GE Healthcare

GE quantitative analysis for left ventricular function

GE quantitative analysis overview

Echocardiography traditionally has been all about the image – a fast moving image. From this image, the experienced eye may be able to identify irregularities in myocardial motion and left ventricular (LV) function. This, coupled with its non-invasive nature, has made echocardiography one of the leading diagnostic imaging techniques.

New generation ultrasound scanners generate images of several hundred frames per second, which is beyond the perception of even the most experienced eye. This created the need for a more precise quantitative assessment tool for LV function, called QScan.

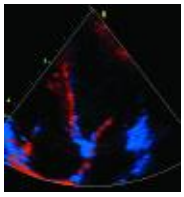
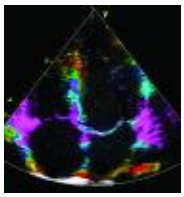
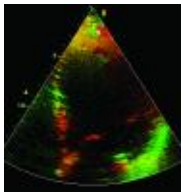
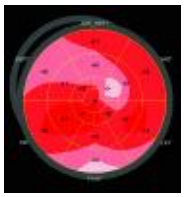
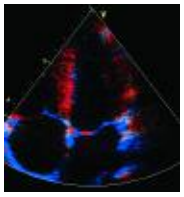
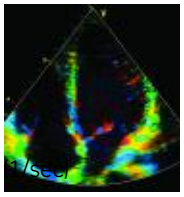
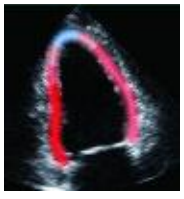
The first QScan tool, Anatomical M-Mode, was introduced in the early 1990s to derive quantitative information from high-frame-rate, raw-data images.

In 1995, QScan technology was applied to Tissue Velocity Imaging (TVI). TVI derives velocity traces and anatomical and curved Anatomical M-Mode information, which initiated new clinical applications.

Building on QScan technology, GE introduced Tissue Tracking for assessment of longitudinal displacement. Strain and Strain Rate Imaging was also introduced with clinical applications for regional assessment of LV function. The Vivid™ 7 Vantage release introduced another new quantitative QScan tool (TSI) developed to support cardiac resynchronization therapy (CRT).

In 2004, on the Vivid 7 Dimension release, GE introduced 2D Strain, a unique, advanced research tool that leverages its leadership in quantitative echocardiography and includes the latest breakthroughs in Strain and Strain Rate Imaging.

GE quantitative assessment tools for LV function

Mode	Parametric image	Measurement	Clinical application
TVI Tissue Velocity Imaging	 **Speed**	Measures longitudinal myocardial velocities (cm/sec)	Assess global and regional systolic function; assess left ventricular relaxation abnormalities
TT Tissue Tracking	 **Distance**	Integrates TVI over time to yield longitudinal wall displacement (mm)	Easy recognition of regional and global left ventricular wall motion abnormalities
TSI Tissue Synchronization Imaging	 **Synchrony**	Color-coded, time-to-peak velocity (ms)	Unique tool to assess asynchrony in the left heart, manage heart failure patients and those patients undergoing CRT
AFI Automated Function Imaging	 **Deformation**	Regional and global peak longitudinal strain (%)	Assessment of left ventricular function at rest
S Strain	 **Deformation**	Measures regional longitudinal deformation (%)	Evaluates ischemic heart disease; true analysis of a specific piece of the myocardium
SRI Strain Rate Imaging	 **Speed of deformation**	Measures regional myocardial compression speed (deformation rate) piece of the myocardium	Evaluates ischemic heart disease; true analysis of a specific
2Ds 2D Strain	 **Deformation**	Advanced research tool based on 2D speckle tracking	Evaluation of longitudinal, radial and circumferential myocardial deformation/strain

Tissue Velocity Imaging

Tissue Velocity Imaging (TVI) uses myocardial Doppler frequency shifts to quantify myocardial tissue motion. TVI can be used to assess global and regional systolic function, as well as left ventricle relaxation abnormalities. The advantage of TVI is that it is based on the Doppler-shifted part of the reflected signal. This gives the clinician a tool to assess myocardial function, even though the two-dimensional image quality may be sub-optimal. Just as with conventional Doppler, TVI can be displayed as pulsed Doppler (Figure 1), color Doppler (Figure 2) and color M-Mode (Figure 3).

GE allows access to raw data, which gives you the ability to quantify TVI live or at a future time by simply storing a 2D color TVI image. You can then go into Q-Analysis and acquire TVI waveforms (Figure 4). You can also convert the TVI information from the raw data to display Tissue Tracking, Tissue Synchronization Imaging, Strain or Strain Rate Imaging.

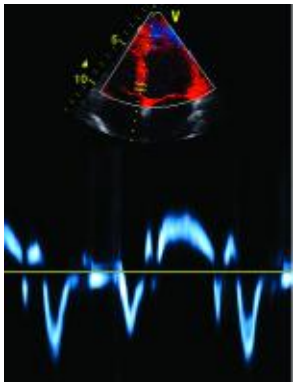


Figure 1. Pulse Wave TVI

Normal spectral wave displays a positive wave in systole and a negative wave in diastole, representing early filling and atrial filling.

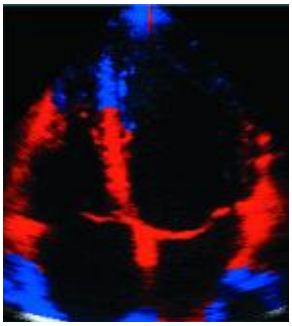


Figure 2. Color TVI

Red color displays motion toward the probe. Blue color displays motion away from probe.

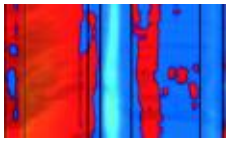


Figure 3. TVI M-Mode

Red color in systole displays tissue motion toward the probe, while blue in diastole displays motion away.

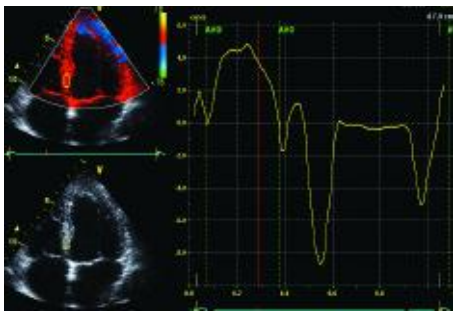


Figure 4. TVI Waveforms

Waveforms may be extracted at any time from color TVI loops in the quantitative analysis mode on Vivid 7 or EchoPAC.

Tissue Tracking

Tissue Tracking displays systolic longitudinal displacement by integrating tissue velocity over time. Tissue Tracking is displayed as a color band representing motion during systole. The system color codes each point in the myocardium with the displacement occurring from end diastole to end systole (see Figure 5).

Tissue Tracking is performed from the apical views. A normal left ventricle will display the lowest motion at the apex, while the mitral annulus will display the greatest motion. Systolic mitral annular displacement, determined by tissue tracking, correlates closely with left ventricular ejection fraction.[2]

Figure 5. Tissue Tracking

Tissue Tracking represents myocardial motion or distance during systole. The motion is displayed as a color band representing distance in mm.

Tissue Synchronization Imaging

Tissue Synchronization Imaging (TSI) is a parametric imaging tool based on Tissue Velocity Imaging that provides clinicians with additional image enhancement for assessing delayed cardiac wall motion.

The TSI parametric image analyzes the tissue velocity signals within the image to determine the peak velocities within a specified portion of the cardiac cycle. Since these peaks will occur in relation to overall motion, delayed wall motion will produce a delayed peak velocity.

The amount of delay within the defined area of the cardiac cycle is used to assign or map a color to that location in the image. With TSI, the color represents the amount of tissue motion delay rather than the absolute value of the tissue velocity. When this technique is applied in real time across the 2D image, the variation in color provides both a qualitative and quantitative representation of wall motion delay, allowing a trained physician to readily identify and evaluate asynchronous wall motion (see Figures 6 and 7).

For more information on quantitative TSI, refer to the "Advanced TSI for Quantitative Analysis white paper" available at www.gehealthcare.com.

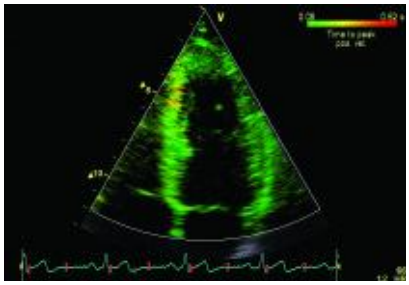


Figure 6. Early Systole

Regions reaching peak velocity in early systole are marked in green.

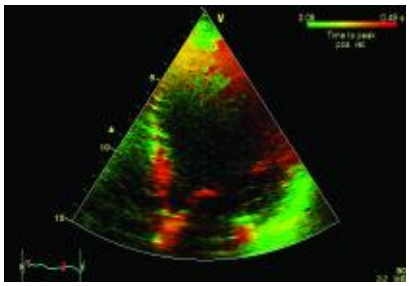


Figure 7. Late Systole/Diastole

Regions reaching peak velocity in late systole or in diastole are marked red.

Synchrony

- Regions reaching peak velocity at the same time
- Regions with the same color

Asynchrony

- Regions reaching peak velocity at different times
- Regions with different colors

Strain and Strain Rate Imaging

Strain Imaging provides regional detection of myocardial contraction. It enables clinicians to determine velocity gradients along the ultrasound beam, thereby helping users analyze tissue contraction and regional myocardial function.

Strain and Strain Rate Imaging have been used by a number of researchers to evaluate ischemic heart disease. Strain Imaging measures percent of regional deformation of the myocardium, while Strain Rate Imaging measures the speed of deformation (see Figures 8 and 9).

The majority of strain rate changes are too fast to be detected by the human eye in real time. With the application of post-processing tools, the comparison of strain or strain rate traces from different myocardial regions allows detailed insight into regional mechanical function. As an added benefit, the analysis of strain and strain rate information is minimally affected by motion or tethering effects of the heart.

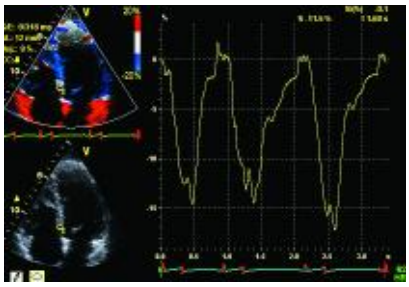


Figure 8. Strain Imaging

Strain Imaging measures change in shape.

$$S = \frac{l - l_0}{l_0} = \frac{\Delta l}{l_0}$$

Figure 8 Strain (S) can be defined as shown, where l is instantaneous length, l_0 is original length, and Δl is change in length.

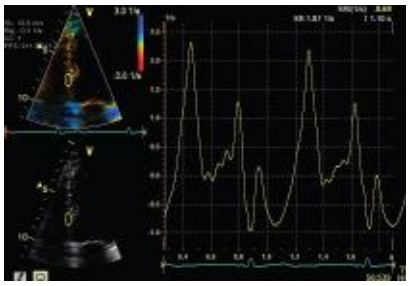


Figure 9. Strain Rate Imaging

Strain Rate Imaging measures how fast the change occurred.

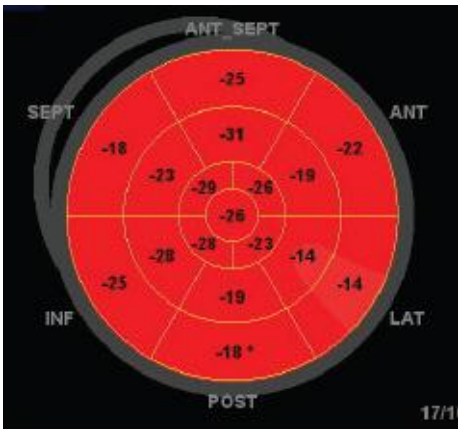
$$SR = \frac{v_a - v_b}{d}$$

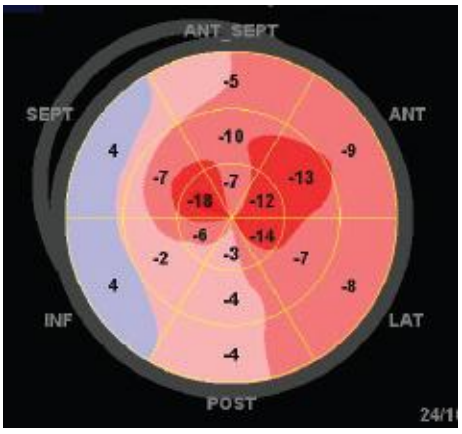
Figure 9 Strain Rate (SR) can be estimated from spatial velocity (v) gradient, where $v_a - v_b$ represents difference in instantaneous myocardial v_a and v_b at points a and b. Distance d represents difference in instantaneous myocardial v points at specific time.

Automated Function Imaging (AFI)

AFI is a semi-automated measurement tool that displays peak longitudinal systolic strain in a bull's-eye display, along with segmental strain values and global peak strain. AFI is a clinical decision support tool for assessing left ventricular function at rest. The measurement is performed from three apical views that are part of your normal protocol, so it is easily incorporated into your routine workflow.

Like in 2D Strain, AFI analyzes myocardial motion by tracking features (natural acoustic tags) in the ultrasound image in two dimensions. The AFI algorithm estimates the percent of wall lengthening and shortening in a set of three longitudinal 2D image planes, APLAX, A4CH and A2CH. It then combines the results of all three planes in a single bull's-eye summary.





Color Bar Explanation

Shortening or negative strain is displayed as red. The higher the percent of shortening the darker the shade of red.

Lengthening or positive strain is displayed as blue. Again, the higher the value, the darker the shade.

2D Strain

2D Strain, an advanced research tool, is a unique imaging mode that allows analysis of the complete myocardial motion throughout the entire heart cycle. Similar in concept to MRI tagging, 2D Strain analyzes motion by tracking features (natural acoustic tags) in the two-dimensional image.

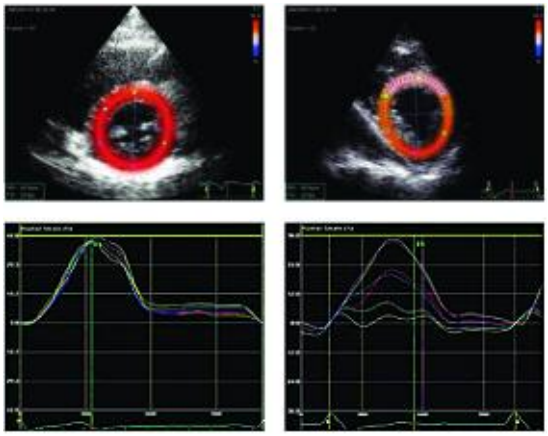
2D Strain is also a natural extension of one-dimensional analysis, which is based on Doppler techniques. Similar to one-dimensional Doppler, myocardial motion is characterized in terms of tissue velocity and tissue deformation parameters, such as strain and strain rate. One of the main advantages of this technique is that it allows the Region of Interest (ROI) to be automatically tracked in the myocardium.

2D Strain is less angle dependent than Doppler-based only techniques. The 2D strain package also offers a torsion calculation tool. After processing the parasternal short-axis view at the mitral valve level (SAX-MV) and the parasternal view at the apical level (SAX-AP), the torsion button will be available.

For more information on 2D Strain, refer to GE Healthcare's "2D Strain white paper" available at www.gehealthcare.com.

Additional educational tools and white papers on TVI, TSI, and Strain are also available at www.gehealthcare.com:

- The Role of Tissue Synchronization Imaging in Cardiac Resynchronization Therapy
- Case Study Review for the Assessment of LV Function-TVI
- Strain Imaging
- Tissue Synchronization Imaging (TSI) in Clinical Practice white paper
- Advanced TSI for Quantitative Analysis white paper
- Introducing 2D Strain: Tagged Echocardiography white paper
- Automated Function Imaging (AFI) white paper



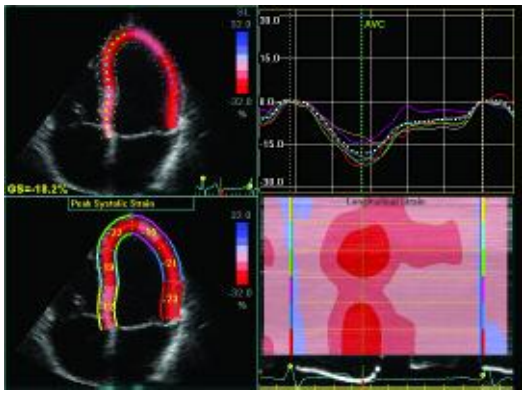
Normal

a) Parametric image
b) Traces

Pathologic

a) Parametric image
b) Traces

Peak radial strain values are low, especially in the anterior part.



Normal longitudinal strain displayed in quad format, and curved anatomical M-Mode.

Not all features may be available in your current software package. Please consult your sales representative to inquire about additional features for your Vivid 7 Dimension or your EchoPAC.