# Near-Infrared Light Penetration in Rat Brain Modeled Using MRI Structural Information

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## INTRODUCTION

Near infrared detection methods are becoming increasingly used to study pathophysiology in a range of tissue by assessing hemoglobin content and oxygenation [1,2]. One of the major difficulties with using light is predicting the optical path that the light travels, and the relative sensitivity of the different tissues to optical detection. Due to NIR's increasing use in study animal models [eg 3,4] it is important to determine the locations of high sensitivity in order to optimize detection methods. We are using MRI imaging to obtain structural data in rat brain that can be used to model the light penetration, and to determine how to maximize sensitivity to the brain. This modeling uses T2w MRI for thresholding and segmentation. We have analysed the effect of separating the optical source and detection fibre on the relative amount of brain that light is passing through.

## METHODS

Wistar rats were imaged using a 9.4T Bruker MRI using a multislice T2w image with TR/TE =2000/40ms, matrix 256x128 and 3x3cm field of view. A total of 12 coronal slices of 1.0 mm thickness where used to generate a 3D finite element mesh using SIMPLEWARE, Exeter UK. The mesh contained 87,483 tetrahedral elements. The mesh was segmented to regions of skin, muscle, skull and brain. Tissue optical properties as published previously [4]. The sensitivity was calculated to a single 0.9 mm light source placed either over the midline, or approximately 5mm lateral to the midline, and 10 0.9mm detectors separated at distances varying from 1.2 to 20mm from the source. Since optical fibres are usually pressed into the skin, they were placed near the bottom of the skin layer for modelling. The wavelength modeled was 826nm.

## RESULTS

An example slice from the MRI is shown in Fig. 1, along with an axial view of the 3D mesh. Fig 2 shows representative light penetration models when the source is either over the midline or lateral to the midline. A separation of 5mm is required for significant sensitivity in the cortical brain region. Figure 3 shows the sensitivity at a spot in the cortex. If the source fiber is above the spot, the sensitivity is slightly higher than if the spot is equidistant between the source and detector. Sensitivity profiles were similar for both wavelengths.

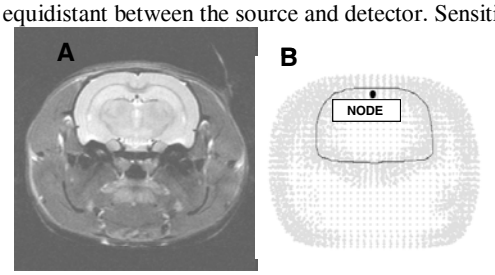


**Figure 1:** Example data set: A) one slice of the T2wMRI in the region of the hippocampus B) a collapsed view of the 3D mesh. Overlaid on the mesh is an ROI of the brain from a slice near that of image "A" and a spot highlighting a node in the centre of the cortex used for modeling in Fig 3.

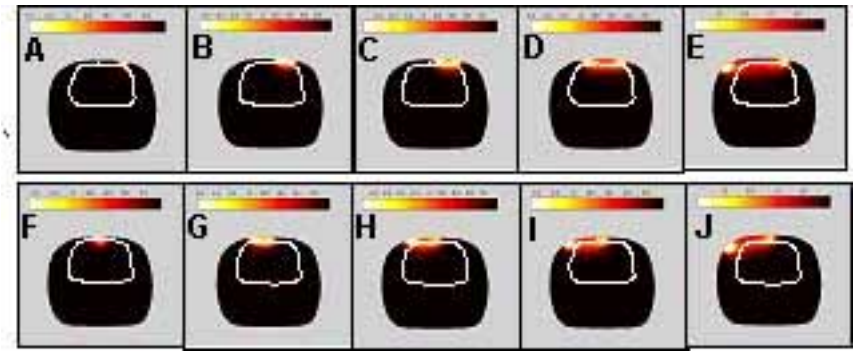


**Figure 2:** Examples of optical images of the 3-D sensitivity profiles in the axis of the optical fibers calculated for 826nm. The brain is outlined and high sensitivity regions are bright yellow. A to E: source fiber was placed 6mm lateral to the midline. The detection fiber placement varied from approximately 1 to 20mm. F to J: the source fiber was placed over the midline and the detector varied to 14mm separation. B and G have a separation of 5mm and cortex is now showing sensitivity.

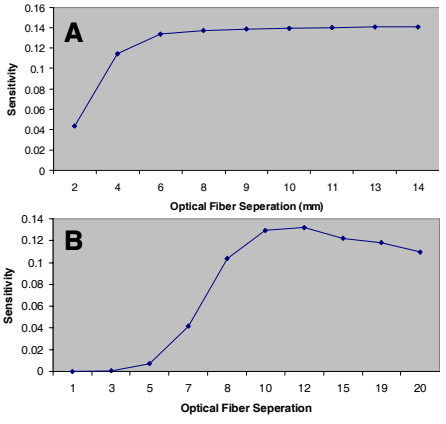


**Figure 3**: A plot of sensitivity in the mid cortical region of the brain at the NODE in Fig 1 vs the fiber separation distance. A) The source is over the midline B) the source is 6mm lateral to the midline. Maximum sensitivity is reached with 6mm separation in "A" and 10mm separation in "B" and a higher sensitivity is reached when the node is directly below the source.

## DISCUSSION

The structural MRI's allowed us to generate 3D datasets thresholded into tissues of varying optical properties. Light propogation modeling showed a characteristic banana shape of sensitivity with high sensitivity near each of the source and detector fibers. The depth of penetration increased with distance. When optimizing signal for the cortex, which is relatively close to the surface (2-3mm) placing the fibers equidistant on either side of the region of interest did not provide maximum sensitivity. Rather, the maximum was achieved with closer separation distances and when the ROI was directly below the source (Fig 3). Also, even at very high separation distances, little sensitivity was obtained in regions below the cortex. These data show the importance of using MRI structural information in determining optical path and regional sensitivity.

## REFERENCES

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