Cine DENSE Strain Imaging of the Right Ventricle: Initial Experience in Heart Failure

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Introduction: Myocardial strain imaging has been used to assess left ventricular (LV) dysfunction; however, due to its thin wall, complex shape, and eccentric motion, strain analysis of the right ventricle (RV) is more challenging. Cine DENSE data acquisition and analysis methods provide cardiac strain imaging at higher spatial resolution than conventional tagging and harmonic phase imaging. We applied cine DENSE MRI in subjects without heart disease and in heart failure (HF) patients to define normal RV function, to detect RV dysfunction, and to investigate potential interactions between LV and RV dysfunction.

Methods: Cine DENSE imaging was performed under an IRB-approved protocol in standard short-axis and long-axis planes in 16 subjects without heart disease and in 16 HF patients scheduled to undergo cardiac resynchronization therapy (CRT). Specific pulse sequence parameters included field of view = 300-350 mm, matrix = 128 x 128 pixels, slice thickness = 8mm, flip angle =15°, TR = 17 ms, TE = 1.08 ms, and number of spiral interleaves = 6. For strain analysis of RV long-axis views, building upon prior methods for LV analysis [1,2], we performed planimetry of a midwall RV contour at a single cardiac phase, and then automatically propagated the contour to all other cardiac phases using motion information intrinsically encoded into the phase of the DENSE signal [1]. A one-dimensional contour strain, similar to longitudinal strain, was computed from deformation of the RV contour (Fig. 1). For the LV, circumferential shortening was computed from short-axis cine DENSE data using methods previously described [2], and LV dyssynchrony was quantified using the LV circumferential uniformity ratio estimate (CURE) [3].

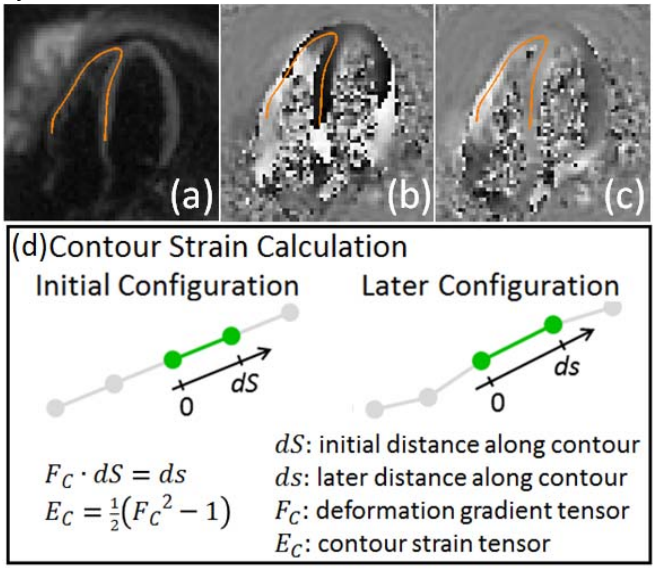

Figure 1. A user defined RV contour indicated in orange is shown on magnitude-reconstructed (a) and phase-reconstructed DENSE images encoded for horizontal displacement (b) and vertical displacement (c). The Lagrangian strain calculated along the RV contour is described in (d).

Results: For the 32 datasets that were analyzed, no manual editing of the automatically-propagated RV contours was needed. The peak values of the RV free-wall contour strains for HF patients were significantly different compared to subjects without heart disease (-0.10±0.03 vs -0.20±0.03, respectively, p<0.01). Figure 2a shows the contour strain data for the midsegment of the RV free wall for subjects without heart disease, representing normal RV function. Interestingly, 7 out of 16 subjects with HF demonstrated prominent RV prestretch (Fig. 2b), while 9 out of 16 subjects with HF did not show RV prestretch in the midsegment of the RV (Fig. 2c). We found a strong association between RV prestretch and LV dyssynchrony, quantified by CURE. Specifically, as shown in Figure 2d, the 7 patients with RV free-wall prestretch had LV CURE < 0.40 (more dyssynchronous LV contraction), while the 9 patients without RV-free wall stretch in the mid segment all had LV CURE ≥0.60 (more synchronous LV contraction).

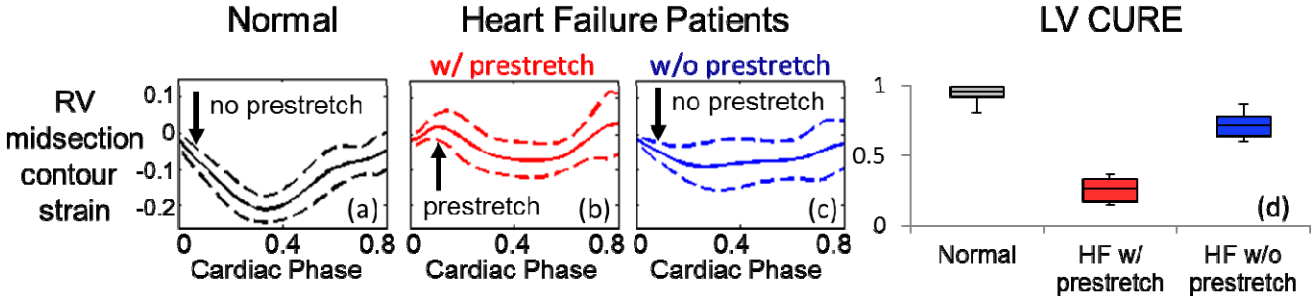

Figure 2: Contour strain of the midsegment of the RV (mean±std) for (a) 16 subjects without heart disease (b) 7 HF patients with RV prestretch (c) and 9 HF patients without RV prestretch. Box plots of the LV CURE for the three groups (d).

Conclusion: Cine DENSE MRI enables high-resolution rapid strain analysis of RV long-axis views. HF patients had significant RV dysfunction as compared with subjects without heart disease, and a very strong association was found between LV dyssynchrony and RV free wall prestretch. This suggests that LV dyssynchrony not only adversely affects systolic function of the LV, but also results in impaired function and decreased work of the RV free wall. Long-axis cine DENSE MRI may provide new clinical insights regarding RV functional abnormalities in patients with heart failure that may be correctable with CRT.

References: 1. Spottiswoode *Med. Image Anal 2009.* 2. Spottiswoode *IEEE-TMI 2007.* 3. Budge *JACC Cardiovasc. Imaging* 2012.

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