Array coil and sample preparation and support system for whole brain ex vivo imaging at 100 µm

Azma Mareyam[1], Jonathan R Polimeni[1,2], Allison Stevens[1], Andre Van Der Kouwe[1,2], Loren D Bridgers[3], Jason P Stockmann[1,2], Matthew D Tisdall[1,2], Lee Tirrell[1], Allison L Moreau[1], Ani Varjabedian[1], Brian L Edlow[1,2], Bruce Fischl[1,4], and Lawrence L Wald[1,2]

[1]*A.A. Martinos Center of Biomedical Engineering, Department of Radiology, Charlestown, MA, United States,* [2]*Harvard Medical School, Boston, MA, United States,* [3]*Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA, United States,* [4]*CSAIL, Massachusetts Institute of Technology, Cambridge, MA, United States*

Target audience: RF coil engineers and neuroscientists/neuroanatomists.

Introduction: *Ex vivo* MRI of intact human brain samples provides a unique opportunity to image fine-scale anatomical structures without the inevitable distortions and tearing introduced by histology via serial sectioning. Although small brain samples can be imaged to reveal extremely highly detailed anatomy [1], whole-brain imaging is required to observe relationships in the anatomy across brain areas, which benefits from the use of large-bore clinical scanners with high magnetic field strengths. Here we present an integrated system for *ex vivo* imaging of whole-brain human specimens at 7T that meets several challenging design requirements. With this system, we demonstrate high-quality 100 µm isotropic imaging over the entire brain in 25 h.

Methods: Fig. 1a shows a custom air-tight brain holder conformed to the shape of the brain (cerebral hemispheres + cerebellum + brainstem), which is an oblate spheroid container (16 × 19 cm) enclosing a whole brain, which was degassed and submerged in Fomblin (which reduces signal from outside the tissue), to reduce the number of air bubbles in the sample [2]. Fig. 1b shows the 3D-printed coil former of slightly larger dimensions than the brain holder which slides inside a volume coil. The 31-channel receive array (Fig. 1c) has 15 elements on the top half (with a diameter of 5.5 cm) and 16 on the bottom half (with a diameter of 8.5 cm) made of 16 AWG wire loops [3] with four or five evenly-spaced capacitors. All elements are tuned to 297.2 MHz and matched to a loaded impedance of 75 Ω to minimize the noise figure of the preamplifiers. Preamp decoupling is achieved with a cable length of 6 cm, with the preamps placed directly on the coil elements yielding a substantial reduction in cable losses compared to a previous 30-channel *ex vivo* brain array [4]. The active detuning circuit is formed across the match capacitor using an inductor and PIN diode. Tuning, matching, and decoupling of neighboring elements was optimized on the bench with the sample in the periodate-lysine-paraformaldehyde (PLP) solution. A shielded detunable volume coil (band-pass birdcage, diameter 26.7 cm, and an extended length of 32 cm to provide transmit efficiency across the A-P axis of the brain samples aligned in *z*) was built for excitation; high-power chokes were used to enable high-voltage, short-duration inversion pulses.

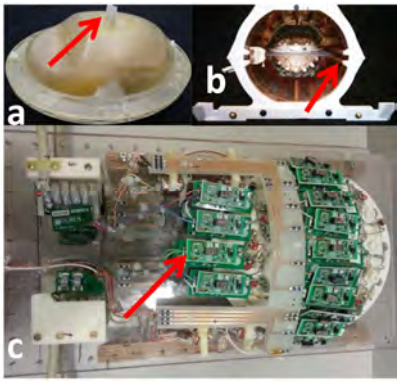

Fig 1. (a) Brain container, arrow indicating degassing channel. (b) Container and array inside birdcage mounted on sliding rails (arrow). (c) Preamps (arrow) mounted to former directly above coil detectors.

The *ex vivo* whole-brain specimen was from a 58yo woman who died of non-neurologic causes. Consent was provided by next-of-kin. Data were acquired on a clinical 7T whole-body MRI scanner (Siemens Healthcare, Erlangen, Germany). Array noise covariance was estimated from thermal noise data acquired without RF excitation, and SNR maps were computed following the method of Kellman & McVeigh [5]. The voltage required for 180º pulse was calibrated using the B_1 map (estimated with the AFI [6] method) with a ROI of 3 cm diameter at the center of the brain. To demonstrate the high-sensitivity afforded by the array, we acquired 100 µm isotropic data (FLASH FA 20º, 1760×1280×1760 matrix, TE=14.2 ms, TR=40 ms, TA= 25 h) streamed off the scanner and reconstructed off-line, as well as a 360×360×600 µm Multi-Echo MPRAGE with FOCI Pulse [7] (2 echoes, 330×528×240 matrix, FA 7º, TE=2.48 ms, TR=2530 ms, TI=1100 ms *R*=2, TA=7min 35sec) reconstructed online.

Results: Fig. 2 shows the SNR gain of 1.6-fold of the 31-channel *ex vivo* array compared to the 31-channel standard coil and a gain of 3.3-fold compared to the 64-channel 3T head array. The noise coupling between channels was 11% for the 31-channel *ex vivo* coil array, a 2-fold improvement relative to our previous array [4]. Fig. 3 shows an example slice from the 100 µm isotropic whole-brain single acquisition with a sample in Fomblin, and Fig. 4 is an example MEMPRAGE slice with inversion time set to null signal from the sample in PLP solution.

Conclusions: The current system incorporates an improved mechanical design, preamps mounted at the coil detectors, and an extended transmit coil design capable of producing high-power pulses. This new design substantially increases the range of *ex vivo* imaging applications.

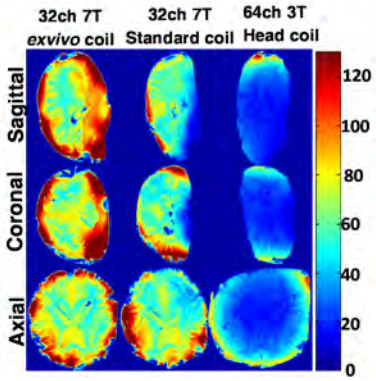

Fig 2: SNR maps using test sample in periodate-lysine-paraformaldehyde

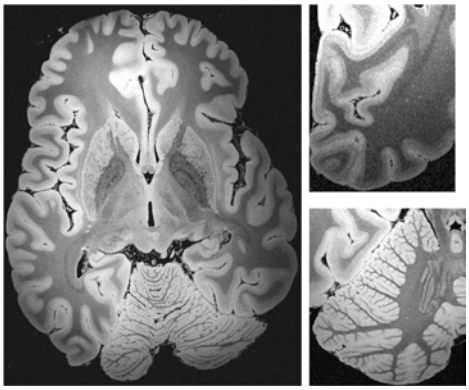

Fig 3 Single acqusition100 µm isotropic whole brain (left); close up of occipital lobe (top right); cerebellum (bottom right)

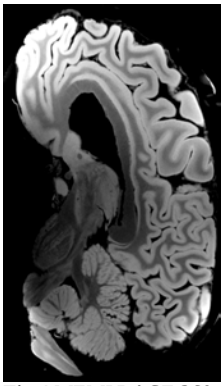

Fig 4 MEMPRAGE 360 x 360 x 600 Resolution

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