PHILIPS

Ultrasound

White paper

AutoStrain LV/RV/LA – automated strain measurements

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Overview

Global longitudinal strain (GLS) measured by echocardiography is increasingly recognized as a more effective technique than conventional ejection fraction (EF) in detecting subtle changes in left ventricular (LV) function and in predicting outcomes.[1,2] It's especially important in monitoring cancer patients undergoing chemotherapy, allowing treatment to be adjusted. It is also important that this measurement of GLS occurs in a fast and reproducible manner directly on the ultrasound system so that it can be applied to everyday clinical practice.

TOMTEC has a long history of providing strain measurements with its software applications, which are well recognized and accepted by clinical users and supported by hundreds of journal publications. AutoStrain is the first TOMTEC application integrated on the Philips EPIQ CVx ultrasound system. AutoStrain, powered by Auto View Recognition, Auto Contour Placement and speckle tracking, enables a robust, reproducible one-button GLS measurement, making it an efficient tool for routine clinical use.

Deformation imaging to assess left atrial (LA) and right ventricular (RV) function is a newer clinical area. AutoStrain LA and AutoStrain RV follow the Strain Task Force standardization[3] document. Based on its fast and easy workflow, AutoStrain makes these measurements available for clinical routine practice.

TOMTEC

Automation

The AutoStrain application utilizes two automation technologies: Auto View Recognition and Auto Contour Placement. While the implementation of these automation tools drives simple, fast workflow for robust and reproducible GLS measurements, the user retains the ability to edit and override the automation to ensure good clinical practice.

Auto View Recognition

Auto View Recognition automatically identifies which selected image is apical 4 chamber (A4C), apical 2 chamber (A2C) and apical 3 chamber (A3C), and automatically assigns the labels to the selected images. The label is shown on the image as a schematic overlay as shown **(Figure 1)**. The algorithm has been validated on more than 6,000 clinical images with a success rate of 99%. This means that only 1 out of 100 cases will require manual intervention.

Auto Contour Placement

A specialized contour detection module for the respective apical view is applied to each of the three image sequences and operates in three steps. First, a complete R-R cycle — end-diastole (ED) start to ED end — is selected from each sequence. Second, in the ED start frame of that cycle, the left ventricle (LV) is automatically located. Third, a view-specific deformable endocardial contour model is aligned to the individual image content **(Figure 2)**.

The same approach is applied for RV Auto Contour Placement while the initial LA contour is placed in the end-systolic (ES) frame. **(Figures 3 and 4).**

Speckle tracking

Once the endocardial border is automatically placed in ED (LV, RV) or in ES (LA), it follows the cardiac motion using speckle tracking over the entire cardiac cycle.

In Tracking Revision and Analysis Workflow step, the user has all the measurements displayed along with the ED and ES borders next to a dynamic display of all views to easily verify that the borders are correctly placed and tracked.

If border editing is needed, it is highly recommended to start editing in ED. Editing the border in ED triggers new speckle tracking of the border throughout the cardiac cycle. When editing the ES border, the edits are propagated to the neighboring frames but the ED border remains untouched.
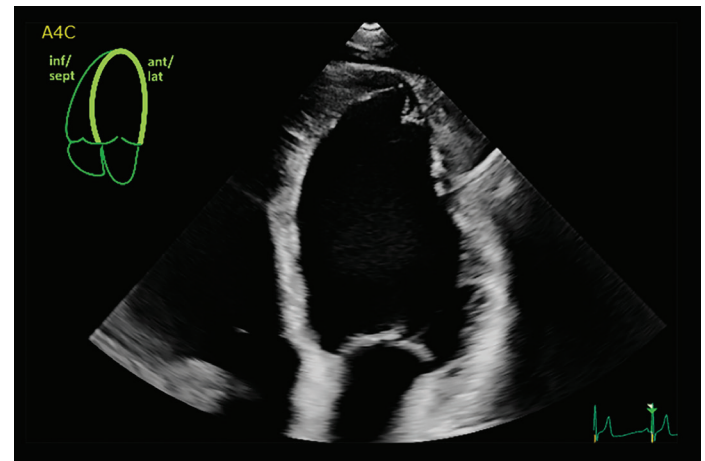

Figure 1 View graphic and label are shown on the 2D image.

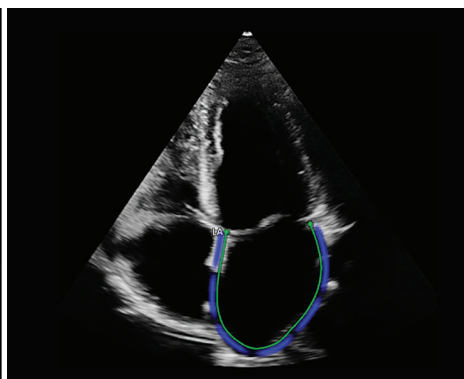**Figure 2** LV focused view with Auto Contour Placement.

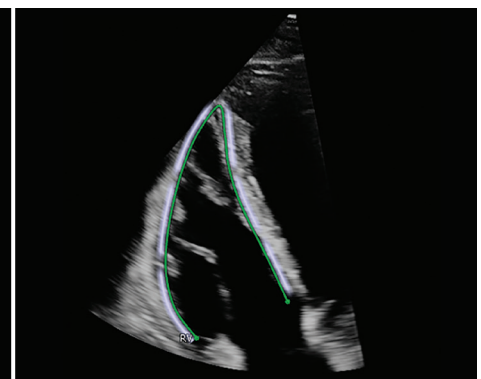**Figure 3** LA focused view with Auto Contour Placement.

Figure 4 RV focused view with Auto Contour Placement.

Strain measurement

Left ventricle (LV)

Longitudinal strain is measured at the endocardial border as indicated by the green line. Instantaneous endocardial strain is visualized by color-coding close to the endocardial border.

The segmental strain values are displayed on an 18-segment bull's-eye plot. The user can select either end-systolic strain (ESS) or peak-systolic strain (PSS) to be displayed in the settings. The difference between these two strain measurements is shown in Figure 3a–b. The segmental values can also be displayed on the three apical images. The ASE and EACVI Speckle Tracking Task Force recommends reporting ESS,[3] however, PSS – the peak value during systole – has been established as an additional reporting parameter.

The ED frame is always the first frame in the selected cardiac cycle. The ES time point is automatically defined as the time point of global peak strain. It can be adjusted according to aortic valve closure (AVC) time in the AVC layout.

GLS is calculated as global shortening of the endocardial border. It is defined as a peak value and thus independent from AVC as shown **(Figure 5)**.

Right ventricle (RV)

Based on the deformation of the green endocardial contour, longitudinal strain is computed for the free wall (RVFWSL), the global 4-chamber contour (RV4CSL) and the three free wall segments.

Left atrial (LA)

The LA cardiac cycle consists of three phases: reservoir phase goes from ED to ES, conduit phase ends at the time point right before atrial contraction (AC) – also denoted as PreA time point – and contraction phase completes the cardiac cycle. The LA strain measurements are visualized in **Figure 6**.

Peak-systolic strain **End-systolic strain** **Global peak strain**
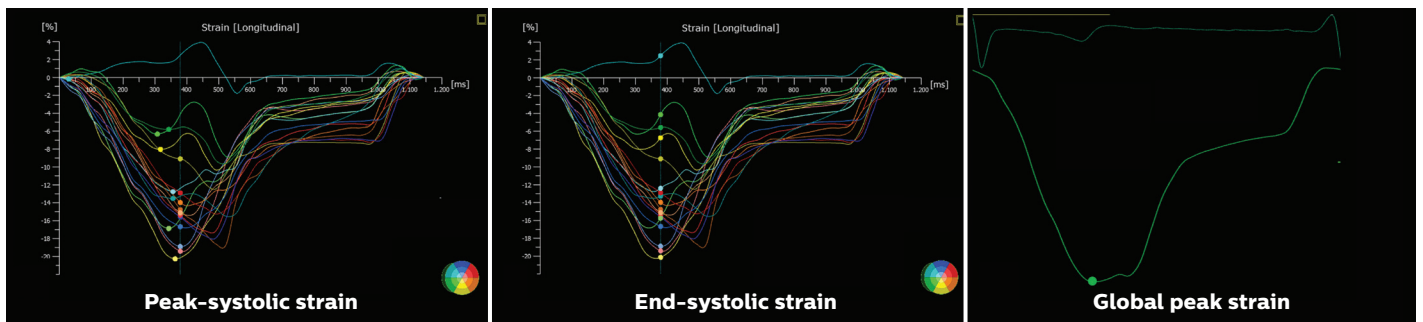
Figure 5 Segmental strain curves and segmental strain values displayed at peak-systolic and end-systolic strain. GLS at peak strain is visualized with the global strain curve.
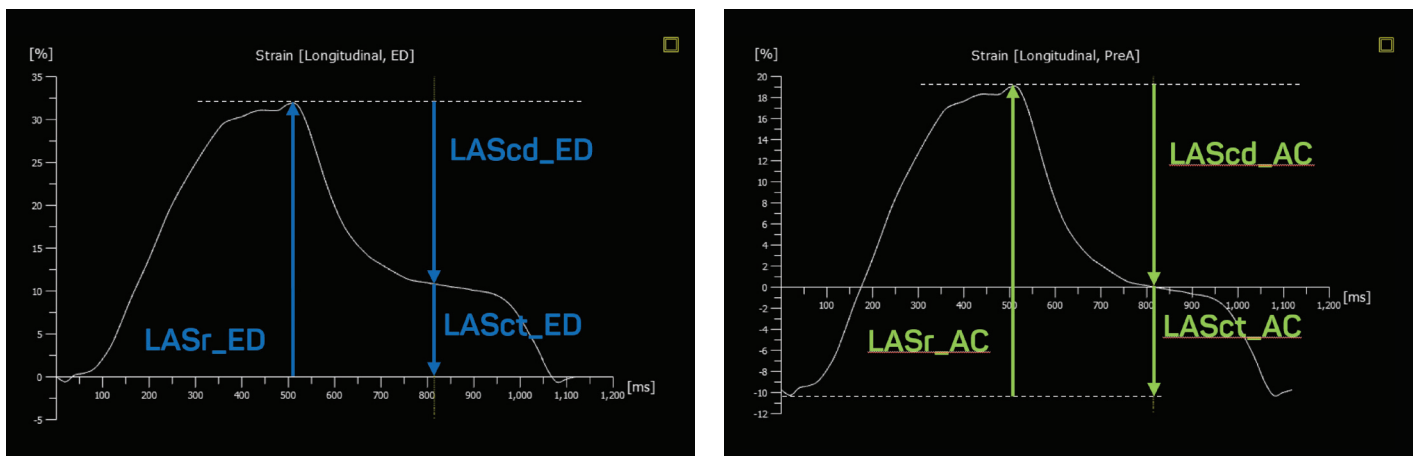

Figure 6 LA strain measurements with reference time point at ED (left) and at PreA (right) for reservoir strain (LASr), conduit strain (LAScd) and contraction strain (LASct).

Bull's-eye display

The bull's-eye view is a comprehensive visualization of the entire left ventricle based on A4C, A2C and A3C views. AutoStrain shows peak-systolic longitudinal strain or end-systolic longitudinal strain and time-to-peak longitudinal strain in two 18-segment bull's-eye plots **(Figure 7)**. In the time-to-peak bull's eye, white represents the end-systolic time point. Blue means the segments reach their longitudinal strain peak before ES, while red means the segments reach minimal strain after ES.
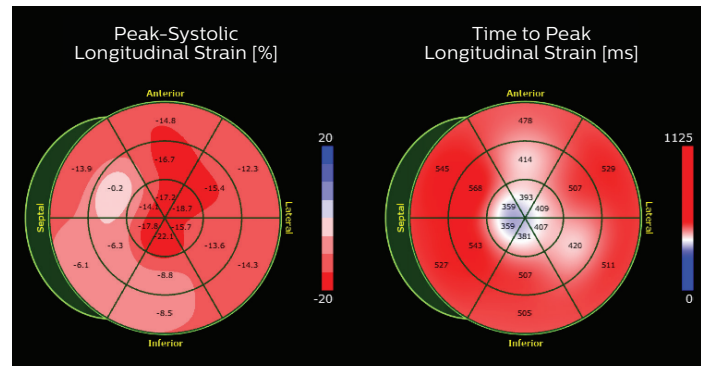

Figure 7 Bull's-eye plots in AutoStrain summarizing strain measurements from A4C, A2C and A3C views.

Validation

Validation of AutoStrain LV has been done in comparison to the well-accepted TOMTEC 2D CPA application, with 225 clips analyzed with 2D CPA and re-evaluated with AutoStrain LV using consistent border definitions and manual corrections where necessary in both packages, with results shown in **Figure 8**.

For AutoStrain LA validation, LA reservoir strain with reference frame at ED (LASr_ED) has been compared to 2D CPA using 71 clips. AutoStrain RV compared RV global 4 chamber longitudinal strain (RV4CSL) in 75 clips with the corresponding 2D CPA measurements. Results are shown in **Figure 9.**

Number of test samples	225
Mean GLS 2D CPA	–16.18 %
Mean GLS 2D CPA	–16.22 %
Bias	+0.03 %
Standard deviation	0.81 %
Limits of agreement	±1.59 %

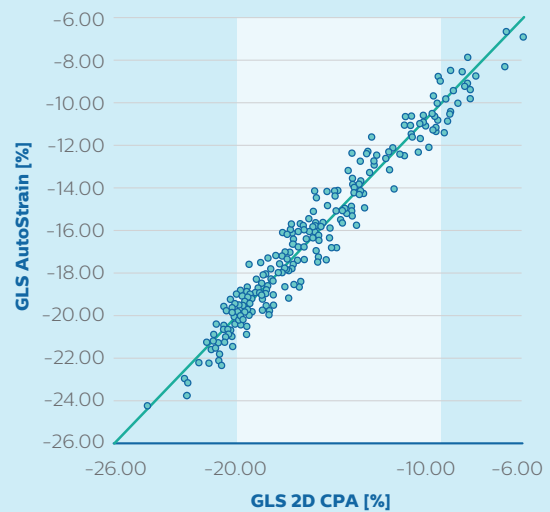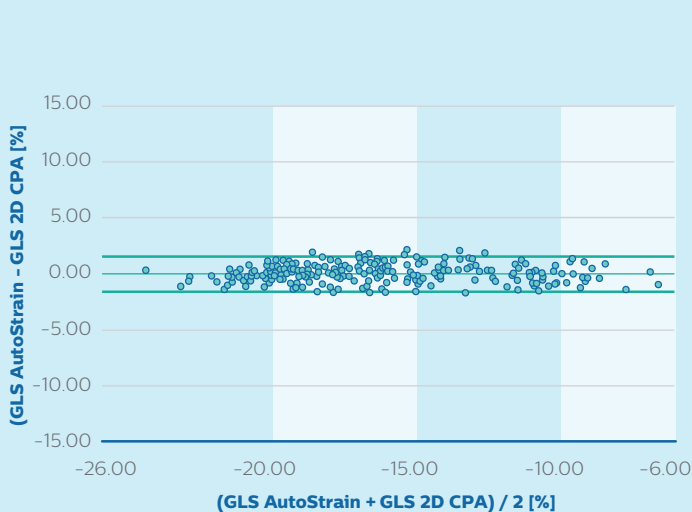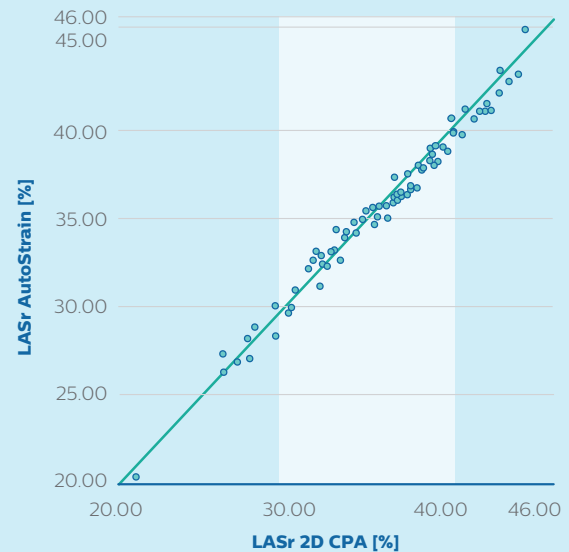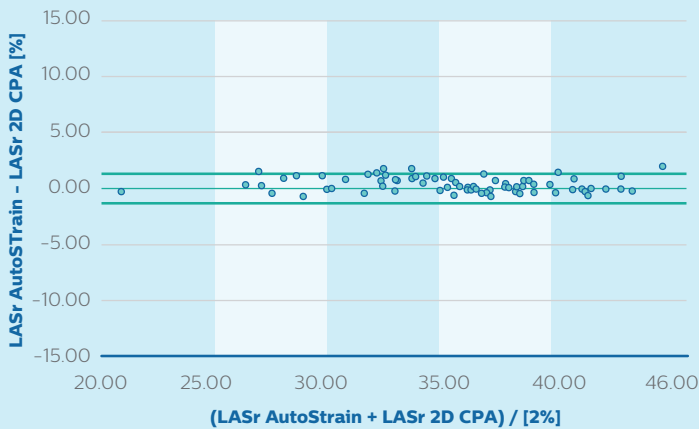|	
Orthogonal regression slope	1.00
Orthogonal regression y intercept	–0.01 %
Correlation coefficient	0.98

Figure 8 Bland Altman and Orthogonal Regression plot comparing AutoStrain and 2D CPA.

Mean LASr 2D CPA	35.56 %		Orthogonal regression slope	0.98
Mean LASr AutoStrain	35.71 %		Orthogonal regression y intercept	0.80 %
Bias	+0.16 %		Correlation coefficient	0.99
Standard deviation	0.65 %			
Limits of agreement	±1.27 %			

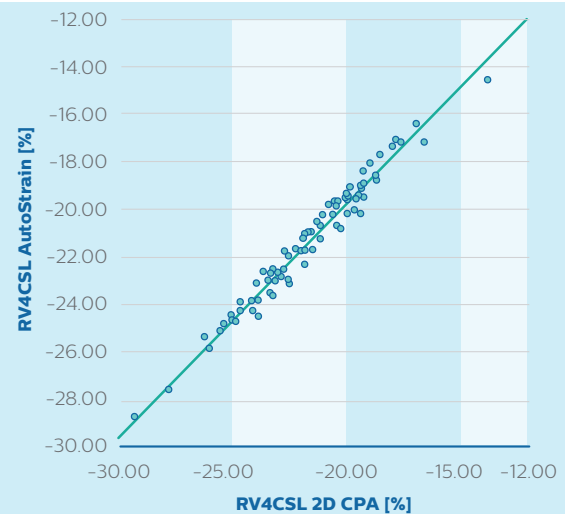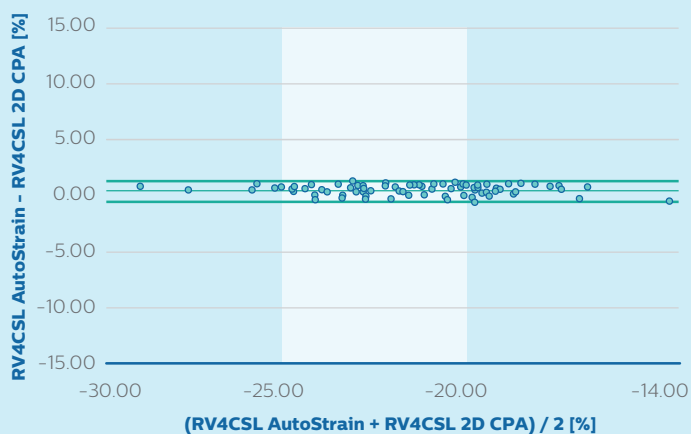|				
Mean RV4CSL 2D CPA	–21.62 %		Orthogonal regression slope	0.98
Mean RV4CSL AutoStrain	–21.33 %		Orthogonal regression y intercept	–0.10 %
Bias	+0.28 %		Correlation coefficient	0.98
Standard deviation	0.46 %			
Limits of agreement	±0.91 %			

Figure 9 Bland Altman plots comparing LASr_ED (top) and RV4CSL (bottom) measured with AutoStrain and 2D CPA.

Robustness

As deformation within the myocardium varies regionally, GLS as a measure of myocardial deformation shows interdependence with initial contour placement. To assess reproducibility of the AutoStrain tracking, the influence of manual adjustments of the initial endocardial contour was evaluated.

Based on 225 user-reviewed initial contours, manual refinements have been simulated by slight modification of all original contour point positions (within ±2 pixels distance). Then resulting GLS measurements were compared against the original readings with results shown in **Figure 10**.

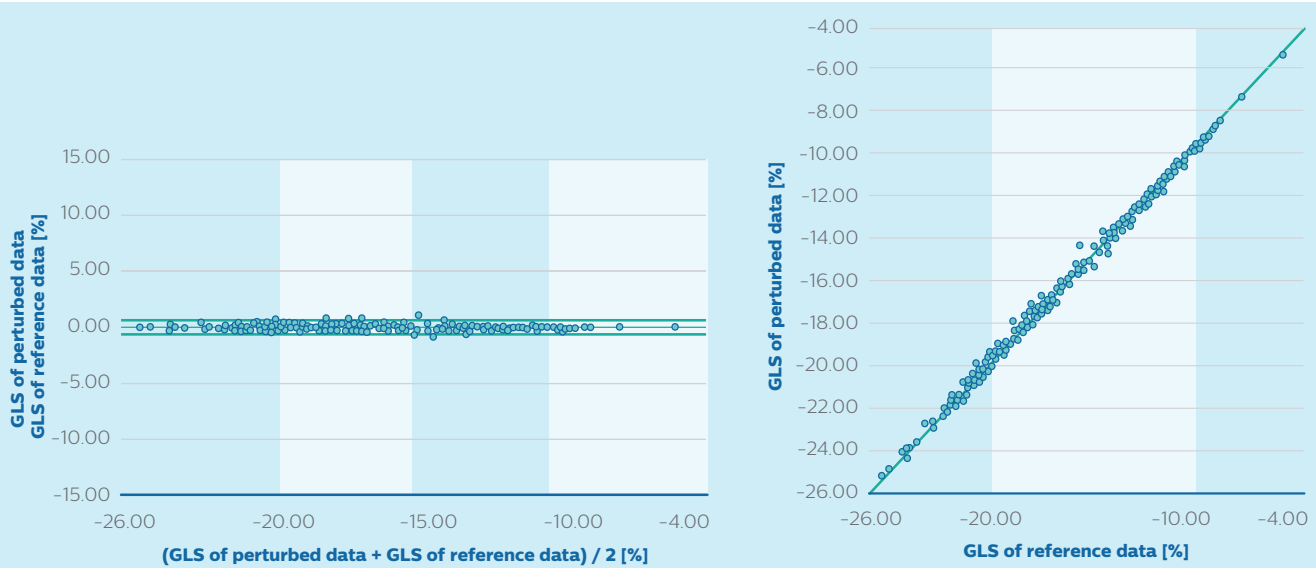|			
Mean GLS of reference data	–16.42 %	Orthogonal regression slope	1.00
Mean GLS of perturbed data	–16.40 %	Orthogonal regression y intercept:	–0.01 %
Bias	+0.02 %	Correlation coefficient	0.98
Standard deviation	0.22 %		
Limits of agreement	±0.44 %		

Figure 10 Bland Altman and Orthogonal Regression plot showing the variation of GLS, when the ED contour is modified within a band of ±2 pixels.

Frequently asked questions

What are the apical views to acquire for optimal LV, LA and RV strain measurements?

According to ASE recommendations for cardiac chamber quantification, the LV, LA and RV focused views should be acquired and used for LV, LA and RV quantifications. Thus, the depth and angle should be adjusted to show the maximum size of the LV, LA and RV **(Figures 2–4)**.

Is the strain measurement comparable between AutoStrain and Automated Cardiac Motion Quantification[A.I] (aCMQ[A.I])?

The calculation of global longitudinal strain following the length–of–line method is the same in aCMQ[A.I] and AutoStrain. The GLS is comparable if the border position on both ED and ES frames is comparable. However, the recommendation from the ASE chamber quantification guidelines is to use the same software for a serial study.

Are results consistent when using AutoStrain on EPIQ or on QLAB and TOMTEC–ARENA?

Contours, GLS and bull's–eye results are identical on–cart on ultrasound systems and off–cart on QLAB with native data. Within TOMTEC–ARENA, AutoStrain is integrated in IMAGE–COM. The same algorithms are applied, but TOMTEC–ARENA uses DICOM JPG images. AutoStrain on QLAB can also analyze DICOM JPG images. The GLS results from analysis of native data and analysis of DICOM JPG images are comparable.

Can AutoStrain measure the GLS at the mid–myocardial or epicardial layer?

AutoStrain measures longitudinal strain along the endocardium, which is widely accepted clinical practice.

Does the software track the full thickness of the myocardium?

Speckle tracking is applied over the entire myocardium. Based on the deformation pattern, the displayed green contour is computed, which in turn forms the basis for derived measurements.
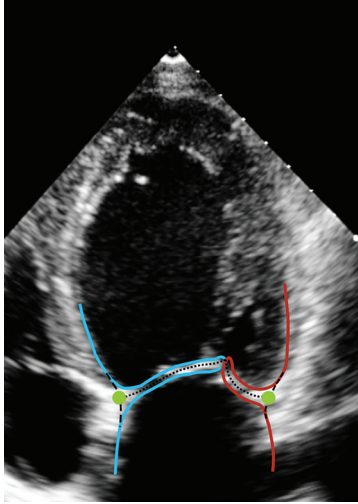
Figure 11 Schematic visualization of the mitral annulus. The dotted center line of the anterior (blue) and posterior (red) leaflet intersects with a dashed continuous junction of LV and LA endocardial border. The mitral annulus is assumed at this point of intersection (green).

How are basal anchor points defined?

The basal anchor points are located where the valve leaflets meet the myocardium. This location provides a consistent definition for both the LV and the LA. This basal location is shown **(Figure 11)**.

Tracking at the mitral annulus failed. What can I do?

When speckle tracking of the mitral annulus fails, try to move the anchor point to a region more towards the mid-segment, where tracking works successfully. Please keep in mind the ED frame should be edited first to trigger new speckle tracking.

Speckle tracking failure is presumably related to over-saturated regions close to the mitral annulus. Try to reduce the gain setting during imaging to ensure a sufficient speckle pattern close to the basal area. Additionally, through-plane motion should be avoided as much as possible. Therefore, the acquisition plane should be optimized so that it crosses the apex and the center of the mitral valve.

Is it possible to exclude segments in which the image quality is not adequate for quantification?

Segments cannot be excluded from the GLS measurement because the GLS calculation is based on the length-of-the-line method. If two or more segments per view are not tracked reliably, the results should not be accepted.

Does the software perform strain drift correction? And if yes, can we switch it off?

The software performs drift correction. This drift correction cannot be disabled.

Assessing the quality of a segment's strain curve, what should one look for?

There are a number of characteristics to be considered. Is the strain curve for a region consistent with the strain curves of adjacent regions? Is the longitudinal strain curve consistent with the visual assessment of the endocardial motion of the region? For the segment in question, does the image show any unusual motion? Are there imaging artifacts close to the segment?

How are R-wave and AVC defined, and where can AVC be edited?

The R-wave is assumed to be the first frame of the analyzed time interval. The default AVC time is the time of minimal contour length and thus corresponds to the time of peak GLS. The AVC time can be edited in the AVC layout by moving the vertical AVC marker to match the frame showing the closure of the aortic valve in the A3C view.

AutoStrain LA: is there a recommendation for how to trace the LA wall?

Due to pulmonary veins and LA appendage orifices, the LA wall is not as smooth as the LV wall. The Strain Task Force[1] recommends tracing the LA to extrapolate across pulmonary veins and LA appendage orifices, up to the opposite mitral annulus side.[3] Therefore only GLS shall be assessed and the LA is not divided into segments.

AutoStrain RV: why are segmental measurements at the free wall only?

According to the Strain Task Force, segmental RV strain shall be measured at the free wall only.[3] Septal segmental strain should be assessed together with the LV. Global measurements are available for the RVFWSL and include the septum in the RV4CSL.

References

1 Voigt JU, et al., Definitions for a common standard for 2D speckle tracking echocardiography: consensus document of the EACVI/ASE/Industry Task Force to standardize deformation imaging. J Am Soc Echocardiogr. 2015;28(2):183–93. doi: 10.1016/j.echo.2014.11.003.

2 Biering-Sorensen T, Biering-Sorensen S, Olsen FJ, et al. Global Longitudinal Strain by Echocardiography Predicts Long-Term Risk of Cardiovascular Morbidity and Mortality in a Low-Risk General Population The Copenhagen City Heart Study. Cardiovasc Imaging. 2017:10. doi: 10.1161/CIRCIMAGING.116.005521.

3 Badano LP, et al. Standardization of left atrial, right ventricular, and right atrial deformation imaging using two-dimensional speckle tracking echocardiography: a consensus document of the EACVI/ASE/Industry Task Force to standardize deformation imaging. Eur Heart J Cardiovasc Imaging. 2018 Jun;19(6):591–600. doi: 10.1093/ehjci/jey042.