Simultaneous single-quantum and triple-quantum filtered sodium images at 4T in vivo

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Introduction

Sodium is the second most abundant MR sensitive nucleus in the human body. Its quadrupolar nature makes it sensitive to the local environment. Triple-quantum filtered (TQF) sodium imaging has been proposed as a method to distinguish intra- from extra-cellular sodium (1, 2). Since the intracellular sodium is strongly linked to cell viability, it is of special interest. In this abstract a novel method is presented which increases the efficiency of a TQF sequence by interleaving the TQF preparation with a radial readout of ultra short echo time, thereby acquiring a single-quantum as well as a triple-quantum filtered image.

Materials and Methods

As shown in Figure 1, the triple-quantum preparation consists of three hard RF pulses (90° flip angles) interleaved by two delays; the pulse phase φ is cycled through 30°, 90°, 150°, -150°, -90°, -30°. For human *in vivo* experiments, the first delay, τ, is around 6ms, while the second delay, δ, is as short as possible: only 40 µs. A short radial readout fits into the 6ms preparation time, and if its gradient moment is completely rewound, it does not alter the preparation of the triple-quantum state. The radial readout is realised as a stack of spokes, i.e. the partition encoding direction is phase-encoded while the readout/phase encode plane is covered by centric radial readouts. The triple-quantum filtered signal is read out with a multi-echo gradient echo sequence. Multiple echoes can be combined for a higher SNR and the signal evolution with time can be used for estimation of the relaxation time.

The sequence was implemented on a home-assembled Siemens 4T whole-body scanner (Erlangen, Germany) and images were acquired of a phantom and of an informed healthy male volunteer.

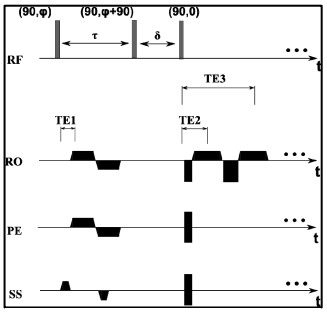

Figure 1: Sequence diagram of the mcTQF sequence.

Results

Figure 2 shows the results from a phantom experiment. Figure 2a shows a TQF image where the radial imaging is active and Fig. 2b where the radial imaging is inactive. Sequence parameters were: TE 4ms, TR 150ms, 60 averages, voxel size 10x10x10 mm. No significant difference between the images is visible indicating that the radial imaging gradients do not interfere with the triple-quantum filter. Figure 3a shows proton, Fig. 3b 23Na density weighted, and Fig. 3c triple-quantum filtered images of an informed healthy male volunteer. Sequence parameters were: echo time of the radial imaging: TE=0.73ms, echo times of the TQF image: TE=5+n*5.79 ms (n=1,2,...7), TR 150ms, bandwidth 80 Hz/pixel, 10x10x10mm voxel size, 48 averages, acquisition time 36 mins.

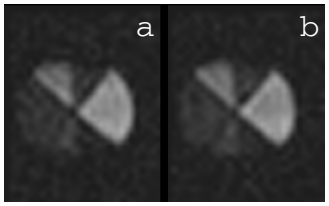

Figure 2: Images from a phantom acquired with (a) and without (b) radial imaging gradients.

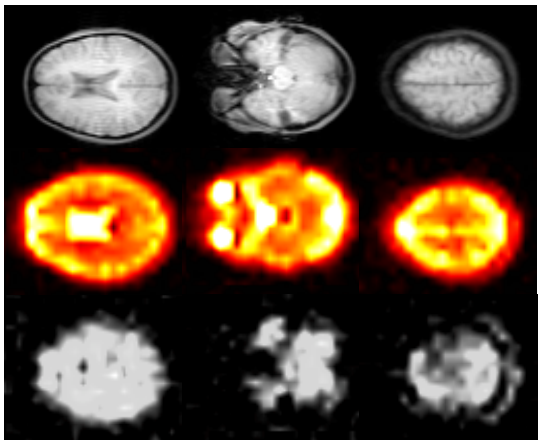

Figure 3: Selected transversal slices of proton (top), sodium UTE (middle) and TQF (bottom) images.

Discussion

The 23Na weighted image shows very good SNR: eyes and ventricles are clearly visible; brain matter is clearly distinguishable from background. Partial volume effects due to the low resolution worsen the visual impression. The triple-quantum filtered images show a significantly lower SNR. Partial volume effects limit the quality of the image here also, but the matter regions appear inhomogeneous, and no sharp separation between matter and ventricles is observable.

Conclusion

The present study has shown that simultaneous acquisition of triple-quantum filtered and tissue sodium concentration weighted images *in vivo* sodium is feasible. This novel method improves the efficiency of TQF imaging allowing for the simultaneous acquisition of 23Na density weighted and TQF images.

References

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(2) Hancu et al., MRM 1999, 42:1146-1154