Measuring cardiac tissue motion and strain

Automated Cardiac Motion Quantification[A.I.] (aCMQ[A.I.])

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Automated Cardiac Motion Quantification[A.I.] (aCMQ[A.I.]) is a clinically focused tool for measuring cardiac tissue motion and strain. These measures can be useful in the evaluation of several cardiac motion abnormalities.

Analysis of cardiac motion can be very challenging and prone to significant variability. By utilizing a semi–automated approach, aCMQ[A.I.] has the potential to reduce the variability of cardiac motion analysis, as well as streamline workflow.

Measurement of strain

aCMQ[A.I.] provides for the measurement of strain within a Region of Interest (ROI) so that the strain of the selected tissue can be evaluated. Establishing the ROI is a very simple process. First, the system will automatically create an ROI template based on the selected view type and an analysis of the image. The user may also manually specify an ROI template by identifying three points – one point on each side of the mitral annulus and one point at the apex. The system will then automatically identify the endocardial boundary and create an ROI that extends from the endocardial boundary a fixed distance outward toward the epicardium. This ROI is divided into seven sub-regions to measure the regional longitudinal strains.

Longitudinal strain is calculated as the change in length of each of the regions as compared to its relaxed length. aCMQ[A.I.] uses Lagrangian strain calculation which is defined as

$$\text{Strain} = (L - L_o) / L_o$$

where L = length and L_o = relaxed length

To measure the strain, the tissue motion is tracked over a cardiac cycle using a speckle tracking algorithm. Similar to MRI tagging, speckle tracking follows features within the image as they move. Each sub-region of the ROI is divided into blocks, which allows the speckle structure in each block to be tracked. The measured deformation for each sub-region is a weighted combination of the displacements from each of the blocks. The weighting gives greater weight to endocardial blocks than to epicardial blocks. The strain is then calculated from the per-region deformation at the endocardial border.

aCMQ[A.I.] can also be used to measure circumferential strain using a short-axis view. In this function, the user initiates the ROI generation process by placing a circle on the image area and adjusting it to the desired size. This ROI is divided into six sub-regions for basal or mid short-axis slices and into four sub-regions for slices near the apex. Circumferential strain is calculated as the change in circumference of each of region as compared to the relaxed circumference of that region. As with the measurement of longitudinal strain, the measured deformation is weighted from the endocardium to the epicardium, with the endocardium being given greater weight. The strain is calculated from the per-region deformation at the endocardial border.

Display of strain results

After approval of the ROI, the strain is calculated over the cardiac cycle. The strain results are shown as a parametric image loop and the tissue motion can be displayed by playing this loop. aCMQ[A.I.] automatically evaluates the quality of the speckle tracking for each of the ROI segments.

When determining the maximum strain, aCMQ[A.I.] gives the user complete control over the interval within which the maximum strain is measured. Common choices are the measurement of maximum strain within only the systolic period or alternatively over the entire cardiac cycle. The user also has the option of manually identifying the time of maximum strain individually for each of the strain waveforms.
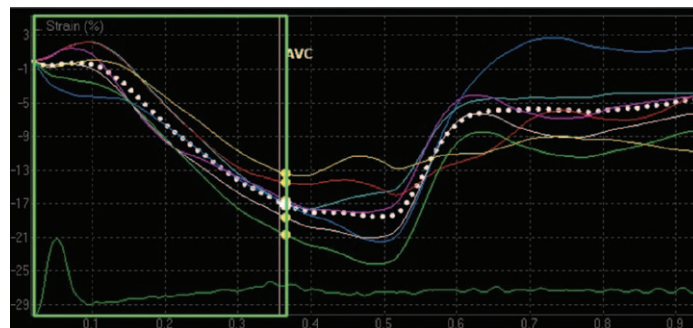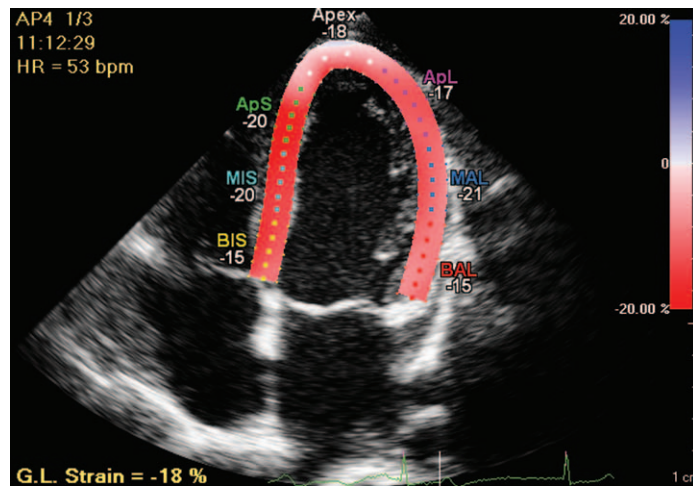

The strain results can also be displayed as strain waveforms. Providing the strain data as a waveform allows the temporal changes in the strain to be appreciated.

The strain waveforms from each of the regions can be combined into a global strain waveform. The aCMQ[A.I.] consolidation process uses a weighted average of the regional strains. The weighting factors are based on the rest length of each of the regions. By using a weighted average, each region's contribution to the global value is based on the size of the region.

The maximum strain from the global longitudinal strain waveforms is denoted as the Global Longitudinal Strain (GLS). In a similar fashion, the maximum strain from the global circumferential strain waveform is denoted as the Global Circumferential Strain (GCS). When determining the maximum strain, it is important to understand in which time period the maximum can be located. aCMQ[A.I.] allows the user to define the time point of the maximum strain.

Regional strain values from either the three apical views (AP2, AP3, and AP4) or three short-axis views (basal, mid, apex) can be combined into a parametric display known as a bullseye diagram. The bullseye diagram allows for quick evaluation of the regional strain behavior of the entire left ventricle. Two bullseye diagrams are pictured below. The image on the right was created by the 17-segment model recommended by the AHA and used by Philips. The diagram on the left is a 16-segment model from another vendor. In order to compare these two models, it is important to note differences that can make direct comparison difficult. One of the differences between the two diagrams is their orientation. The 16-segment model has the AP3 axis oriented vertically while the 17-segment model has the AP2 axis oriented vertically. This has the effect of rotating the two diagrams 60° with respect to each other. The other difference concerns the handling of regional data at the apex. Both diagrams have six segments in the outer and middle rings.

The 16-segment model has four segments in the apical region. The 17-segment model includes four segments in an apical ring and a segment directly at the apex. The 17-segment model used by aCMQ[A.I.] is created from seven segments in each of three apical views. Other vendors use six segments for each of the three apical views. Due to this difference in the number of segments, there is a corresponding difference in the length of each of the segments. These differences in segmentation approach can lead to differences in the strain reported for each segment.
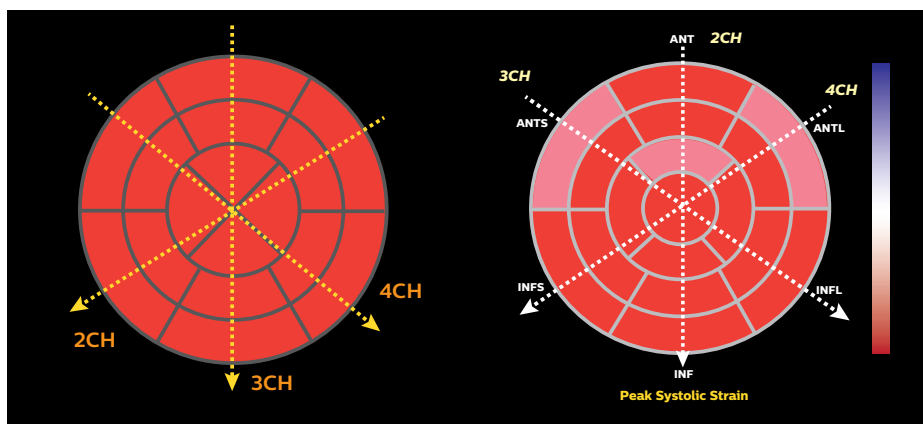
16-segment model   **AHA/ASE 17-segment model**

Conclusion

Speckle tracking is an exciting technique which shows excellent results. aCMQ[A.I.] combines this new technique with a user-centered workflow to provide a valuable tool for evaluating cardiac motion.

Frequently asked questions

1. Does the software measure full thickness strain, mid-wall or endocardial strain?

In the Langrangian strain calculation of Strain = Displacement/ Relaxed Length, the Displacement is measured as a weighted average of the myocardial deformation across the myocardium with the weighting greatest at the endocardium. The Relaxed Length is measured at the endocardial boundary.

2. How is the global strain calculated (weighted versus averaged)?

GLS is calculated as a weighted combination of the regional strains with the weighting based on the length of the endocardial boundary for each region measured at diastole.

3. Does the software perform strain drift correction? And if yes, can we switch it off or see how much error is actually there?

The software does perform drift correction to match the diastolic boundary at the beginning and end of the cardiac cycle. This drift correction can't be disabled.

4. If a segment is tracking so poorly that we need to exclude it (no more than one per view), how does the software calculate the global strain?

The contribution from the excluded segment is excluded, from the GLS calculation. When any segment has been excluded it indicates that the tracking may be suspect on other segments. The most conservative practice is to not use the GLS measures if any segments have been excluded. These same comments also apply to Global Circumferential Strain (GCS).

5. 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 wall thickening of the region? For a segment in question, does the image show any unusual translational motion?

6. Is the peak negative pre- or post-systolic? If the peak negative is post, then does the software report the peak negatives for the calculation of the global curve regardless of closure or only what precedes aortic valve closure?

On the strain waveform display, the time region within which the peak strain is identified is fully controllable by the user.

7. How does aCMQ[A.I.] set the R-AVC automatically? Can it be changed?

The aCMQ[A.I.] Auto R-AVC is set as the time from the R-wave to the minimum volume measured on the AP3 image. The user can override the automatically generated R-AVC.

8. Does the software use regularization? Can this be switched off?

The software uses limited regularization to reduce random variations. This regularization can't be disabled. Allowing the regularization to be disabled would introduce variability between the results with and without regularization.

9. Can I directly compare the segment strain for the 17-segment vs. 16-segment model?

Because the individual segments for the 17-segment model are in slightly different locations than the individual segments for the 16-segment model, the two bullseye diagrams can't be directly compared, segment for segment.

10. Is the strain measurement consistent in QLAB between different versions of the releases?

The aCMQ[A.I.] software is periodically enhanced and minor differences between the strain values may be observed. If feasible, older images should be reanalyzed with the latest software to provide for maximum consistency of results.

11. Is aCMQ[A.I.] global longitudinal strain (GLS) validated?

At the present time, there is no objective standard, such as a phantom, with which to validate the strain results. But there are published clinical papers and abstracts that compared aCMQ[A.I.] to other vendors' GLS with very favorable results, such as, "Quantification of the variability associated with repeat measurements of left ventricular two-dimensional global longitudinal strain in a real world setting" (JASE 2014; 27:50-54) and "Global left ventricular systolic strain: An inter-vendor comparison in 298 patients with known or suspected cardiomyopathy" (JASE 2013;26:B4).

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