Novel robotic solutions for functional MRI studies of preterm infants

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Abstract—we have studied and characterized the somatosensory cerebral response of premature infants using functional magnetic resonance imaging (fMRI) and bespoke MR safe robotic interfaces.

I. INTRODUCTION

The incidence of premature birth is rising, and despite advances in neonatal care, the prevalence of adverse neurodevelopmental outcome in survivors remains high. Neuroimaging techniques have the potential to identify the structural and functional brain correlates of the neurological impairments associated with conditions such as cerebral palsy well before the clinical signs are evident, and provide the opportunity for early, targeted intervention. Advanced robotics and functional magnetic resonance imaging (fMRI) allow the characterization of the spatial and temporal nature of functional brain activity in the premature newborn. We have combined tailored robotic stimulators and fMRI in an objective and robust method to study cortical responses in preterm infants. This has allowed us to characterize the premature infant’s haemodynamic response function (HRF), and to identify specific areas of cortical activation in response to both passive and active motor tasks.

II. METHODS

We have developed MR-compatible robotic interfaces to deliver proprioceptive stimulation and record the spontaneous movements of premature infants during fMRI studies within a 3.0 Tesla Philips MRI scanner. Actuation is synchronized with image acquisition allowing for accurate fMRI image analysis. The output from the robots can be used as a regressor in fMRI data processing to detect the cortical activation associated with both passive and spontaneous hand opening, and wrist flexion/extension movements.

Figure 1. The custom balloon (left) wrist (middle) stimulating devices attached to a premature infant. An infant in the MRI scanner (right)

An event-related hand stimulation paradigm was used to characterize the neonatal HRF. Block paradigms of wrist and hand stimulation were used to identify the area of cortical activation associated with passive movement. The wrist interface was used to record spontaneous movements during a resting state sequence.

III. RESULTS

Characterization of the neonatal HRF revealed significant differences in comparison to the canonical HRF used in adult fMRI studies, and showed a significant maturational trend in the key parameters through the preterm period. The neonatal HRF was thus used to analyze results throughout our study.

Well-localized activation in the contra-lateral primary somatosensory cortex was identified in preterm infants in response to both passive wrist and hand movements. Preliminary experiments have identified cortical activation associated with spontaneous wrist movements, adjacent and anterior to that elicited by passive wrist movements.

Figure 2. Evolution of the neonatal HRF (left), functional area of activation following passive right wrist stimulation in a preterm infant (right).

In infants studied following neonatal stroke, the functional response to hand movement was found to be present but displaced by the focal area of damage.

IV. DISCUSSION

We have developed a set of tools to allow for objective and reliable functional studies of the premature brain using fMRI. The newly characterized neonatal HRF and synchronized stimulation paradigm have allowed us to identify cortical activation within the infants’ primary somatosensory cortex in response to passive movement. Early work has revealed that spontaneous movements correlate with neural activity adjacent and anterior to the activity elicited by passive movements. This is in agreement with adult studies where the primary motor cortex lies adjacent to the somatosensory cortex.

We now aim to utilize our tools to build a more comprehensive sensorimotor brain map of the premature brain. We will stimulate the lower limbs, examine the development of lateralization, and explore cortical reorganization following focal brain injury. It is hoped that these studies will deliver important insights into the pathophysiology of neurodevelopmental disorders such as cerebral palsy.