

Non-invasive investigation of cerebral autoregulation and flow metabolism coupling following acute brain injury

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Introduction

Impaired cerebrovascular reactivity may place the brain at risk of secondary hypoxia-ischaemia after acute brain injury (ABI) [1]

- Cerebral autoregulation (CA) ensures constant cerebral blood flow (CBF) despite changing perfusion pressure.
- Indices of dysautoregulation have been associated with poor outcome after ABI and are promoted as a monitor of the injured brain [1].
- However these do not monitor the adequacy of cerebral perfusion in a particular region of interest

Neurovascular coupling (NC) mediates the CBF response to increased metabolic demand by coupling oxygen and metabolic substrate requirements to metabolic activity [2].

- Normal NC manifests as an increase in cerebral oxy- [HbO₂] and reduction in deoxy- [HHb] haemoglobin
- NC is the basis of functional MRI and functional near infrared spectroscopy (fNIRS)
- Following ischaemia NC is disrupted and a different pattern of change is seen in response to increase in metabolic demand – namely a rise in [HbO₂] and [HHb] [2,3]
- These changes have not been extensively investigated following ABI

We hypothesise that a common underlying disturbance of vascular reactivity may impair CA and neurovascular coupling.

This study investigates the neurovascular coupling response during impaired CA following ABI.

Method

20 ventilated, sedated patients with severe ABI were recruited following ethics approval and representative consent.

- One hour datasets were collected during transcranial Doppler (TCD) ultrasound and in-house developed broadband NIRS monitoring.
- Scaled absolute [HbO₂] and [HHb] were derived using spatially resolved spectroscopy from 4 detectors at 20mm to 35mm to minimize extracerebral ‘contamination’ of the NIRS signals [4].
- The mean velocity index (Mx) was derived from arterial blood pressure (ABP) and TCD as a continuous index of CA as previously described [1].
- The relationship between [HbO₂] and [HHb] during spontaneous oscillations was investigated using wavelet semblance (0.1Hz – 0.003Hz) in which a measure of phase tending towards 1 indicates in-phase (abnormal response) and -1 out-of-phase (normal response) [5].
- [HbO₂]/[HHb] phase relationship was compared to Mx using Pearson correlation.

Results

20 patients were studied during 36 recording episodes.

- Mean (+/-SD) [HbO₂]/[HHb] phase relationship (semblance) was 0.15 (+/-0.36).
- Mean Mx correlated with [HbO₂]/[HHb] phase ($r=0.43$ $p<0.01$).
- Figure 1 shows the relationship between ABP, Mx and phase for every 10 second time point recorded,
- Figure 2 shows typical normal and abnormal haemoglobin oscillations.

Discussion

We identified abnormal [HbO₂]/[HHb] oscillations in patients with ABI that are consistent with findings in ischaemia [2,3].

- These are associated with impaired CA which might be attributed to the underlying brain injury or vascular abnormalities common between neurovascular coupling and CA.
- [HbO₂]/[HHb] holds considerable promise as a marker of metabolic compromise after ABI and can be monitored non-invasively using a single modality (NIRS).
- Further work is required to elucidate the exact pathophysiology encoded in these optical signals and temporal relationships which might identify windows for intervention

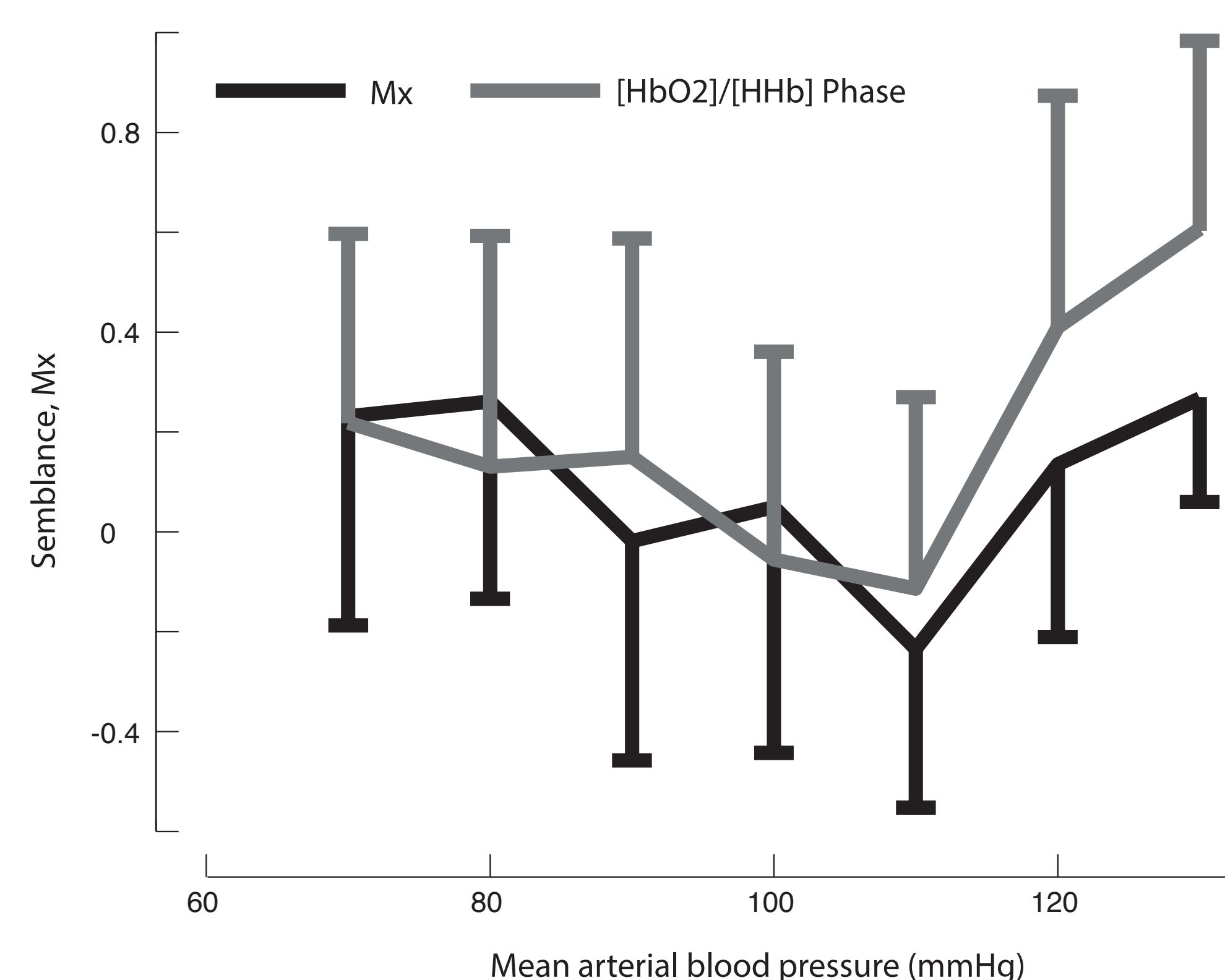


Figure 1
The relationship between 10 second epochs of Mx (an index of cerebral autoregulation) and [HbO₂]/[HHb] phase (a marker of neurovascular coupling) and arterial blood pressure. Error bars denote standard deviation. It can be seen that the blood pressure distribution of each variable is similar. Note the the pressure “plateau” where both phase and Mx tend towards normal.

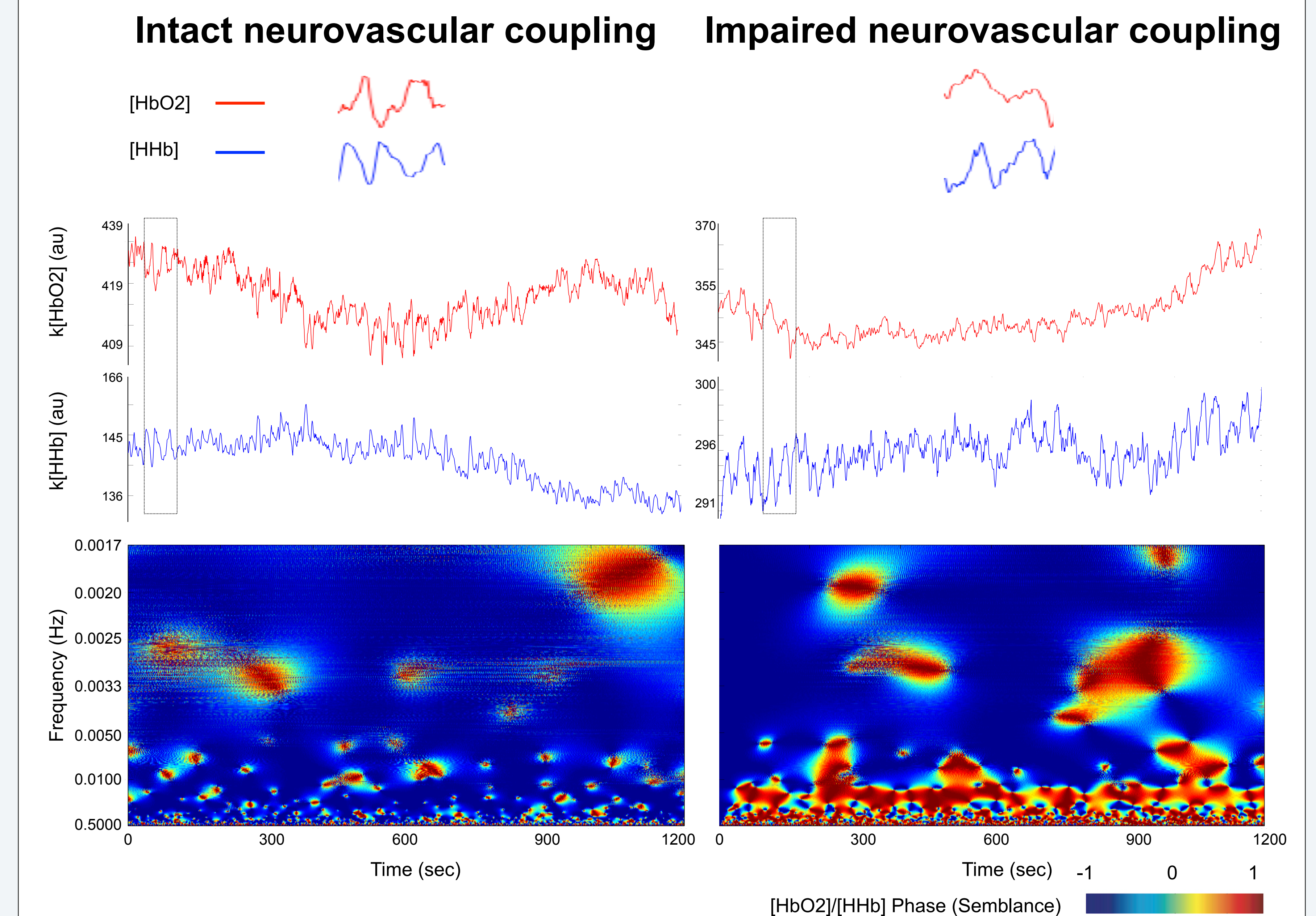


Figure 2
Normal (left) and abnormal (right) neurovascular coupling are shown. In the left plot antiphase oscillations in [HbO₂] and [HHb] are apparent and result in the blue appearance of the wavelet semblance plot (semblance -1). The expanded boxed area illustrates these antiphase [HbO₂]/[HHb] oscillations. The right plot demonstrates the opposite. 0.1Hz-0.01Hz in-phase oscillations are seen as a red band through the wavelet semblance plot and are again highlighted in the expanded boxed area.

References

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