

Advanced Multi-Layer Speckle Strain Permits Transmural Myocardial Function Analysis in Health and Disease:

Clinical Case Examples

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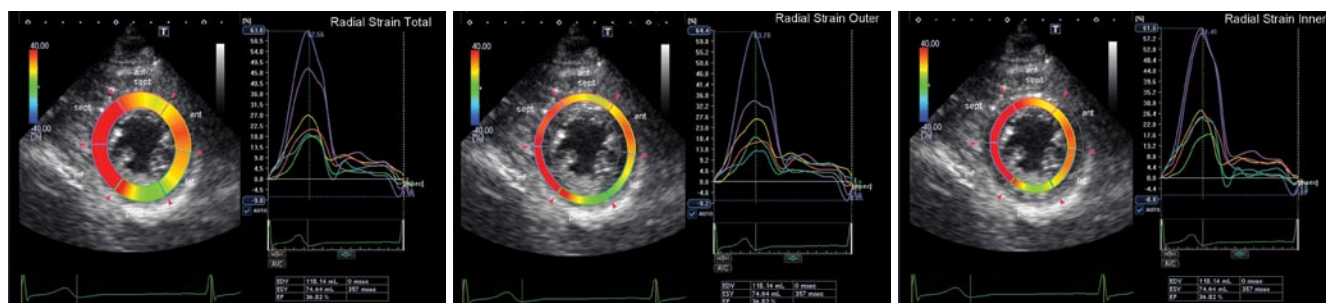
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Two-dimensional (2D) speckle tracking echocardiography (STE) is now used to measure deformation and percent change (i.e., strain) in the myocardium for regional and global function. STE is based on conventional B-mode acoustic backscatter, permitting tracking of myocardial reflectivity (i.e., speckles) throughout the cardiac cycle¹. Current STE methods measure the subendocardial-epicardial border interface, but do not permit analysis of deformation of the subepicardium or epicardium-to-endocardium. Recent advancements in STE by means of 2D wall motion tracking (2D WMT) have emerged allowing measurement of strain within layer-specific regions of the myocardium. This novel approach has been evaluated in normal subjects, patients with LV dysfunction and dyssynchrony, and validated against cardiac MRI in patients with non-transmural and transmural infarction^{2,3}. The 2D-based STE multi-layer approach may provide further information on the heterogeneity of myocardial mechanics.

Here we present two cases. The first case is from a 41-year-old male with a history of hypertension who was referred to the echocardiography laboratory for evaluation of structural heart disease. The echocardiogram showed a left ventricular ejection fraction (LVEF) estimated in the range of 65–70% and no significant valvular disease. The second case is from a 61-year-old male with a history of ischemic cardiomyopathy. The echocardiogram showed normal left ventricular size with a LVEF estimated in the range of 40–45%. Findings included moderate hypokinesis of the inferior, basal-mid inferolateral, and entire septal wall. There was mild concentric hypertrophy and no significant valvular disease.

2D WMT SPECKLE STRAIN PROTOCOL	axis imaging, and acquisition during quiet respiration or apnea may improve tracking of the myocardium and reliability of data. To obtain 2D WMT, the on-line quantification program is accessed and the radial strain modality is chosen. The trace function is activated and four points along the LV endocardial border are chosen; a caliper is placed in a counterclockwise direction at nine	o'clock, six o'clock, three o'clock and twelve o'clock. The last point (twelve o'clock) automatically creates an epicardial border that is of equal distance from the endocardial border. The corresponding radial strain waveforms representing data from 6 myocardial segment are positive, and displayed above the baseline (Figure 1). The processing time of 2D WMT from the point at
2D WMT was assessed in the parasternal short axis view at the papillary muscle level to obtain three-layer (inner, outer, total) radial strain analysis. Briefly, when acquiring images for 2D WMT, care is taken to optimize both the endocardial border and epicardial borders. Good image quality, on-		

which the raw data are obtained to strain results from each myocardial segment is roughly 35 to 40 seconds.

CASE 1: NORMAL MULTI-LAYER RADIAL STRAIN ANALYSIS

2D WMT radial strain demonstrated a layer-specific gradient across the myocardium during systole (Figure 2). As predicted, the inner half subendocardial strains were normal and had the highest mean strain values, equalling 51% (Figure 2A); there was a significant decrease

in both regional and mean strains in the outer half, subepicardium equals 35% (Figure 2B), with the total, mean transmural strains equal 43% (Figure 2C). Of note, the majority of the radial strains from the corresponding segments peaked normally, occurring at the end of the T-wave on the ECG (i.e., aortic valve closure). These results demonstrate the uniformity in regional contraction and that a transmural gradient exists, with higher strain values in the subendocardial layer as confirmed previously by cardiac MRI³.

CASE 2: ABNORMAL MULTI-LAYER RADIAL STRAIN ANALYSIS

2D WMT radial strain failed to demonstrate layer-specific differences with significant heterogeneity in the peak strains (Figure 3), which is in contrast to the normal findings. The majority of the inner half (subendocardial) strains were abnormal, with the lowest strain in the septal region equaling 18%. The mean inner half strain was abnormal, equaling 27% (Figure 3A). Similar to the inner half subendocardial strains, the majority of the outer

half subepicardium were abnormal with severe delay in the septal, inferior and posterior segments (arrows).The lowest strain was in the septal region, equaling 16%. There was no significant decrease in both regional and mean strain in the outer half subepicardium, equaling 28% (Figure 3B). The total, mean transmural strain equaled 27% (Figure 3C). These findings demonstrate no significant difference in strain at different layers of the myocardium with significant heterogeneity in peak strain.

DISCUSSION

To elucidate the differences between heterogeneity and non-heterogeneity in the normal myocardium, radial strain or thickening is greater in the subendocardial layer than in the subepicardial layer. This transmural heterogeneity is explained by an increase in subendocardial wall stress, differences in myocardial blood flow, intramyocardial vascular resistance, myocardial metabolism, and contraction and relaxation dynamics⁴.

In abnormal myocardium, following periods of interrupted coronary blood flow, there is ischemia/necrosis that begins in the subendocardium and can extend through the ventricular wall resulting in transmural myocardial damage. This phenomenon is known as the “wavefront phenomenon”⁵. Furthermore, in the ischemic cascade, the subepicardial layer is reported to compensate for the decreased systolic thickening of the subendocardial layer which is referred to as “vertical

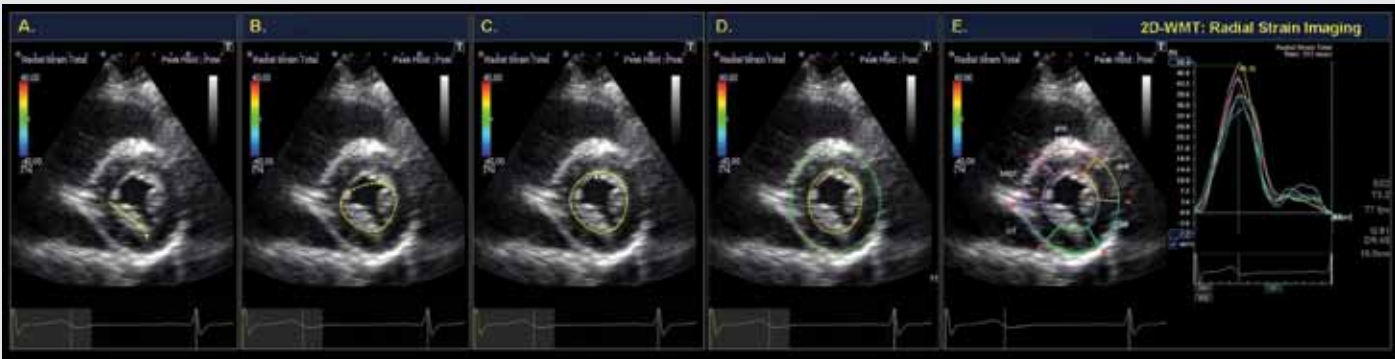


Figure 1A-E: 2D WMT speckle imaging protocol. The 2D image is frozen at end-systole and a caliper (arrow) is placed at the endocardial border at 9 o'clock, then located at 6 o'clock in a counterclockwise direction to activate the speckle tracking algorithm (A); the caliper is then indicated at 3 o'clock (B), then 12 o'clock (C). A double-click on the arrow creates an epicardial layer that is equally distanced (D). The image is then processed to create 6 equally spaced linear polygons with the corresponding radial strain waveforms shown in the extreme right panel (E).



Figure 2A-C: 2D WMT radial strain imaging in a patient with HTN and normal myocardial function. Mean subendocardial radial strain equals 51%, with the peaks occurring at end-systole at or near the end of the T-wave on the ECG (arrow). The vertical dotted line represents aortic valve closure (A). To the far right are the corresponding radial strain values from the 6 segment model; mean subepicardial radial strain equals 35% (B); mean transmural strain (average of both subepicardial and subendocardial strains) equals 43% (C).

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compensation”⁵. This new multi-layer speckle strain approach for the evaluation of different layers of the myocardium, may improve interpretation of regional wall motion. This technique can provide insight into pre-clinical changes in ischemia and other disease that may originate from the subendocardial regions.

LIMITATIONS

As with any ultrasound modality, the reliability and integrity of the data is highly predicated on 2D image

quality. Newer ultrasound systems now have improved transducer technology which, when combined with harmonic imaging, can enable better visualization of myocardial structure and both endocardial and epicardial border definition. 2D frame rates for STE need to be between 40 and 80 frames per second (fps) in order to accurately characterize layer specific myocardial function. The average frame rate for the case studies was 74 fps.

CONCLUSION

Novel 2D WMT multi-layer speckle tracking was able to provide insights into regional differences in the myocardial deformation in both health and disease.



Figure 3A-C: 2D WMT radial strain imaging in a patient with ischemic cardiomyopathy and abnormal myocardial function. Mean subendocardial radial strain equals 27%, with a significant reduction and heterogeneity of the peaks (A); mean subepicardial radial strain equals 28% with significant delay in the septal, inferior and posterior regions (arrows) (B). This delay most likely represents active ischemia with late thickening occurring after aortic valve closure. Of note, the mean subepicardial strain gradients were greater than the subendocardial gradients; mean transmural strain (average of both subepicardial and subendocardial strains) equals 27% (C).

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