

vascular and respiratory status.<sup>12</sup> Unexpected rapid paralysis and loss of glottic reflexes can increase the risk of aspiration of gastric contents.

This case illustrates a problem that one could encounter following the use of a small dose of muscle relaxant. It points out that priming doses may not be innocuous and that further studies are needed to define the optimum, safe priming dose in awake patients. Patients who are to be given a priming dose should be monitored for unusual sensitivity to the relaxant and for the possible consequences of an unexpected paralysis. It would seem prudent to have patients breathe oxygen before a priming dose is administered and be prepared to induce general anesthesia and intubate the trachea, should one find evidence of muscle weakness or impending paralysis. In spite of our close observation and early intervention, our patient may have aspirated before the trachea was intubated and the airway was properly secured.

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Anesthesiology  
64:519–521, 1986

## Pulmonary Air Embolism in the Pediatric Patient Undergoing Central Catheter Placement: A Report of Two Cases

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Pulmonary air embolism is a well known, potentially fatal complication of certain surgical procedures, especially neurosurgical procedures in the sitting position.

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Received from the Departments of Anesthesiology and Clinical Investigation,\* Naval Hospital, San Diego, California; and the Childrens Hospital and Health Center,† San Diego, California. Accepted for publication November 27, 1985.

The opinions or assertions expressed in this paper are those of the authors and are not construed as official or as necessarily reflecting the views of the Department of the Navy or the Naval Service at large.

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Key words: Embolism: air. Equipment: Broviac®/Hickman® catheter.

However, air embolism can occur in the nonneurosurgical, noncardiac pediatric patient.

We describe two cases of air embolism that occurred within 1 week of each other in pediatric patients undergoing central venous insertion of a Broviac® or Hickman® catheter.

#### REPORT OF TWO CASES

*Case 1.* A 7-month-old, 4 kg girl (born 34 weeks gestation), status-post patent ductus arteriosus ligation, with short gut syndrome secondary to necrotizing enterocolitis, was scheduled for Broviac® catheter insertion for hyperalimentation. The patient had been doing well with oral feedings until 7 days before admission, when she developed an upper respiratory infection with fever and decreased oral intake. A left external jugular iv was placed the evening before surgery for hydration. After premedication with 60 µg of atropine iv, anesthesia was induced with halothane, N<sub>2</sub>O, and O<sub>2</sub> without incident.

Anesthesia was maintained with the same agents *via* an oral endotracheal tube with ventilation being assisted but not controlled. The patient was monitored with an ECG, automated blood pressure cuff, esophageal stethoscope, thermistor probe, and a pulse oximeter. The patient was placed in Trendelenberg's position with a small bolster under her shoulders. The surgeon introduced a 20-g needle into the right internal jugular vein, and a wire was passed toward the heart with some difficulty. After an infant Broviac® catheter was tunneled up under the skin of the chest wall into the neck wound, a 5-French vein dilator and a peel-away cannula were passed over the wire, and the wire was removed. The surgeon requested that the patient be taken out of Trendelenberg's position to avoid excessive blood loss during insertion of the catheter. On removal of the vein dilator from the cannula, air was heard being sucked into the cannula. The Broviac® catheter was immediately inserted into the cannula to prevent further ingress of air. Simultaneously, the O<sub>2</sub> saturation decreased steadily from approximately 93–98% to 17% over the next 60 s. The N<sub>2</sub>O was immediately turned off, and the surgeon was requested to withdraw from the Broviac® catheter and once more place the patient in Trendelenberg's position. Approximately 90 s later, the systolic blood pressure decreased from 70 to 38 mmHg, and the heart rate decreased from 130 to 40 beats/min. Crystalloid was rapidly infused, and hyperventilation with 100% O<sub>2</sub> was continued. Over the next two min, the O<sub>2</sub> saturation gradually increased to 75%, and arterial blood pressure and heart rate returned to normal levels. No drugs were given. The O<sub>2</sub> saturation remained 70–80% for the next 5 min and then gradually increased to 100%. The vital signs and the oxygen saturation remained stable throughout the remainder of the surgery and the recovery period. The patient was discharged without sequelae after a 5-day hospital stay for rehydration and antibiotic therapy.

*Case 2.* A 5-yr-old, 22 kg boy with acute lymphocytic leukemia was scheduled for placement of a large bore, double-lumen, central catheter. The evening before surgery, a small peripheral iv was started for hydration and antibiotic therapy. General anesthesia was induced with halothane, O<sub>2</sub>, N<sub>2</sub>O *via* a mask, and 100 mg thiopental iv after 160 µg atropine. The trachea was intubated orally, and ventilation continued spontaneously. The patient was monitored with an ECG, automated blood pressure cuff, thermistor probe, and esophageal stethoscope. The patient was placed in Trendelenberg's position, where the left subclavian vein was entered with a 20-g needle following several failed attempts to enter the right subclavian vein. Under image-intensifier fluoroscopy, the wire was passed into the superior vena cava. A 14-French, peel-away cannula and an introducer were passed over the guidewire without difficulty. During the removal of the introducer, the patient was given a large, forceful inspiration producing an apparent steady back-flow of blood, which was maintained as the surgeon attempted to pass the catheter into the cannula. The advancement of the catheter proved extremely difficult. Suddenly, heart sounds were noted to be inaudible, although the ECG still showed normal sinus rhythm. Arterial blood pressure rapidly decreased to near zero, and the ECG then showed severe sinus bradycardia. The N<sub>2</sub>O and halothane were immediately turned off. External cardiac massage was begun, which produced an arterial systolic blood pressure of approximately 100 mmHg. The patient was resuscitated with lactated Ringer's solution, atropine 200 µg, calcium chloride 200 mg, sodium bicarbonate 25 mEq, and epinephrine 400 µg given in two equal doses. Normal sinus rhythm was immediately restored, producing a systolic blood pressure of 70 mmHg. A radial arterial line was inserted, and a dopamine drip at a rate of 5 µg · kg<sup>-1</sup> · min<sup>-1</sup> was initiated, which resulted in a systolic arterial blood pressure of 105 mmHg. The patient was taken to the recovery room where his trachea was extubated after he was fully awake and alert. Neurologic examination was normal. The patient was monitored in the special care unit for several days, and after control of his leukemic process, he was discharged without apparent sequelae.

## DISCUSSION

The potential for pulmonary air embolism is present in any procedure where there exists an open vein under negative pressure relative to atmospheric pressure. In Case 1, entrainment of air into the cannula, which was heard and seen, was followed by an immediate decrease in O<sub>2</sub> saturation, followed by a decrease in arterial blood pressure and heart rate. Two causative but avoidable factors in this case were discontinuance of Trendelenberg's position before insertion of the catheter into the cannula, and allowing the patient to breathe spontaneously.

The causative factor in the second case is less obvious, but could be attributable to one of several factors. The absolute size of the cannula used (14-French), combined with the difficulty encountered by the surgeon in advancing the catheter into the cannula, could contribute to the entrainment of air. As in the first case, this patient was also breathing spontaneously. Despite the anesthesiologist's attempt to maintain continuous back-bleeding out the cannula by maintaining continuous positive pressure on the reservoir bag, some air may have been entrained. Perhaps the lumens of the large catheter were not completely filled with heparinized saline, and as it was advanced, air was entrained into the venous system.

Both incidents occurred in cases where similar surgical technique was employed. That is, a central vein is punctured, either percutaneously or by cutdown, and a guidewire is inserted. Over the guidewire an introducer with a peel-away cannula sleeve is inserted. The guidewire and introducer are removed, leaving the cannula in the vein with its large lumen open to the atmosphere. The catheter is then quickly passed into the lumen, and, when in place, the cannula is peeled away from around the catheter. The critical period of vulnerability to air embolism obviously is during the insertion of the catheter into the open lumen of the peel-away cannula after the introducer has been removed. The clinical question that arises, then, is how should these patients be monitored, and what measures should be taken to prevent or minimize air entrainment in these procedures? In contrast to craniotomies, where minute amounts of air may be entrained over a relatively long period of time, the "at risk" period in Broviac®/Hickman® catheter placement occurs over a known, relatively short, interval. Therefore, elaborate methods to detect the entrainment of small amounts of air such as pulmonary artery pressure monitoring, transesophageal echocardiography, and precordial doppler reflections may be impractical for these procedures and not cost effective.

In light of the previously mentioned considerations, it is our contention that in this clinical setting the emphasis should be placed on prevention. Therefore, we recommend the following simple measures for all pediatric patients undergoing Broviac®/Hickman® central catheter

placement: 1) preoperative hydration; 2) endotracheal intubation and controlled positive pressure ventilation; 3) skeletal muscle relaxation; 4) maintenance of Trendelenberg's position until after the catheter has been successfully passed through the cannula and the cannula has been removed; and 5) discontinuance of N<sub>2</sub>O before instrumentation of the vein. The first measure, adequate preoperative hydration, should be stressed as these patients are frequently dehydrated by the underlying disease process necessitating the placement of the central catheter. Adequate hydration will help prevent entrainment of air by maintaining greater pressure in the central venous system, and furthermore, may make resuscitation more successful should air embolism occur. The second, third, and fourth measures help maintain positive intrathoracic pressure and back-bleeding in the open vein. They insure that the patient does not initiate a spontaneous breath, which would create negative pressure relative to atmospheric pressure. The fifth measure, elimination of N<sub>2</sub>O before instrumentation of the vein, is a prophylactic measure in the event air is entrained. Although the use of positive end-expiratory pressure has been promoted to decrease the likelihood of air embolism by also increasing

back-bleeding,<sup>1</sup> its use is not recommended. Recent evidence demonstrates that positive end-expiratory pressure may reverse the pressure gradient between the atria and thereby increase the likelihood of paradoxical air embolism if a patent foramen ovale or atrial septal defect exists.<sup>2</sup> Given that 25–30% of the population may have a patent foramen ovale, the possibility of increased risk of paradoxical air embolism is worrisome.

We present two cases that illustrate the danger of air embolism imposed by the placement of Broviac®/Hickman® catheters in the pediatric patient. Prevention of intraoperative air entrainment should be a major goal in the successful management of these patients. We have outlined several simple measures to prevent air entrainment, which, if followed, should reduce the risk of air embolism.

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Anesthesiology  
64:521–523, 1986

### Bradycardia and Asystole Following the Rapid Administration of Sufentanil with Vecuronium

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#### REPORT OF THREE CASES

Sufentanil, a fentanyl analogue, has been demonstrated to be five to ten times more potent than fentanyl and to provide similar or greater cardiovascular stability in the clinical setting.<sup>1</sup> The recently released nondepolarizing neuromuscular blocker, vecuronium, has minimal effects on heart rate (HR) and blood pressure (BP) when used with inhaled or narcotic anesthetics.<sup>2,3</sup> Hemodynamic responses with the simultaneous administration of these two drugs have not been described. We report three patients scheduled for coronary artery bypass grafting (CABG) in whom the association of sufentanil and vecuronium resulted in severe bradycardia or asystole during induction of anesthesia.

*Case 1:* A 61-yr-old man (80 kg) was scheduled for elective, three-vessel CABG. Past medical history included hypertension, hyperlipidemia, obesity, gout, and bilateral internal mammary implantations (Vineberg operation) performed 16 yr before this admission. Cardiac catheterization showed normal left ventricular function. The patient was taking propranolol 40 mg tid, diltiazem 30 mg tid, nitroglycerin patch 5 mg qd, allopurinol 300 mg qd, and probenecid bid. Premedication included diazepam 10 mg orally, scopolamine 0.4 mg im, and nitroglycerin patch 10 mg. The usual dose of propranolol was given on the morning of operation. This patient was monitored *via* a radial 20-g arterial catheter, an 18-g central venous pressure (CVP)-catheter placed in the internal jugular vein, and ECG, lead V<sub>6</sub> continuously with limb leads intermittently. The following patients were monitored likewise. Baseline hemodynamics were HR = 60 beats/min, BP = 130/76 mmHg, and CVP = 10 mmHg. Breathing 100% oxygen *via* mask, anesthesia was induced with sufentanil 500 µg and vecuronium 10 mg given iv over approximately 1.5 min. Arterial blood pressure fell to 100/50 mmHg and was accompanied by severe bradycardia and a brief period of asystole, which responded to 0.4 mg iv atropine (fig. 1). The subsequent anesthetic course was uneventful. HR and BP were recorded continuously on a paper strip recorder.

*Case 2.* A 64-yr-old man (87 kg) was scheduled for elective four-vessel CABG. Past medical history included hypertension, adult onset

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Received from the Department of Cardiothoracic Anesthesia, Cleveland Clinic Foundation, 9500 Euclid Avenue, Cleveland, Ohio 44106. Accepted for publication November 27, 1985.

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Key words: Anesthetics, intravenous: sufentanil. Complications: asystole. Neuromuscular relaxants: vecuronium.