Magnetic Resonance Imaging of Stickleback Fish Brains Using Cryo-Cooled Surface Coils

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Introduction: Small animal imaging is increasingly important for biological and genomic research. The three-spined stickleback fish (*Gasterosteus aculeatus*) is an important model for evolutionary research. Stickleback fish have evolved independently in many isolated locations; they exhibit a wide variety of morphological and behavioral traits[1]. Magnetic resonance imaging offers a unique opportunity to study simultaneously both structure and function in these small fish. In order to image such small specimens with high resolution in a 3T system, it is essential to optimize the signal-to-noise ratio (SNR) through careful coil design. Wright et al[2] have shown that cooling copper coils to liquid nitrogen temperatures offers a significant increase in SNR.

Purpose: To assess the potential improvement in SNR at 3T with a small, cryo-cooled copper coil for MRI of zebrafish and stickleback fish. If the image contrast-to-noise (CNR) and SNR are adequate, the routine use of 3T clinical MR systems for high throughput imaging of animals would be cost effective for assessments of phenotypes by generating anatomic and probabilitistic atlases and in preclinical drug research.

Methods and Results: A cryo-cooled (77K) surface coil was used to image euthanized stickleback fish. The coil was octagonally-shaped, 25 mm in diameter, and inductively coupled to a matching loop. The coil was held in a custom-built cryostat fabricated from G10, a fiber-reinforced plastic. The bottom of the cryostat introduced a spacing of 9.5 mm between the coil and the surface of the sample. The coil was used as a receive coil only; a Helmholtz pair at 90 degrees to the surface coil was used for transmission. The fish were immobilized in a 1% agarose gel solution in a tissue culture flask (figure 1). The specimens were 5-7 cm long. Images were obtained the same day the fish were sacrificed. All scans were made in a Siemens Allegra 3T system. Several contrast weightings were evaluated, as well as 3D acquisitions. A stickleback fish in agarose gel is shown in figure 1, a single 'axial' slice image of the stickleback brain in figure 2 and a single 'sagittal' slice image of the same fish is shown in figure 3. These images were taken using a 2D turbo spin echo sequence, with TR = 3780 msec, TE = 20 msec, and ten averages. The slice thickness is 400 microns, and the in-plane resolution is 125x125 microns. The total acquisition time for 14-20 slices was about 20 minutes. Several structures within the brain are identifiable, including the optic tectum (ot), toris semicircularis (ts), optic ventricle (ov), telencephalon, cerebellum, medulla and pituitary gland. The nitrogen-cooled coil was found to improve the SNR by a factor of 4 or more over a room-temperature coil with identical dimensions. With this SNR improvement, we are able to routinely obtain high-resolution scans showing detailed brain anatomy of stickleback fish.

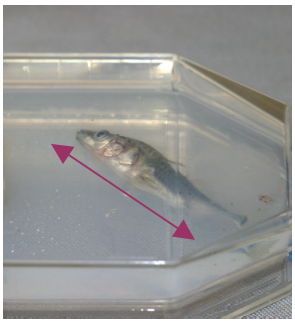

Figure 1: A stickleback fish in gel; This specimen is 55 mm long.

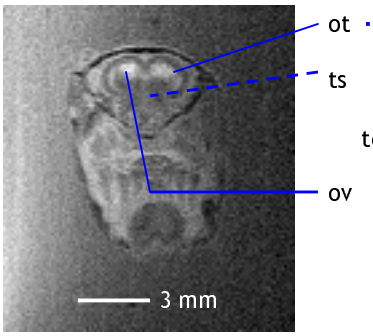

Figure 2:PD image of a stickleback fish head, acq. time= 20 min,TR=3780 msec, TE= 20 msec, in-plane resolution= 125x125 microns, slice= 400 microns

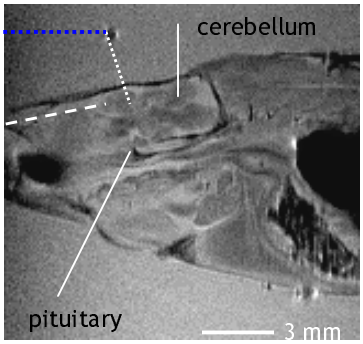

Figure 3: PD image of a stickleback, acq. time = 20min, TR= 3780 msec, TE= 20 msec in-plane resolution = 125x125 microns, slice= 400 microns

Discussion and Conclusions: Cryo-cooled copper surface coil designs are relatively simple to implement. A significant improvement in SNR has been achieved using a small, cryo-cooled copper RF coil at 3T. Imaging of fish neuroanatomy at 3T is practical; high throughput imaging and image analysis for phenotypic and morphometric comparisons is a feasible objective. Images comparable to those obtained on a much larger fish[3] at 7T have been demonstrated. We have shown that detailed neuroanatomy of a stickleback fish can be imaged in a conventional 3T MRI scanner. These techniques can be extended to live fish, and to fish that have been exposed to Mn++ for functional imaging[4]. The next phase of this work will involve the scanning of live fish, and the development of a cryo-cooled volume coil.

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