Whole Heart Free-breathing Extracellular Volume Mapping at 3.0 Tesla

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Purpose: Myocardial tissue characterization by extracellular volume (ECV) mapping has potentially important applications in diagnosing cardiovascular disease, in particular diseases that diffusely affect the myocardial extracellular space. ECV mapping requires native and post contrast T1 information. An established technique for myocardial T1mapping is the modified Look-Locker inversion recovery (MOLLI) sequence[1]. This technique requires a 17 heart beat breath-hold for every slice, and is therefore typically acquired in a few slices. This results in limited heart coverage and contraindicates patients who have difficulty holding their breath. To eliminate the need for breath-holds and to obtain ECV for the whole heart, a free-breathing method is desirable. However, quality and accuracy of T1 mapping can deteriorate because of respiratory motion both within and through the imaging plane. The purpose of this work is to establish the feasibility of a free-breathing T1-mapping method to evaluate whole heart ECV.

Method: Acquisition of T1-maps was performed with a free-breathing MOLLI 5-5-5-5 technique as proposed by Tsai et al[2]. This is a MOLLI based method with 4 look-locker groups of 5 ECG-triggered readouts. The free-breathing ECV maps of the myocardium were based on a stack of 10 mm short axis slices covering the whole heart, acquired before and approximately 20 minutes after administration of a gadolinium based contrast agent (DOTAREM, Guerbet, France). For comparison, two breath-hold MOLLI short axis slices, either basal and apical or midcavity and apical, were acquired prior to and after contrast injection. In total 7 patients (5 male, age 54.6.±16.9 years) were imaged on a 3.0 Tesla Ingenia MR-scanner (Philips Healthcare, The Netherlands) with free-breathing MOLLI (acquisition resolution 1.7x2.1x10 mm³, 10 slices) and breath-hold MOLLI (acquisition resolution 1.7x2.1x10 mm³, 2 slices). Besides cardiac triggering to compensate for cardiac motion, an external pneumatic belt was used to assess respiratory motion. Based on respiratory information, free-breathing acquisitions that were acquired during inspiration were excluded from further analysis retrospectively.
Both free-breathing and breath-hold acquisitions were analyzed using a MOLLI dedicated post-processing registration method[3] to correct for in plane respiratory motion. For all subjects ECV maps were calculated with ECV= ΔR. (100-Ht)/ ΔR_{blood}. The ΔR_{blood} was calculated from an ROI in the blood pool in the left ventricle. The hematocrit (Ht) value was determined for all patients prior to the examination.

Results: Total acquisition time of the free-breathing technique was approximately 5 minutes, depending on heart rate. For the breath-hold approach, acquisition duration was approximately 15 seconds per slice, depending on heart rate. See Figure 1 for ECV maps acquired with the free-breathing and breath-hold techniques and Bland-Altman analysis.

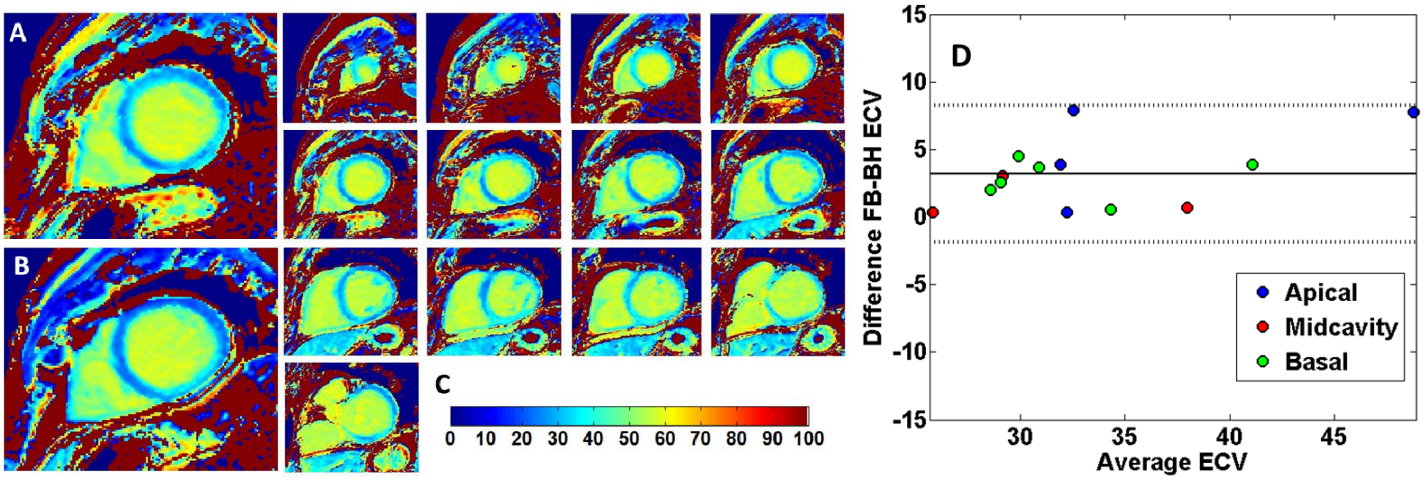

Figure 1 A. ECV map acquired with the free-breathing method, and B. the ECV map in the same slice acquired with breath-hold MOLLI. C. Whole heart free-breathing ECV map for patient with dilated cardiomyopathy. D. Bland Altman plot of the average ECV in the myocardium per slice for free-breathing (FB) and breath-hold (BH) MOLLI. Note the difference between free-breathing and breath-hold in apical slices, where the effect of out of plane movement is most severe.

ECV values calculated based on free-breathing method were not significantly different from the ECV based on the breath-hold method (34.4 ±6.7 vs. 32.8 ±5.8, P=0.12). The Bland Altman plot in figure 1D indicates a difference for an increased ECV calculated with the free-breathing method.

Conclusions: Whole heart free-breathing extracellular volume mapping at 3.0 Tesla is feasible. The free-breathing approach is less demanding for patients and allows whole heart ECV-mapping. Free-breathing ECV yields similar values as compared to the breath-hold approach.

References: 1. Messroghli et al. Magn. Reson. Med. 2004; 52(1): p141-146, 2. Tsai et al. Med. Phys. 2012; 39(12): p. 7291-7302, 3. Tao et al. ISMRM 2014, #5886