STRUCTURAL MAGNETIC RESONCNE IMAGING OF ZEBRAFISH BRAIN USING DEDICATED RADIO FREQUENCY MICROCOILS

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INTRODUCTION: Dedicated radio frequency (RF) coils matched to the sample allow signal-to-noise ratio (SNR) to be increased [1], without changing the static field of the MRI instrument [2]. Ideal matching of the coil and its electronic components to the sample allows increases in coil quality factor (Q-factor), and this notion has allowed micron resolution images of samples to be obtained [3]. Careful considerations should be made towards the size of the sample and RF coil used for the experiment, as certain configurations lead to unwanted image artefacts. The artefacts persist as distortion and signal loss in images [4, 5]. A number of methods investigated how image artefacts associated with dedicated RF coils can be reduced [6-8]. It appears that to maximize imaging performance, the coil needs to be re-evaluated and newly developed given a new, different size sample [9]. We have been working on an MRI based atlas of the adult zebrafish brain [10]. To improve our existing results, we have developed a new RF solenoid coil for *ex vivo* imaging of the zebrafish brain. We provide a quantitative analysis of five different 5mm RF coils. Moreover, we compare images obtained using the Bruker 16.4T small animal imaging system proprietary 5mm RF coil and our chosen 5mm coil. Use statistics relating to the SNR of image slices, we quantitatively analysed coil performance having acquired data on the 16.4T MRI scanner. We also acquired three-dimensional high-resolution adult zebrafish brain gradient echo data, and reconstructed images of six micron isotropic resolution.

Coil	Diameter (mm)	Conductor (coating)	Mean SNR	Max CV [%]	SD of CV
1	0.89	copper (silver)	14.18	5.93	2.24
2	0.40	copper (enamel)	14.64	5.16	1.75
3	0.30	copper (enamel)	14.61	3.80	1.05
4	0.06×0.70	copper (silver)	14.18	4.19	1.38
5	0.49	composite (matched)*	14.18	3.76	1.20

Table 1. Specifications of the various 5mm solenoid RF coils are provided along with performance results. Coil number two provided the best performance, as measured by SNR, coefficient of variation and how it varied across contiguous image slices. We also used a susceptibility matched (*) wire as used for high-frequency Bruker Biospin RF coils.

COIL ANALYSIS METHOD: Table 1 states coil specifications. The conductor diameters varied between 0.30mm to 0.89mm, and one conductor had a rectangular cross-sectional area ($0.06\text{mm} \times 0.70\text{mm}$). These conductors were chosen as they induce magnetic field variations to different extents [11]. The sample tubes were filled with a liquid comprising 80% deuterium (D_2O), 20% water (H_2O) and 0.1% copper sulphate ($CuSO_4$). Our samples mainly included D_2O to avoid signal saturation. $CuSO_4$ was added to shorten relaxation times allowing a reduction in scan times. The glass tubes filled with the liquid were centrifuged to remove air bubbles. A spin echo sequence with the following data acquisition parameters was used: T_R = 500ms, T_E = 11ms, matrix size = 256×256, slice thickness = 0.4mm, bandwidth = 50,000Hz and FOV = $1.5 \times 1.5\text{cm}^2$. We quantified SNR and the impact of susceptibility to find the coil with the best performance. Raw MRI data of the liquid mixture were acquired using all coils. Data acquisition and image reconstruction were performed on a 16.4T Bruker® scanner interfaced to a computer running Paravision version 4 [12]. SNR and signal variations across differently sized regions of interest (ROIs) were measured. We considered various regions of interest (ROIs) within the liquid sample in the analysis and calculated an SNR map for each coil. Given different ROIs, the variation in SNR was used to assess coil performance. The standard deviation (SD) of the SNR map was calculated for each of the image slices, enabling analysis of spatial variations in signal across images. The measures were used to quantify the influence of conductor material and its diameter on the SNR and signal uniformity. Subsequently, the best performing coil was chosen to obtain *ex vivo* structural images of the adult zebrafish brain. A detailed SNR analysis of coil performance will be provided as part of the presentation.

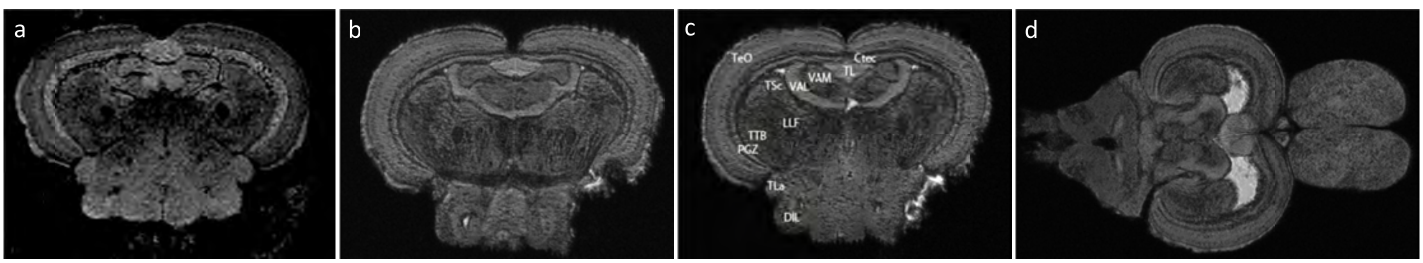

Figure 1. Images of adult zebrafish brain obtained using (a) Bruker proprietary 5mm RF coil and (b-d) using coil number three. Image (a) has a resolution of 10 microns, whereas (b-d) have a resolution of six microns (around a factor of five reduction in voxel volume). Images (b-d) have an isotropic resolution of six microns, zero-filled from the eight micron acquisition. In (c) structures of the adult zebrafish brain have been labelled [10], which have been difficult to delineate previously.

***Ex vivo* zebrafish experiment**: The head of a zebrafish adult was amputated and the dorsal cranium and low jaw was removed. The sample was rinsed in 0.1M phosphate buffer and mixed with 0.5 % Magnevist. After this the brain was placed in fomblin to avoid air-bubbles. Three-dimensional gradient echo (Bruker 3D FLASH sequence) data with a field-of-view of $0.9866 \times 0.3 \times 0.3\text{cm}^3$ was acquired. The standard scanner supplied diffusion sequence was used without acceleration and with the following parameters: matrix size = $1{,}166 \times 360 \times 360$, TE = 10ms, TR = 70ms, flip angle = 33^o, number of averages = 24 and bandwidth = 50,000Hz.

RESULTS: In Table 1 coil number three has the largest mean SNR and a reasonable coefficient of variation (CV), as computed using the mean SNR and SD. We also studied the SD of CV of the acquired data. Given the three indicators of coil performance, we concluded that a 0.3mm diameter copper conductor with enamel coating provides the best performance out of materials tested. The *ex vivo* adult zebrafish brain images are provided in Figure 1. The eight micron raw data was reconstructed using zero-filling to achieve an isotropic resolution of six microns. We were able to illustrate structures in more detail than previously [10], which enables the formation of an atlas with improved detail.

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