Single and Triple Quantum Sodium MRI of Primary Human Brain Tumors

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Abstract

We demonstrate the use of triple quantum (TQ) filtered sodium MRI in a group of patients undergoing clinical evaluation for primary brain tumors. The TQ images were acquired using a twisted-projection readout in tandem with a three-pulse triple quantum filter. Our results demonstrate that TQ sodium MRI provides a source of contrast that it is not biased by the large sodium content of the extracellular pool and is, therefore, better suited for monitoring the changes in intracellular sodium content associated with the development of neoplastic changes.

Introduction

Brain tumors account for about 60% of all intracranial neoplasms diagnosed each year in the United States. Because of their heterogeneous behavior and poor prognosis, the treatment regime for malignant brain tumors is usually designed considering a number of prognostic factors such as cell density, neuronal displacement, mitotic activity and vascular proliferation. Sodium MRI techniques have the potential to provide information about proliferative activity in a non-invasive fashion as the intracellular sodium concentration has been previously found to have a positive correlation with mitotic activity in various types of human neoplasms [1]. These changes in intracellular sodium content, however, are difficult to detect through measurement of the total tissue sodium concentration (TSC) due to the large sodium content of the extracellular pool. Triple quantum (TQ) sodium imaging has been proposed as a means for monitoring the changes in intracellular sodium content during the course of disease. The weak nature of the TQ sodium signal, however, has previously hindered TQ sodium imaging using conventional spatial encoding schemes. Recently, the use of efficient spatial encoding schemes [2] has allowed the demonstration of in vivo TQ sodium MRI in normal human brain [3] and articular cartilage [4]. In this work we demonstrate the use of TQ sodium MRI in a group of subjects diagnosed with primary brain tumors.

Methods

Single and triple quantum sodium MRI was performed in a pool of patients (n=7) undergoing clinical evaluation for the treatment of brain tumors. The sodium data were acquired on a 3 Tesla whole body scanner (GE MS, Milwaukee, WI), using a 22cm, custom built, dual-tuned (23Na/1H), dual-quadrature birdcage RF coil [5]. The TQ pulse sequence (figure 1, left) consisted of a sequence of 3 equal amplitude RF pulses $90_\phi \pm 90_\phi, 90_\phi, 90_\phi$ with a 6-step phase cycle [3]. This use of the three-pulse multiple quantum filtered is key to ensure that TQ signal loss from B1 inhomogeneities can be minimized. These preparation pulses are followed by a twisted projection imaging [2] readout, which allows for efficient coverage of k-space leading to a total imaging time of 16 minutes for each one of the TQ images acquired during the study. Calibration standards of known sodium concentration in 10% agarose gel were also placed inside the FOV to allow the quantification of the sodium signal. Finally, single quantum images, B1 maps (at the sodium frequency) and conventional proton MRI scans were acquired in order to facilitate the interpretation of the findings.

Results

Figure 2 (bottom row) presents selected slices from the brain of a 43 year old female diagnosed with a glioblastoma multiforme in the left parietal lobe. The circular structures at the inferior aspect of the images correspond to the calibration standards. The single quantum images clearly demonstrate the location of the lesion and illustrate the severity of partial voluming effects due to the large sodium content of the necrotic foci often found with this type of pathology. The TQ sodium image (figure 2, top), on the other hand, exhibit a signal void in the location of the necrotic center and edema and it only demonstrates a small area of slight hyper-intensity on the left hand side of the lesion (arrows). This type of features have been previously found to correspond to areas of re-current (or new) tumor in follow up studies for some of the patients in our study. Overall, our experience suggests that TQ sodium MRI, used as a complementary tool, could be of significant value for the diagnosis and staging of primary brain tumors.

Conclusions

Our preliminary experience demonstrates that the TQ sodium MRI can be easily performed at 3.0T using commercially available scanners. We have found that the sodium TQ signal is relatively immune to partial voluming effects making it better suited for the depiction of the sodium concentration changes taking place in the intracellular compartment of neoplastic brain tissue.

References: