# High Resolution Sodium MRI on Human Brain at 7T

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## INTRODUCTION

Sodium MR imaging has been limited in clinical applications by its low spatial resolution (3.4mm) due to intrinsically low signal to noise ratio (SNR). The 7T MRI scanners have capability of doubling SNR as compared with the 3T scanners. This advantage encourages pursuit of high resolution sodium imaging at 7T. The major challenge to this pursuit is the maintenance of SNR at a reasonable level, because increasing spatial resolution by a factor of two leads to a decrease in SNR by a factor of eight due to three-dimensional (3D) isotropic imaging (1). Alternative schemes for data acquisition are therefore needed to address the challenge. In this study we utilized the acquisition-weighted stack of spirals (AWSOS) sequence for reducing loss of SNR by defining in-plane resolution and slice-thickness independently. This rendered an opportunity to increase in-plane resolution without changing slice thickness (or without losing much of SNR). The feasibility of this idea is demonstrated below via studies on phantoms and healthy human brains at 7T, with an achievement of spatial resolution as high as 0.86mm.

## EXPERIMENTS

Sodium MR imaging on brains of healthy subjects was performed on a whole-body 7T scanner (Magnetom MRI 7T, Siemens Medical Solutions, Erlangen, Germany) with a volume sodium head coil (Advanced Imaging Research, Cleveland, OH, USA), under an approved IRB protocol. A home-developed three-dimensional (3D) ultrashort echo time (UTE) pulse sequence, AWSOS (2), was used for data acquisitions. The acquisition parameters for the human scans were: rectangular RF pulse duration = 0.8ms, flip angle = 90º, TE/TR=0.5/100ms, averages =5, FOV=220mm, matrix size=64/128/256, in-plane resolution = 3.4/1.72/0.86mm, slices = 60 at a thickness of 4.0 mm, spirals=16/32/64, spiral readout Ts=3.36/5.76/10.72ms, TA=8/16/32min. The parameters for the phantom scans were: rectangular RF pulse of 0.8ms duration, flip angle = 90º, FOV = 220mm, matrix size = 128/256, Ts= 5.60/10.24ms, slices = 40 at a thickness of 5mm, TE/TR=0.5/100ms, averages = 4, TA= 8.5/17min. For comparison, the same experiments were implemented on a whole-body 3T scanner (Magnetom Trio Tim, Siemens Medical Solutions, Erlangen, Germany) with a dual-tuned ($^{1}H$-$^{23}Na$) volume head coil (Advanced Imaging Research, Cleveland, OH, USA). For all experiments manual shimming was used to minimize FID linewidth. A 90º flip angle was achieved via specially designed sequence (home-developed) which automatically stepped across possible RF amplitudes to search the most-likely RF amplitude. No corrections for $B_1$-field inhomogeneity were performed.

## RESULTS AND DISCUSSION

Phantom sodium images at 7T are shown in Fig. 1. The high resolution (1.72mm) enhanced appearance of the smallest plastic bars (dark holes of 2mm in diameter) in the phantom. When the resolution was further increased to 0.86mm, the structural details became sharper (Fig. 1b). When the same experiments were performed at 3T, the images were degraded by low SNR, 2.5-2.9 times lower than at 7T (Figs. 1a-d). The 7T scanner is therefore a potential platform for high resolution sodium imaging.

Human brain sodium images at 7T are demonstrated in Fig. 2 from low resolution 3.4mm (Fig. 2a) to high resolution 1.72mm (Fig. 2b) and to higher resolution 0.86mm (Fig. 2c). The high-resolution image (Fig. 2b) has less blurring than the low-resolution one (Fig. 2a) and uncovers small changes in intensity of cerebrospinal fluid (CSF) inside the ventricles. With further increasing in resolution (Fig. 2c), the structures in the brain becomes sharper too, as compared with the high-resolution image (Fig. 2b). The SNR at higher resolution 0.86mm is, however, a little bit low (SNR=9.4), leading to some small structures vanishing into background noise. This might be addressed in future with array coils which are capable of doubling SNR compared with the volume coil used in this study. Therefore, high-/higher-resolution sodium imaging on the brain is feasible while the SNR needs to be further enhanced.

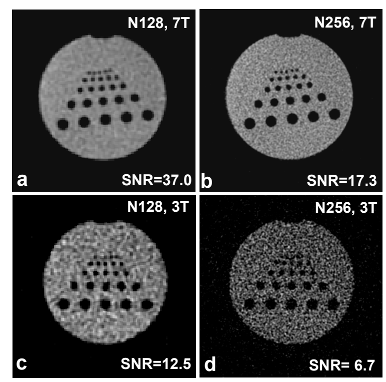


**Fig. 1**. High-resolution sodium images of a phantom at resolutions of **(a)** 1.72mm (N128) and **(b)** 0.86mm (N256) at 7T, compared with those (**c**, **d**) at 3T, showing an increase in SNR at 7T by a factor of 2.5-2.9.

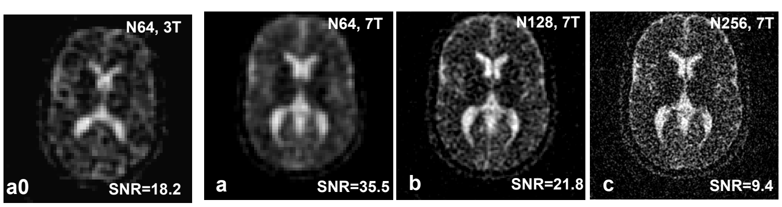


**Fig. 2.** High resolution sodium images of a healthy human brain at 7T (**a-c**) and at 3T (**a0**), showing a 2x increase in SNR when field strength increased from 3T (a0) to 7T (a). The high resolution images (b, c) showed brain structures sharper than the low resolution (a, a0).

**In conclusion**, high (1.72mm) and higher (0.86) resolution sodium imaging on human brain at 7T has been shown to be technically feasible when slice thickness is defined separately from in-plane resolution with the AWSOS sequence. Further improvement of SNR is still needed before high resolution sodium imaging is used for clinical applications.

**REFERENCES:** [1] Boada FE, etc. MRM 1997; 37:717-725. [2] Qian Y, etc, MRM 2008; 60:135-145.