Conventional and Radial K-space Sampling for ^{23}Na MRI at 1.5T and 4T

S. Nielles-Vallespin[1], M. Bock[1], A. Bankamp[1], T. Thiel[2], A. Bongers[1], R. Umathum[1], L. R. Schad[1]

[1]German Cancer Research Centre, Heidelberg, Germany, [2]Bruker BioSpin MRI, Ettlingen, Germany

Introduction

^{23}Na MRI has the potential to differentiate viable and non-viable tissue [1]. However, compared to ^{1}H, ^{23}Na NMR sensitivity is low due to the lower spin density, smaller gyromagnetic ratio and shorter T_2. This leads to reduced SNR and, thus, to low spatial resolution images and long acquisition times due to signal averaging. As the NMR sensitivity is directly proportional to the magnetic field strength B_0, higher B_0 may allow ^{23}Na MRI to become a relevant clinical application. In this work ^{23}Na NMR images have been acquired at 1.5T and 4T using a gradient-echo and a radial technique to compare their performance in terms of SNR and resolution.

Materials and Methods

Phantom and volunteer experiments were carried out on a Bruker/Siemens MedSpec 4T system (Bruker Biospin MRI, Germany) equipped with Siemens Sonata Gradients (40mT/m, 200$Tm^{-1}s^{-1}$) and a double-resonant (44.5/168.2 MHz) TEM volume head coil (MR Instruments Inc.) [2] as well as in a 1.5T Symphony (Siemens AG Medical Solutions, Germany) equipped with Siemens Quantum Gradients (30mT/m, 100$Tm^{-1}s^{-1}$) and a home-built single-resonant (16.84MHz) birdcage coil. Both systems are based on the same clinical user interface (syngo) using identical software for image acquisition.

Images were acquired with a standard 3D FLASH sequence (TR=30ms, TE=2.25ms, FOV=400mm, matrix 128×128, partition thickness 10mm, BW=190Hz/pixel, 48 averages, acquisition time=33min). A 3D Radial sequence was designed to scan k-space from the centre to the surface of a sphere, following cones from north to south of the sphere. After a 400µs rectangular RF pulse and 200µs delay to avoid transmitter ring-down, the radial readout gradients and signal acquisition started simultaneously (TR=30ms, TE=0.4ms, FOV=400, BW=190Hz/pixel, 2500 projections×128 samples per projection, 10 averages, acquisition time=12min). An offline reconstruction regridded the data with nearest-neighbour interpolation (taking into account ramp-sampling) onto a Cartesian grid followed by a conventional 3D FFT. The resulting isotropic data set can be viewed in any of the three orthogonal directions [3].

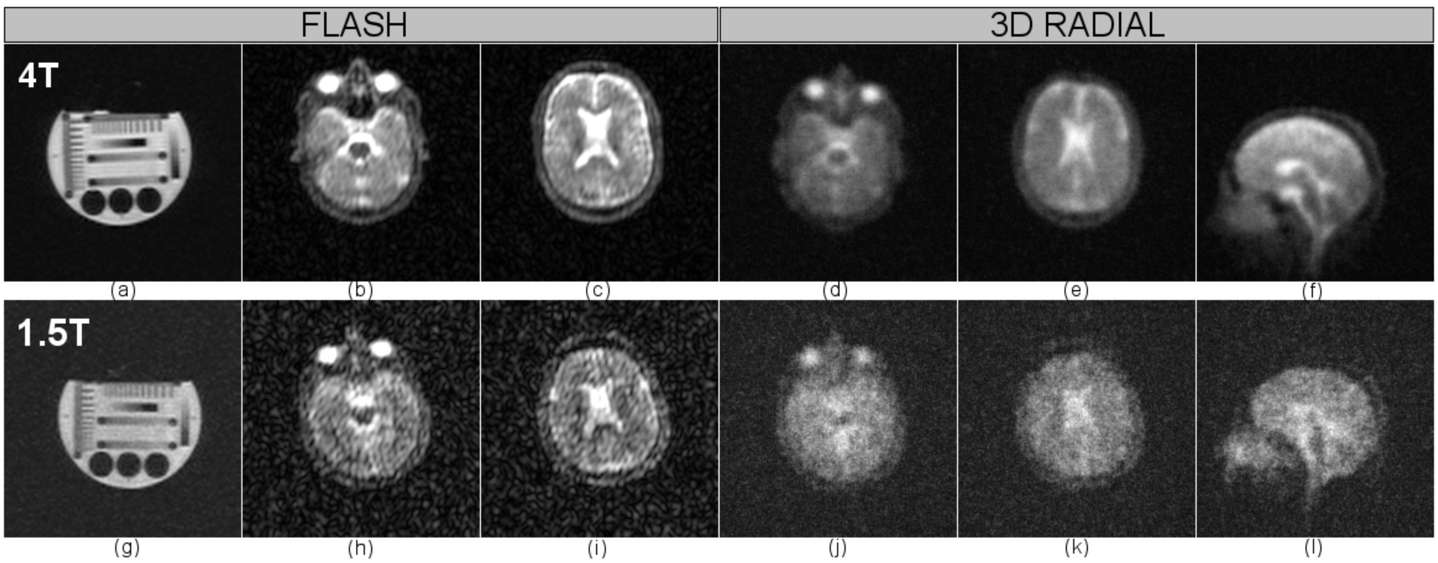

Figure 1. 2D FLASH images at 4T(a) and 1.5T(g) of a resolution phantom (TR=30ms, TE=2.31ms, FOV=400mm, 128×128, slice thickness 20mm, BW=190Hz/pixel, 64 averages, T_{acq}=4min). 3D FLASH images (TR=30ms, TE=2.25ms, FOV=400, 128×128 interpolated to 256×256, partition thickness 10mm, BW=190Hz/pixel, 48 averages, T_{acq}=33min) at 4T(b-c) and 1.5T(h-i) and 3D radial images (TR=30ms, TE=0.4ms, FOV=400mm, BW=190Hz/pixel, 2500 projections×128 samples per projection, 10 averages, T_{acq}=12min) at 4T(d-f) and 1.5T(j-l) of the head of a volunteer. The sagittal views (f, l) demonstrate the isotropy of the 3D radial data set.

Results

2D FLASH images of a resolution phantom are shown in Fig.1a (4T) and 1g (1.5T). The ratio $SNR_{4T}/SNR_{1.5T}$ is 2.7. Figures 1b-c and 1h-i show two of the 20 slices of the 3D FLASH in-vivo data set, and Fig. 1d-f and 1j-l show three slices of the 3D Radial in-vivo data set. Table 1 shows the SNR values calculated from the images in Fig.1. Comparing the in-vivo 3D FLASH data, $SNR_{4T}/SNR_{1.5T}$ is around 4.0. In order to compare the SNR of both imaging techniques, the SNR of the radial data must be corrected by a factor 2.19 reflecting the different number of signal averages. This correction results in a ratio SNR_{RADIAL}/SNR_{FLASH} of 2.5 at 1.5T and 1.3 at 4T.

Tabel 1. SNR = $Signal_{ROI}$ / Standard $deviation_{Bakground}$

	4T		1.5T	
	3D FL	3D RAD	3D FL	3D RAD
Eyes	101	61.6	22	25
CSF	102	60	20	25
Brain tissue	25	38	6.3	14

Discussion

While SNR increased with increasing B_0 as seen in the phantom data consistent with the theoretical value of 4/1.5=2.7, the improvement observed in the in-vivo data of a factor of 4 is superior to that. This indicates that the performance of the 16.84MHz birdcage coil is very sensitive to loading. The higher SNR achieved by the 3D Radial technique can be explained by its shorter TE. Due to the ^{23}Na signal bi-exponential T_2 decay (T_{2short}~1ms, T_{2long}~15ms at 1.5T) sequences with short TE are required. T_2 shortening with increasing B_0 might make it impossible at high B_0 to measure the short T_2 component. However, SNR evaluation shows that at 4T the radial technique still performs better than the FLASH, indicating that the T_2 decrease does not impair the diagnostic usefulness of the method at 4T. Due to the very low SNR at 1.5T, it is not possible to evaluate reliably the SNR improvement between both techniques.

Further work will focus on data acquisition at 1.5T with higher SNR, as well as proper measurement of the in-vivo relaxation times. The use of measured trajectory values and other interpolation methods will be tested to improve the radial reconstruction and minimise blurring. It has been shown that ^{23}Na MRI benefits from higher B_0, achieving images of high SNR at acceptable measurement times. Clinical applications such as the assessment of stroke, edema, vascular malformations and tumours [4] might become possible with ^{23}Na MRI at 4T.

References

1. Kim RJ et al., Circulation 95 :1877-79, 1997
2. Vaughan JT et al., Magn Reson, Med. 32(2):206-18, 1994
3. Jerecic et al., Proceedings ISMRM 2002
4. Hilal SK et al., *Sodium Imaging* In: Stark & Bradley eds. Magn. Res. Imaging 1988:715-29