T1-weighted and Diffusion-weighted Line Scan MR Imaging of the Human Heart

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Introduction: There is an increasing interest to measure in vivo diffusion and tensor quantities of the myocardium in patients with cardiac disease. However, the diffusion displacement of a water molecule per second is generally on the order of a tenth of a millimeter or less, which is considerably smaller than bulk motion of the heart caused by cardiac pulsation and respiration. Line scan imaging employs multiple column excitations to create a two dimensional image and is less sensitive to motion and susceptibility artifacts. The purpose of this study was to demonstrate the feasibility of diffusion weighted MR imaging of the human heart by using high-speed line scan MR imaging technique. Velocity compensated gradient was implemented in line scan MR pulse sequence in order to compensate the signal attenuation caused by first order motion.

Methods: MR images were acquired in 5 healthy volunteers with a 1.5 Tesla MR imager (GE CV/i, GE Medical Systems). T1 weighted line scan MR images were acquired with TR of every cardiac cycle, TE of 17ms, FOV of 28x14cm, slice thickness of 5mm, acquisition matrices of 128 x 64, receiver bandwidth of ± 7.8kHz, views per segment of 8, imaging time of approximately 10 seconds. Line scan diffusion weighted MR images were acquired with two types of diffusion gradients, one with conventional diffusion gradients and another with velocity compensated diffusion gradients. The imaging parameters included TR of every cardiac cycle, TE of 57ms, FOV of 28x14cm, slice thickness of 7mm, acquisition matrices of 128 x 64, receiver bandwidth of ± 7.8kHz, views per segment of 8 and effective b value of 250 sec/mm^2. ADC measurements were made in the anterior wall, septum, lateral wall and postero-inferior wall by placing round regions of interest within the myocardium.

Results: Quality of line scan MR images was considerably influenced by delay time after ECG R wave trigger. T1 weighted line scan MR images acquired during mid-diastole provided an excellent delineation of cardiac morphology (Figure 1). Flow artifacts from flowing blood in the ventricular chambers were effectively eliminated by applying low diffusion gradients (b=2sec/mm^2). MR signal from myocardium was completely lost on line scan diffusion weighted MR images acquired with conventional diffusion gradients, due to bulk motion of the heart. The use of velocity compensated diffusion gradients permitted visual delineation of left ventricular myocardium on line scan diffusion weighted MR images. The averaged ADC measured in the chest wall muscle (0.39±0.02μm^2/ms) seemed to be reasonable since imaging planes were perpendicular to the muscle fiber orientation. The averaged ADC of the myocardium obtained by velocity compensated diffusion gradients (1.90±0.68μm^2/ms) was significantly lower than that by conventional diffusion gradients ($p<0.001$), but was greater than the ADC value previously reported in the isolated animal hearts.

Conclusions: The optimization of the trigger delay time is important when acquiring line scan MR images of the human heart. T1 weighted line scan MR imaging can provide an excellent morphological delineation of the cardiac structures. The use of velocity compensated diffusion gradients significantly reduces the influence of bulk motion on line scan diffusion weighted MR images. Further improvement is required for an accurate quantification of ADC and diffusion tensor in human myocardium.

Figure 1. T1 weighted line scan MR image on short axis imaging plane of the LV (left), velocity-compensated diffusion weighted line scan MR image on axial imaging plane (middle) and ADC image (right) of the human heart.