Evaluation of left ventricular longitudinal global and segmental strain – *AFI 2.0*

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Introduction

Objective global and segmental quantification of heart function by speckle tracking technology has gained a lot of momentum for the past 15 years, not only for researchers, but also for clinical routine applications.

GE Healthcare has pioneered development in this field, and introduced *2D Strain* in 2004, *AFI* in 2006 and now *AFI 2.0* in 2019 using strain to take left ventricular quantification to the next level.

Definition of strain

Strain is a measure of deformation or change in shape of the myocardium between two points, usually shown in a percent of deformation. Per definition strain values are negative when the measured distance (L) is smaller than original distance (L_o) as shown. (See Figure 1).

Strain [%] = (L-Lo)/Lo x100%

By combining data from multiple "two-point calculations" spatially as well as temporally, quantification of the left ventricle throughout the heart cycle can be obtained in whatever two-dimensional views that are analyzed.

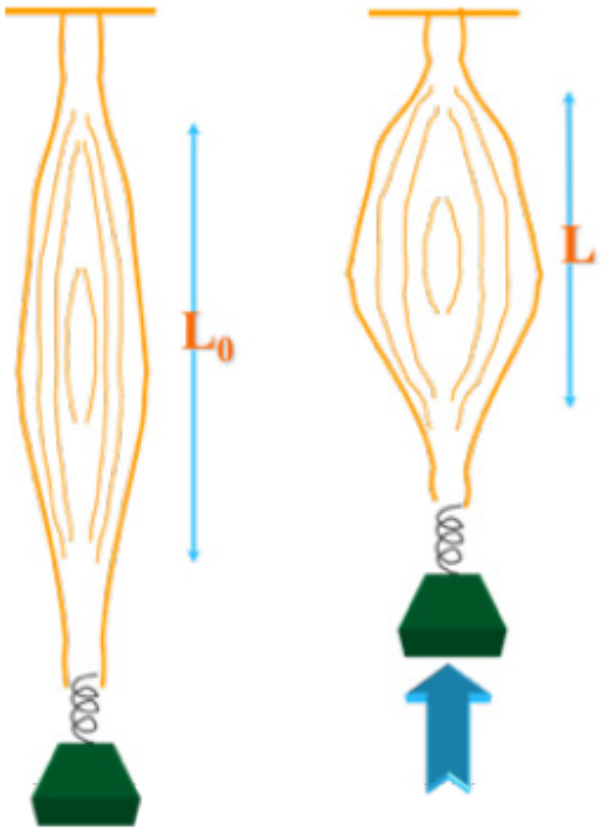

Figure 1: Strain definition

2D Strain

Introduced in 2004 *2D Strain* is an advanced research tool designed for left ventricular quantification, though its versatility enables use for the other chambers as well. It is still available today in our EchoPAC™ software offering.

2D Strain is based on similar principles that are utilized with tagged MRI. One of the main differences is that instead of using external, short-lived magnetic tags, *2D Strain* uses inherent features ("natural acoustic markers") for frame-to-frame tracking of the myocardial tissue. (See Figure 2).

2D Strain supports calculations of strain, strain rate, velocities and distance (tissue tracking) in longitudinal, circumferential and radial directions, in addition to rotation and torsion.

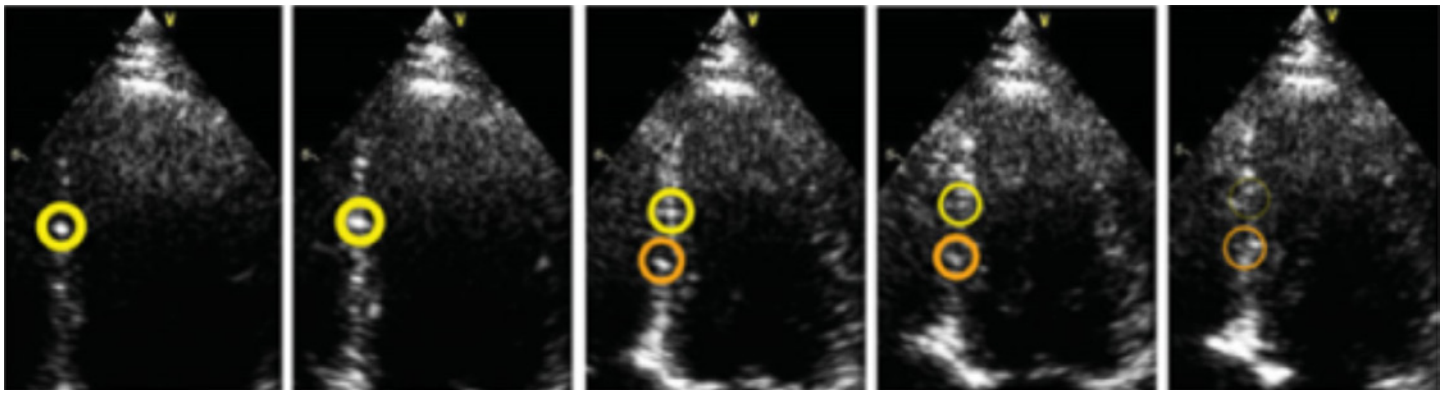

Figure 2: "Natural acoustic tagging": New features/"speckles" (orange circles) keep coming into the image as old ones fade out (yellow circles)

Automated Function Imaging (AFI)

In 2006 GE introduced *Automated Function Imaging (AFI)*, a clinical derivative of 2D Strain focused on streamlining the workflow and assessing only left ventricular longitudinal global and segmental strain. Unlike *2D Strain*, AFI was made available on the GE Vivid™ scanners in addition to on EchoPAC.

AFI allows objective quantitative analysis of the complete myocardial longitudinal motion of the left ventricle throughout the heart cycle, in two dimensions. The system can be set up to automatically find the location of the endocardial borders of the walls, or one can utilize a so-called 3-point click method to place two landmarks at the base and one at the apex to help the Region of Interest (ROI) placement. Once the ROI has been placed it can, if necessary, be edited by dragging on the bullets on the endocardial border line. When the system is in the "processing stage" speckles within the ROI are tracked in two dimensions, and the strain along the ROI (longitudinally) is calculated. The ROI is dynamic in the sense that it follows the underlying tissue movement. If it doesn't, the ROI must be edited, and processing must be repeated.

The dynamic ROI excludes spurious signals originating from outside the ROI (e.g. from the intracavity blood pool or from the pericardium) from affecting the strain values.

To obtain the complete assessment of the left ventricle all three apical views must be analyzed. In *AFI* one is required to start with the apical long axis view, followed by the apical four and apical two chamber views.

One of the endpoints of the *AFI* analysis is a parametric left ventricular bulls-eye displaying segmental as well as global peak strain values, with easily recognizable colorization of the different LV segments according to a strain color map as shown below where red shows contraction and blue relaxation. See Figure 3. A green/yellow/red ("good/bad") color map is also available in addition to a Post Systolic Index (PSI) map (see Figure 4) and a Time to Peak (TTP) strain map (see Figure 5).

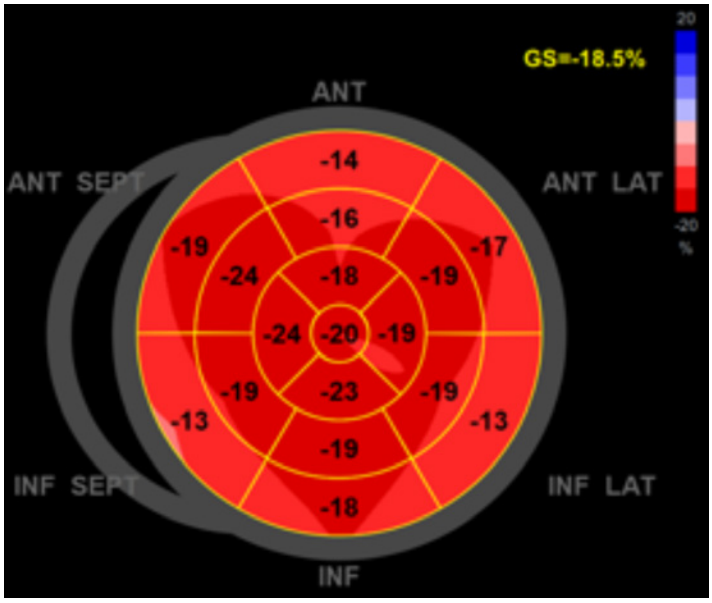

Figure 3: *AFI* Bulls-Eye with color coding and segmental and global values

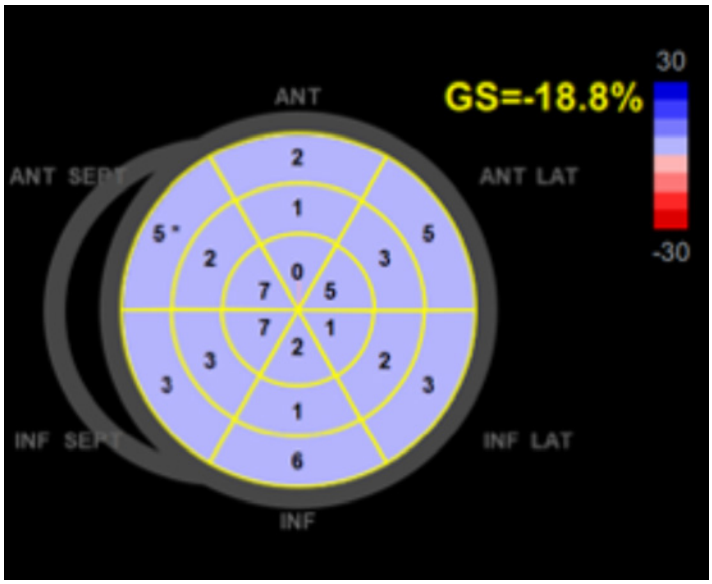

Figure 4: Post Systolic Index map indicating contraction delay post AVC closure

For those interested in more timing and curve shape details a trace layout is also available per LV view. (See Figure 6).

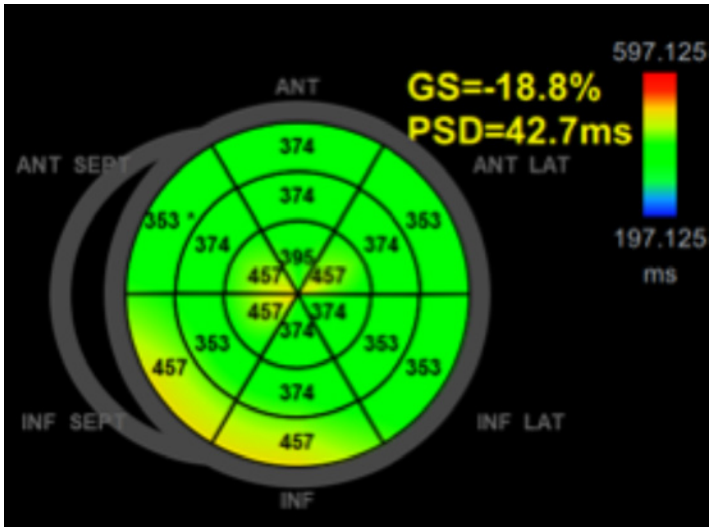

Figure 5: Time to Peak (TTP) strain (a.k.a. Peak Strain Dispersion (PSD) indicating synchronicity

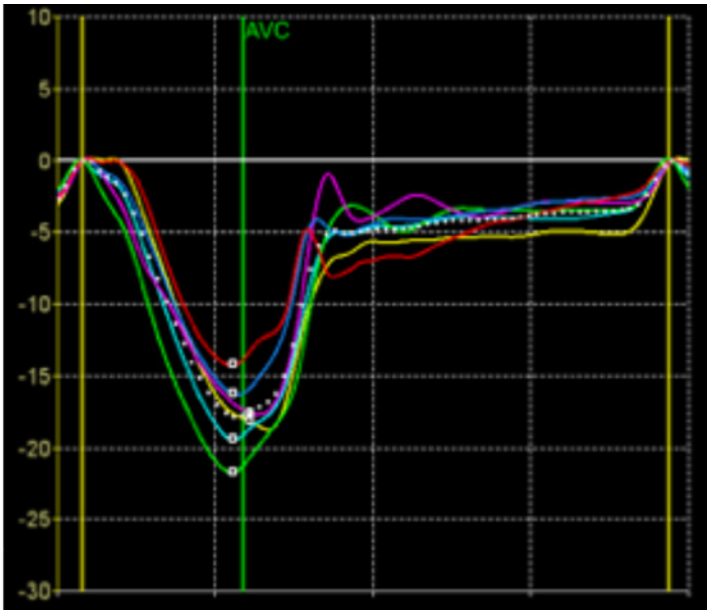

Figure 6: *AFI* traces of one apical view (6 segments) showing strain over time for one heart cycle

AFI 2.0

Though a few new features were added to the original *AFI* package (like *Peak Strain Dispersion (PSD)*[1] and *Myocardial Work (MW)*,[2]) there was a need to revise the package to accommodate for new requirements, driven by end customers as well as the ASE/EACVI communities.

So, in 2019 GE introduced *AFI 2.0* extending the functionality and enhancing the workflow based upon user feedback from more than 13 years of use of the AFI package, and in preparation for these new requirements.

The principles of operation of *AFI 2.0* are the same as for *AFI*, though the algorithm was rewritten to improve tracking. Several other enhancements have been added as well, listed throughout the rest of the document.

Workflow

While the *AFI* package was stringent when it came to workflow, *AFI 2.0* offers much more flexibility:

- One can start analysis with any of the three apical views.
- Automation has also been extended such that when analyzing images from a Vivid scanner running the AI based *View Recognition* workflow is enhanced. *View Recognition* is a new feature running on the Vivid E80/E90/E95. It automatically labels the most common 2D images according to the acquired view (e.g. 4CH, 2CH, APLAX, etc.). Labelling is done during Image Store. *AFI 2.0* then automatically selects the most appropriate images from all apical views so that both frame rate and heart rate requirements are met prior to starting the analysis.
- Yet another new feature is that the user can go back and repeat prior steps without having to start from the beginning.

The user interface is divided up in stages or steps, as shown below. (Figure 7). One can at any time run/stop the loop, single step frame by frame, zoom and apply more or less gain, provided that the loop is from a Vivid scanner (raw data).

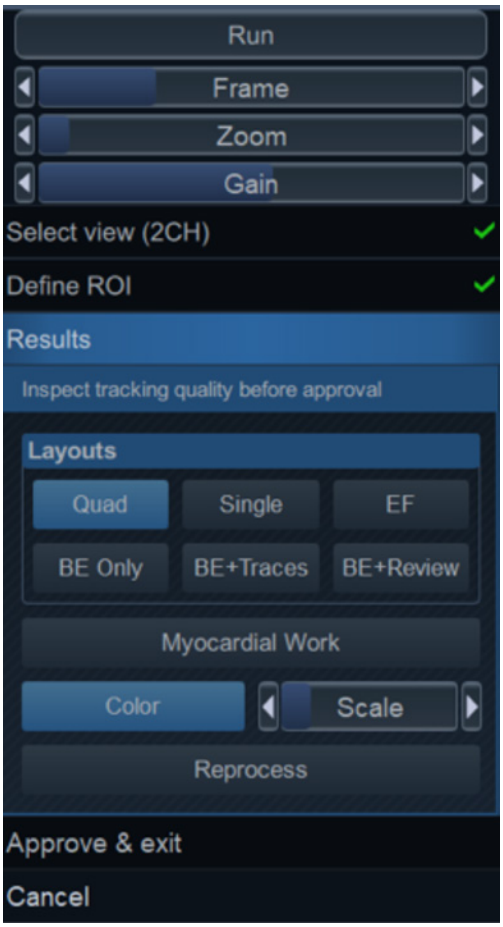

Figure 7: Control panel with Stage menu

The various stages are as follows:

Select View:

To start analysis *AFI* must be initiated from the Measurement menu. One of the 2D apical views must be selected from the clipboard. If *View Recognition* was applied during acquisition the two remaining apical views will now be highlighted/ selected in the clipboard for easier selection later.

If multiple cycles have been acquired one can select the desired one in the Select View stage. One can also edit the start and stop markers manually.

Define ROI:

The system will automatically place a ROI based upon the system's ability to recognize the structures ("speckles") in the image. If "Autoprocessing" is enabled in Config the system will initiate the speckle tracking algorithm ("Processing") which then will track the various recognizable speckle patterns as described earlier. If editing is needed that must be done prior to tracking being initiated (select "Reprocess" to revert to the Define ROI editing step if processing is completed prior to editing).

AVC timing can be either set to Auto (default), Manual or Event Timing (in Config).

New in AFI 2.0 is the ability to change the ROI width individually at segment level. This is done by grabbing and pulling the outer dotted line in the Define ROI stage. This may be important to enhance tracking depending on individual segmental difference in wall shapes and thickness

Results:

When processing (tracking) is completed the system will show a quad screen with a moving 2D loop with the color overlay, a frozen 2D with a color overlay and the segmental peak systolic strain values, as well as a trace for the 6 segments and an anatomical color M-Mode. (See Figure 8).

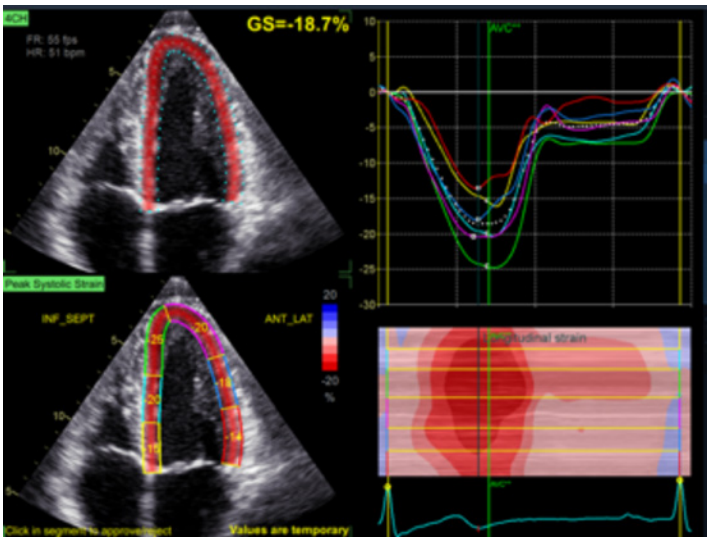

Figure 8: Quad screen

In *AFI 2.0* one can approve/reject each individual segment by clicking on the segments in the lower left quadrant. (See Figure 9).

Also new in *AFI 2.0* is the ability to store the quad with the moving loop in the upper left quadrant, for later documentation of the actual tracking by visual observation. This loop also plays on DICOM® workstations.

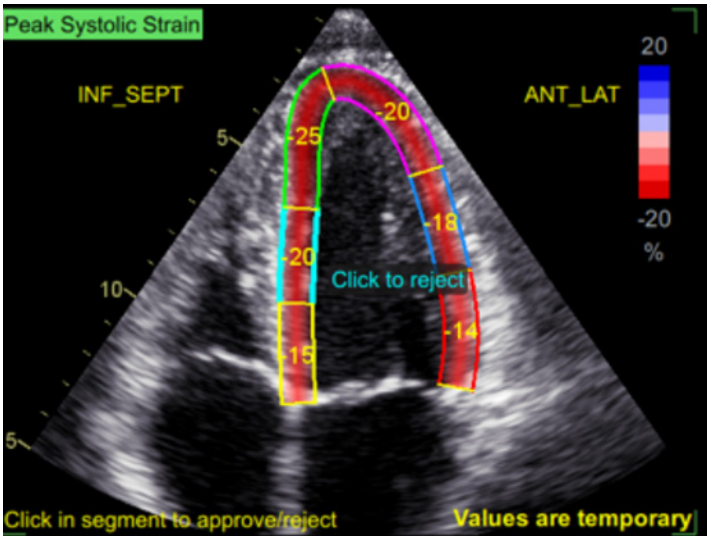

Figure 9: Single screen

Introduced in *AFI 2.0* is the ability to calculate and display Ejection Fraction (EF) and LV Volumes within the tool. (See Figure 10). By pressing the EF button in the stage menu, the LV EF per view as well as for the whole LV is shown (when both 4ch and 2ch are completed). Biplane Simpson is the method used when doing the volume calculations for the ventricle.

Figure 10: Ejection Fraction and Volume results

When analysis of one view is completed one can either exit ("Approve and Exit") or analyze the next view. If *View Recognition* was applied during acquisition pressing "Approve and select next" automatically launches the next view for analysis. Otherwise one must manually select it from the clipboard and click on the appropriate view button in the "Select View" stage. (See Figure 11).

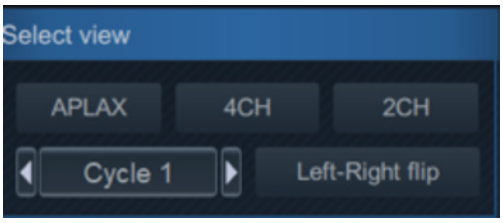

Figure 11: Ejection Fraction and Volume results

When all three views have been completed one can chose which layout one wishes to display. (See Figure 12). Again, note that if Quad is selected the moving upper left loop can now be stored (see Figure 8 on previous page).

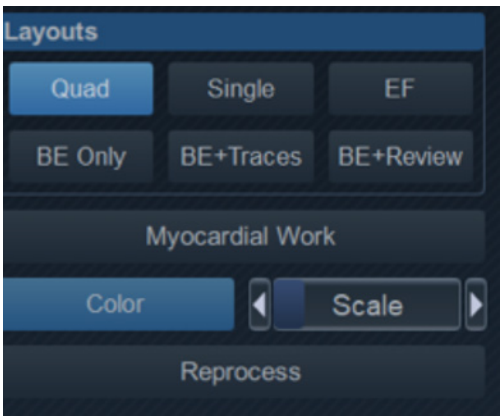

Figure 12: Available layouts (some of which are shown previously)

Note that with *AFI 2.0* one must complete all three views consecutively when inside the tool to complete the analysis of the whole left ventricle and obtain a bulls-eye.

For the strain values to be transferred to the Worksheet one must end the analysis with “Approve and exit”.

While *AFI* showed the strain values from the full wall, *AFI 2.0* can show either the full wall values or the endocardial values. If selecting the latter (in Config) one still tracks the full wall, but then calculates the endocardial values based upon the distribution of strain values within the ROI.

AFI had two bulls-eyes; an 18-segment model, and a 17-segment model, both oriented 60 degrees off the normal ASE standard of orientation.

In *AFI 2.0* the ASE orientation and segment labelling of the bulls-eyes is supported, in addition to the *AFI* orientation. Thus, four bulls-eyes are available (selectable from Config). The old AFI bulls-eyes shown to the left in Figure 13 below.

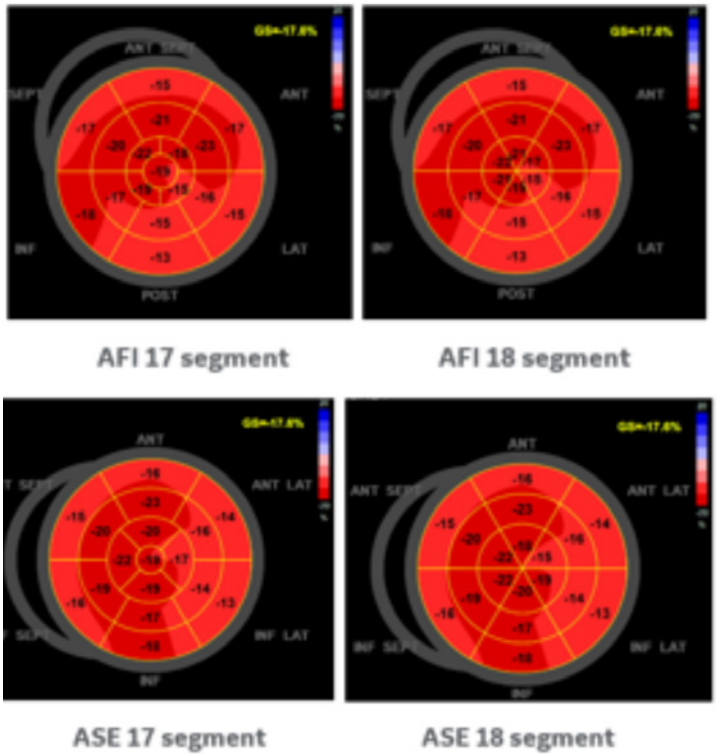

Figure 13: Available bulls-eyes

Both 18 segment bull-eyes show the segmental strain numbers from each of the three apical views (6 segments x 3 views), while in the 17 segment bulls-eyes the five apical segments, including the cap, are derived differently.

In the *previous version* they are mathematically calculated from the six apical segments from the 18-segment model:

- Apical_inferior is 2/3 * apical_inferior + 1/3 * apical_ inferolateral (posterior)
- Apical_lateral is 1/3 * apical_inferolateral + 2/3 * apical_ anterolateral
- Apical_anterior is 2/3 * apical_anterior + 1/3 * apical_ anteroseptal
- Apical_septal is 2/3 * apical_inferoseptal + 1/3 * apical_ anteroseptal

In *AFI 2.0* the values for the apical segments are based upon the actual data found during the tracking process, and as such should be more accurate.

Comparison of *AFI 2.0* vs. previous *AFI* version

Analyzing data sets with both the previous *AFI* version and *AFI 2.0* has shown that on a large cohort of patients (an internal study comparing results from analysis of 650 segments) there is no bias neither in the global longitudinal strain value nor the basal, mid and apical segmental values.

However, at patient level there may be variability both in global as well as segmental values when comparing results from the previous *AFI* and *AFI 2.0*. As such, care must be taken if switching AFI version in the middle of a research study, or during follow up of patients. In the 2019 release (v203 – “Patient Care Elevated” release) of EchoPAC the 2D Strain package continues to use the previous tracking algorithm, so as such one can use this package for follow up of such patients, should this be required. Alternatively, one could reprocess historic studies with the new *AFI 2.0* package to eliminate potential differences in strain values if needed

The *AFI 2.0* tool's ability to detect scar, as classified by MRI, has also been monitored. Using a sample size of approximately 650 segments (same internal study as highlighted above), the Receiver Operating Characteristics (ROC) in Figure 14 shows that the *AFI* and *AFI 2.0* tools have similar scar detection capabilities.

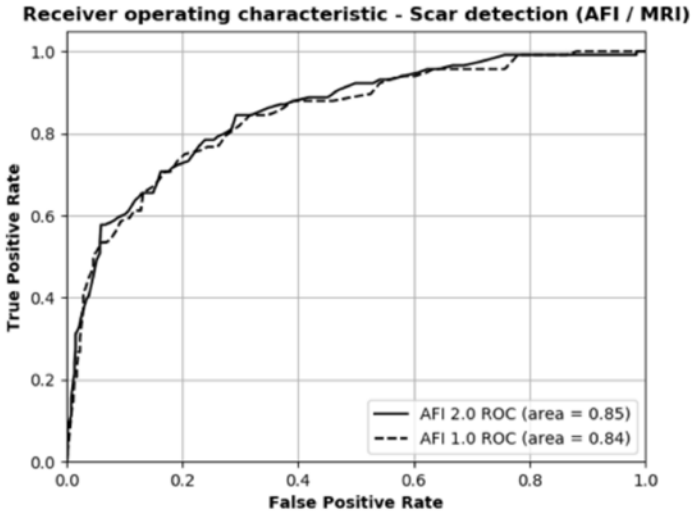

Figure 14: ROC curve of scar detection for AFI and AFI 2.0.

The Bland and Altman plot of the global strain measurements of *AFI* and *AFI 2.0* in Figure 15 illustrates a 95% confidence interval of the difference [-1.78, 1.84] percentage points and shows no sign of systematic differences.

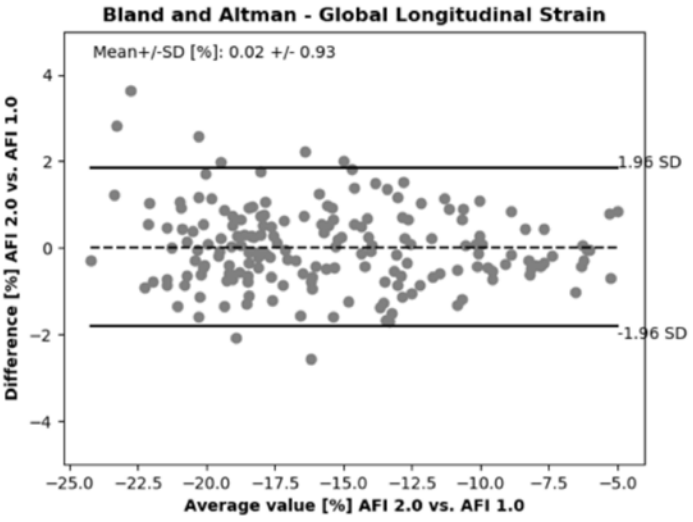

Figure 15: Bland and Altman plot of the differences between AFI 2.0 and AFI

This is also confirmed by a simple scatter plot (See Figure 16) showing excellent correlation between the two versions.

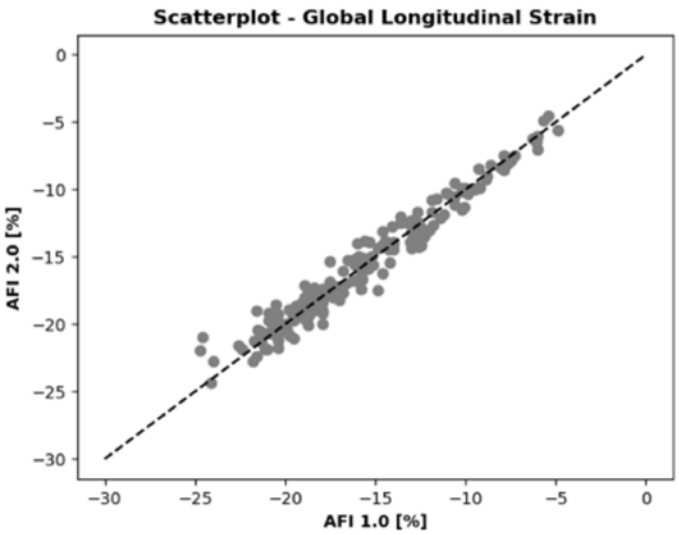

Figure 16: ROC curve of scar detection for AFI and AFI 2.0.

Clinical use of *AFI*

Literature search shows that Longitudinal Strain (LS) can add diagnostic information on left ventricular global and regional function. There have been hundreds of publications on the use of *AFI* over the years. The examples listed below are from a December 2018 publication[3] and summarizes the use of *AFI* in clinical use cases.

1. LV Hypertrophy (LVH) with preserved Ejection fraction (HFpEF)
2. Heart Valve disease (HVD)
3. Acute coronary syndrome and chronic ischemic cardiomyopathy
4. Acute myocarditis
5. Systemic Diseases and Neuromuscular Disorders
6. Cardiotoxicity from cancer therapy

Summary

With introduction of *AFI 2.0*, GE is well prepared to further advance and expand the use of speckle tracking assessing cardiac function, and to meet new requirements from the ASE/EACVI standardization committee as they continue their work to introduce this methodology into daily mainstream echocardiography.

[1] "Peak Strain Dispersion white paper" (JB27632XX)

[2] "Myocardial Work" white paper (JB49049XX)

[3] "Ten Years of 2D Long Strain for Early Myocardial Dysfunction detection: A Clinical Overview", Hindawi BioMed Research International Volume 2018, Article ID 8979407, 14 pages https://doi.org/10.1155/2018/8979407 (JB69145XX)

[4] "Expert Consensus for Multimodality Imaging Evaluation of Adult Patients during and after Cancer Therapy", Plana et al, JASE, September 2014. (JB24109XX)

Imagination at work

JB68066XX(1)