Comparison of FLASH and TPI Techniques for Sodium Imaging

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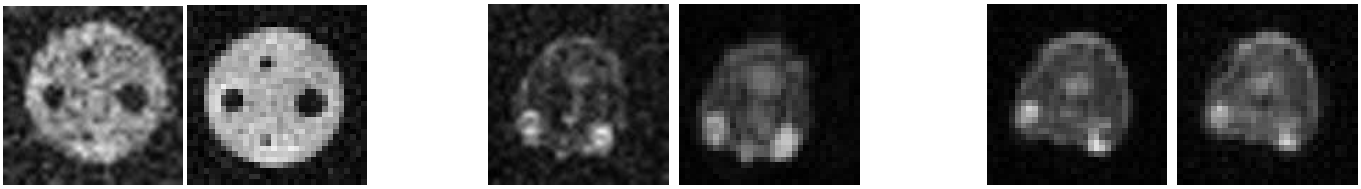
Introduction

Sodium (^{23}Na) is the second most abundant MR-observable nucleus in living tissue. The application of sodium MRI in diagnostic radiology and clinical research has been limited for two main reasons. The first is due to the relatively low concentration of ^{23}Na *in vivo*. In normal brain tissue, the intra- and extracellular concentrations of ^{23}Na are approximately 12-14 and 140-160 mM respectively[1]. The second is due to the short spin-spin (T_2) relaxation times of ^{23}Na *in vivo*. This results from the strong interactions of the ^{23}Na nuclear quadrupolar moment with its local environment[2]. Biological tissue, such as human brain tissue, shows a fast T_2 component in the order of a few milliseconds, and a slow component of approximately 10-30ms. These short relaxation times, combined with the low sensitivity of ^{23}Na make it a challenging nucleus to image with adequate signal-to-noise (SNR) and scan time for clinical use. Twisted projection imaging (TPI), an efficient method for sampling k-space has provided sodium images with high SNR in a fast imaging time[3]. We have implemented a TPI technique with a complete interactive user-interface for ^{23}Na imaging. We compared phantom and *in-vivo* FLASH and TPI sodium images obtained with the same resolution and scan time.

Materials and Methods

Data acquisitions were performed on a 4.47T/40cm animal system (Bruker Biospec, ParaVision 3 beta test version) operating at a sodium frequency of 50.32 MHz, equipped with a single-tuned linear saddle coil. The gradient waveform equations for TPI were programmed so that the user maintains control over the field-of-view, nominal resolution, radial fraction p (% of the maximum k-space radius traversed by a radial line), and maximum gradient strength (G_{max}). ^{23}Na TPI data were reconstructed using a convolution gridding method with a Kaiser-Bessel window described by Jackson et al[4]. A 3D gradient echo sequence was modified to decrease the echo time by reducing the duration of the phase-encoding lobe, omitting the delay between the prephasing gradient lobe of the readout gradient, and by using partial echo acquisition (30%). Both TPI and FLASH acquisitions utilized a short (400us) 70° non-selective RF pulse and a TR of 30ms, a 3D isotropic nominal resolution of 4mm and field-of-view of 13cm. A 100mm x 100mm cylindrical phantom filled with 40mM NaCl and 10% by weight gelatine and four solid tubes of 6mm, 10mm, 16mm, 20mm diameter was used for resolution measurements. *In-vivo* experiments were performed on anesthetized newborn piglets.

Results



(a) SNR= 4 (b) SNR= 8 (c) SNR=7 (d) SNR=16 (e) SNR=18 (f) SNR=13

Figure 1: Phantom (left) and *in-vivo* piglet (middle and right) ^{23}Na images acquired with a FOV=13cm, 3D isotropic nominal resolution of 4mm, and a total scan time of 8 minutes, where (a),(c) FLASH: TR/TE=30ms/1.9ms, SW=25kHz, NEX=16 (b),(d) TPI: TR/TE=30ms/0.23ms, p=0.3, G_{max}=3.7mT/m, NEX=16. TPI ^{23}Na images acquired with the same readout and scan time are shown in the far right, where (e) p=0.4, G_{max}= 3.7mT/m, NEX=12 (f) p=1.0, G_{max}=1.6mT/m, NEX = 5. Images (c-d) and (e-f) were acquired from different piglets.

Images obtained with p=0.4 at two different maximum gradient strengths gave an SNR of 18 (G_{max} = 3.7mT/m) and 11 (G_{max} = 7.2mT/m) as summarized with the SNR measurements from Fig. 1 in the table below.

SNR	FLASH	TPI (p=0.3)
Phantom	4	8
In-vivo	7	16

Table 1.

p	G_{max}	Readout time	NEX	SNR
0.4	3.7mT/m	7ms	12	18
0.4	7.2mT/m	3.7ms	12	11
1.0	1.6mT/m	7ms	5	13

Table 2.

Table 1: SNR of phantom and *in-vivo* images obtained with FLASH and TPI techniques acquired at the same resolution (4mm) and scan time (8mins).
Table 2: Summary of the TPI parameters used to acquire images with the same resolution and scan time as in Table 1, with the use of two different radial fractions and maximum gradient strengths.

Discussion

TPI ^{23}Na images revealed over double the SNR compared with short-TE FLASH images acquired at equivalent resolution and FOV. Although short echo times are achievable with gradient echo schemes, this requires high bandwidths – resulting in images with poor SNR. Although decreasing the bandwidth at the expense of TE generally increases the SNR, the resulting loss of most of the short T2 component may complicate *in-vivo* concentration measurements. Although small radial fractions result in less sampling of central k-space, they facilitate the use of more averages for a given scan time, resulting in a higher SNR as shown in Table 2. However, the gain in SNR through the use of small radial fractions may be lost with poor selection of the maximum gradient strength. One disadvantage of TPI is that the inherently 3D isotropic nature of the scheme means that, unlike FLASH imaging, partial Fourier encoding is not easily achievable.

References

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