First evidences of cerebral resting-state networks in human neonates using Functional Ultrasound

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Background, Motivation and Objective

Functional Ultrasound (fUS) based on ultrafast imaging has opened new perspectives for human neuroimaging. Although MRI is able to provide 3D structural information on the neonate brain, no available modality can assess functional information on deep brain networks at bedside. A preclinical study on rodents [1] has recently shown the interest of studying the functional brain connectome with fUS as a marker of pathological neurodevelopment. Here we demonstrate the feasibility of functional brain connectomics at bedside with fUS for the first time on human neonates.

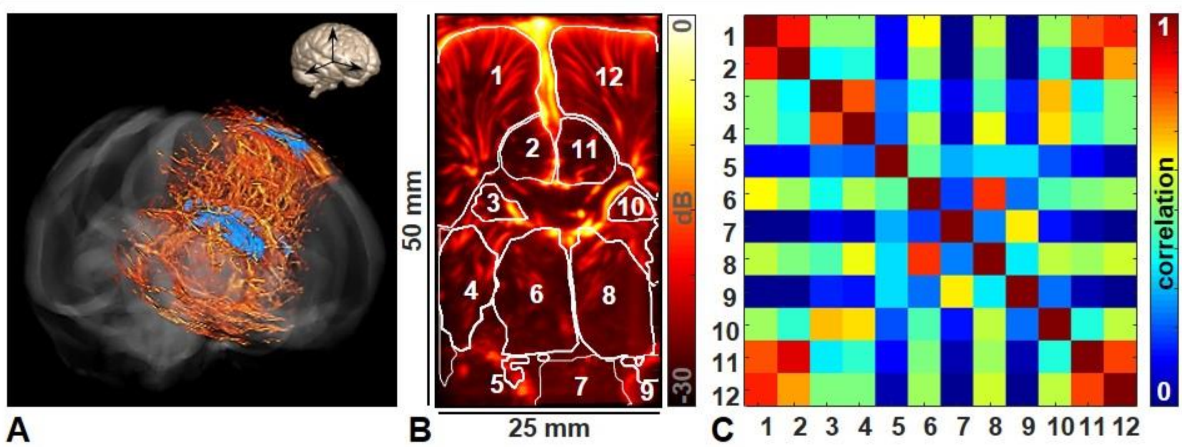
Statement of Contribution/Methods

A custom ultrasonic probe (128 elements, 0.2mm pitch, 6.4MHz) was mounted on a proprietary newborn-adapted headset along with 8 electrodes. An ultrasound research system was used to acquire custom fUS sequences (3 compounded plane waves, PRF 1800Hz, 370 frames) recording Ultrafast Doppler every 1s, giving access to the Cerebral Blood Volume variations (CBV) with acoustic intensities far below FDA requirements. The probe was placed on the fontanel and was rotated with a servo-motor to acquire plane-by-plane scans. Cerebral landmarks were automatically segmented on the 3D ultrasound scans and registered on a MRI neonate atlas [2]. The fUS sequence was acquired in a plane of interest and the corresponding parcels were extracted from the matched MRI atlas. Parcel-to-parcel Pearson's correlations of mean CBV time courses were computed to obtain connectivity matrices.

Results/Discussion

During 10min-long phases of quiet sleep on 5 preterm neonates and 2 healthy term babies, the connectivity matrices revealed the inter-hemispheric connectivity, showing strong left-right correlations between frontal lobes and cingulate cortices (correlation coefficients r>0.8). Interestingly, when applied to a pathological term neonate exhibiting "burst-suppression" EEG pattern, the contra-lateral inter-hemispheric connectivity strongly decreases (r<0.3). These results pave the way to bedside quantification of functional brain alterations and monitoring of therapeutics in the critical early weeks after birth. It also provides a unique tool for the fundamental understanding of human brain networks development.

[1] Mairesse *et al*, *Glia*, 2019, [2] Makropoulos *et al*, *Neuroimage*, 2016



(A) 3D ultrafast ultrasound scans of a neonate brain with blood vessels (red) and cerebrospinal fluid (blue), registered on a MRI atlas (gray) (B) Coronal Doppler slice used for fUS analysis with MRI-based atlas overlaid. (C) Connectivity matrix resulting from the correlation from the CBV mean signal between the different areas. High coefficients along the anti-diagonal reveal the inter-hemispheric connectivity.