

IMAGING THE DEVELOPING BRAIN AT THE BEDSIDE: A COMPARISON OF DIFFUSE OPTICAL TOMOGRAPHY AND FUNCTIONAL MRI

Silvina L. Ferradal¹, Steve M. Liao², Adam T. Eggebrecht¹, Joshua S. Shimony¹, Terrie E. Inder³, Joseph P. Culver¹, and Christopher D. Smyser²

¹Radiology, Washington University in St. Louis, St. Louis, MO, United States, ²Pediatrics, Washington University in St. Louis, St. Louis, MO, United States, ³Harvard Medical School, Boston, MA, United States

Introduction

Adverse neurodevelopmental outcomes in preterm infants remain a clinical concern. Resting-state functional connectivity MRI (fcMRI) provides a mechanism to investigate functional deficits in the neonatal brain [1]. Longitudinal monitoring using MRI is often restricted and delayed in the sickest infants due to technique-related demands [2]. Diffuse optical tomography (DOT) is a portable imaging modality that has the ability to provide early and continuous monitoring of brain function. The initial step to establish functional connectivity DOT (fcDOT) as a bedside tool for neonatal brain monitoring is to define normal fcDOT patterns in healthy, term infants and validate them against the gold standard of fcMRI. In this work, we show non-concurrent fcDOT and fcMRI maps obtained in a cohort of nine full-term neonates scanned within the first days of life. The strong spatial agreement between both modalities suggests that fcDOT provides satisfactory spatial localization and resolution, and illustrates its potential as a viable imaging tool for monitoring neonates at the bedside.

Methods

Nine healthy, full-term infants (gestational age at birth: 39-41 weeks) were recruited from the Newborn Nursery at Barnes-Jewish Hospital within the first 48 hours of life. Non-concurrent MRI and DOT data sets were obtained within one day. Functional MRI data acquisition was performed on a Siemens 3-T scanner (TR/TE 2910/28 ms, voxel size 2.4x2.4x2.4 mm³). fcMRI data analysis was performed according to the methods described in [3]. Resting-state DOT data was collected over 30 minutes using an imaging cap (Fig. 1a) and preprocessed according to [4]. A subject-specific light propagation model was created for each infant based on its structural MR images (Fig. 1a). Based on this model, optical measurements were converted into volumetric reconstructions of both HbO₂ and HbR. Seed correlation analysis was used to create resting-state maps for DOT and fMRI data sets in reference to predefined seeds (Fig. 1b). Each individual correlation map was co-registered to a neonatal T2-weighted atlas and averaged across subjects in order to obtain group maps for each modality.

Results

fcDOT identified multiple resting-state networks in term neonates. The spatial extension of these networks is consistent with the maps obtained using fcMRI at the individual (Fig. 1c) and group levels (Fig. 2a). Correlation matrices obtained using each modality confirms these maps are quantitatively comparable (Fig. 2b).

Conclusions

Due to its portability, fcDOT is well-suited for continuous monitoring of brain function at rest. Here we demonstrate that our fcDOT system generates resting-state maps exhibiting strong agreement with non-concurrent fcMRI maps in identical subjects. These results represent a critical step towards establishing a normative data set necessary for studying resting-state networks in high-risk neonates at the bedside. The continuous use of DOT, complemented with other portable modalities such as EEG, may improve prognostic information and therapeutic interventions available in these populations.

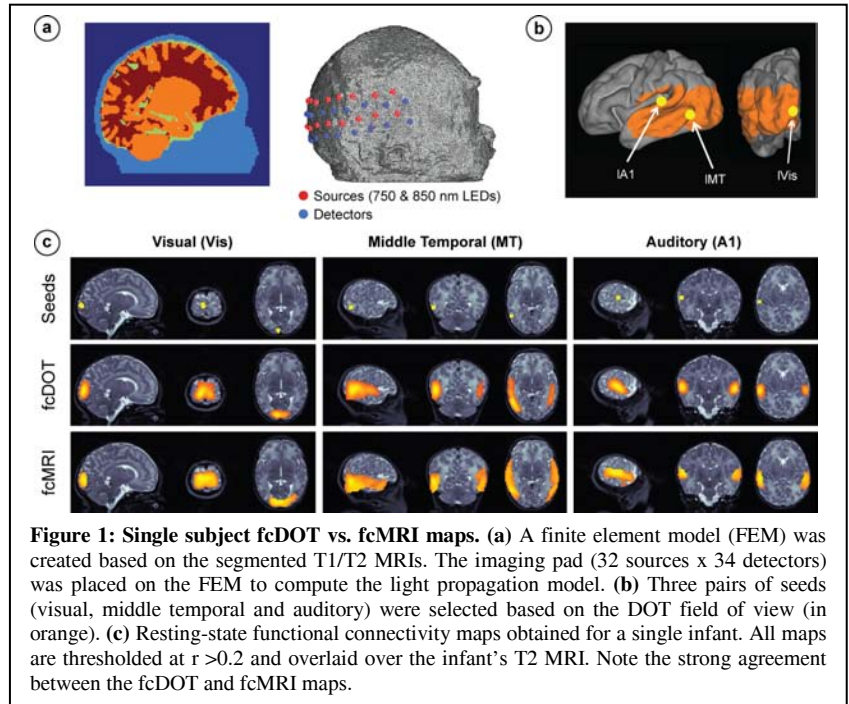


Figure 1: Single subject fcDOT vs. fcMRI maps. (a) A finite element model (FEM) was created based on the segmented T1/T2 MRIs. The imaging pad (32 sources x 34 detectors) was placed on the FEM to compute the light propagation model. (b) Three pairs of seeds (visual, middle temporal and auditory) were selected based on the DOT field of view (in orange). (c) Resting-state functional connectivity maps obtained for a single infant. All maps are thresholded at $r > 0.2$ and overlaid over the infant's T2 MRI. Note the strong agreement between the fcDOT and fcMRI maps.

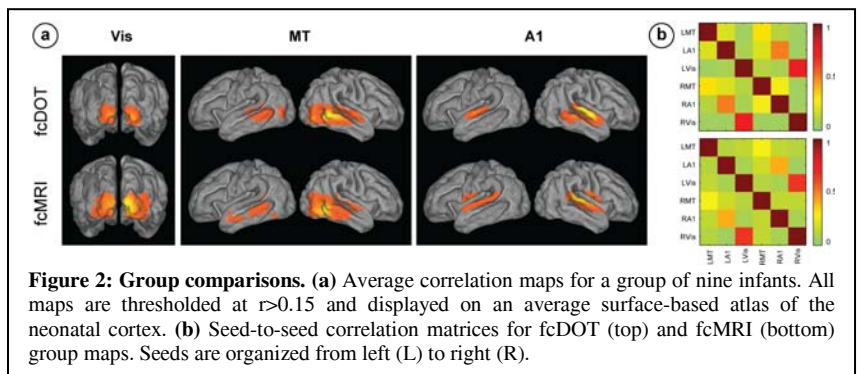


Figure 2: Group comparisons. (a) Average correlation maps for a group of nine infants. All maps are thresholded at $r > 0.15$ and displayed on an average surface-based atlas of the neonatal cortex. (b) Seed-to-seed correlation matrices for fcDOT (top) and fcMRI (bottom) group maps. Seeds are organized from left (L) to right (R).

1. Smyser, C.D. et al. Effects of white matter injury on resting state fMRI measures in prematurely born infants. *PLoS One*, 2013.8(7).
2. Glass, H.C. et al. Neurocritical care for neonates. *Neurocritical Care*, 2010. 12: p. 421-429.
3. Smyser, C.D. et al. Longitudinal analysis of neural network development in preterm infants. *Cerebral Cortex*, 2010. 20 (12): p. 2852-62.
4. White, B.R. et al. Bedside optical imaging of occipital resting-state functional connectivity in neonates. *Neuroimage*, 2012. 59 (3): p. 2529-38.