Quantitative cardiac diffusion imaging using double echo steady-state free precession

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Introduction

Diffusion weighted double echo steady-state free precession (*dwDESS*) imaging is a diffusion weighted imaging technique that is relaxation time independent (1,2). In contrast to common SSFP DWI techniques, both primary echo paths of nonbalanced SSFP are acquired. So far, only dwDESS results on the direction independent diffusion coefficient D have been presented. Here, porcine cardiac *dwDESS* images were used to indicate correct direction dependency of the obtained diffusion parameter D as a result of the myocardial fiber structure. A human heart with suspected older and acute cardiac infarcts was analyzed for investigation of the influence of both acute and older infracts on the obtained diffusion parameter values.

Methods

All measurements were performed on a 1.5T whole body scanner. SSFP diffusion experiments were performed in 3D with a 1.33x1.33x1.33mm^3 voxelsize on a porcine and a human heart, post-mortem. Three sets of *dwDESS* acquisitions were performed on each sample with diffusion gradients in the read-, phase- and slice-direction. Each acquisition included two scans: one with and one without a diffusion sensitizing gradient ($G\tau$ = 150mT/m·ms) for calculation of the diffusion related signal attenuation as presented in (1). Further parameter settings of the *dwDESS* sequence were: TR = 17.19ms; TE = 3.57ms/25ms; and $\alpha = 30°$.
After the human cardiac MRI scans, autopsy was performed on the corpse with special interest in the heart. The autopsy report was compared the *dwDESS* results.

Results

Within the porcine myocardium it is clearly observed that the obtained D-value is higher in those regions where the muscle fibers are along the direction of the applied diffusion gradient (Fig. 1a-c). Within the direction independent D-map, the myocardium shows a homogeneous D-value as expected.

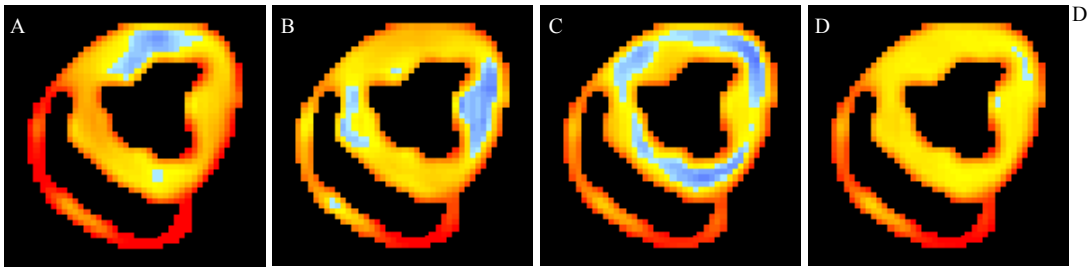

Fig. 1: Porcine heart in sodium solution. Direction dependent D-maps with diffusion gradient in the top-bottom (A), left-right (B) and through-plane direction (C). The diffusion independent D-map is shown in (D) and is homogeneous.

The autopsy report on the human case describes myocardial infarct scar tissue from older infarcts as well as acute infarcts in the posterior wall of the left ventricle and scar tissue at the anterior wall. The direction independent D-map shows lower values in the scar tissue (D = 0.27±0.07mm^2/s) and higher values in the acute infarct region (D = 1.36±0.2mm^2/s) compared to the healthy myocardium (D = 0.97±0.09mm^2/s) (Fig. 2). The conventional DESS image derived from the nondiffusion-weighted DESS scan proves that the region addressed as acute infarct is myocardial tissue and no fluid, as might be suggested by the higher D-value shown.

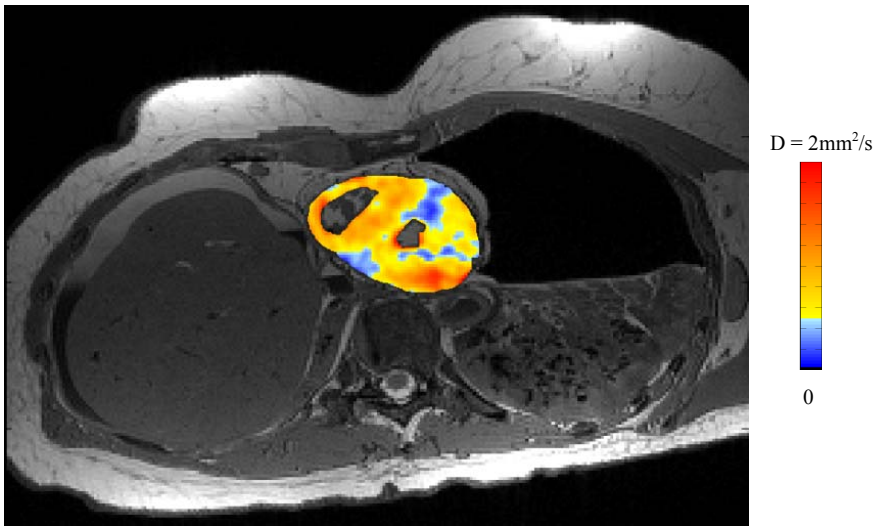

Fig. 2: Human heart, post mortem. Fusion of the derived direction independent D-map onto a conventional DESS image derived from the nondiffusion-weighted DESS scan. Regions of scar tissue as a result from older myocardial infarcts show lower D-values (blue regions) while acute infarct tissue results in elevated D-values (orange-red).

Conclusion

We have shown that *dwDESS* imaging can be used to indicate the fiber direction within the myocardium. Next to that, the direction independent D-value has proven to be able to tell the difference between scar tissue resulting from old infarcts, acute cardiac infarct regions and healthy myocardium.

(1) Bieri et al., MRM 000:000-000 (2011). DOI 10.1002/mrm.23275. (2) Bieri et al. ISMRM 2011 Proceedings, p380.