In vivo triple-quantum (TQ) sodium MRI on the human brain: SNR benefits at 7T

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INTRODUCTION

Triple quantum (TQ) sodium imaging is an effective means decreasing the contribution from the intracellular and fluid spaces to the sodium (^{23}Na) signal. This increased intra-cellular contrast is highly desirable for the study of pathologies such as cancer and stroke. The sodium TQ signal is, however, much weaker than the single quantum (SQ, or total tissue) signal (~1/10). It is, therefore, a challenge to obtain TQ sodium images on humans with reasonable signal-to-noise ratio (SNR) at clinical field strengths such as 1.5T or 3T. 7T MRI has the potential to yield higher SNR for TQ imaging due to the increased polarization of the equilibrium magnetization. In this study, we evaluate the SNR performance of TQ sodium MRI of the human brain at both 7T and 3T. Our results demonstrate that the theoretical SNR gains of 7T have tremendous benefits for TQ sodium MRI.

EXPERIMENTS

TQ sodium MRI was performed on a whole-body 7T scanner (Magnetom MRI 7T, Siemens Medical Solutions, Erlangen, Germany) with a single-channel sodium head coil (Advanced Imaging Research, Cleveland, OH, USA). Adult healthy volunteers were scanned under an IRB approved protocol. Data acquisitions for whole brain were implemented using a home-developed three-dimensional (3D) TQ sequence with a twisted projection imaging (TPI) trajectory (1). The TQ acquisition parameters were as follows: RF pulse width of 1.0ms, preparation time (τ) of 8-10ms, delay time (δ) of 0.1ms, 6-step phase cycling starting at 30^0 (60^0 steps, six cycles), flip angle of 90^0, TE=8-10ms, TR=351ms (minimum value from SAR restrictions), four signal averages, FOV=220mm, matrix size=64×64×64, isotropic resolution and TPI trajectory with 204 projections. Offline image reconstruction was carried out with a k-space filter of size 8-64 in diameter. For comparison purposes, the same TQ experiments were implemented on a whole-body 3T scanner (Magnetom Trio Tim, Siemens Medical Solutions, Erlangen, Germany) with a dual-tuned (^{1}H-^{23}Na) birdcage head coil (Advanced Imaging Research, Cleveland, OH, USA) as well as the same acquisition parameters as in the 7T experiments. For all experiments manual shimming was used in order to ensure optimal FID linewidth. Also, a FID sequence designed to automatically step through RF amplitude was used in order to determine the most likely RF amplitude for the 90-degree flip angle. No corrections for B_0 inhomogeneity were performed [2].

RESULTS AND DISCUSSION

Fig. 1 shows triple-quantum sodium images from a healthy brain at both 7T and 3T, along with single-quantum images for reference. The TQ images have a SNR: 12.3 at 7T and 3.2 at 3T (Fig. 1, right column), when a full acquisition matrix is used. Fig. 2, top-row, demonstrates the changes in SNR obtained from the TQ experiments at 3T as a function of the spatial resolution. The SNR increases from 3.2 for a high resolution scan with k-space size of 32 (Fig. 2, top left) to 11.8 at the lowest resolution with a k-space size of 8 (Fig. 2, top right). Use of the 7T scanner yields a more than two-fold increase in SNR for the TQ brain images. Fig. 2, bottom-row, also presents the SNR of the TQ images as the flip angle is varied. The SNR decreased down to 10% when the flip angle changes from 90^0 to 70^0, indicating a strong B_1 dependence due to the low spatial homogeneity of the excitation B_1 for this 3T coil [3]. This latter finding poses a practical limitation since, in practice, it is not easy to accurately scale the coil voltage so that a flip angle of 90^0 is obtained throughout the observation volume. Under these conditions, large flip angle errors ensue, leading to poor experimental results. Consequently, with the current technological trend of separate transmission and reception coils, it is highly likely that the excitation errors demonstrated above could be efficiently overcome through the use of large, yet homogeneous, excitation coils. This strategy combined with high-sensitivity local coils should have tremendous benefits for a SNR demanding application such as TQ sodium MRI.

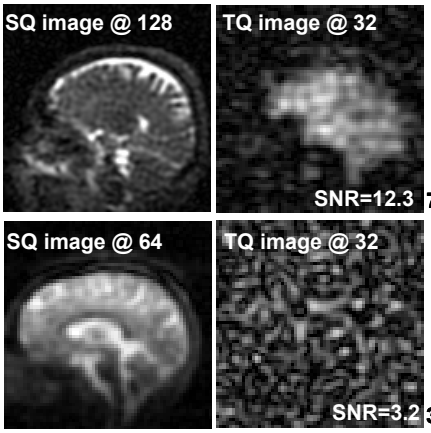

Fig. 1. Single- and triple-quantum sodium images of a healthy human brain. The measured SNR of TQ image at 7T (top) is more than 2-times higher that that at 3T (bottom).

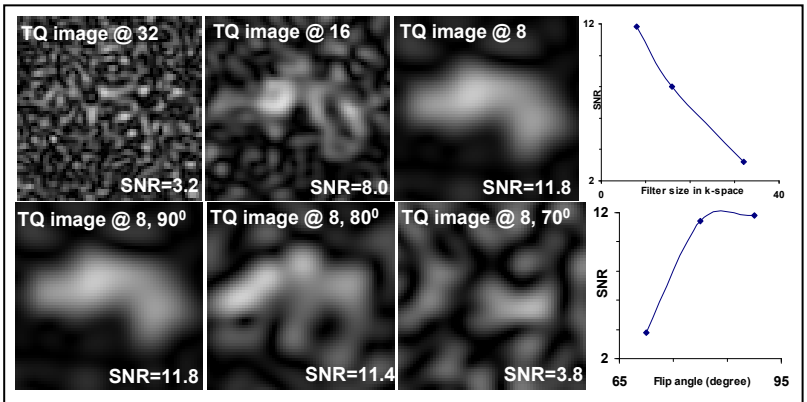

Fig. 2. Triple-quantum sodium images of a healthy brain at 3T for: 90^0 flip angle and three different resolutions (top row), and three different flip angles and the same resolution (bottom row).

REFERENCES: [1] Boada FE, etc. MRM 1997; 37:717-725. [2] Tanase et al., JMR, 2005; 174: 270-278. [3] Hancu et al., MRM, 1999; 42: 1146-1154.