Cardiac Motion Quantification

Measuring cardiac tissue motion and strain
David Prater, MS

Overview
Cardiac Motion Quantification (CMQ) 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 challenging and prone to significant variability. By utilizing a semi-automated approach, CMQ has the potential to reduce the variability of cardiac motion analysis as well as streamline workflow.

Measurement of strain
CMQ measures strain within a Region of Interest (ROI) so that the strain of the selected tissue can be evaluated. Establishing the ROI is a simple process. An apical view is used to evaluate longitudinal strain of the left ventricle. To start the process, the user identifies 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 to the epicardial boundary. 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:

\[ \text{Strain} = \frac{L - L_0}{L_0} \] where \( L \) = length and \( L_0 \) = relaxed length

To measure the strain, 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 within each block to be tracked. The measured deformation for each sub-region is a weighted combination of the displacements from each of the blocks. 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.

CMQ can also be used to measure circumferential strain using a short axis view. In this function, the user initiates the ROI generation process placing a circle on the measurement 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 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 can be shown as a parametric image loop and the tissue motion can be displayed by playing this loop. CMQ automatically evaluates the quality of the speckle tracking for each of the ROI segments. The user can set an adjustable threshold to control when the tracking is to be considered questionable. Regions judged to have questionable tracking will not be displayed unless the user chooses to display them. A Confidence Index provides a measure of the tracking quality. The ability to adjust the threshold controlling the tracking acceptance is intended primarily for research institutions. The default threshold is optimal for typical clinical situations.

The strain results can also be displayed as strain waveforms. The characteristics of the strain waveforms can have a significant impact on their utility. If not properly constructed, the waveforms can be quite noisy. However, care must be taken not to excessively process the waveforms since this can negatively impact the determination of maximum strain. The CMQ waveforms are optimally processed to provide maximum utility. An example of the strain waveforms generated by CMQ is shown below.

When determining the maximum strain, CMQ gives the user the option of using the maximum strain over the entire cardiac cycle; or if the aortic valve closure (AVC) point is defined, the user can use the maximum strain over only the systolic period.

The strain waveforms from each of the regions can also be combined into a global strain waveform. The CMQ consolidation process uses a weighted average of the regional strains. The weighting factors are based on the relaxed 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. This enables the larger regions to contribute more to the global average than the smaller regions.
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).

GLS values from 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 Bulls Eye diagram. The Bulls Eye diagram allows for quick evaluation of the regional strain behavior of the entire left ventricle. Two Bulls Eye 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 degrees with respect to each other. The other difference concerns the handling of regional data at the apex. Both diagrams have 6 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.

**Conclusion**

Speckle tracking is an exciting technique which shows excellent clinical promise. CMQ combines this new technique with a user centered workflow to provide a valuable tool for evaluating cardiac motion.