of embolized gas not causing more profound cardiovascular symptoms.

An alternative possibility is that a considerable portion of the N₂ was dissolved in blood passing through this richly perfused area and was then transported to the lungs. Nitrogen is poorly soluble in blood (Oswald solubility coefficient at 37°C = 0.015), with only 1.5 ml of N₂ dissolved in 100 ml of blood at equilibrium. Because the PE₅₅ was nearly zero just before the liquid N₂ was instilled, it is possible that the size of embolized N₂ bubbles would have been slightly reduced by dissolving in the venous blood, but it is unlikely that 2.6 l of N₂ could have been carried to the lungs in the dissolved state in 1 min. Furthermore, the second blood gas determination indicates that there was a considerable alveolar-arterial gradient for CO₂ present 10 min after the acute event. This is compatible with a residual effect of gas bubbles in the pulmonary circulation, a process that continues in excess of 10 min both clinically and experimentally.¹⁰

Nitrogen embolism during cryosurgery is presumably a rare event. In over 800 orthopedic cases in which free gas egress was facilitated by venting the bone cavity, Marcoe reported no clinical symptoms of embolism or shock.⁶ However, the possibility of N₂ entering the bloodstream as gas bubbles does exist and may be reflected merely as the appearance of ET₅₅ and a decrease in ET_CO₂; alternatively, it may produce cardiovascular collapse or paradoxical embolization to the cerebral or coronary circulation. Accordingly, anesthesia personnel should be suspicious whenever liquid nitrogen is being instilled into a body cavity. Appropriate diagnostic and therapeutic modalities for detection and treatment of gas embolism should be in use.

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Anesthetic Complications in an Infant with Hyperexplexia

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Hyperexplexia is a hereditary disease with an autosomal dominant inheritance pattern with incomplete penetrance.¹ The condition is characterized by neonatal onset of excessive muscle rigidity with repeated myoclonic jerks, increased muscle tone, prolonged seizures, life-threatening apnea spells, and an exaggerated response to startle.

There has been only a single case report describing anesthesia for such a patient to date, an infant who received an anesthetic for bilateral inguinal hernia repair. We present here the preoperative evaluation and anesthetic management of a 4-month-old infant with hyperexplexia complicated by two episodes of sudden apnea and stiffness.

REPORT OF A CASE

A 4-month-old male infant born of a spontaneous vaginal delivery without complications was found to have excessive response to loud noises (the child would contract its upper and lower extremities, returning to normal shortly after being held by the parents). Shortly after birth the child was evaluated and diagnosed as having hyperexplexia. Consistent with the inherited nature of the disease, the child's father, paternal grandmother, and paternal grandmother's mother were described as having excessive response to startle. No medications were prescribed at that time, and the child had no episodes of apnea or cyanosis according to the parents. The child was discovered to have bilateral inguinal hernias and was scheduled for surgical repair.

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Physical examination revealed a stiff and irritable child. The child had good head control and normal reflexes. Although pliable, the muscle tone was noted to be slightly increased. The examination was otherwise unremarkable. Chest x-ray showed a mildly elevated right hemidiaphragm. The urine analysis and complete blood count were unremarkable.

A preoperative pediatric neurology consult concurred with the diagnosis of hyperexplexia. No associated neuromuscular problems were found, but it was recommended that the anesthetic be free of any malignant hyperthermia (MH) or neuroleptic malignant syndrome triggering agents.

The 6.9-kg patient was brought to the operating room with an intravenous (iv) catheter in place. No preanesthetic medication was administered. Precordial stethoscope, blood pressure cuff, ECG leads, and pulse oximeter sensor were applied. The patient was then administered 100% oxygen via mask. Cricoid pressure was applied while giving an initial dose of 25 mg sodium thiopental followed shortly thereafter by an additional dose of 12.5 mg sodium thiopental. The lungs were easily ventilated via mask and 0.7 mg of iv pancuronium bromide was given for muscle relaxation. The trachea was intubated with a 3.5 mm endotracheal tube, and a Bain circuit with an in-line humidifier/warmer was used to deliver 70% N₂O in oxygen. End-tidal CO₂, oxyhemoglobin saturation (SPO₂), blood pressure, heart rate, and esophageal temperature were within normal limits throughout the case. The patient was given 30 μg of fentanyl at the beginning of the case followed by another 15 μg 30 minutes later (total 6.8 μg/kg fentanyl). The bilateral hernia repair proceeded without complication, and at the end of 1 h the patient was given 0.1 mg atropine followed by 0.25 mg neostigmine to antagonize residual neuromuscular blockade, the nitrous oxide was discontinued, and 100% oxygen was administered. The child readily responded with good strength, vigorous spontaneous respirations, and eye opening. After suctioning a modest amount of oral secretions, the trachea was extubated. Immediately after extubation he failed to have any spontaneous respirations even with external stimulation, and within approximately 30 s the SPO₂ began to decrease. The chest wall appeared rigid, and positive pressure by mask did not result in chest wall movement. In approximately 60 s spontaneous ventilation began and the SPO₂ increased from a low of 60% to 100%. Heart rate and blood pressure remained stable throughout the episode. The patient was then given 20 μg of naloxone intravenously to reverse any residual narcosis that might be exacerbating his lack of ventilation. The patient was awake and breathing spontaneously for approximately 3 min when he again became apneic, rigid, and the SPO₂ began to decrease. These events occurred with nearly identical timing to the previous episode both in onset and recovery. As before, it was not possible to ventilate the lungs via mask. The patient responded with spontaneous respirations before any pharmacologic intervention was deemed appropriate.

After a 15-min period in the operating room with no additional episodes of apnea or rigidity, the child was transferred to the recovery room breathing 50% oxygen via mask. The patient did well in the recovery room and did not require further intervention. Notably, however, the oxygen saturation did transiently decrease to the low 80s following stimulation on two occasions without any evidence of rigidity. On discharge from the recovery room, he was breathing 40% oxygen and monitored overnight with pulse oximetry and ECG. The remainder of the postoperative course was uneventful. The child is currently being treated chronically with clonazepam and has been free of any episode of stiffness or apnea.

**DISCUSSION**

Hyperexplexia is a rare disease, with only about 70 cases having been reported. The physiologic basis of the disorder is unknown but has been postulated to be a hyperexcitability of the brain stem structures involving the normal startle response. Newborn infants experience repeated myoclonic jerks, increased muscle tone, and have sudden and prolonged seizure-like episodes, with life-threatening apnea due to contraction of the respiratory muscles. Electrophysiologic studies are somewhat controversial, but most authors believe that there is no true seizure activity involved in the attack. Several case reports of life-threatening apnea not responsive to traditional anticonvulsive therapy have been reported.

Although no cases of perioperative apnea have been reported, our patient's course suggests that this event may be an important complication when these patients undergo surgery. Children with hyperexplexia are known to have an increased incidence of hernias (due to muscle rigidity), which might increase their presentation to surgery. The single case described in the anesthesia literature reports a halothane anesthetic for a bilateral inguinal hernia repair. In this patient the authors measured twitch depression and recovery time of succinylcholine and reported a significant resistance to the drug in their patient with no change in time to recovery. They also reported no change in twitch depression or recovery time with pancuronium. There were no complications associated with extubation or postoperative ventilation.

Our anesthetic differed from the above case in that it included fentanyl for maintenance in an attempt to avoid triggering agents for malignant hyperthermia. This choice may have inadvertently exacerbated the postoperative stiffness as discussed by Weinger who suggested that the stiffness seen with hyperexplexia may operate by the same mechanism as the stiffness induced by opioids. Apnea and inability to ventilate the lungs secondary to chest wall rigidity and glottic closure caused by opioids has been described. Rodent studies suggest that the area of the brain responsible for serotonergic innervation may be responsible for both opioid-induced and nonopioid rigidity. Correspondingly, the current drug of choice for the chronic treatment of hyperexplexia is the serotonin agonist and benzodiazepine, clonazepam. There may also be a role for α-2-adrenergic agonists in the intraoperative treatment of stiffness in these patients. A recent publication demonstrated the ability of high-dose dexmedetomidine to prevent opioid-induced rigidity and startle response in laboratory rats receiving high-dose alfentanil anesthesia. There are no histopathologic studies reported in hyperexplexic patients to determine if there is similar involvement in humans.

In one report the authors described several successful attempts to intervene in the acute rigidity episodes by forcibly flexing the patient at the waist. This maneuver was successfully used on one patient for several episodes of apnea secondary to rigidity and was also used effectively in two other cases for similar presentations.
In conclusion, as suggested by Weinger,\textsuperscript{5} it may be prudent to avoid opioids in patients with hyperkplexia and to attempt the flexion maneuver described by Vigevano et al.,\textsuperscript{1} if any unremitting apnea or stiffness occurs in these patients. Other anesthetic agents, such as sodium thiopental, benzodiazepines, and propofol, may be more appropriate choices.

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Intraarterial Injection of Propofol

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A single case of accidental intraarterial injection of 4 ml propofol into the left brachial artery has been reported.\textsuperscript{1} Neither the concentration nor formulation of the drug was reported. The injection caused blanching in an oval area 4 cm wide, 6 cm proximal and 4 cm distal to the point of injection within 5 s, and a hyperemic appearance 30 min later. We report the effects of an intraarterial injection of 8 ml of a 1% solution (Diprivan,‡ Stuart Pharmaceuticals.)

CASE REPORT

A 44-yr-old, 80-kg man was scheduled for a reduction and repair of a C6–7 cervical fracture. The patient arrived in a Stryker frame. An intravenous catheter was inserted in each forearm, and a 20-G catheter was inserted in the left radial artery. A three-way stopcock was inserted in the tubing leading to the left intravenous catheter, and the tubing was taped to the center post of the frame with the stopcock ready for infusion of induction drugs. A three-way stopcock present in the arterial catheter was also taped to the frame, and the cap of the stopcock was removed to permit zeroing of the arterial pressure tracing. A nondisposable sensor from a pulse oximeter was put on the patient’s right index finger.

An infusion of 16 ml of propofol containing 10 mg/ml was prepared for induction of anesthesia. The syringe was attached to the stopcock, and 8 ml was injected from a syringe over an 8-s period. The patient complained of severe pain in his left hand, and the propofol did not continue infusing through the tubing despite a rapid infusion drip rate. It was then realized that the propofol had been injected into the tubing connected to the arterial catheter.

The tubing was immediately disconnected at the needle hub and the catheter flushed with 0.9% sodium chloride. Arterial blood pulsed from the needle hub. The hand was inspected and found to have good color, and the nailbeds of each finger rapidly assumed a pink color after pressure. The arterial pressure monitor continued to function normally. After complaining of pain for a few seconds, the patient became drowsy, and the remainder of the propofol was injected intra-

venously, the patient was paralyzed with 8 mg of pancuronium, and a sufentanil infusion was begun. After ventilating the lungs the trachea was intubated with a plastic endotracheal tube. The hemoglobin saturation (\textsuperscript{2}S\textsubscript{2}O\textsubscript{2}) in the right index finger was 97%. The \textsuperscript{2}S\textsubscript{2}O\textsubscript{2} was then measured in each of the fingers in his left hand and was found to vary between 97% and 99% on 100% oxygen. At the conclusion of the 2.5-

h procedure, the patient said he felt no pain in the hand or arm, and the hand and fingers perfused well.

DISCUSSION

Chong and Davis\textsuperscript{1} reported blanching and hyperemia after the injection of 4 ml of a “standard solution” of propofol into the brachial artery. We found no physical evidence of injection, no apparent impairment of arterial flow, and measured a normal \textsuperscript{2}S\textsubscript{2}O\textsubscript{2} in each finger shortly after a radial artery injection. Propofol has been available in the past in different formulations, and it is possible that