Recovery of Regional Cerebral Blood Flow and Brain Tissue Oxygenation by 24 Hours After Asphyxial Cardiac Arrest

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INTRODUCTION

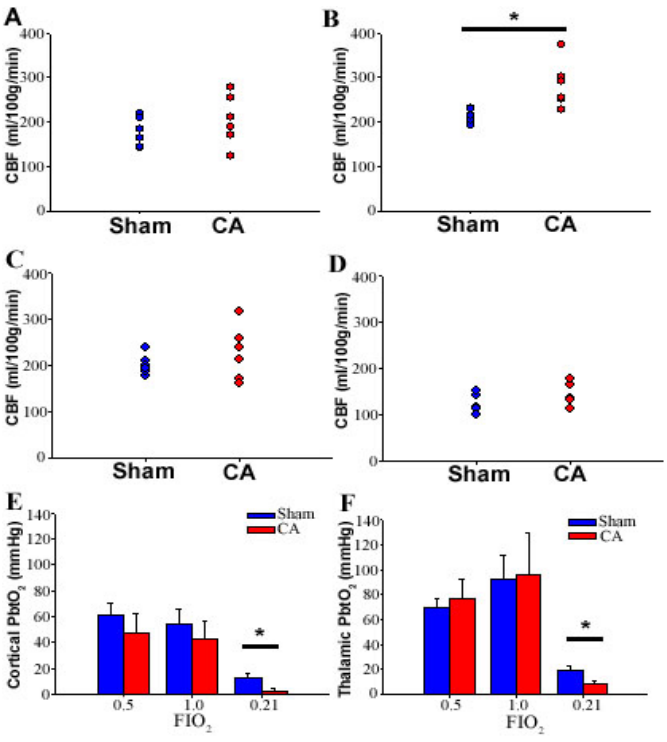
In the United States, it is estimated that 87% of children that suffer unexpected cardiac arrest do not survive, whilst 50% of survivors suffer an unfavorable neurological outcome [1,2]. It has been suggested that changes in cerebral blood flow (CBF) after cardiac arrest plays an important role in irreversible brain damage. After 6 min of cardiac arrest cerebral perfusion pressure should be greater than 35 mm Hg to restore cerebral perfusion and cerebral energy metabolism [3]. Disturbances in cerebral blood flow (CBF) and brain tissue oxygenation (PbtO2) during post cardiac arrest (CA) syndrome may be important factors in ultimate neurological outcome after CA.

Our research team has modified an adult model of asphyxial arrest, simulating the pediatric population using postnatal day (PND) 17 rats. This model allows for invasive physiological monitoring and acute resuscitation that closely mimics guidelines used in humans. The aim of this study was to determine if CBF and PbtO2 disturbances persist 24 h after pediatric asphyxial CA.

MATERIALS AND METHODS

PND 17 rats (shams = 6, CA = 6) were used for this study. Isoflurane (1:1 O_2/N_2O) anesthetized rats were intubated, mechanically ventilated and femoral catheters were inserted. Isoflurane was discontinued and anesthesia was maintained by an infusion of Fentanyl and Vecuronium during which baseline CBF measurements were obtained. Asphyxial cardiopulmonary arrest was produced by disconnecting the ventilator from the rats for 9 min. After this period, rats were then resuscitated with epinephrine, sodium bicarbonate, respiratory ventilation, and chest compressions performed until spontaneous circulation returned, rats were returned to their cages 1 h post resuscitation. Body temperature was maintained throughout the MRI assessment at 37 ± 0.5 ˚C using warm air, regulated with a rectal temperature probe. During each MRI study, $PaCO_2$, PaO_2, MABP, HR and rectal temperature was recorded throughout.

MR studies were performed on a 7-Tesla, 21cm bore Bruker Biospec system, equipped with a 12 cm diameter shielded gradient insert and a 72 mm volume RF coil. For all imaging experiments, an FOV = 3 cm and slice thickness = 2 mm were used. Maps of T_{1obs} [4] were generated from a three-parameter exponential fit to a series of spin-echo images with variable *TR* (*TR* = 8000, 4300, 2300, 1200, 650, 350, 185, 100 msec, 2 averages, 128 x 70 matrix). Perfusion spin-echo images were acquired in duplicate using the arterial spin-labeling technique [5] (*TR*/*TE* = 2000/10, 20, 30, summation of 3 echoes, 2 averages, 128 x 70 matrix) with labeling applied ± 2.5 cm from the imaging plane. CBF (cerebral blood flow) maps were generated from: $CBF = \lambda \cdot (T_{1obs} \cdot 2\alpha)^{-1} \cdot (M_C - M_L) \cdot (M_C)^{-1}$, where M_C and M_L are the magnetization intensities from the control and labeled images, respectively. A spatially constant value of 0.9 mL · g^{-1} was assumed for the blood brain partition coefficient for water (λ). The spin labeling efficieny (α) [6] was determined in each study with gradient echo images on the carotid arteries and spin-labeling applied at ± 11 mm (*TR*/*TE* = 100/9.6 msec, 45˚ flip angle, 8 averages, 256 x 256 matrix). CBF measurements were performed 24 h after cardiac asphyxial arrest.



RESULTS AND DISCUSSION

CBF disturbances of the cortex, amygdala, and hippocampus recover by 24 h after CA (Figures 1A, 1C and 1D). CBF in the thalamus is increased when compared with shams at 24 h after CA (Figure 1B). Regional $PbtO_2$ disturbances seen minutes after experimental pediatric asphyxial CA are not present at 24 h when FiO_2=0.5. The response of $PbtO_2$ to increase in FiO_2 at 24 h after CA is comparable to shams. Lowering FiO_2 to 0.21, decreases $PbtO_2$ below acceptable thresholds in the cortex and thalamus (Figures 1E and 1F).

This is the first study to define regional $PbtO_2$ during the intermediate phase (12-72 h) of the post CA syndrome in a developing animal. The pathology and significance of thalamic hyperemia during the intermediate phase of the post CA syndrome is unknown. Thalamic hyperemia may be secondary to vasoactive factors produced in neurons, glia or endothelium and may signify ongoing derangements of cellular metabolism during this phase. Cortical and thalamic normoxia at 24 h after CA suggest that cortical and thalamic oxygen metabolic demands are met by cerebral perfusion when FiO_2=0.5. Cortical and thalamic hypoxia at 24 h after CA when FiO_2 was reduced to 0.21, suggest that $PbtO_2$ is dependent on FiO_2 in our model, assessment of PaO_2 is also needed. These data suggest that when FiO_2 is titrated during post CA syndrome brain tissue O_2 may decrease below acceptable levels. Monitoring $PbtO_2$ during post CA syndrome may be warranted to guide oxygen therapy after pediatric asphyxial CA.

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Figure 1: CBF values 24 H post resuscitation following CA. (A) Cortical, (B) Thalamic, (C) Hippocampal and (D) Amygdalic. (E) Cortical FIO_2 values for sham and CA rats. (F) Thalamic FIO_2 values for sham and CA rats.

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