Whitepaper

eSie VVI

Velocity Vector Imaging Technology

2D Speckle Tracking

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1. Introduction

Ultrasound-derived myocardial strain information is gaining clinical acceptance for diagnostic as well as prognostic reasons. Siemens Healthineers eSie VVI velocity vector imaging technology is a clinical application designed to provide visual as well as quantitative assessment of cardiac dynamics on the ACUSON SC2000 PRIME ultrasound system. A previous version of this application is also available on the ACUSON X700 ultrasound system and ACUSON S Family systems. From 2D clips, eSie VVI technology utilizes B-mode speckle information to analyze tissue motion throughout the cardiac cycle(s). Deformation and kinematic parameters are derived from tissue motion and displayed qualitatively and quantitatively. With this information, physicians can reliably evaluate and manage their patients' cardiac health.

Why Velocity Vector Imaging – 2D Speckle Analysis
Cardiologists strive to assess a patient's cardiovascular health using all clinically available tools. Historically, the only imaging modality available was static images of the heart provided by chest X-rays, which allowed measurement of the heart's size. Function was an indirect assumption based on the visual appearance of the heart. Today, physicians have imaging techniques that not only provide size but also detailed anatomy, including function and flow. These techniques include ultrasound, computed tomography (CT), and cardiac MRI. Information from different modalities have recently been utilized to complete clinical diagnoses, but they still have one inherent limitation – the techniques are all qualitative mired with interpretation variability.

Clinical studies have proven that visual inspection of patients' echocardiography images are insufficient to consistently and accurately assess the heart for wall motion abnormalities. The addition of advanced imaging and testing methods, such as Doppler tissue imaging and stress echo, developed to enhance the visual inspection improved the qualitative analysis, but were still subjective and prone to misdiagnosis. Quantitative, objective and reproducible methods were still missing.

Multiple image-based quantitative wall motion analysis methods are now available. Numerous research papers have been published touting the usefulness of Doppler-based tissue imaging in quantifying wall motion analysis. This method is, however, dependent on transducer placement and only measures velocity in directions toward and away from the transducer. Tissue Doppler Analysis still lacks wide clinical acceptance due to its many technical limitations. Doppler information is limited by its angle of acquisition, requiring proper alignment of the ultrasound beams with the myocardial wall. The clinical applications developed to extract the kinematic motion from the images is also time-consuming. This restricts the information that can be derived from the analysis. eSie VVI technology breaks through these limitations and provides multi-directional quantification of wall motion.

eSie VVI technology measures cardiac motion of the entire myocardial wall from standard 2D imaging clips. It tracks change in tissue position based on speckle pattern from sequential image frames acquired from any imaging window or transducer. Once subjectively assessed subtle and obvious wall motion abnormalities can now easily be measured, allowing for an objective diagnosis of both clinical and pre-clinical conditions providing the opportunity to evaluate progression of disease and its treatment quantitatively.

eSie VVI technology provides quantitative global and regional wall motion analyses of the heart providing strain, strain rate, displacement, and velocity parameters. In addition, when left ventricular endocardial borders are tracked, end-diastolic, end-systolic volume and ejection fraction are provided.

2. Technology

eSie VVI technology achieves robust wall motion analysis by utilizing advanced speckle tracking methods. From an initial contour, defined by the user, eSie VVI technology tracks the endocardium, epicardium or a user defined contour. Motion analysis is extracted and displayed in graphical and text form allowing for both qualitative and quantitative review. Velocity vectors (hence the name of the application) are overlaid on the tracked contour providing a graphical display for all parameters provided. Summarized parameters as well as a bullseye display are all available for the user to best interpret the analysis results.

Imaging

Accurate results are achieved with good image-quality data. This is accomplished by utilizing the optimum imaging frequency and gain settings for each patient scanned. Imaging artifacts such as rib artifacts, image drop-outs or suboptimal system settings with gains set too low or too high reduce analysis accuracy and can result in underestimated strain values. It is critical to minimize these whenever possible and always set the system gains to visualize anatomy without inducing noise.

Acquisition

The best analysis results are achieved by acquiring B-mode clips at frame rates equal to or greater than 40 Hz with the number of images within a cardiac cycle at no less than 15 (see Figure 1). Although often misunderstood, this principle is key. Clips can be acquired as movie captures or cine data acoustic captures. System acquisition settings should be set to acquire all imaging frames and not limited to 30 Hz, which can result in peak strain underestimation. Acquiring B-mode clips at these settings, will result in slightly larger-sized clips but increased accuracy.

Acquisition Tips

- An accurate strain analysis is dependent on ECG and the QRS complex. Always try to have the best quality possible.
- Acquire images on axis as it is important not to foreshorten apical views. This will result in overestimation of peak values and incorrect diagnosis.
- Position the patient in left lateral decubitus position to find the optimal window. Use a breath hold technique when needed to get the best image.
- Select a depth and sector size (2D ROI) to include only the desired anatomy.
- To increase the frame rate, narrow the B-mode sector to include the region of interest and adjust the depth (to make the image bigger).
- After processing, check and readjust the contours. If the segments are not tracked well, exclude them from the analysis results by de-selecting the segments on the LV graphic and capture an image to record the results.
- Clips can be acquired as 60 Hz DICOM clips or acoustic clip captures.
- eSie VVI analysis cannot be performed on color Doppler clips or secondary reference clips from volume imaging.
- eSie VVI analysis should also not be performed on clips acquired for perfusion contrast imaging as these result in varying speckle brightness throughout the cardiac cycle. This does not apply to LVO studies and GLS method of line analysis.

Optimization

Always optimize the image to obtain the best image quality possible by utilizing the right transducer for the patient. It's important to match the frequency to the patient being imaged. Always strive for the highest resolution without losing penetration.

Tips

- Narrowing the B-mode sector to include the region of interest provides a higher frame rate, but also provides the highest line density.
- If RES is available, it can be useful in providing higher spatial resolution.

	Effective frames per cycle at corresponding heart rates		
Frame per Cycle	30 bpm	60 bpm	120 bpm
30 fps	30	30	15
60 fps	60	60	30
90 fps	90	90	45

Figure 1: Effective frames per cycle at corresponding heart rates and acquisition frame rates

Frame rates ranging from 40 to 80 Hz can be used to measure motion and deformation at normal heart rates. When performing speckle tracking analysis, the frame rate is not as important as the frames per cycle (FPC) or number of images in an R-R interval. As mechanical events become shorter with an increasing heart rate, the frame rate needed to resolve a particular physiological event becomes higher. Therefore, the frame rate should be increased with the increase in heart rate, especially for pediatric studies, exercise, and pharmacological stress exams with agents (e. g. Dobutamine), which increase the heart rate. Frames per cycle (FPC) are intrinsically connected with overall tracking quality, with > 30 FPC being adequate for assessment of GCS and GLS. FPC is the number of images in an R-R interval. For instance, if a patient has a HR of 60 bpm (1 second for 1 heart cycle), and the imaging is at 60 fps, the result is approximately 30 frames in the R-R interval (1 frame every 15 ms).

Rösner et al. (E. Heart J. – Cardiovascular Img. 2015) provided an eloquent analysis of this relationship and its impact on speckle tracking results. In order to capture the peak contraction of the heart, it is important to always include enough imaging frames during the heart's systolic motion when it moves at higher speeds. In their analysis, Roesner found that 15 frames in an R-R interval was the minimum number of frames required to safeguard underestimated strain values. The minimum frame rate limit was approximately 40 for a heart rate of 60 bpm.

Tracking

eSie VVI technology extracts cardiac motion estimates by tracking a user-defined contour, which is typically drawn along the endocardium. Equidistant points are positioned along the contour, which is tracked for one or more cardiac cycles. Robust estimates of the cardiac motion are then provided for each point along the contour, and points within a segment are then averaged. The individual steps are explained in greater detail below.

First, the user defines a contour on the endocardium in an apical view, in which the anatomy is best seen (Figure 2). The contour is used to identify the initial region of interest to be tracked or followed from frame to frame. This is generally from end diastole to end diastole or peak of the R to peak of the next R.

Because the ventricle shortens (from base to apex) when it contracts, the position of the points along the trace are adjusted during the cardiac cycle. The locations of the contour end points are propagated to the other frames by maximizing the local correlation of the point location on adjoining frames. For example, points halfway up each wall are adjusted to move with half of the motion of the mitral annulus. This maintains the topological shape of the trace throughout the cardiac cycle. This is also known as regularization.

At each stage of the tracking, Fourier analysis is used and a drift compensation constraint is applied so that the trace returns to baseline for the subsequent cardiac cycle.

A confidence measure based on the uncertainty of the results based on the imaging frame rate and the image pixel size (transducer-dependent) is provided to help assess how good or reliable an analysis can be. Assuming all imaging conditions are perfect, there is a minimum uncertainty of displacement of one pixel because it's not possible to see below that resolution: the minimum possible visualized displacement that can be seen between two frames is about one pixel. In addition, the uncertainty of small displacement also occurs at high frame rates since very small displacement differences between two frames cannot be visually appreciated. In general, any velocity value has, in principle, a confidence band. The accuracy measure can be computed as follows:

Accuracy = 0.5*pixel size/frame time interval (ms)
dV = ± 0.5*pixel size 27 (mm)/15 ms frame time interval

In the example above this band is confidence dV (displacement Velocity) = 0.5*0.0272/0.0158 = 0.86 cm/s

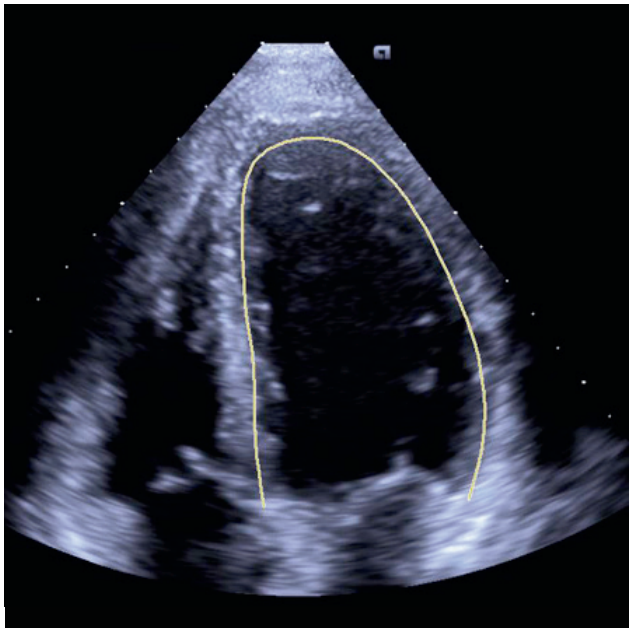


Figure 2: Tracking of the reference plane

3. Performing an Analysis

Selecting Data to Analyze

A good analysis always begins with high-quality images. Homogeneous speckle brightness throughout the image depth and image sequence improves tracking results. This can be achieved by using the highest imaging frequency to achieve maximum imaging penetration for each individual patient. Native TEQ ultrasound technology and IN Focus technology on the ACUSON SC2000 system are imaging optimization tools that can be used to achieve these imaging requirements. Gain and depth compensated (DGC) settings should also be set to provide good penetration and structure definition without over-gaining which creates noise in the image. Noise is speckle tracking's worst enemy and can play havoc on results. 2D speckle tracking algorithms cannot differentiate between structure speckle or noise, and will track both.

Images from technically-difficult exams can be analyzed with eSie VVI technology, but increased noise levels tend to underestimate strain and increase uncertainty.

It is also important that the whole ventricle or area of interest be in the field of view for the whole heart cycle during the acquisition. A full R-to-R interval is required as the algorithm takes advantage of the periodicity of the cardiac motion.

The analysis can be performed from images acquired from all Siemens B-mode clips. This includes standard transthoracic transducers, transesophageal transducers, the ACUSON AcuNav ultrasound catheter family, all vascular transducers as well as curved arrays utilized for fetal echo examinations. eSie VVI technology analysis can be retrospectively done on previously collected clinical images documenting patient progression.

eSie VVI technology can analyze any vendor's data as long as it is stored in a DICOM format.

Imaging artifacts such as breathing, rib noise, and translation motion should be kept to a minimum. Again, the algorithm cannot differentiate artifact from anatomical speckles, and this can introduce uncertainties in the tracking results.

eSie VVI technology cannot be performed on color Doppler clips or secondary reference clips from volume imaging. eSie VVI technology also should not be performed on clips acquired with imaging contrast agents as these have varying speckle brightness throughout the cardiac cycle, which can impact tracking.

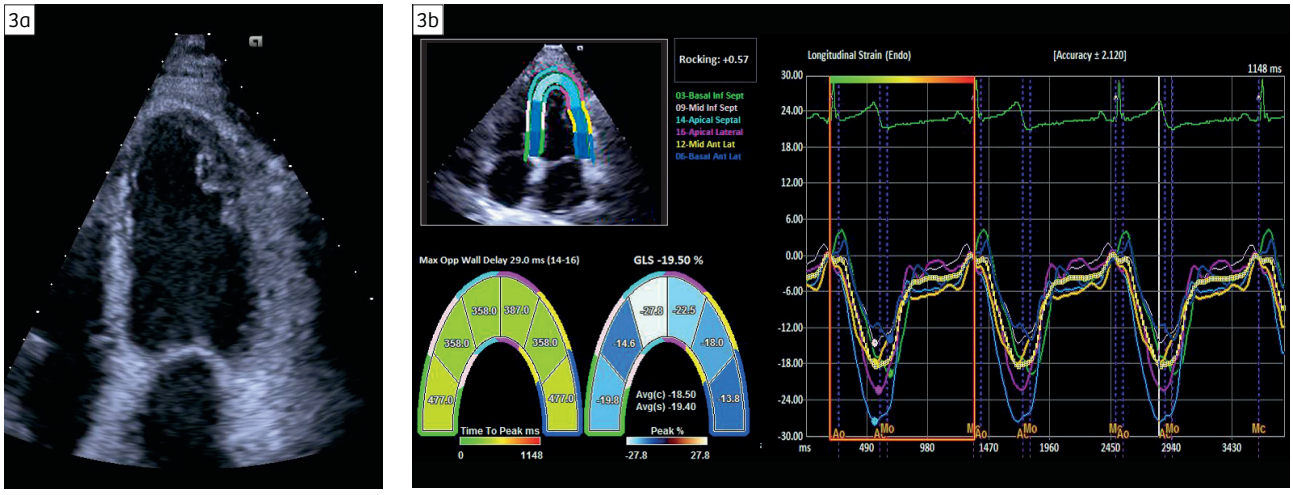


Figure 3a: Represents ideal image quality without imaging artifacts where overall gain and depth compensated (DGC) gains have been ideally optimized.

Figure 3b: Should not be used for 2D speckle analysis as the anterior wall is not visualized. There would be high uncertainty when drawing the contour, which would result in poor tracking and inaccurate strain analysis.

4. How to analyze a clip

Setup

Clips with and without physio information can be analyzed with eSie VVI technology. Clips with physio data will load in the "Contour" step. A clip without physio information will load in the "Setup" step. The user should identify the R-wave frame that corresponds to the end-diastolic frames as closely as possible. The user will also need to mark an imaging frame as the end of the cardiac cycle. In order to allow tracking, a clip must have a minimum of two ED frames for one heart cycle. Left clicking on the M-mode strip to the right of the frame indicator will set an ED/R-wave marker (Figure 4).

eSie VVI technology allows the user to modify incorrect physio R-wave information. Clicking on an existing marker will delete an ED/R-wave detection. Users can then proceed to set new ED markers to identify the start or end of the heart cycle (Figure 5).

eSie VVI technology's flexibility allows users to exclude frames or heart cycles to be tracked. Users can exclude frames by clicking and dragging the red bars on each end of the physio strip display to the desired frames.

In addition, users can also add a free-form M-mode. This provides qualitative wall motion information that should match the resulting curves. The user constructs an arbitrary-shaped line through the heart wall and/or valves, and an associated M-mode image is created, which will be displayed in the background of all of the graphs. Users can also perform measurements on the resulting M-mode information.

Types of Contouring

Open, Closed, and Free-Form Contours

Tracking can be initiated by tracing an open contour on the apical views and a closed contour on the short axis views. A free-form method is also provided where individual points can be set on any moving anatomy and tracked over time.

Drawing a Contour

The user should select the clip to be analyzed and proceed to outline the chamber wall being examined. For the left ventricle the papillary muscle should be excluded with the contour drawn along the compact myocardium.

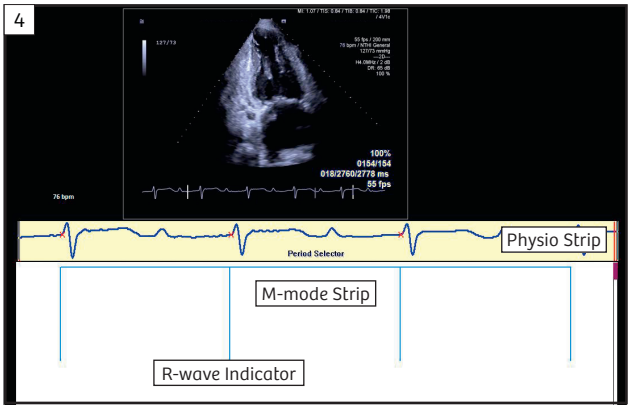


Figure 4: Setup screen display with Physio and M-mode strip. The first and last heart cycle have been cropped and will be excluded from the analysis results. The blue lines in the M-mode strip represent the peak of the R-wave.

Figure 5: Displays the M-mode strip with blue bars representing the R-wave display and workflow required to add or delete R-wave information.

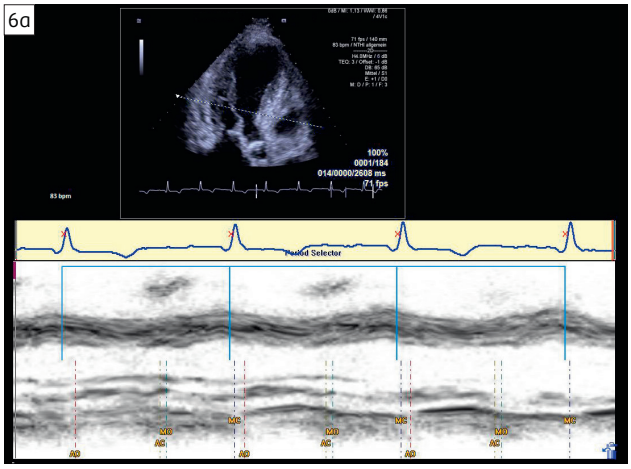


Figure 6a: Example of eSie VVI technology virtual M-mode where a user has drawn a line across the left ventricle at the mid level. The resulting M-mode is displayed below the image, and temporal information is displayed on the horizontal axis.

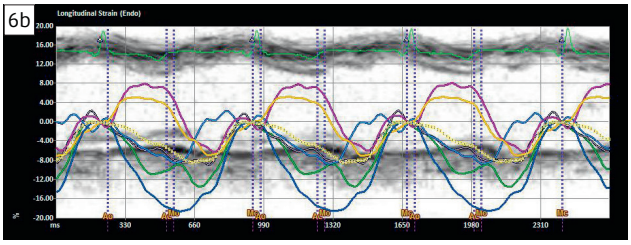


Figure 6b: Resulting graphical display with virtual M-mode displayed behind the curves. This additional information provides visual wall motion information.

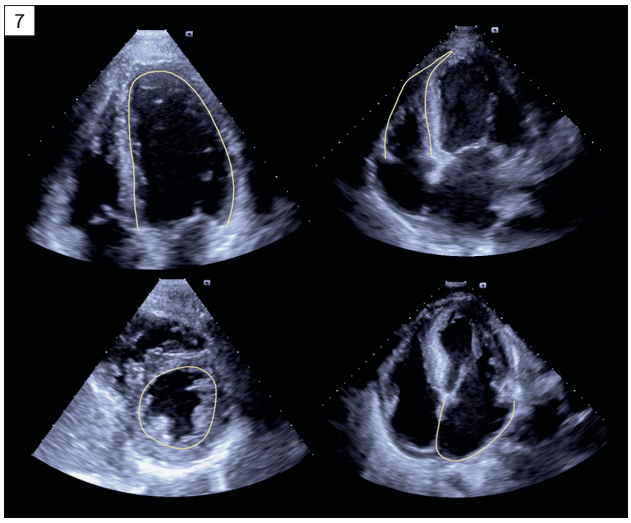


Figure 7: Example of contours for an A4C, A4C for the right ventricle, SAX and A4C for the left atrium. The contour should be on the inner edge of the compact myocardium. The contour should exclude trabeculations and papillary muscles similar to LV volume measurements.

See Figure 7 to review the position of the contour for the apical left ventricle, right ventricle and left atrium.

If a full myocardial thickness analysis is required, the user can add an epicardial contour. This will provide endocardium, full wall, and epicardium (endo, myo, and epi) analysis results. The user should select the „Endo and Epi" option in the „Contour" step. The epi contour will be displayed at a default 10 mm distance from the endocardium. It can then be adjusted globally and regionally.

If the clip being analyzed was acquired without an ECG trace, the user must manually add ED markers to define the start and end of each heart cycle. This is performed in the "Setup" step of the eSie VVI technology application. Providing ED markers identifies heart cycles and is critical for an accurate strain analysis. (Figures 3 and 4). It is also key for the eSie VVI technology tracking performance.

When the contour tracking is complete, the user should review the results and modify the trace if necessary.

Tracking results should be inspected visually to assess the contour and how it follows the anatomy. The resulting curves are also useful to assess the tracking results as each curve represents a segment of the tracked contour. If the contours do not follow the anatomy, the user can modify the initial contour. On any frame where the contour did not follow the anatomy, the user should move the contour so that it is consistent with anatomical motion and re-start the tracking.

It is recommended to draw the initial trace on a frame where the endocardial border is best seen. This is generally, but not always, a mid-systolic frame.

5. Analysis Options

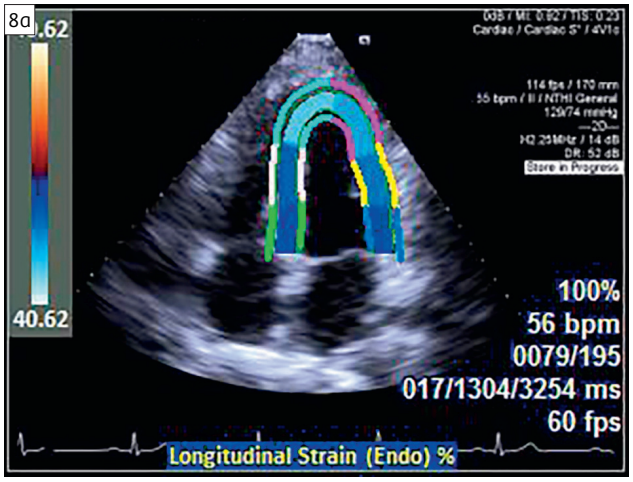
Regional, segmental, and global analysis results are available in the "Analysis" step. All results (parameters) are computed from tracked contours. The user can choose to review tracking results for each point on the curve, segments or global volumetric results.

Regional Analysis
Regional information can be derived from any tracked contour, and regions of interest can be set along the curve. Resulting curves for strain, strain rate, velocity or displacement are provided. Measurements can be performed to derive peak, slope, or time-to-peak on each curve. A resulting parametric color M-mode of the tracked contour is provided.

Segmental Analysis
Reviewing the tracked contour with segments provides a more robust, noise-independent analysis. Segmental analysis is available for the left ventricle, right ventricle and atriums. American Heart Association (AHA)'s 16 and 17 segment analysis is provided for the left ventricle.

Segment division is performed on the first frame of the heart cycle. The LV A4C, A2C and A3C and the A4C RV are divided into six even segments. The SAX basal and mid-short axis views are also divided into six even segments, and the SAX apex is separated into four segments. For the 17 segmentation model, the apex is again divided into two even layers, and the top layer or apical cap can be added (Figure 9).

Atrium analysis also available, with the segmental analysis is divided into three segments – two walls and the roof. Peak and time-to-peak measurements are available for each analyzed segment (Figure 9). The three segmental curves and the mean curve of all the segments are displayed with the systolic and overall peak detected automatically.



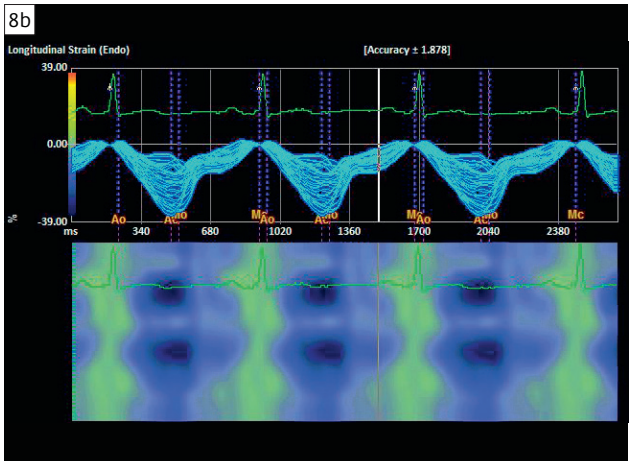
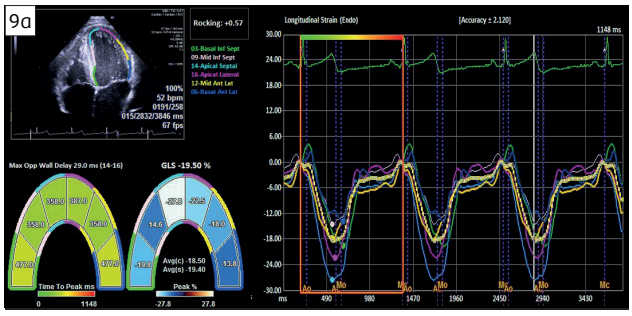
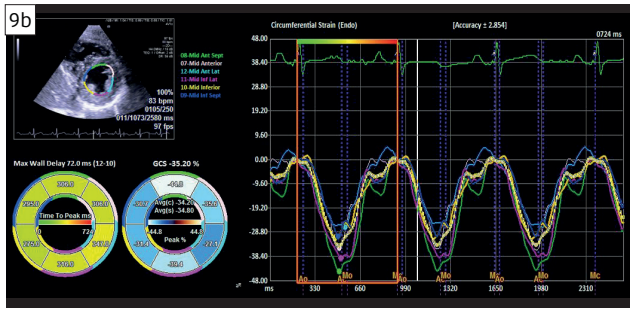


Figure 8a: Six color-coded regions of interest have been set on the tracked contour at the base, mid and apical left ventricular regions.

Figure 8b: Graphical display of the six regions of interest, longitudinal strain curve results. Below the graph is a color M-mode representing the longitudinal strain of the tracked curve over time: light to dark purple represents increasing negative strain, yellow to red positive strain, and green zero strain. The lower portion of the color M-mode shows results for the septum, mid region, apices, and top section results for the lateral wall. Temporal information is represented on the horizontal axis for both the graph and color M-mode.





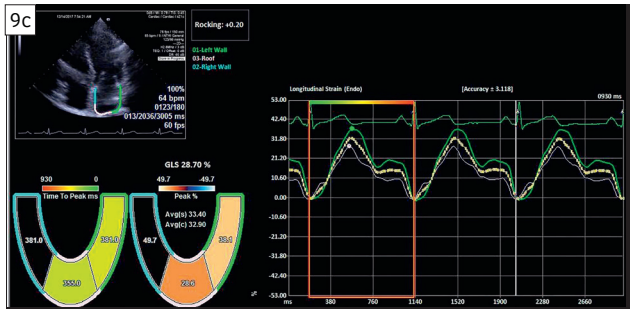


Figure 9a: Represents the longitudinal segmental strain analysis results of an A4C view. The longitudinal strain for the endo layer tracking results are displayed. The LV graphic for the time-to-peak and peak overall longitudinal strain are displayed as well as the segmental curves and average curve for longitudinal strain.

Figure 9b: Represents segmental short-axis analysis for the mid-parasternal left ventricular short-axis view. Radial and circumferential strain analysis results are displayed with SAX LV graphic and curve displays.

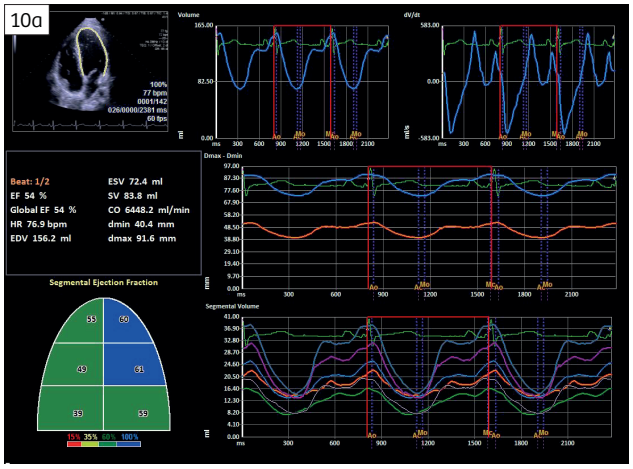
Figure 9c: Represents the longitudinal segmental strain analysis of the left atrium.

Global Analysis

Global Longitudinal Strain (GLS) and Global Circumferential Strain (GCS) are the most recent clinical developments for global functional assessment. The joint ASE/EACVI Strain Task Force has recommended that endocardial GLS be utilized to assess left venticular function. The recommendation comes after an inter-vendor comparison of commercially available software that showed good correlation between vendors for the new parameter.

This new parameter is the result of the joint EASE/EACVI Strain Task Force recommendation. It measures the overall difference of the tracked endocardial contour length. There is no segmentation of the contour and as for all Strain measurements the initial contour is measured at the R wave for consistency and reproducibility.

The ventricular GLS and GCS results are negative values while the atrial GLS measurement is a positive value.



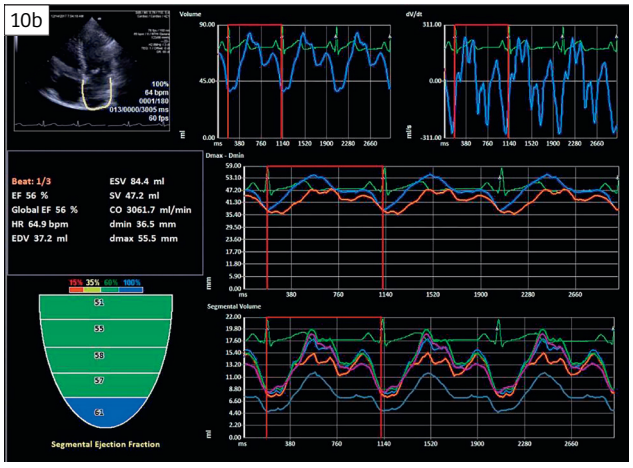


Figure 10a: Global volume analysis for an A4C view. Global time volume curve, volume change rate, the min and max LV diameter curves, the segmental volume curves and internal LV ejection fraction cartoon are displayed. A summary of the volume analysis results is also provided.

Figure 10b: Example of left atrium global and segmental volume analyses. The user has modified the ED frames to coincide with the left atrium maximum filling, contoured the left atrial endocardium from annulus to annulus, and then tracked. The volume time curve, volume filling rate curve, minimal and maximal LA diameter curve as well as the segmental volume curve are displayed. The segmental analysis is divided in layers to evaluate the left atrial suction performance. A summarized volume analysis is provided.

The joint ASE/EACVI Strain Task Force has recommended that endocardial GLS be utilized to assess left venticular function. The recommendation comes after an inter-vendor comparison of commercially available software that showed good correlation between vendors for the new parameter.

Average (c) – The Average (c) parameter is the peak value of the average curve. The average curve is the result of averaging the six segmental curves.

Average (s) – The Average (s) value is the average of the six overall peaks from each segmental curve. This value is also mathematically equivalent to GLS or GCS for strain.

Volume Analysis

A modified Simpson's analysis is performed, and the resulting time volume curve for LV apical views is utilized to compute end diastolic volume, end systolic volume, and ejection fraction. In addition, minimum (width) and maximum (length) diameter over time is displayed. Segmental volume time curves are derived from internal cavity division where the LV is divided in half, then in equal thirds (Figure 11).

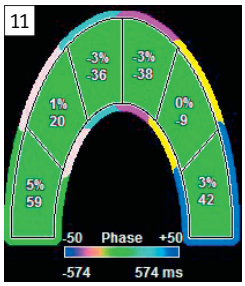
An area-over-time curve is provided when LV SAX, RV and atrial views are analyzed. The segmental atrium curves are the result of five layers from annulus to roof.

Phase Analysis

Phase is computed from the Fourier analysis of each segmental and global curve for all parameters and represents the sinusoid that best fits the specified waveform. It is reported in ms or % phase. A negative phase indicates earlier motion, and a positive phase indicates delayed motion. Phase information is computed for each segmental curve irrespective of the selected anatomy.

eSie VVI Technology Display Options

The multiple display options in *eSie* VVI technology are meant to aid wall motion analysis. These include velocity vectors, point trajectory, segmental deformations, and parametric display. The 3D M-mode display provides a third dimension to the parametric M-mode regional analysis results (Figure 11).



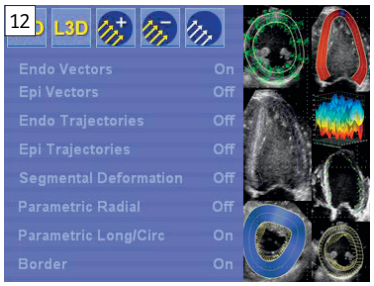


Figure 11: Phase results reported as percentage and milliseconds from a normal patient analysis. When all segments are within a normal range, the segment is displayed in green. When a segment contraction is delayed, it is displayed in blue. Early contraction is displayed as pink.

Figure 12: Represents the various display options available in eSie VVI technology including: normal trajectory points for a mid LV SAX view, parametric velocity for a normal A4C view, segmental deformation for a normal A4C view, 3D M-mode strain rate, trajectory points for normal A4C view, velocity vectors for endocardial border tracking and parametric strain, and endocardial and epicardial velocity vectors of a SAX mid LV tracking.

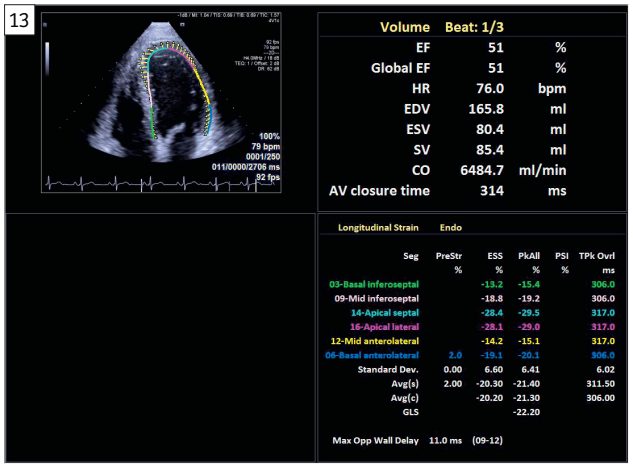


Figure 13: Example of a summarized endocardial longitudinal strain for an A4C view. Each segment is numbered and labelled. PreStretch (early stretch), End Systolic Strain, Peak Overall Strain, Post Systolic Index, and Time to Peak Overall Strain are provided for each segment. The Standard Deviation, Average of all segments (AVG(s)), the peak of the average segmental Strain curve (AVG(c)), the Global Longitudinal Strain (GLS) derived from the contour length are also provided. The maximum opposing wall delay is computed, and the segments from which it is derived provided.

6. Analysis Options

eSie VVI Technology Results

This step provides additional parameter results for each segmental analysis. Included are volume information and parameter specific measurements. The user can select to display results for strain, strain rate, velocity, and displacement. All parameters include peak and time to peak measurements. In addition, PreSretch Strain, Peak Overall Strain, and Post Systolic Index are provided (Figure 13).

Global Longitudinal Strain and Global Circumferential Strain

Global Longitudinal Strain (GLS) and Global Circumferential Strain (GCS) are the measured difference of the tracked contour length and a global functional assessment. The parameters are available for apical views (GLS) and for sax views (GCS).

Formula:

Ventricle GLS/GCS = ((min (ES) contour length – max (ED) contour length)/max (ED) contour length) *100

Atria GLS = ((max (ES) contour length – min (ED) contour length)/max (ES) contour length) *100

The GLS calculation method is modified for the atria when compared to the ventricular formula. In the ventricular GLS formula the longest contour length occurs at ED while the maximum contour length of the atrial wall occurs at end systole.

PreStretch

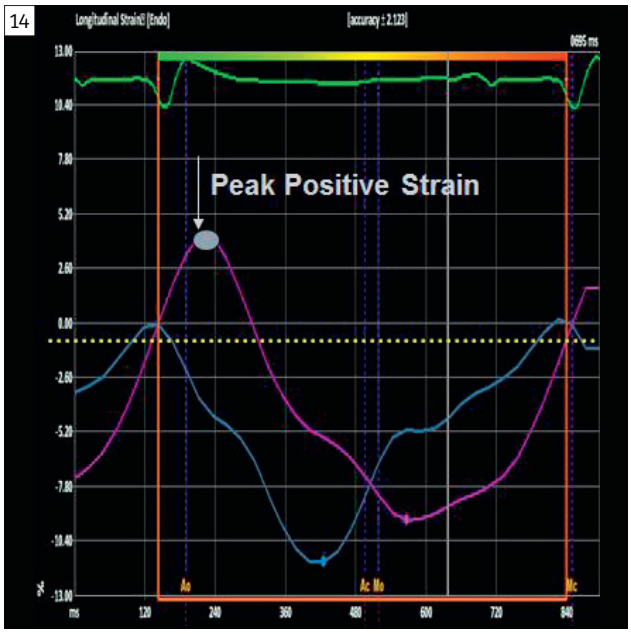
PreStretch, also known as Peak Positive Strain, is the amount of early systolic stretching occurring in the first 100 ms of the heart cycle relative to the total combined thickening, defined as the sum of the systolic thickening (Smaxsyst) and thinning (Smaxneg) (Figure 14).

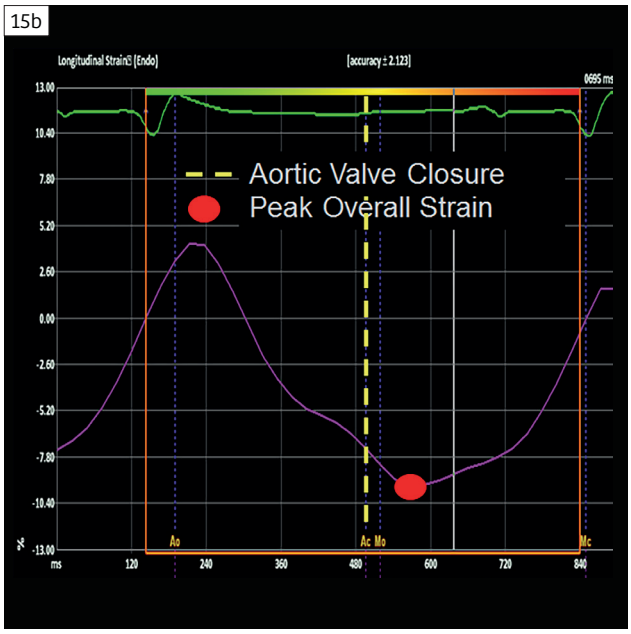
Formula:

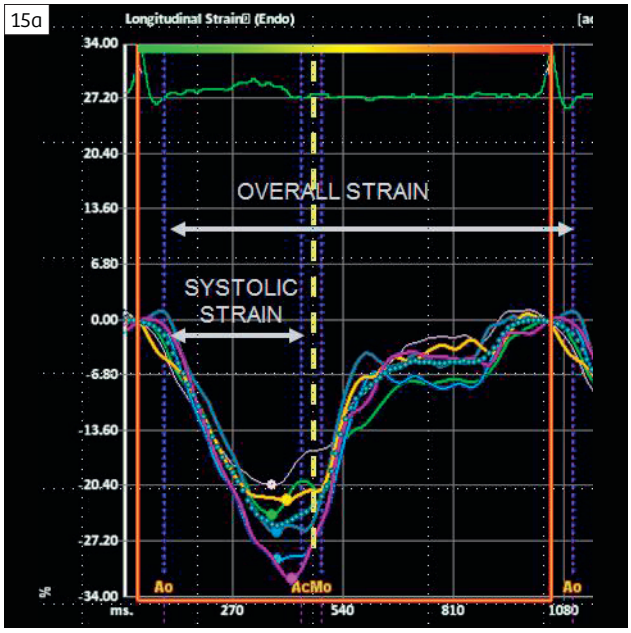
Pre-stretch = 100*Smaxneg/(Smaxneg – Smaxsyst).

End Systolic Strain and Overall Strain

End-Systolic Strain is measured at the aortic valve closure. In normal myocardial physiology, the overall peak and systolic peak occur at the same time. In patients with wall motion abnormalities from electro-mechanical disease (coronary artery disease, LBBB, RBBB), segments can contract in a discoordinated pattern with some segments reaching their maximum contraction during systole and others after end systole (Figure 15).







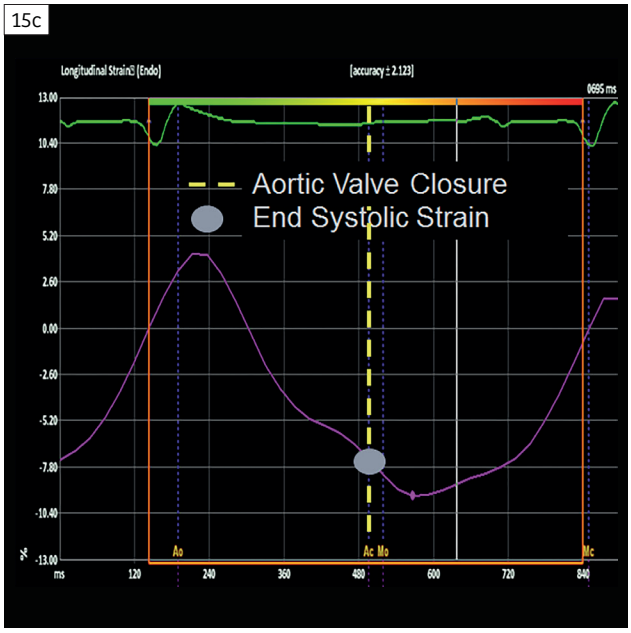


Figure 14: Represents an example of early stretching from a segment seen in the magenta curve. The blue curve has normal deformation and does not display any significant prestretch.

Figure 15: Represents a) Time period where systolic strain and the overall strain are measured. b) Aortic valve closure time and measured Peak overall Strain measured after aortic valve closure time. c) End-systolic strain measured at the aortic valve closure time.

Post Systolic Index (PSI)
The amount of strain occurring after the aortic valve closure has been used as an ischemic marker. The formula to compute the post systolic index is as follows:

PSI = 100*(PS-ESS)/PS

where ESS = end systolic strain and PS = Overall strain
If overall peak strain occurs prior or at the aortic valve closure time aortic valve closure, then both strains are the same:

PSI = 100*(12-12)/12 = 0

If a contraction delay is present, then the overall peak occurs after the aortic valve closure:

PSI = 100*(7.0 – 10)/7.0 = 30%

Valve Timing Events
eSie VVI technology provides derived valve opening and closing events. Markers are available for each heart cycle.

This is done by initially converting the heart cycle from ms to percentages. Each heart cycle is valued at 100%. Valve timing is then set for each heart cycle.

- The first marker aortic valve open is set at 5% after the first R-wave.
- The aortic valve closure event is set at + 2% time after the minimum time volume curve.
- The mitral valve opening is set at 5% after the aortic valve closure.

The mitral valve closure is set at the last R-wave. Timing events are derived after the first analysis and not modified with further trackings.

Tools are provided for the user to modify the timing events. Users can grab the timing indicators on the graph to the desired location.

If valve timing was measured from pulse wave Doppler or M-mode imaging, the timing bars can be modified to match.

Bullseye Report
A patient's eSie VVI technology Strain, Strain Rate, Velocity, and Displacement analysis results can be reviewed and archived in a 16-segment bullseye display. Separate parametric maps are provided for Strain, Strain Rate, Velocity, and Displacement as well as Time to Peak. Overall peak and time to peak segment results are displayed in each segment. The average results per view are displayed as well as the average of six basal segments. The global average for 16 segments and the maximum opposing wall delay (MOWD) are computed and displayed (Figure 16).

16

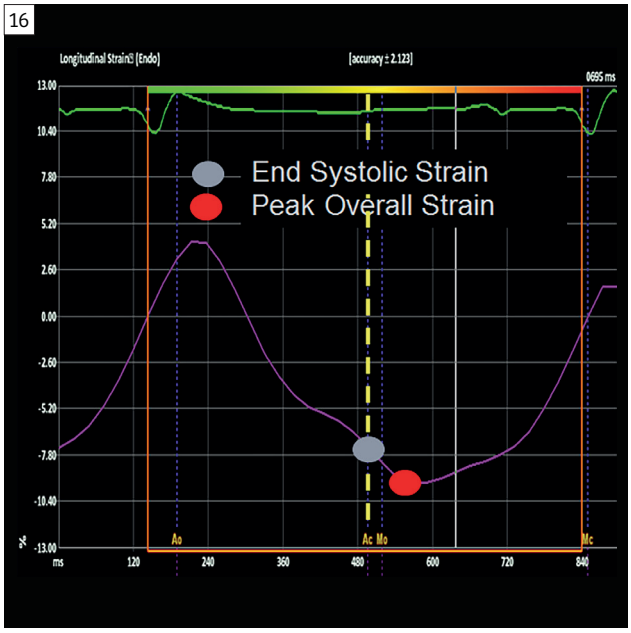


Figure 16: Example of post systolic strain with peak overall strain of a segmental curve occurring after the aortic valve closure.

17

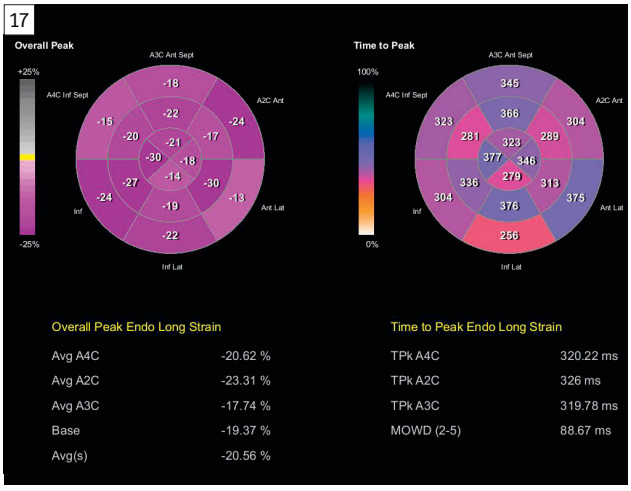


Figure 17: Represents the segmental longitudinal strain results of an A4C, A2C, and A3C views bullseye display. The peak overall and time to peak endocardial overall strain is displayed. The gray and magenta color map utilized displays negative values in increasing magenta intensity and positive values in increasing grey intensities to provide a quick visual qualitative analysis. A summarized text display provided average values for each view and basal segments as well as the average value of all available segments (AVG(s)).

7. Useful Tips

Echocardiography and 2D speckle tracking have become clinical practice to monitor cardiotoxicity for patients undergoing chemotherapy.

The key points from a 2014 ASE and EACVI expert consensus for multimodality imaging evaluation of adult patients during and after cancer therapy are:

- GLS is the optimal parameter of deformation for the early detection of subclinical LV dysfunction.
- Ideally, the measurement during chemotherapy should be compared with the baseline value. In patients with available baseline strain measurements, a relative percentage reduction of GLS < 8% from baseline appears not to be meaningful, and those > 15% from baseline are very likely to be abnormal.
- If baseline GLS is -20%, a 15% reduction of the relative percentage strain is equal to a 3% reduction of overall strain.
- When applying 2D strain for longitudinal follow-up of patients with cancer who underwent chemotherapy, the same vendor-specific 2D strain application should be used.
- Since the consensus document publication, there has been added emphasis on the use of Global Circumferential Strain (GCS) measurement combined with GLS to better assess myocardial performance.
- Even if GLS has truly declined, EF may still be normal and GCS normal. An additional clue that a decreased GLS is genuine is if it is accompanied with an e' velocity < 8 cm/s.
- In addition, when GLS and GCS are abnormal, the EF is abnormal (< 55%) in almost all patients.
- Strain should not be performed if image quality is suboptimal as a general rule. The user should select an alternative image or do not perform strain for this patient.

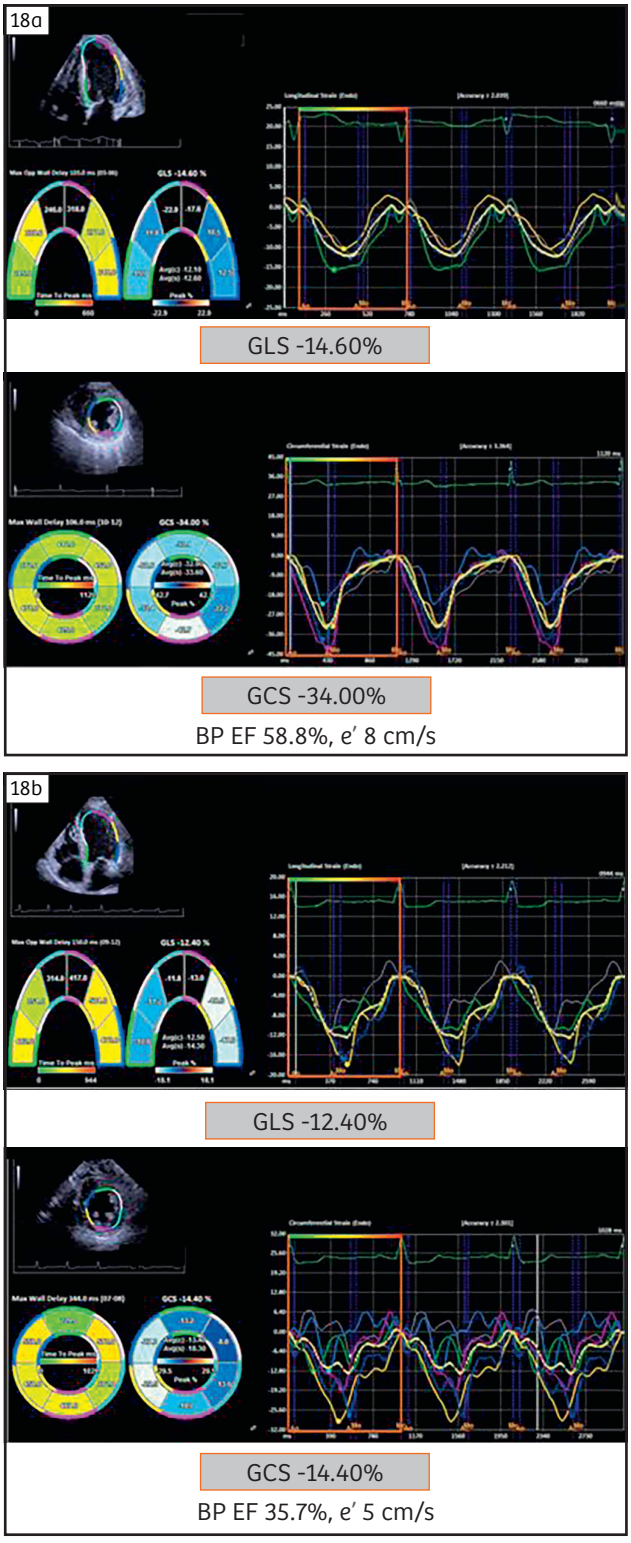


Figure 18a:
Patient with normal EF, low GLS, normal GCS, and normal e'.

Figure 18b: Patient with low EF,low GLS, low CSC, and low e'.

8. FAQs

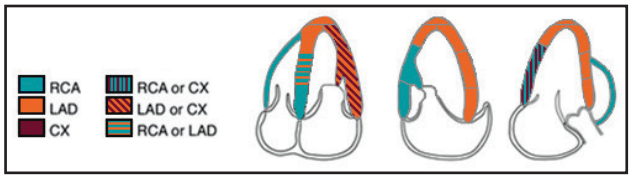
Is VVI tracking based on speckle tracking?
Yes, VVI tracking is based on speckle tracking. For a full description please review the Technology section.

Which Strain approach does VVI use?
The Lagrangian strain approach is used and is the ASE/EACVI Strain Task Force recommended method.

If a segment poorly tracked can it be excluded from the results?
A segment can be excluded from the analysis for the average segmental and average contour results. It cannot be excluded from the GLS or GCS results as these two are measured from the overall change in length of the tracked contour.

Why is the apical segment excluded when evaluating the segmental strain results (AVGc and AVGs)?
The left ventricular apex rotates more than it shortens. The mid and basal segments shorten more than they rotate. The apical segments are excluded for an improved assessment of longitudinal myocardial function.

Should there be a focus on the A4C view to measure GLS or should A2C and A3C also be included?
- The difference between the apical views averaged vs. the 4-CH by itself is negligible.
- To achieve the best reproducibility, it is easier to get a high-quality 4-CH view for processing than all three apical views.
- Also, in CAD, all coronary branches are included in the 4-CH view (see diagram below). In the instance of a small localized lesion (not included in the 4-CH), abnormal deformation will translate through the myocardium, affecting the 4-CH strain results.



Which measurements should be performed for a standard echo exam?
- GLS – global longitudinal strain
- GCS – global circumferential strain
- RV GFWS – right ventricular global free-wall strain

Does the software provide a segmental tracking confidence indicator?
A confidence score is provided. It is an indicator of the best possible results given the frame rate and image resolution. Please see the Technology section for a detailed description. In addition a visual assessment of the tracked contour should be performed. In good results the tracked contour follows the underlying anatomy. If this is not the case the position of the original contour should be moved and tracking repeated. If tracking a particular segment proves to be difficult that segment should be excluded from the results. The resulting segmental curves are also indicators of tracking results and should be used to identify poorly tracked segments.

How does the software define the automated AV closure time?
The automated AV closure is the result of the corresponding clips volume time curve. The minimum volume + 2% of the heart cycle length are used to define the AV closure time for each analyzed cycle. The user can modify the automated AV closure time by measuring the closure time on Doppler tracing of the AV. The measured time can then be used to reposition the automated AV closure indicator. The aortic valve closure can also be visualized on the A3C view. From the A3C view advance the frames to a frame identified as the AV closure fame. Move the timing indicator to match the frame indicator. If multiple beats are analyzed this step should be repeated for each beat.

Has VVI been validated?
There have been multiple strain validation works published based on VVI speckle tracking. These include validation work utilizing simulated data, in-vitro strain models, in-vivo sonomicrometry and cardiac MRI comparisons in addition to normal vs pathological clinical validation work. VVI was included in the joint ASE/EACVI strain task force simulation, GLS and segmental strain inter-vendor comparison work.

9. Conclusion

eSie VVI technology is an advanced 2D speckle tracking application for the assessment of global and segmental myocardial mechanics using 2D B-mode image sequences. It is applicable to the left and right ventricles as well as both atria, and supports accurate and reproducible clinical analysis of adult, pediatric and fetal heart. Parameters like global longitudinal strain (GLS) are readily available. eSie VVI technology provides strain, strain rate, velocity and displacement deformation parameters allowing a quantitative analysis of myocardial wall motion.

A summary of results are displayed in an easy-to-read graphical bullseye display. With this tool, a mechanical cardiac analysis can be performed at the bedside.

10. Publications

Head-to-Head Comparison of Global Longitudinal Strain Measurements among Nine Different Vendors. The EACVI/ASE Inter-Vendor Comparison Study in the Journal of the American Society of Echocardiography
onlinejase.com/article/S0894-7317(15)00463-0/abstract

Definitions for a common standard for 2D speckle tracking echocardiography: consensus document of the EACVI/ASE/Industry Task Force to standardize deformation imaging in the European Heart Journal
academic.oup.com/ehjcimaging/article/16/1/1/2403449/Definitions-for-a-commonstandard-for-2D-speckle?searchresult=1#38867678

Two-dimensional speckle tracking echocardiography: standardization efforts based on synthetic ultrasound data in the European Heart Journal
academic.oup.com/ehjcimaging/article-lookup/doi/10.1093/ehjci/jev197#35895903

Left Ventricular Systolic Myocardial Deformation – A Comparison of 2D and 3D Echocardiography in Children
ncbi.nlm.nih.gov/pubmed/28802483

Expert Consensus for Multimodality Imaging Evaluation of Adult Patients during and after Cancer Therapy: A report from the American Society of Echocardiography and the European Association of Cardiovascular Imaging, EHJ-CV and JASE, 2014
ncbi.nlm.nih.gov/pubmed/25172399

Geometry as a Confounder When Assessing Ventricular Systolic Function Comparison Between Ejection Fraction and Strain, JACC, 2017
ncbi.nlm.nih.gov/pubmed/28818204

ASE/EACVI Strain task force publication from 2018 on LA and RV strain standardization recommendations

Standardization of Left Atrial, Right Ventricular and Right Atrial Deformation Imaging Using 2D Speckle Tracking

Echocardiography. A Consensus Document of the EACVI/ASE/Industry Task Force to Standardize Deformation Imaging

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