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Impairment of cerebral autoregulation in pediatric extracorporeal membrane oxygenation

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Background: Extracorporeal membrane oxygenation (ECMO) is a rapidly expanding, life-supporting therapy for critically ill patients with severe respiratory and/or cardiovascular failure. Cerebrovascular impairment can result in hemorrhagic and ischemic complications commonly seen in the patients supported on ECMO. The healthy brain is protected by cerebral autoregulation, which maintains an adequate cerebral blood flow in face of blood pressure changes.[1] Pre-ECMO factors, such as hypoxia, hypercarbia, and hypertension, can disrupt blood flow regulation, leaving the brain vulnerable to changes in blood pressure.[2] Cannulation of large blood vessels[3] and alterations of pulsatile flow patterns during ECMO also play a role in altered cerebral autoregulation.[4]

A reliable methodology that can assess the status of cerebral autoregulation during ECMO and provide early indication of neurological injury is critical for optimization of bedside management to improve clinical outcomes. Wavelet transform coherence (WTC) is a time–frequency domain analysis that characterizes the cross-correlation and relative phase between spontaneous fluctuations in blood pressure and cerebral oxygenation measurement by oximetry. We implemented WTC[5] to assess the degree of cerebral autoregulation impairment in neonatal and pediatric ECMO and evaluated its usefulness as an early predictor of acute neurological complications. Further, we examined cerebrovascular parameters, blood gas changes, and anticoagulation parameters as potential causes of autoregulation impairment during ECMO.

Methods: Spontaneous fluctuations of mean arterial pressure (MAP) and cerebral tissue oxygen saturation ($S_{ct}O_2$) were continuously measured during the ECMO run. The dynamic relationship between the MAP and $S_{ct}O_2$ fluctuations were assessed based on

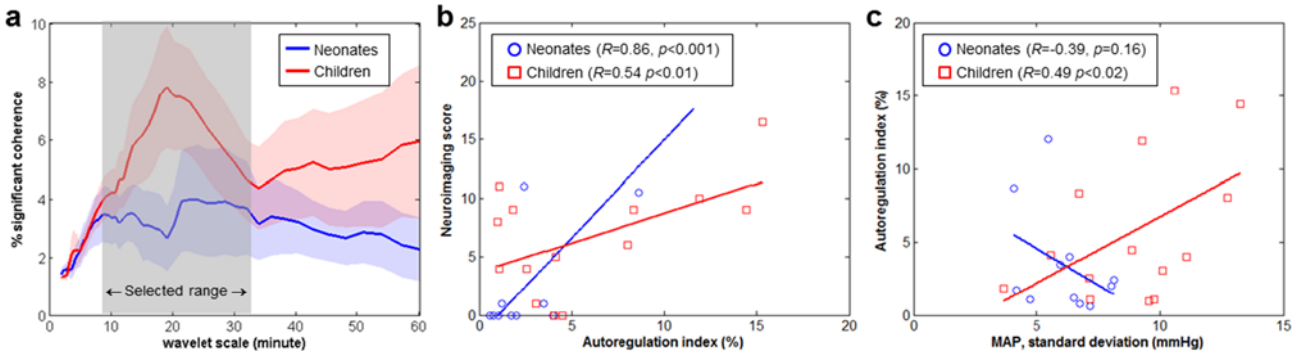

Figure 1. Results of cerebral autoregulation at the group level: (a) Scale characteristics of the in-phase coherence between the spontaneous fluctuations of MAP and $S_{ct}O_2$. For both the neonates and children, predominant in-phase coherence was seen in a time scale range of 8 – 32 min (the shaded area), which was then selected to calculate the autoregulation index. (b) Relationship between autoregulation index and neuroimaging score. (c) Effects of intra-ECMO blood pressure variation on autoregulation index.

wavelet transform coherence (WTC) to derive an index of cerebral autoregulation impairment. The Institutional Review Board at the University of Texas Southwestern Medical Center at Dallas approved the study.

Results: A total of 25 neonatal (11) and pediatric (14) patients were studied. In-phase coherence between the MAP and $S_{ct}O_2$ fluctuations was predominant in a time scale range of 8 – 32 min. Significant correlations between individual autoregulation indices and neuroimaging scores were found in both neonates and children. There was a significant association between individual blood pressure variations with autoregulation indices in the children, but not in the neonates (Figure 1).

Discussion and conclusion: We found that intra-ECMO autoregulation impairments derived from WTC were apparent even before clinically observable changes occur at the bedside. Furthermore, these impairments correlated with the patients' neuroimaging abnormalities. This finding remained constant for both VA ECMO and VV ECMO in contrast to evidence of increased incidence of neurological complication with carotid artery cannulation in the literature. Blood pressure variability in ECMO patients appeared to be associated with impaired autoregulation in the non-neonatal population.

Continuous assessment of cerebral autoregulation based on WTC has the potential to be a useful bedside tool to predict acute neurological events in patients on ECMO. Our study shows that high blood pressure viability, for which these patients are at risk, appears to be a cause of cerebral autoregulation impairment. This finding suggests a new approach to bedside management that may lead to a decrease in cerebral autoregulation impairment, thereby improving neurological outcomes in these patients.

Keywords: extracorporeal membrane oxygenation (ECMO), cerebral autoregulation, wavelet transform coherence (WTC), neurological injury, blood pressure, case study

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