Investigating Neurovascular Coupling in Infants with Brain Injury and Seizures

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E-Poster

Introduction:

Brain injury is a significant cause of life-long disability in sick infants. Brain injury caused by reduced blood flow and oxygen to the brain at the time of birth can lead to seizures. Accurate diagnosis remains challenging because abnormal seizure movements can be absent in infants, therefore seizures are under diagnosed and difficult to treat. The excessive neuronal activity that characterizes electrographic seizures results in an increased metabolic demand. If regional oxygen supply fails to match this demand, the brain is vulnerable to further hypoxic damage. A better understanding of the relationship between electrical brain activity and the vascular response during seizures (neurovascular coupling) is fundamental to improving understanding of the potential damage caused by such events. EEG is the gold standard for diagnosing seizures but is limited to measuring electrical activity alone and is unable to provide information on the metabolic or hemodynamic impact of seizures on the brain. Diffuse optical imaging (DOI) is a non-invasive method that produces images of changes in cerebral tissue oxygenation and blood volume. We have begun to apply a novel brain-imaging system, combining EEG and DOI, to infants who have suffered hypoxic injury. We intend to prove that the application of these tools will represent a significant advance in the brain-orientated care of sick infants.

Methods:

A brain-imaging system was developed combining continuous wave DOI (University College London Optical Topography System) and EEG (MicroMed, Italy) to simultaneously record whole-head electrical and haemodynamic activity using a head-cap (EasyCap, Germany) with 32 DOI optodes (58 channels) and 13 EEG electrodes (PHOTO 1). As the DOI-EEG system is portable and non-invasive, infants can be scanned in the NICU at the cot-side (PHOTO 2). Eleven infants were recruited: Five healthy term, two healthy near-term and four with hypoxic ischaemic encephalopathy (HIE) were scanned at median ages of 38+4, 36+4 and 40+5 weeks respectively. Infants were scanned over a 1-hour period. HIE infants treated with therapeutic cooling were scanned for 1-hour periods over different stages of cooling. Images of concentration changes in oxy and deoxyhemoglobin, and blood volume were reconstructed. EEG data was inspected by two independent clinical electrophysiologists to identify seizure events. Neurovascular coupling analysis was performed using methods previously described[1]. A detailed spatial and temporal analysis was performed on any identified electrographic seizures.

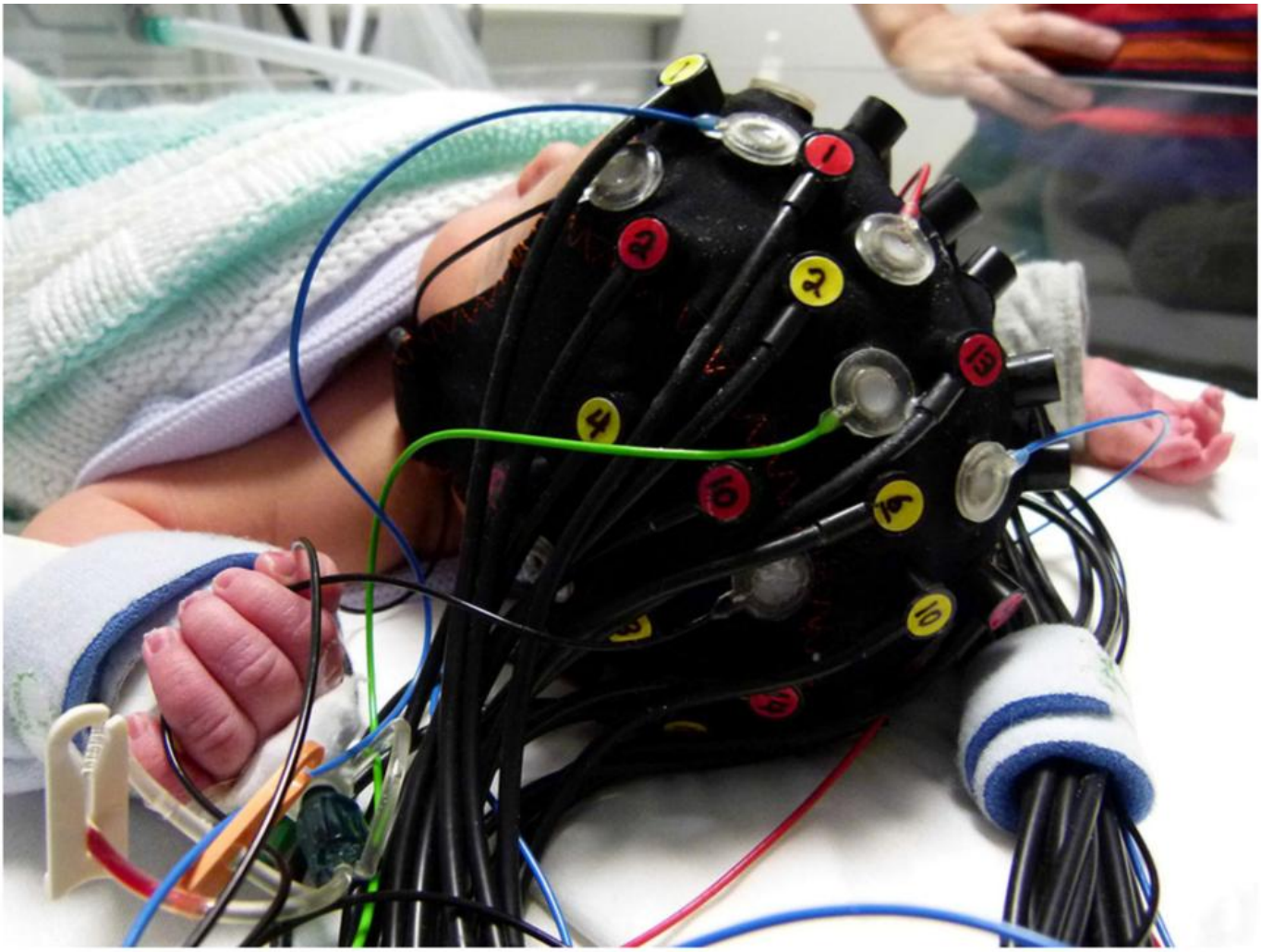

PHOTO 1: The DOI-EEG cap on a healthy term infant during a study.

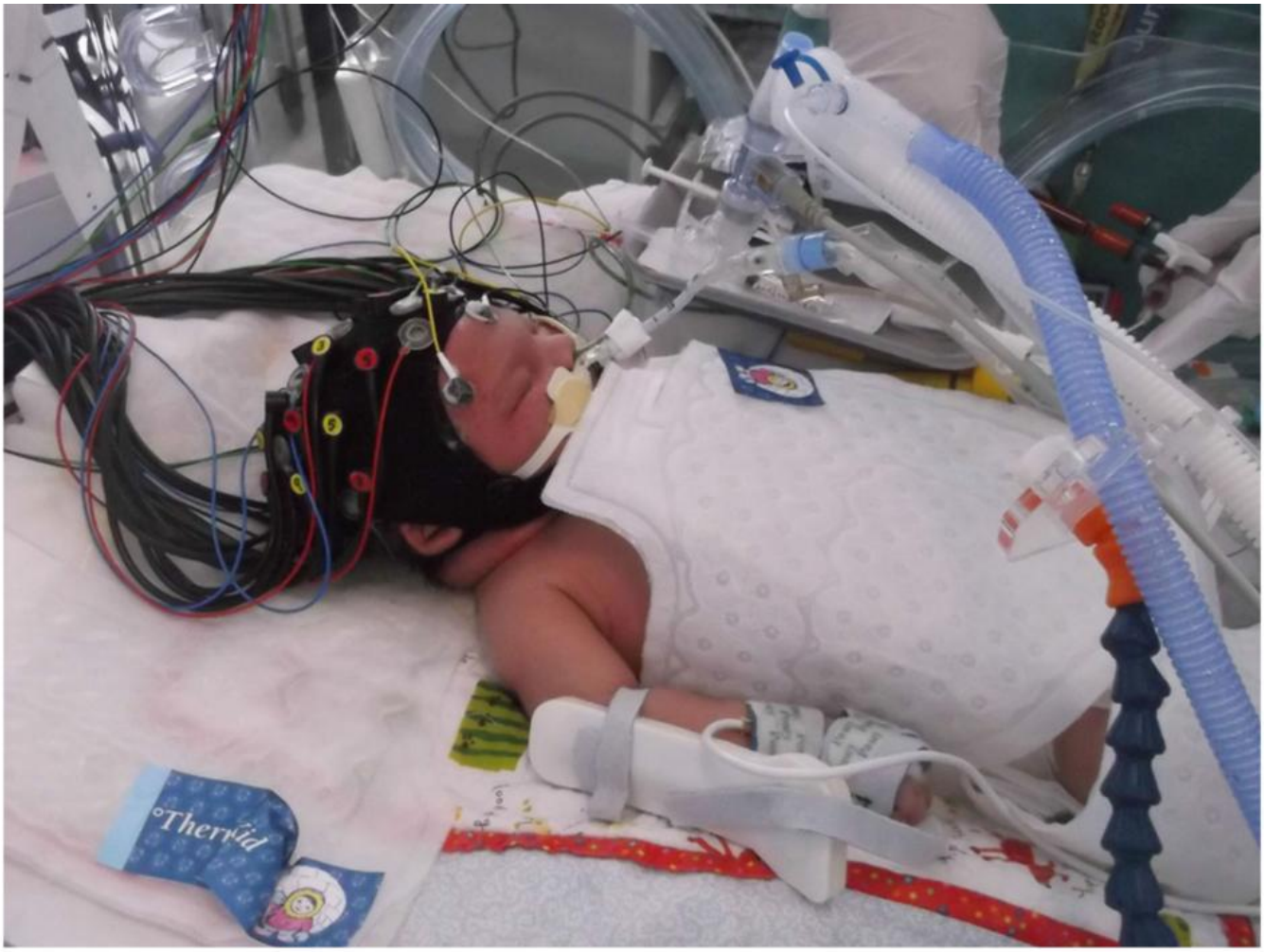

PHOTO 2: The DOI-EEG cap on an infant with hypoxic-ischaemic brain injury during a study in the neonatal intensive care unit.

Results:

The results demonstrate individual neurovascular coupling correlations ($R \geq 0.4$) between resting-state frequency ranges (0.009-0.08Hz) of DOI data and EEG Delta band power energy (0.5-4.0Hz) in each term and late preterm subjects although no clear pattern was found among or between patient groups. In one HIE infant, six electrographic seizures were identified during the rewarming phase after cooling. This allowed the reconstruction of the first ever images of cortical hemodynamics in an infant during a seizure (FIGURE 1). The hemodynamic response to these seizures consists of a large, general global increase in cortical blood volume followed by a significant decrease to well below the baseline level (FIGURE 2). Although the underlying cause of these changes is unknown, this phenomenon has been previously observed by the research group in infants with brain injury in the absence of seizures[2], and may represent a significant indication of brain injury.

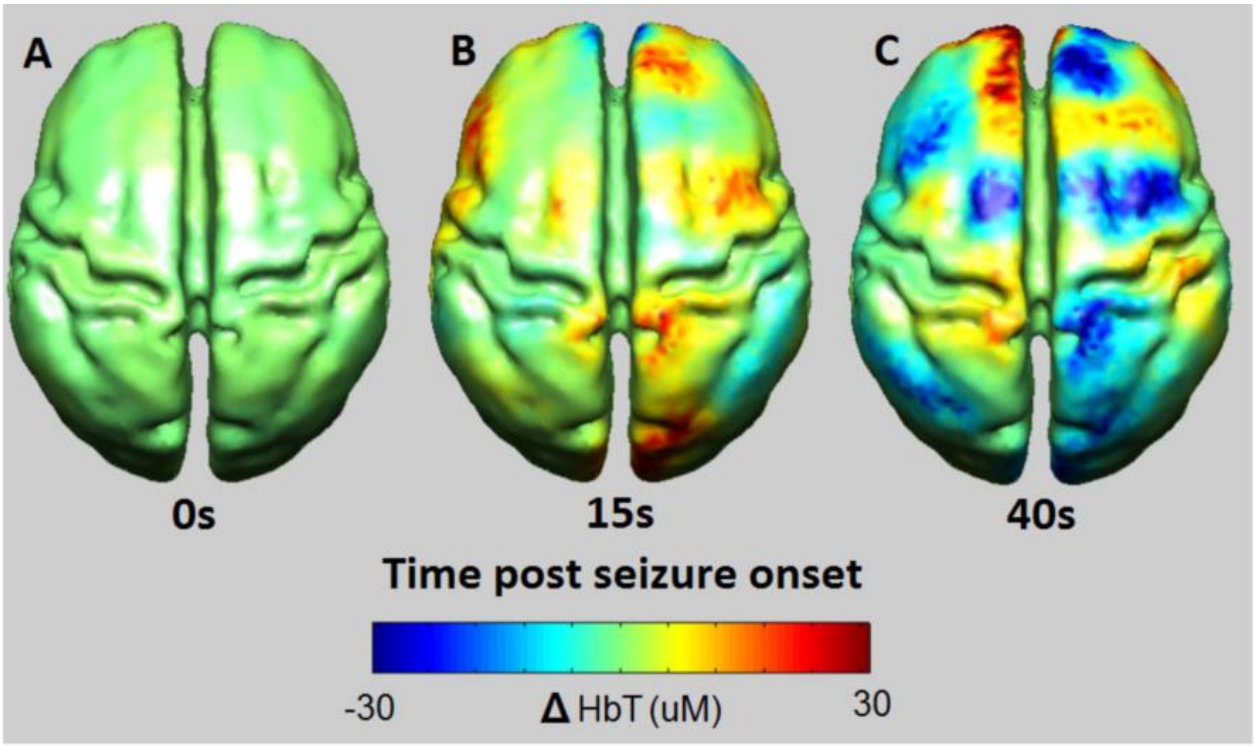

FIGURE 1: The cortical representation of the changes in total haemoglobin concentration for 0, 15 and 40 seconds after the onset of one seizure reconstructed relative to a baseline defined by the 10 seconds prior to seizure onset.

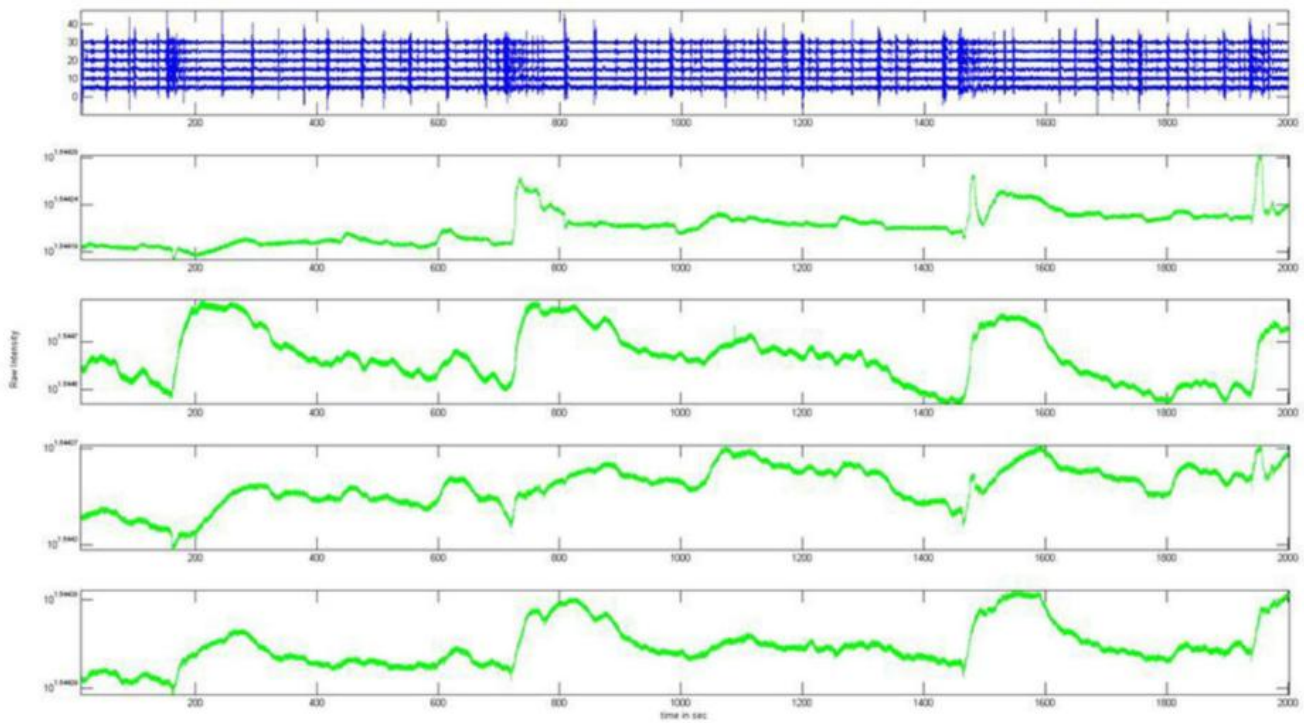

FIGURE 2: Patterns of changes in cerebral blood volume seen in DOI (green traces) correlate with electrical burst EEG activity (blue traces) in an infant with hypoxic-ischaemic brain injury.

Conclusions:

Our preliminary results show DOI-EEG to be a useful brain-imaging system for investigating neurovascular coupling in high-risk infants. Further analysis could yield novel information about cerebral function and pathology in the developing brain creating valuable biomarkers for clinicians for the accurate detection of brain injury and evaluation of future neuroprotective therapies.

Imaging Methods:

Multi-Modal Imaging

Abstract Information

Would you accept an oral presentation if your abstract is selected for an oral session?

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Please indicate below if your study was a "resting state" or "task-activation" study.

Resting state

Healthy subjects only or patients (note that patient studies may also involve healthy subjects):

Patients

Internal Review Board (IRB) or Animal Use and Care Committee (AUCC) Approval. Please indicate approval below. Please note: Failure to have IRB or AUCC approval, if applicable will lead to automatic rejection of abstract.

Not applicable

Please indicate which method was used in your research:

EEG/ERP

Optical Imaging

What post processing software packages do you use?

Other, Please list - HomER

References

Reference

1. Pfurtscheller, G. (2012), 'Coupling between intrinsic prefrontal HbO2 and central EEG beta power oscillations in the resting brain', PLoS One, 7(8):e43640
2. Cooper R.J. (2011), 'Transient haemodynamic events in neurologically compromised infants: a simultaneous EEG and diffuse optical imaging study', Neuroimage, 2011;55(4):1610-1616.