Cerebral venous volume changes and pressure autoregulation in sick infants

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Background

Impaired cerebral pressure autoregulation (CPA) plays a significant role in the brain injury in critically ill newborns. CPA is dependent on the cerebral perfusion pressure (CPP), i.e., the cerebral arterio-venous pressure gradient. Clinically mean arterial pressure (MAP) is used as a surrogate for CPP. Critically ill infants may have tenuous mean arterial pressures (MAP) and may require positive pressure ventilator (PPV), which may cause fluctuations in cerebral venous volume and create a high-risk scenario for insufficient CPP.

Objective

We sought to study the relation between ventilator-related changes in cerebral blood volume (ΔCBV) on CPA, in sick newborn infants receiving critical care.

Methods

In this prospective study, continuous measures of NIRS and MAP from indwelling intra-arterial line were collected from sick infants requiring PPV. The NIRS-derived hemoglobin difference (HbD = oxygenated minus de-oxygenated hemoglobin) and total hemoglobin (HbT = oxygenated + de-oxygenated hemoglobin) were used as surrogates for cerebral blood flow and cerebral blood volume, respectively [1]. For every 10 minutes, coherence between HbD and MAP ($COH_{HbD\text{-}MAP}$) in 0.05-0.25 Hz frequency band (the CPA frequency band) [2], and the logarithm of spectral power of HbT at the ventilator frequency (a marker for ΔSvO_2) were calculated. The epochs were categorized into two groups as pressure passive (PP: $COH_{HbD\text{-}MAP} > 0.3842$) or autoregulating (AR: $COH_{HbD\text{-}MAP} <= 0.3842$) [2]. For each group the median of the logarithms of HbT spectral power at the ventilator frequency was calculated and compared (paired t-test).

Results

We studied 68 infants (50% male) with a mean gestation age of 34.6 ($\pm$6.4) weeks. The clinical and demographics data are summarized in Table 1. Mean postnatal age was 5.6 ($\pm$11.2) days. Fifty three (78%) infants had epochs of CPP. Spectral power of HbT was significantly higher in the PP epochs compared to the AR epochs, in the left ($p=0.0001$) and right hemispheres ($p=0.009$) (see Figure 1).

Conclusion

In newborns undergoing intensive care, we demonstrate a significant correlation between ventilator-induced CBV changes and failure of CPA. Our data suggest that ventilator-induced changes in cerebral venous volume may play an under-appreciated role in the prevalence of CPP, and possibly brain injury, in critically ill infants. Further studies are needed to assess the value of this technique for advancing neonatal critical care.

[1] M. Tsuji *et al.*, Pediatr Res **44**, 591 (1998).

[2] R. B. Govindan *et al.*, Front Hum Neurosci **8**, 266 (2013).

Table 1. Patient Population (n = 68)

Clinical Characteristics	**n (%)**
Male	34 (50)
Inotropic Support	40 (58.82)
Premature Infants (≤36 weeks)	16 (23.5)
Encephalopathy	38 (55.1)
Congenital Heart Disease	10 (14.7)
Patent Ductus Arteriosus	8 (11.8)
Brain Injury	22 (36.8)
Deaths	8 (11.8)

*Twenty-one diagnosed with Magnetic Resonance Imaging and four diagnosed with Ultrasound.

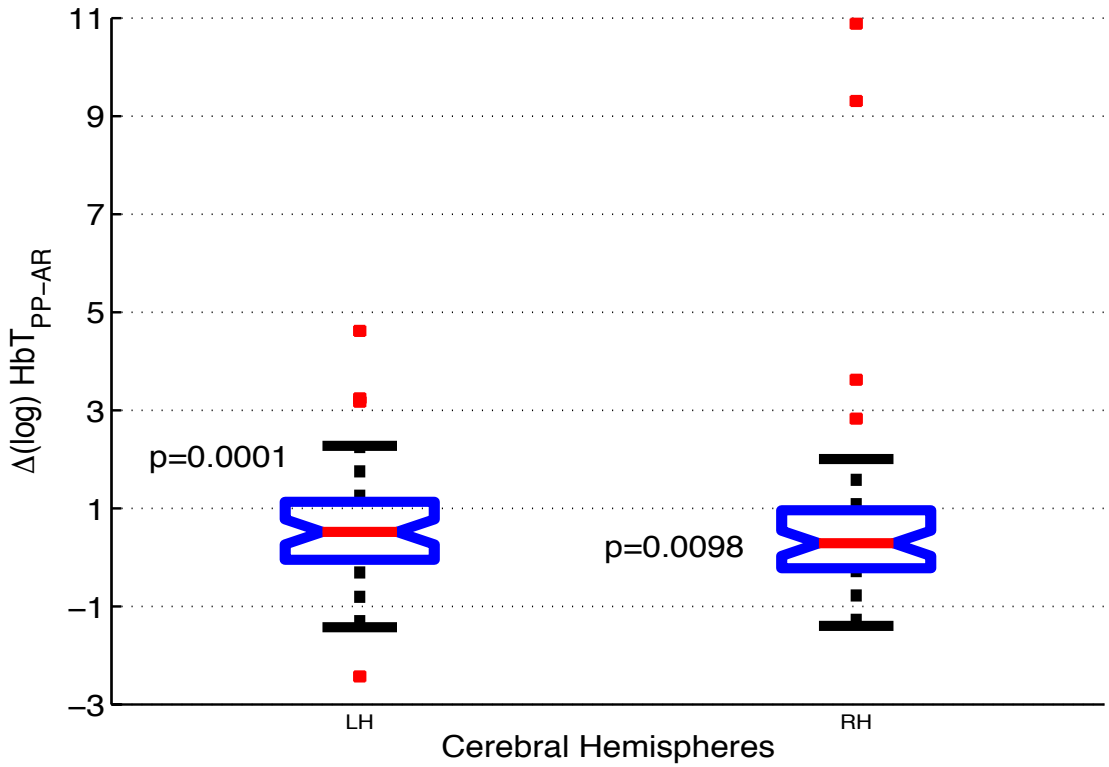

Figure 1. Boxplot of the difference in the logarithm transformed HbT power [Δ(log) HbT] between PP and AR epochs at the ventilator frequency. RH:Right hemisphere; LH=Left hemisphere.