Volume Based Determination of Global Left Ventricular Strain: A Comparison to Tissue Tagging

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Introduction: Left ventricular (LV) ejection fraction (EF) is the most commonly used measure of cardiomyopathies. LV strain has been shown to be a more sensitive measure of cardiac performance, as EF may be preserved in some conditions[1]. Current MRI methods used to measure LV strain, including tissue tracking or phase-based methods, require onerous post-processing or specialty pulse sequences. We propose an alternative method for the determination of peak systolic global circumferential, longitudinal and radial strains that does not rely on tissue tracking based on basic SSFP cines LV volume analysis. The purpose of this study is to compare this new method to conventional tissue tagging-derived strains.

Methods: Forty-eight consecutive subjects enrolled in a clinical trial to study diastolic heart failure (the Alberta Heart Failure Etiology and Analysis Research Team, Alberta HEART), underwent MRI exams on a Siemens Sonata 1.5 T scanner. Eight subjects were excluded based on poor tagging image quality. The remaining 40 included subjects at risk for heart failure (n=7), those with disease (coronary artery disease, diastolic and systolic heart failure, n=17) and healthy controls (n=16). SSFP cines were acquired for a short axis stack spanning the LV length and 2-, 3- and 4-chamber long axis views (1.3/2.6ms TE/TR, 144×256 matrix, 51° flip angle, 300×400mm^2 field of view (FOV), 8mm slice thickness, 2mm gap between slices, rate 2 parallel imaging, 10–14 views per segment (VPS), 29–40ms temporal resolution reconstructed to 30 phases). Grid tagging was acquired for a basal, mid and apical short axis slice and a 4-chamber view (2.8/3.6ms TE/TR, 97×192 matrix, 14° flip angle, 275×400 mm^2 FOV, 8mm slice thickness, 8mm spacing between tags, 7 VPS, 25 ms temporal resolution).

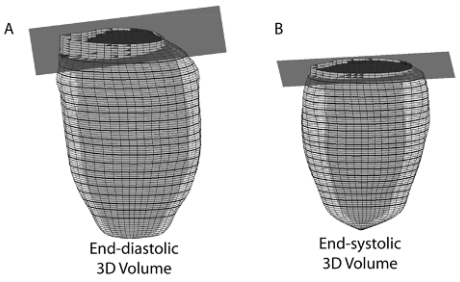

Fig. 1. Interpolated 3D volume.

LV volumes were determined by manually tracing the myocardium for short axis slices. Long axis slices were used to identify the base (basal plane in Fig. 1) and apex, allowing for the fractional inclusion of slices. 3D endo- and epicardial surfaces were interpolated from the short and long axis tracings (Fig. 1). Endo- and epicardial circumferential and longitudinal lengths, as well as radial thicknesses, were derived along the entire LV (Fig. 2). Global circumferential endocardial, circumferential epicardial, longitudinal endocardial, longitudinal epicardial and radial peak-systolic strains were calculated using the strain equation, $\varepsilon = (L_{ES}-L_{ED})/L_{ED}$, ($L$ is length, *ES* is end-systole, *ED* is end-diastole). Average circumferential and longitudinal strains were calculated by taking the mean of endocardial and epicardial strains.

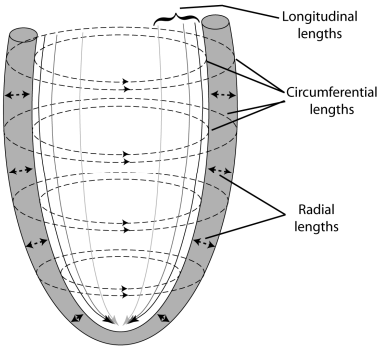

Fig. 2. Schematic of length measurements.

Average circumferential strain was calculated for tagging studies from the mean of the 3 short axis slices and longitudinal strain was calculated from the 4-chamber slice. The myocardium was tracked using open source image registration software[2]. Radial strains were not determined due to insufficient tag resolution in the radial direction.

Results: Volume-derived strains are shown in Table 1. Fig. 3 compares circumferential and longitudinal strains to tagging-derived strain. For circumferential strain, Bland-Altman analysis yielded a bias of −0.2 ± 4.1% strain. For longitudinal strains, the bias had a slope of (0.95+0.20x) ± 4.0% strain.

Table 1. Volume-derived strains

	Control	At risk	Disease
Circumferential strain			
Endocardial, %	−28±5	−27±6	−17±7
Epicardial, %	−11±3	−11±4	−7±2
Average, %	−19±4	−19±5	−12±4
Longitudinal strain			
Endocardial, %	−19±3	−16±6	−12±5
Epicardial, %	−15±3	−14±4	−9±4
Average, %	−17±3	−15±5	−11±4
Radial strain, %	48±8	43±10	29±14

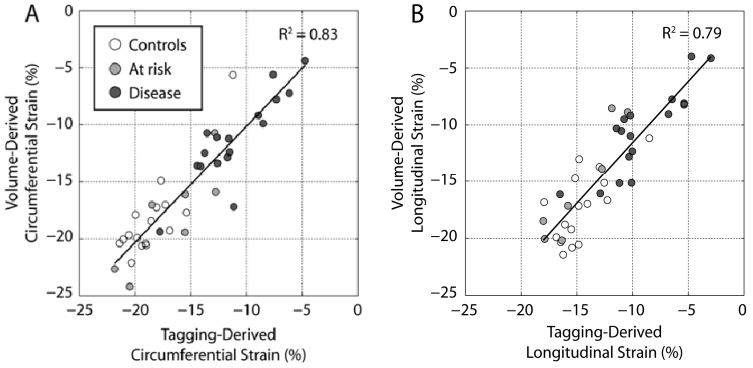

Fig. 3. Comparison between volume- and tagging-derived strains.

Conclusions: Volume-derived measurements of global strain are possible without specialized acquisition protocols and minimal additional post-processing. Values were found to agree well with MRI tissue tagging. Images for this technique can be acquired on any standard MRI scanner and the proposed method can be used on newly or previously acquired volume data to calculate global strains.

References: 1. Kosmala et al. *J Am Soc Echocardiogr*. 2008, 21:1309-17. 2. Klein et al. *IEEE Trans Med Imaging* 2010, 29:196-205.