Noninvasive Continuous Imaging of Reduced Cerebral Perfusion with a Novel Diffuse Optical Tomography System: A Hyperventilation Study in Pig and Human

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Introduction

Cephalogics has developed a wearable Diffuse Optical Tomography (DOT) imaging device to help clinicians monitor perfusion and oxygenation from multiple brain regions on the bedside in disease states such as ischemic stroke, vasospasm, and traumatic brain injury. This study investigated the sensitivity of the system to changes in cerebral tissue oxygenation ($SctO_2$) induced by hyperventilation in a pig and human subjects.

Methods

A 45kg Yorkshire pig was placed in prone position, anesthetized, and mechanically ventilated. The first DOT sensor was positioned on the pig's head along the sagittal line, and the second sensor was positioned on the hind leg muscle for monitoring systemic tissue oxygenation ($SstO_2$). DOT measurements were performed continuously during baseline (8 mins, $PaCO_2$ = 40mmHg), transient hypercapnia (4 mins, $PaCO_2$ = 15mmHg), and recovery (25 min, $PaCO_2$ = 40mmHg) periods controlled by the respiratory rate of the ventilator. DOT data were recorded to a laptop for off-line analysis. StO_2 images were reconstructed every 1 minute, and image means ($\pm$SD) were computed for comparison of results across measurements. The approach was also investigated in three human volunteers, who were instructed to hyperventilate during DOT recordings.

Results

$SctO_2$ estimates in pig markedly decreased during hyperventilation from baseline ($-15\% \pm 6\%$), consistent with reports of reduced cerebral blood flow during hypocapnia. In contrast, $SstO_2$ modestly increased during hyperventilation ($+3\% \pm 1\%$), indicating elevated systemic perfusion. Both parameters fully recovered to baseline values during the recovery period. $SctO_2$ response to hyperventilation in human volunteers were consistent with the results in pig.

Conclusions

Hyperventilation induced reduction in $SctO_2$ was noninvasively imaged in human subjects and a pig despite the large scalp-cortex distance in pig. The results of this study demonstrate the sensitivity of the Cephalogics' DOT system to $SctO_2$ values and its ability to separate $SctO_2$ from systemic perfusion.