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Perianesthetic Intracranial Hemorrhage in Preterm Neonates

ROBERT H. FRIESEN, M.D.,* ALBERT T. HONDA, M.D.,† RITA E. THIEME, B.S.N.‡

Intracranial hemorrhage (ICH) occurring as intraventricular or periventricular hemorrhage is a leading cause of morbidity and mortality in preterm neonates, occurring in 40–60% of neonates of less than 34 weeks gestation.[1–4] The etiology of ICH apears to be related to cerebral blood flow (CBF) fluctuations in patients with immature subependymal blood vessels and impaired CBF autoregulation.[5] Many clinical factors that affect CBF have been found to be associated with ICH development.[2–4,6–10] Such associated factors may often occur during the perianesthetic period; indeed, the perianesthetic period has been suggested to be one of increased risk for ICH development in preterm neonates.[11,§] Accordingly, this study was undertaken in an attempt to determine the perianesthetic risk of ICH.

MATERIALS AND METHODS

This was a study of preterm (conceptual age <37 weeks; weight <2500 g) neonates who required anesthesia for surgical procedures. By methods approved by the institutional review board, data were gathered from hospital records of patients who were the populations of two prospective studies of the effects of anesthetics on changes in cardiovascular and anterior fontanel pressure.[12,13] To be included in the population for this report, patients must have had both pre- and postoperative cranial ultrasonography (CUS) (Phillips Ultrasound SDR 2000, Santa Ana, CA) for detection and grading of ICH. Ninety-three patients met this requirement and comprise the patient population shown in table 1. Both the technique and accuracy of CUS in the diagnosis of ICH has been described.[14,15] ICH was graded by the system described by Papile *et al.*:[1] grade 0: no hemorrhage; grade I: subependymal hemorrhage; grade II: intraventricular hemorrhage without ventricular dilatation; grade III: intraventricular hemorrhage with ventricular dilatation; grade IV: intraventricular hemorrhage with parenchymal hemorrhage. The timing of CUS in relation to the perianesthetic period was not controlled; thus, CUS was performed hours to days pre- and postoperatively. The radiologist interpreting CUS and grading ICH was unaware of the existence of this study.

Anesthetic management was similar in all patients, who received atropine 0.02 mg/kg and pancuronium 0.1 mg/kg iv followed by one of four randomly assigned anesthetics; inhaled isoflurane 0.75%, inhaled halothane 0.5%, iv fentanyl 20 μg/kg, or iv ketamine 2 mg/kg. Patients were ventilated with a nonrebreathing system with a FI_{O_2} appropriate for each patient. Mechanical positive pressure ventilation was required by 74 patients preoperatively and by all patients postoperatively. Seventy-four patients had endotracheal tubes in place preoperatively, having been intubated without anesthesia or muscle paralysis in the neonatal intensive care unit or the delivery room. Thirteen patients were intubated awake in the operating room, and six were intubated in the operating room following induction of anesthesia and paralysis. Intravenous fluid infusions

TABLE 1. Characteristics of 93 Preterm Neonates

Conceptual age (weeks)	31.6 ± 2.9*
Postnatal age (days)	15.6 ± 14.1*
Weight (g)	1317 ± 420*
ASA physical status (no. patients)	
III	37
IV	56
Surgical procedure (no. patients)	
Patent ductus arteriosus ligation	36
Central venous catheter insertion	30
Bowel resection	16
Ventriculoperitoneal shunt	4
Tracheo-esophageal fistula repair	2
Lung lobectomy	1
Gastroschisis repair	1
Cutaneous vesicostomy	1
Leg amputation	1
Inguinal herniorrhaphy	1

* Mean ± SD.

* Associate Director of Anesthesiology, Associate Clinical Professor of Anesthesiology and Pediatrics.
† Fellow in Pediatric Anesthesia.
‡ Perinatology Research Nurse.
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Address reprint requests to Dr. Friesen: Department of Anesthesiology, The Children's Hospital, 1056 East 19th Avenue, Denver, Colorado 80218.
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§ Bejar R, Schneider H, Osorno L, Edwards D, Coen R, Gluck L: Association of early aortograms and PDA ligation with intraventricular hemorrhage (abstract). Pediatr Res 15:650, 1981

were maintained at preoperative requirements and were supplemented by additional infusions of glucose-free crystalloid or blood products as needed.

Results

The results are depicted in table 2.

There was no change in ICH diagnosis or grade in any patient following anesthesia and surgical operation.

TABLE 2. Perianesthetic Change in Intracranial Hemorrhage (ICH) Grade in 93 Preterm Neonates

Preoperative ICH Grade*	No. of Patients	Postoperative Change
0	61	None
I	11	None
II	11	None
III	4	None
IV	6	None

* 0 = no hemorrhage; I = subependymal hemorrhage; II = intraventricular hemorrhage without ventricular dilatation; III = intraventricular hemorrhage with ventricular dilatation; IV = intraventricular hemorrhage with parenchymal hemorrhage.

Discussion

The results of this study suggest that the perianesthetic period is not one of high risk for the development or progression of ICH in preterm neonates. The 61 patients who had normal findings on CUS preoperatively had normal CUS postoperatively. None of the 32 patients with preoperative ICH exhibited progression of ICH on postoperative CUS.

Many clinical factors known to be associated with the development of ICH can occur during the perianesthetic period, particularly in patients with cardiorespiratory instability often observed with severe hyaline membrane disease, patent ductus arteriosus (PDA), sepsis, and necrotizing enterocolitis. ICH-associated factors that may be present in the sick neonate include wide fluctuations in blood pressure,[3] increases in intracranial pressure,[6,8] hypercapnia,[2,4] hypoxia,[7] acidosis,[2,7] and hypothermia.[2] Some therapeutic measures employed by the anesthesiologist or neonatologist are also associated with ICH development or CBF fluctuation, including intermittent positive pressure ventilation,[2,4,7,10] rapid intravenous colloid infusions,[3] and, possibly, awake tracheal intubation.[16]

Suggestions that the perianesthetic period may be risky regarding ICH development have been associated with two reports of experience with ligation of PDA in preterm neonates, during which rapid fluctuations in blood pressure can occur. Marshall *et al.*[11] confirmed ICH in two of 13 patients a few days following PDA ligation, and recommended gradual closure of the PDA in order to avoid an abrupt increase in blood pressure. However, preoperative detection of ICH was not attempted in those patients. Bejar *et al.*¶ reported that a high percentage of preterm neonates with preoperative ICH experienced progression of ICH following PDA ligation. Those patients also had preoperative aortography, during which injection of contrast medium could have caused an abrupt blood pressure increase. On the other hand, Strange *et al.*[17] reported 20 patients in whom development or progression of ICH did not occur in association with PDA ligation. The 36 patients in our report who underwent PDA ligation support Strange's conclusion that the operation does not add to the risk of ICH.

Young postnatal age is closely associated with ICH development in preterm neonates, with most ICH occurring within 24 h,[9] 30 h,[4] or 72 h[2] after birth. All of the patients reported by Bejar *et al.*¶ who had progression of preoperative ICH following PDA ligation were less than 96 h of postnatal age. Our study includes only 12 patients under 96 h of age. While none experienced development or progression of ICH, we think that more patients in this high-risk group should be studied before conclusions are drawn concerning their risk.

Our results suggest that the perianesthetic period is not one of high risk for ICH development or progression in preterm neonates. While these data are reassuring, further investigation is necessary before definitive conclusions can be drawn. We recommend that a large prospective study of patients less than 34 weeks conceptual age be undertaken, in which the timing of perioperative CUS is controlled and a large number of patients less than 96 h of postnatal age is included.

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Venous Embolism during Craniectomy in Supine Infants

MARK M. HARRIS, M.D.,* TERRY A. YEMEN, M.D.,* ALEX DAVIDSON, M.D.,†
MAUREEN A. STRAFFORD, M.D.,‡ RICHARD W. ROWE, M.D.,‡ STEPHEN P. SANDERS, M.D.,§
MARK A. ROCKOFF, M.D.¶

Venous air embolism (VAE) is a well-known complication of neurosurgical procedures. Its reported incidence ranges from 6–45% in seated adult neurosurgical patients,[1–3] and, occasionally, it is detected in the lateral, prone, or supine positions.[3–5] VAE is thought to occur among seated pediatric neurosurgical patients with approximately the same frequency as among adults.[6,7] Many neonates and small infants undergo neurosurgery, but the incidence of VAE among this population is unknown. Because several case reports have documented VAE in supine infants having neurosurgery,[5,8] we began a prospective study of VAE among infants undergoing craniectomy in the supine position.

MATERIALS AND METHODS

Following approval from our institution's Human Investigation Committee, 12 consecutive infants under 1 yr of age scheduled for elective repair of craniosynostosis were prospectively monitored for VAE. General anesthesia was induced with halothane, nitrous oxide, and oxygen by mask in 11 infants, and by intramuscular ketamine in one. Peripheral intravenous and arterial catheters were inserted, and oral or nasal endotracheal intubation was performed after administration of iv pancuronium bromide and fentanyl. Air filters were put on all of the intravenous lines to minimize microbubbles, but abandoned as ineffective after the first few patients had been studied. Infants were positioned supine with the head supported by a soft ring. Blood loss was estimated by the anesthesiologist, who administered crystalloid and blood products as needed.

Monitoring for VAE was planned with precordial Doppler and two-dimensional echocardiography

* Fellow in Anesthesiology.
† Fellow in Cardiology.
‡ Instructor of Anesthesiology.
§ Assistant Professor of Cardiology.
¶ Assistant Professor of Anesthesiology (Pediatrics).

Received from the Departments of Anesthesiology, Neurosurgery, and Cardiology, The Children's Hospital and Harvard Medical School, Boston, Massachusetts. Accepted for publication May 28, 1987.

Address reprint requests to Dr. Harris: Department of Anesthesiology, University of Virginia Medical Center, Box 238, Charlottesville, Virginia 22908.

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