Pediatric Anesthesia

Title: THE EFFECT OF CARDIOPULMONARY BYPASS ON CEREBRAL BLOOD FLOW IN INFANTS AND CHILDREN

Authors: W.J. Greeley M.D., F.G. Brusino M.D., R.M. Ungerleider M.D., L.R. Smith Ph.D. J.G. Reves, M.D.

Affiliation: Departments of Anesthesiology and Surgery, Duke University Medical Center, Durham, North Carolina 27710

Introduction: Cardiopulmonary bypass (CPB) is associated with a significant incidence of permanent and transient central nervous system complications after repair of congenital heart defects in infants and children. Occurrences of cognitive and intellectual impairment, seizures, motor and/or sensory loss, choreoathetosis, coma and brainstem injuries have been reported. Current methods of CPB management in children involve extensive externally controlled alterations in temperature (14-32°), systemic perfusion pressure (MAP) and $PaCO_2$. The effect of altering temperature, MAP, and $PaCO_2$ on cerebral blood flow (CBF) during CPB are unknown in infants and children. It is possible that these standard techniques of CPB management cause decrements in CBF and/or deleterious alterations in autoregulation in CBF during CPB, contributing to known neuropsychologic morbidity and mortality. Therefore, we assessed the effect of regional CBF before, during and after CPB in infants and children, and determined the effect of temperature, systemic perfusion pressure, and $PaCO_2$ on CBF.

Methods: After IRB approval and informed parental consent, 35 pediatric patients undergoing cardiac surgery using CPB were studied. Ages range from 3 days - 16 years. An additional group of 14 infants who had total circulatory arrest (TCA) were compared to a subgroup of the study population, assessing CBF changes with reperfusion. Anesthetic management for all patients consisted of fentanyl 25-100 mcg/kg, incremental doses of pancuronium and controlled ventilation. Light planes of anesthesia during surgery were treated with additional fentanyl or a low concentration of halothane (< 0.5%). CBF was measured using $Xenon^{133}$ clearance methodology. Two extracranial gamma emission detectors were placed over the left and right temporal lobes and the values from both sites were averaged to determine CBF. Five CBF determinations were made in each patient at three predefined intervals during surgery: A) pre-CPB, B) during CPB at stable hypothermic conditions at 5 and 25 minutes, and after complete rewarming, C) after CPB. CBF determinations during CPB were made over a wide range of MAP and hypothermic conditions (nasopharyngeal temperature 14-32° C). No vasoactive agents were used before or during the study intervals. Blood gas management during the study period was directed at maintaining a pH of 7.4 (range 7.29-7.51), $PaCO_2$ of 35 mmHg (range 22-50) which were not corrected for temperature. Data were analyzed using linear regression techniques. Because there were several observations of variables - hematocrit, pH, $PaCO_2$, MAP, nasopharyngeal temperature and regional CBF-for each patient, patient-to-patient variability was removed using stepwise linear regression.

Results: Half of the patients studied were under 1 year of age with a mean age of 3.7 yrs. Hypothermic CPB conditions were mild (32°) in 10 patients, moderate (24-28°) in 15 patients, and deep (14-22°) in 10 patients. Initiating CPB and terminating CPB were the most important variables in influencing CPB ($p<0.001$, Table I). There was a significant correlation of nasopharyngeal temperature with CBF during CPB ($p<0.01$). There was also a significant positive association between $PaCO_2$ and CBF during CPB ($p<0.03$). Hematocrit before CPB negatively correlated with CBF ($P<0.03$). There was a highly significant reduction in CBF in the TCA group after CPB ($p<0.01$). There were poor correlations between regional CBF and MAP, CBF and CPB flow, and CBF and hematocrit during CPB (Table I).

Discussion: These data demonstrate that the most important interventions altering CBF are initiating (decreases CBF) and terminating (increases CBF) CPB. This study suggests that there is a significant decrease in CBF during hypothermic CPB, and is most likely related to the decrease in cerebral metabolic rate for oxygen under these conditions. There was a poor association between regional CBF and MAP, a finding consistent with preserved autoregulation. During hypothermic CPB, the lower limit of autoregulation appears to be 20 mmHg. These data also show that $PaCO_2$ is an important factor modifying CBF during CPB. In these patients with acyanotic and cyanotic heart disease with varying levels of hemoglobin, there was a negative correlation between HCT and CBF. That is, the higher the preoperative HCT the lower the CBF. This study also demonstrates that cerebral reperfusion is impaired after TCA, supporting the hypothesis of the "no reflow" phenomenon.

Table I FACTORS INFLUENCING CBF DURING CPB

VARIABLE*	PROBABILITY VALUE
Interventions (initiating CPB, terminating CPB)	p>0.001
NPT	p>0.01
$PaCO_2$	p>0.03
Preoperative HCT	p>0.03
CPB Flow	NS
MAP	NS
HCT	NS

* The variables are ranked in order of the greatest influence on CBF

CBF=cerebral blood flow; CPB=cardiopulmonary bypass; NPT=nasopharyngeal temperature; MAP= mean arterial pressure; HCT=hematocrit.