In vivo Sodium Imaging of the Human Brain using Conical-SPRITE

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Introduction:

Sodium has great importance in many physiological and pathological processes. In particular, changes of sodium concentration are correlated directly to diseases that alter cell function or that are responsible of metabolic changes. Stroke, ischemia, and cancer are examples of diseases that can be readily interpreted by the local concentration change of sodium. MR Imaging of ^{23}Na, however, is not straightforward. Being a spin 3/2 nucleus means it has a large nuclear quadrupole moment and therefore has a fast relaxing component in restricted environments. Imaging of sodium requires special imaging strategies. In this study we present the first *in vivo* Conical-SPRITE sodium images of the human brain.

Methods:

Conical-SPRITE is a fast, centric adaptation of the Single Point Imaging (SPI) technique and therefore it is advantageous for imaging, in relatively short acquisition times, systems with short T_2^* (1). Figure 1a depicts the timing diagram of Conical-SPRITE. A short, non-selective RF excitation pulse is applied in the presence of three-dimensional phase encoding gradients and after an encoding time $t_p << T_2^*$ a single datum point falling on the Cartesian grid is acquired. After a recovery time, allowing for partial longitudinal magnetization recovery, the excitation-detection scheme is repeated for each net gradient step of the waveforms describing cones in the k-space (Fig.1 b). Conical-SPRITE, even though it is considerably faster than the original SPRITE, it is still not efficient compared to frequency encoded techniques because only a single datum point is acquired after each excitation pulse. In this work, however, we have implemented a more time-efficient variation of Conical-SPRITE; during the same repetition time, TR, following each RF pulse we sample a series of FID points at equally spaced time intervals, Δt_p, in addition to the point acquired at the encoding time, t_p (Fig.1a). The multiple FID points thus acquired can be used to reconstruct independent k-spaces. However, each of these k-spaces will have slightly different k-space step sizes and therefore the resultant images will have different fields-of-view. The chirp-Z Transform algorithm was employed to re-zoom the images to a common FOV (3), allowing for final signal averaging in image space. The multiple point Conical-SPRITE sequence was implemented on a whole-body 4T Unity *Inova* scanner (Varian, Palo Alto, CA) with maximum gradient performance of 40 mT/m and 160 mT/m/ms.

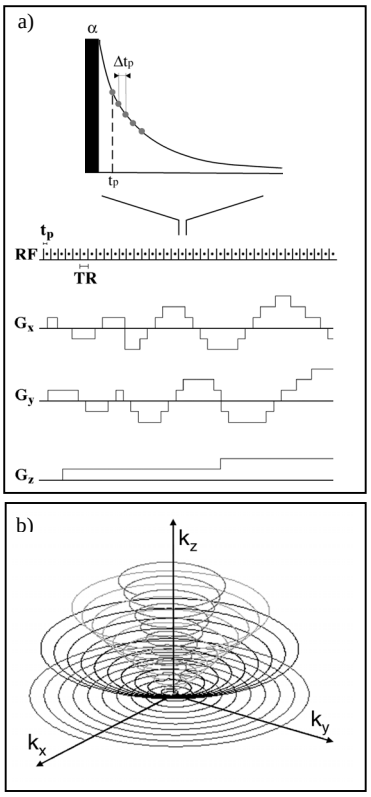

Fig.1 a) The timing diagram of the Conical SPRITE with multiple point acquisition; b) a pictorial representation of three selected conical k-space trajectories.

Results:

Figure 2 shows the first *in vivo* sodium images of a healthy human brain obtained using Conical-SPRITE featuring the multiple FID point acquisition. A field-of-view of 256×256×256 mm and a matrix size of 32×32×16 were selected resulting in a nominal spatial resolution of 8×8×16 mm. The acquisition parameters were as follows: repetition time TR=1ms, encoding time t_p=500µs, flip angle α=3º. Five multiple FID points with a dwell time of Δt_p=25µs were acquired after each excitation pulse. The acquisition time was 15 minutes allowing signal averaging of NEX=128. By virtue of the multiple-point acquisition, the images in Fig 2 are equivalent to 640 usual averages. The sodium density-weighted images presented in Fig 2 show reasonable resolution and highlight the areas of the brain where the local sodium concentration is naturally higher, such as in the CSF and also the eyes. An SNR of 13 was obtained from a region of interest of uniform brain tissue, while a SNR of 19 was calculated from the eyes.

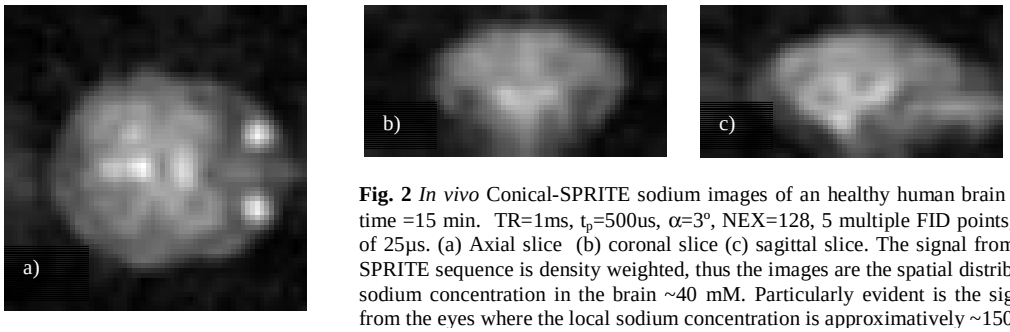

Fig. 2 *In vivo* Conical-SPRITE sodium images of an healthy human brain at 4T. Acq. time =15 min. TR=1ms, t_p=500us, α=3º, NEX=128, 5 multiple FID points, dwell time of 25µs. (a) Axial slice (b) coronal slice (c) sagittal slice. The signal from a Conical-SPRITE sequence is density weighted, thus the images are the spatial distribution of the sodium concentration in the brain ~40 mM. Particularly evident is the signal coming from the eyes where the local sodium concentration is approximatively ~150 mM

Discussion:

Conventional sequences tend to underestimate the sodium signal because the fast-decaying component is neglected. The Conical-SPRITE sequence, combining the intrinsic advantages of SPI sequences in imaging fast-decaying systems with the more efficient multiple FID point acquisition scheme presents the oppurtunity to image the total sodium concentration in the brain quantitatively. Using this sequence *in vivo* images of the sodium distribution in a healthy human brain were obtained in 15 minutes. Good SNR in the images was achieved. In conclusion, Conical-SPRITE with optimized acquisition of FID points and controlled SAR offers a fast, and reliable way to image the sodium concentration in the brain which may be critical for the diagnosis and the monitoring of pathologies leading to sodium changes in the brain.

References:

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3. O. Heid, Proc. 6th Annual Meeting of the ISMRM (1998) 2186.