps.
5. High-quality ECG required for automated tracking
6. A careful visual verification of the tracking result is always mandatory. Segments in which tracking lines do not follow the myocardium must be excluded from further analysis.

Spectral curves derived from strain & strain rate- 4 basic parameters are extracted:

- Velocity
- Motion (displacement)
- Strain rate (rate of deformation)
- Strain (deformation)



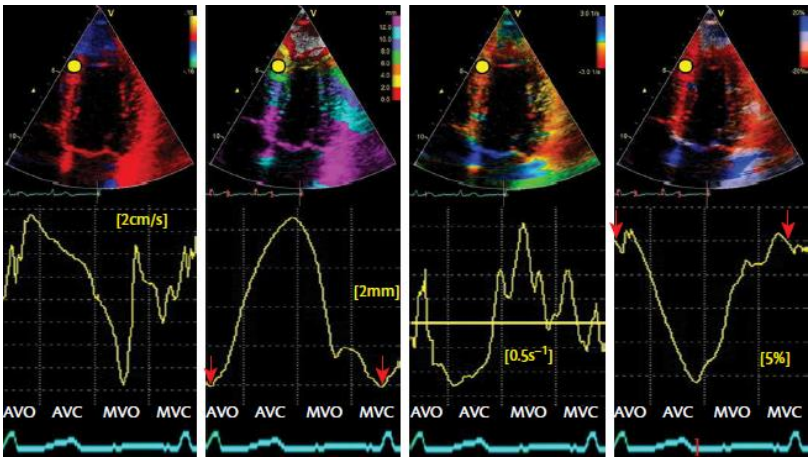
The relationship of strain and strain rate to the initial Doppler tissue velocities:

Myocardial velocity is the initial raw data in DTI.

Strain rate (change in velocity) between 2 points is the primary parameter (calculated by integrating the velocity over time)

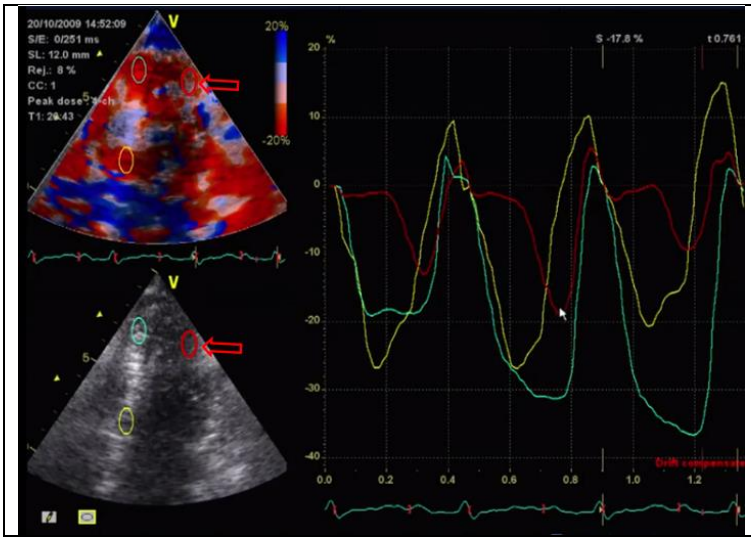
Strain (change in distance) is, therefore, the derived variable.

Notice that normal contraction is defined by negative longitudinal systolic strain followed by biphasic diastolic strain related to early and late diastolic filling, respectively. Normal radial strain, reflecting wall thickening is positive in systole.

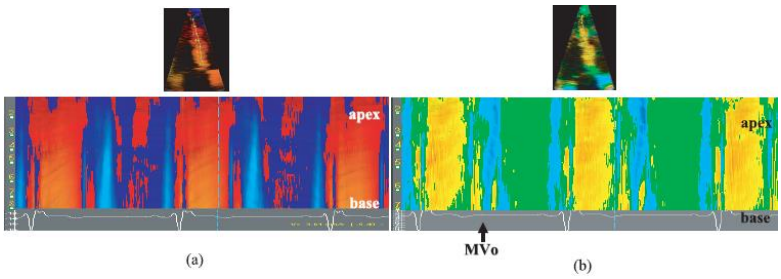
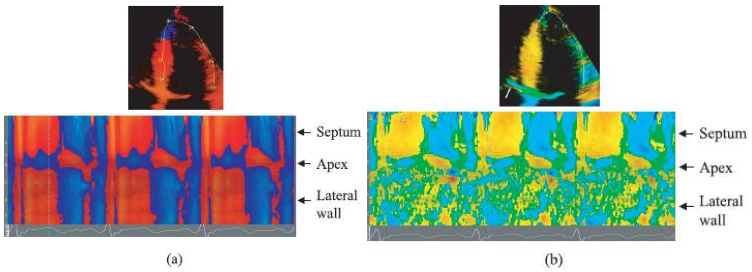


Velocity (A), **motion** (B), **strain rate** (C), and **strain** (D) images with typical septal curves (yellow dot).

Since cardiac function is cyclic, the definition of baseline in motion and strain curves is arbitrary. In most applications, zero is defined at end-diastole, usually derived from the ECG trigger signal (red arrows)

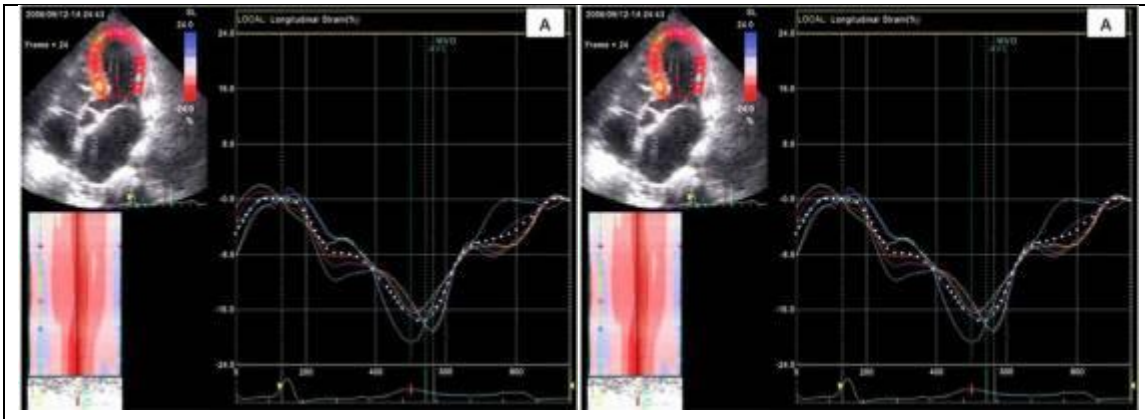
	Abnormal strain curve in apical anterolateral segment (red curve) shows very limited shortening during systole, but there is post-systolic shortening indicating myocardial ischemia.

Curved M-mode images derived from strain & strain rate

	**A curved M-mode image** can be constructed to represent the velocity or strain rate profiles of several segments within the myocardial wall simultaneously,. Therefore, the velocity or strain rate information of all points along a manually indicated curved line within the image is colour-coded and shown as a function of time. The vertical axis indicates different points in the septum while the horizontal axis represents time. Notice the synchronous nature of the velocity and strain rate changes throughout the septal wall in this normal volunteer.
	**A curved M-mode velocity (a) and strain rate (b) image of a patient with severe lateral wall ischaemia**. The abnormal strain rate profile within this wall is obvious. However, the velocity information does not resolve the abnormal regional function.

Global longitudinal strain (GLS)

- The most commonly used strain-based measure of LV global systolic function
- Obtained often with speckle tracking, less frequently with Doppler tissue imaging (DTI)
- GLS is the relative length change of the LV myocardium between end-diastole and end-systole
- GLS measurements obtained in the three standard apical views should be averaged
- GLS calculation can be obtained using endocardial, mid-wall, or average deformation
- Most of data come from mid-wall GLS, which is reproducible and robust
- In a healthy person, a peak GLS around −20% can be expected (*this represents the percentage of overall muscle shortening during contraction, it is negative due to the direction of the shortening away from the transducer*)
- GLS decreases with age and is slightly higher in women



Global longitudinal strain (dotted white curve) and **regional longitudinal strain curves** (distinctively coloured curves for 6 left ventricular wall segments) obtained from apical 4-chamber views by speckle-tracking 2D-strain imaging in a patient with Takotsubo cardiomyopathy. Although during catecholamine induced severe LV dysfunction with apical ballooning **(A)** the apex appeared nearly akinetic (no visible relevant inward movement) the longitudinal strain curves showed the same uniform longitudinal shortening as after recovery **(B)**, when also visually no regional wall motions were detectable. Thus, the visual analysis of inward movement used in conventional echocardiographic examinations can be misleading in the evaluation of regional myocardial contraction because it can not exclude the existence of longitudinal shortening (not visible with the naked eye) in the apparently akinetic region.