Using MRI Images for Determination of Near-Infrared Regions of Sensitivity in Rodent Brain

H. Dehghani[1], J. F. Dunn[2,3]

[1]School of Physics, University of Exeter, Exeter, United Kingdom, [2]Radiology, University of Calgary, Calgary, AB, Canada, [3]Experimental Imaging Centre, University of Calgary, Calgary, AB, Canada

INTRODUCTION

Near-infrared (NIR) spectroscopy and imaging provides sensitive and quantitative information on tissue hemoglobin saturation and hemoglobin content. Its use is increasing in areas of brain and muscle research, including studies on stroke and functional brain mapping [1,2]. It is also being used increasingly in studies of animal models, including rat stroke models and transgenic mouse studies [3,4]. A matter of importance to the interpretation is quantifying what part of the brain is being detected and sampled. This study uses MRI images to obtain 3D structural data from rodent models which are then used as a-priori knowledge to predict the light path in rodent brain. These predictions are modeled with variations in fibre positioning and wavelength, allowing those applying NIR/MRI to predict the sensitive volume in rodent studies.

METHODS

MRI was obtained on Wistar rats using multi-slice T2w MRI at 9.4T with TE=20ms, FOV=3x3cm, matrix=256x128, slice=1mm. Mouse images were obtained from a published segmented model, the MOBY mouse [5], which was based on mouse MRI from the Duke NMR microscopy laboratory and had dimensions of 18x18x9mm. A total of 19 coronal slices of 0.5 mm thickness where used to generate a 3D finite element mesh containing 20136 nodes corresponding to 114369 linear tetrahedral elements. The mesh has been segmented to 3 regions of muscle, skull and brain with properties of total hemoglobin of 50, 10 and 100 μM respectively with 70% oxygenation and 85% water content. The sensitivity was calculated to a single light source placed at midline over the brain and a total of 7 detectors ranging from 1 to 7 mm separation from the source. The wavelengths modeled were 661, 761, 785, 808, 826, and 849nm.

RESULTS

A typical MRI used for rat modeling is shown in Fig. 1. The MOBY mouse MRI had already been converted to a structural model. Only mouse modeling data will be shown in the abstract due to space limitations. Fig. 2 shows that the light penetration at 3mm separation or less did not contain significant data from the brain. A 5mm separation optimized cortical data while 7mm results in weighting that favors bone, skull and surface data. Results will also be presented for rat models.

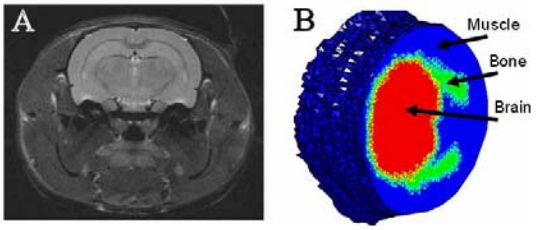

Figure 1: Data used for 3D modeling: A) Example slice from rat brain; and B) 3D rendering of mouse brain based on MRI data showing regions of interest used for assigning optical properties – muscle, bone and brain.

DISCUSSION

The wavelengths modeled ranged from 661 to 849nm. This covers the range of most commercial instruments (e.g., The NIRO200 from Hamamatsu uses 775, 810 and 850nm and the ISS spectroscopy system uses 670, 690, 800 and 834nm.). There was little effect of wavelength on the predicted optical path. The banana-shape profile is characteristic of light sensitivity profiles. This modeling strongly indicates that there are both minimum and maximum separations, outside of which the data will be erroneously weighted to tissues other than brain. This model takes into account bone, brain and muscle, even though only brain is outlined in the examples in Fig. 2. The skin is considered insignificant since we press the optical fibers tightly against the skull, effectively removing contribution of the blood in the skin. Such models are made possible by combining the structural information from MRI with the growing data on optical properties of tissue and the improved models of optical trajectories.

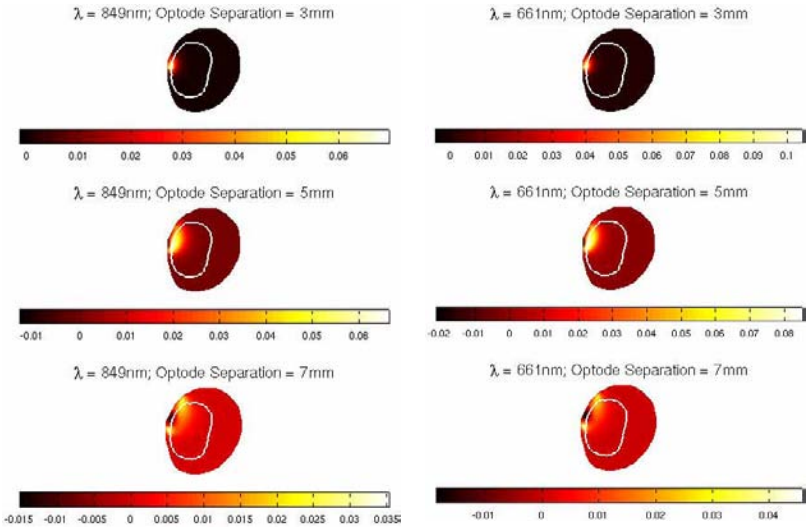

Figure 2: Optical images of 2D cross sections of the calculated 3D sensitivity at the plane of interest (where the source and detectors are placed). The outline represents the mouse head shown in Fig 1B. The white circle is the outline of the brain. The left column is at 849nm and the right is 661nm representing the two extremes of the 5 modeled wavelengths.

REFERENCES

1. Firbank M, Okada E, Delpy DT. *Neuroimage* 1998; 8(1): 69-78.

2. Strangman G, Culver JP, Thompson JH, Boas D. *Neuroimage* 2002; 17(2):719-731.

3. Thiagarajah JR, Papadopoulos MC, Verkman AS. *J Neurosci Res* 2005; 80(2):293-299.

4. Xu H, Dehghani H, Pogue BW, Springett R, Paulsen KD, Dunn JF. *J Biomed Optics* 2003; 1:102-110.

5. Segars WP, Tsui BM, Frey EC, Johnson GA, Berr SS. *Mol Imaging Biol* 2004; 6(3):149-159.