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Lipsø, Hans Kasper Wigh; Magnusson, Peter; Søgaard, Lise Vejby; Ardenkjær-Larsen, Jan Henrik

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CEREBRAL ANGIOGRAPHY IN RATS: COMPARISON OF 1H TOF-MRA, SPIO ENHANCEMENT AND HYPERPOLARIZED 13C BSSFP

Kasper Wigh Lipsø1,2, Peter Magnusson1, Lise Vejby Søgaard1, and Jan Henrik Ardenkjær-Larsen2,3
1Danish Research Centre for Magnetic Resonance, Copenhagen University Hospital Hvidovre, Hvidovre, Denmark, 2Department of Electrical Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark, 3GE Healthcare, Brøndby, Denmark

Introduction Magnetic resonance angiography (MRA) is an important tool in the diagnostics of abnormal vasculature, and proton imaging can provide excellent sub-millimeter resolution of blood vessels in small animals. MRA can be further optimized with Gd-based or blood pool agents. However, the acquisition time is several minutes at best, and thus the technique fails in cases that require subsecond temporal resolution, e.g. imaging within a single heartbeat or breath hold to avoid movement artifacts. Several attempts to shorten the acquisition time have applied hyperpolarized 13C-substances. As the signal is increased by orders of magnitude and the background signal is negligible due to the low natural abundance of 13C, the repetition time can be lowered significantly. We demonstrate that subsecond, submillimeter resolution can be achieved with hyperpolarized 13C-enriched agents and provide important information about the cerebral vasculature in the rat.

Methods Pulse sequence design: Data were acquired on a 4.7 T imaging system (Agilent, Direct Drive, VnmrJ 3.2) using a 13C/H RF volume coil combined with a 13C four channel array coil (receive-only) (RAPID Biomedical GmbH, Germany). The receive coil was placed dorsal with the animal supine. The hyperpolarized signals were acquired using a bSSFP sequence with an α/2 preparation pulse and a flip back pulse in a 30 mm slab with field of view of 60×60 mm², matrix 128×128 and 60° flip angle. The dependence on acquisition bandwidth was investigated by performing series of experiments with bandwidths of 20, 50 and 100 kHz, respectively. Higher SNR can be obtained by lowering the bandwidth, however the echo time is increased correspondingly resulting in artifacts in the image. A bandwidth of 50 kHz has proven to give a large SNR and minimal artifacts. The repetition time and the echo time were the shortest possible on the system, corresponding to TR/TE = 6.65 ms / 3.10 ms for 50 kHz bandwidth, yielding a total image acquisition time of 851 ms. The flip angle dependence was also investigated and the 60° was found to provide optimal image quality. The proton angiographic time-of-flight (TOF) images were acquired with a 3D gradient echo sequence with TR/TE = 90 ms / 1.09 ms, α = 40° and magnetization transfer of 1200°, duration of 6 ms and 3 kHz offset. The FOV and resolution were similar to the hyperpolarized measurements, with a resolution of 0.85 mm × 0.85 mm × 0.85 mm. The total scan time for the 1H image is 24 minutes. 50 μL Clariscan™ was injected before scanning in the contrast enhanced images.

Results and Discussion The image in Fig. 1 was acquired in less than a second. The signal is highest in the superior sagittal sinus (sss) and the transverse sinuses (trs), the anchor-like shape, which are the large vessels closest to the surface coil. An SNR of 15 is observed in the coronal orientation, whereas SNR above 30 are obtained in axial orientation of the slab. Due to the coil sensitivity, only the vessels within ~10mm from the surface coil appear on the 13C-MRA. The MIP of a 1H-TOF-MRA in the slab is shown in Fig. 2. The arteries dominate due to larger blood flow velocities and hence larger TOF effect, especially the carotids arteries are apparent, and none of the large veins appear. The large veins are shown in Fig. 3, where the vessels are enhanced with SPIO. Only the top 12 mm have been used in the MIP in Fig. 3 in order to avoid the carotids arteries etc. and only show the anchor-like sinuses. Fig. 4 shows an anatomical spin-echo image for navigation, the rat brain is centered in the FOV.

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References