Investigating the Pancreatic Function: Robust 3D MR imaging of Mouse Abdomen

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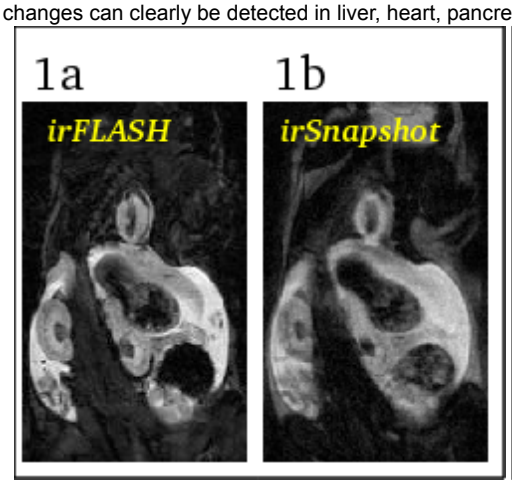
Introduction: Diabetes research and therapy will strongly benefit from non-invasive methods of analysing pancreatic beta-cell mass. A promising strategy is to measure Manganese (Mn^{2+}) uptake in pancreatic tissue by T1-weighted *in-vivo* MR imaging [1-3]. In order to characterize its activity, an accurate detection of Mn^{2+} uptake rate and total amount is important. While many T1-weighted methods have been developed for the brain, the reliable T1-weighted imaging of the abdomen is more difficult: i) Typically, abdominal MR imaging is breathing-triggered to reduce motion artifacts. Thus, especially T1-weighted images are compromised by T1-effects due to breathing rate dependent TR changes. ii) Inversion-recovery sequences are very sensitive for changes of T1. Depending on the breathing rat, long inversion times (TI) may shift the signal readout into the next breathing cycle. iii) A short imaging time is inevitable for the accurate characterization of the Mn^{2+} uptake rate into the tissue by many time points but this may be hampered by long TI and TR. iv) A 3D-coverage of the abdomen is strongly desirable in order to allow correction for inevitable tissue dislocations during data analysis. v) Mn^{2+} exhibits a T1-shortening effect but also severely affects the T2-relaxation of the tissue. This concentration dependent effect prohibits the usage of T1-weighted sequences which are also sensitive to T2 (e.g. multi-spin-echo sequences like RARE).
Considering these boundary conditions, we propose the usage of a breathing triggered, 3D "snapshot FLASH" sequence with inversion-recovery preparation which was originally proposed by Haase et al. [4].

Methods: All measurements were done at 7T on a Bruker Biospec 70/20. A quadrature volume coil was used for both RF transmission and reception. 3D-"Snapshot FLASH" images with inversion recovery preparation were acquired for kinetic measurements of the Mn^{2+} uptake. The 3D-encoding scheme permits the spin inversion over the entire body and thus reduces the sensitivity against inevitable body motions between inversion pulse and signal readout. TI was set to 700ms as a compromise between sensitivity for Mn^{2+}-uptake and preservation of residual signal for tissue discrimination. The scanTR was set to 6s in order to ensure the full relaxation of the magnetization and to avoid breathing rate dependent T1-effects. The FLASH-type signal readout (TE=0.9ms, TR=1.9ms, pulse angle=10°, matrix=192x96x16, FOV=80x40x16mm, BW=500kHz, centric phase encoding) takes 190ms and is essentially inert to T2-relaxation. TR+TI=890ms are shorter than the fastest typical breathing rate (60bpm). The minimal acquisition time per 3D-volume is 1min 36sec. C57Bl/6J mice received glucose (2g/kg i.p.) 30min before the $MnCl_2$ injection (25mg/kg i.p.) and were anaesthetized by isoflurane. The tissue specific ROI selection was assisted by 2D ir-FLASH images (TE=3.4ms, TR=1200ms, TI=600ms , resolution=312x312x1000µm^3) coregistered to the Snapshot data.

Results: Representative MR images are shown in Fig. 1 below. While the *irFLASH* images (Fig. 1a) present more structural details of the tissue, the signal changes in the *irSnapshot* images (Fig. 1b) are remarkably insensitive to fluctuations of the breathing rate (40-65 bpm). Mn^{2+} induced signal changes can clearly be detected in liver, heart, pancreas and the injected fluid containing glucose and $MnCl_2$ during 40 min after injection (Fig. 2).



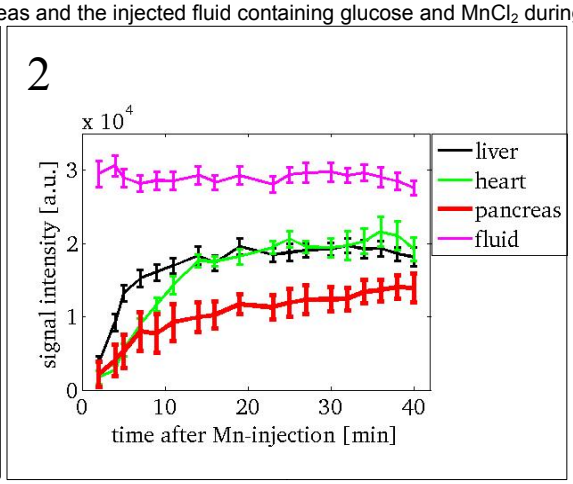


Fig 1: Representative *irFLASH* and *irSnapshot* images cropped to fit to this figure.

Fig 2: Time courses of Mn^{2+}-induced signal changes in different tissues. Graph represents data from one experiment as calculated from ROIs in *irSnapshot* images of 417x417x1000µm^3 resolution. The *irFLASH* images were used for improved tissue selection.

Discussion and Conclusions: This optimized protocol of T1-weighted imaging of the mouse abdomen fulfills the requirements of least-invasive MR imaging of tissue specific Mn^{2+}-accumulation: i) image signal intensities are independend from changes of the breathing rate, ii) any tissue dislocations due to peristaltic and other movements can be corrected in the 3D-data set by an appropriate adjustment of the ROI in 3 dimensions, iii) the time resolution of approx. 2 min is sufficient to characterize tissue-specific accumulation of Mn^{2+}. In comparison to 2D acquisition schemes, the 3D-data collection results in a significantly higher SNR per unit time. Further optimization will allow using such analysis for measuring beta-cell mass.

References:

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