High-Resolution Sodium Imaging of the Human Brain at 4T

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Introduction

The ^{23}Na ion is closer to the cell physiology than the ^{1}H nucleus, and therefore tumour monitoring (1) and stroke diagnosis (2) have been shown to be areas of application for sodium MRI. The lower *in vivo* concentration and lower MR sensitivity compared to protons make sodium images generally low in SNR and resolution. A question to be answered is what details are we missing when using low resolution only? To answer this question, a set of 16 high resolution 3D images of the head of an informed healthy volunteer were acquired in as many separate sessions, co-registered and complex averaged (3) to obtain a final 2mm isotropic 3D dataset.

Materials and Methods

A dual 1H/23Na head coil (Rapid Biomed, Rimpar, Germany) was used in a home-assembled Siemens 4T whole-body scanner (Erlangen, Germany). An RF-spoiled 3D gradient-echo sequence was set up for 2mm isotropic resolution (FOV 256x256x176, matrix size 128x128x88): TE 2.6 ms, TR 8 ms, 210 Hz bandwidth per pixel (BW), RF duration 500μs, 35° flip angle, 30 averages, total acquisition time 35 mins for 23Na; TE 2ms, TR 10ms, BW 1000Hz, 10° flip angle, 1 average, total acquisition time 2 mins for 1H. Elliptical scanning was performed in the sodium measurement in order to achieve a higher number of averages without sacrificing a high degree of resolution. An asymmetric echo was used to shorten the echo time and further increase SNR, as well as keeping T2* influences to a minimum. Images were reconstructed using a Hanning-window in *k*-space; this pushes the SNR sufficiently high to co-register the sodium datasets to each other (see Figure1 (a) and (b)). Each of the 16 measurements was performed within a month and always at the same time of the day. The co-registration (estimation and reslicing) of the 16 images to the first session has been performed using SPM 8.0 (http://www.fil.ion.ucl.ac.uk/spm/).

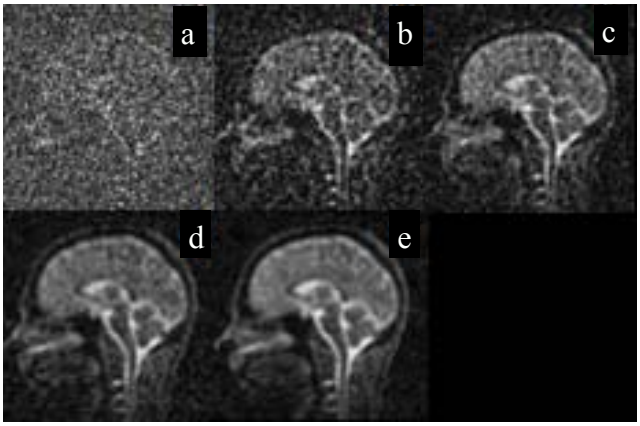

Figure 1: Sagittal slice after 1 session without (a) and with (b) Hanning filter. SNR is increasing and finer details become visible when 3 (c), 8 (d) and 16 (e) sessions.

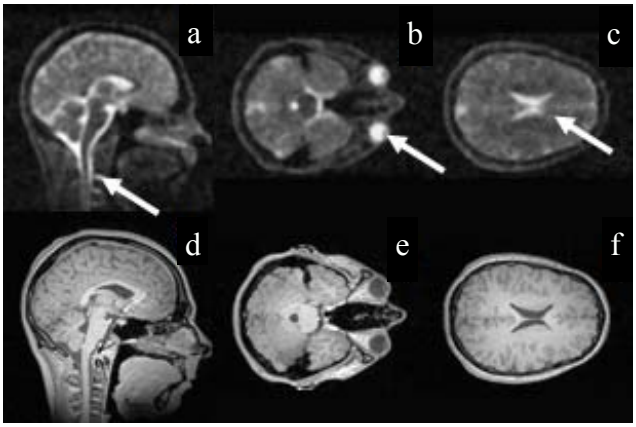

Figure 2: Sagittal and transversal slices through the human brain. a-c show sodium images, d-f the corresponding proton images. Anatomical detail can be seen: the arrow in (a) indicates the spinal discs, (b) highlights the lens visible in the eye . In (c) the limitations of the worse PSF in sodium images are obvious in tip of the right ventricle.

Results and Discussion

Despite the low SNR during the co-registration process, excellent anatomical correspondence between proton and sodium images can be seen. Fine detail is visible in the sodium images: spinal discs (Figure 2a), the lens in the eye (Figure 2b) and gyri and sulci in the brain. Thin CSF structures, well visible in the proton images, cannot be resolved in the sodium images, despite the same nominal resolution. For example, the right tip of the butterfly-shaped ventricle (Figure 2c). This is due to the lower SNR, but also due to the worse PSF of the sodium images, caused by the sequence parameters chosen such as the asymmetric echo, the elliptical scanning, the lower bandwidth and image reconstruction related reasons such as Hanning filtering, inter-session co-registration and median filtering.

Conclusion

High-resolution sodium imaging by complex inter-session averaging has been demonstrated. Very good alignment with corresponding proton images has been shown, revealing what anatomical detail can be resolved in sodium imaging.

References

(1) Nielles-Vallespin et al., MRM 57:74-81
(2) Stobbe et al., Ann Neurol 2009; 66:55-62
(3) Oros-Peusquens et al., Magn Reson Imaging. 2010 28:329-40(3).