Hypotension\(^1\)\(^-\)\(^3\) and cardiac arrest\(^4\)\(^-\)\(^5\) have been reported to occur during total hip arthroplasties using methylmethacrylate (acrylic) cement to fix implants to the acetabulum and the femur. These complications have been attributed to the absorption of methylmethacrylate monomer,\(^6\)\(^-\)\(^7\) or embolism of fat,\(^8\)\(^-\)\(^9\) or other tissue debris.\(^9\) We report here three cases of air embolism occurring shortly after the insertion of the prosthesis into the femoral shaft.

**REPORT OF THREE CASES**

**Case 1.** A 61-year-old woman with degenerative disease of the hip joints was scheduled for a left total hip arthroplasty. Medical history, physical examination and laboratory findings were essentially within normal limits except for obesity (body weight 70 kg) and nonspecific depression of the ST segment of the electrocardiogram. Preanesthetic medication consisted of meperidine, 50 mg, diazepam, 10 mg, and atropine, 0.5 mg, given intramuscularly 30 minutes prior to anesthesia. Induction of anesthesia with thiopental (250 mg) and endotracheal intubation with the aid of succinylcholine (80 mg) was uneventful. We monitored the arterial pressure conventionally, digital pulse with a Datascope finger plethysmograph, and lead II electrocardiogram. In addition, an esophageal stethoscope and a temperature probe were placed in the esophagus. Anesthesia was maintained with nitrous oxide (66 per cent) and enflurane (0.5–0.7 per cent) using a total gas flow of 6 l/min with assisted respiration. The patient was kept supine during the operation. Ninety minutes after the operation was started the proximal prosthesis was implanted onto the acetabulum. By this time she had received 2,000 ml of whole blood, 500 ml of 5 per cent dextrose in water, and 1,000 ml of Ringer’s lactate solution. The arterial blood pressure was maintained in the range of 130–105/90–70 torr and was quite stable; the pulse, 90–95 beats/min. Fifteen minutes later, when the distal prosthesis was being inserted in the femoral shaft, previously reamed to a depth of 15 cm, typical mill-wheel murmurs were heard through the esophageal stethoscope. Percordial auscultation yielded the same murmur. Arterial blood pressure fell to 85/60 torr. Nitrous oxide was discontinued; the operating table was rotated approximately 45 degrees, right-side up. Ephedrine, 20 mg, given intravenously, restored arterial blood pressure to 120/70 torr. The operation continued. The murmurs gradually decreased in loudness and disappeared after 8–10 minutes. At this time the patient started to move. We added nitrous oxide to the enflurane–oxygen mixture. Within minutes the murmurs were again heard, only to disappear after discontinuation of nitrous oxide. The subsequent course of anesthesia and immediate postoperative recovery were uneventful.

**Case 2.** A 77-year-old woman had had chronic and persistent pain in her right hip following a fracture five years previously. A total hip arthroplasty was scheduled. We considered the patient’s ASA physical status to be class III because of hypertensive arteriosclerotic cardiovascular disease and pulmonary emphysema with bullae in the right middle lobe. Electrocardiogram showed left axis deviation, low T-waves, and a left ventricular strain pattern. Preoperative arterial blood pressure was 170/110 torr. Medications included lanoxin and chlorothalidone (Hyproton). The patient was also being treated with pilocarpine and echothiophate eye drops for chronic glaucoma. We administered 300 mg of thiopental in divided dose for the induction of anesthesia and 0.1 mg/kg of pancuronium to help with endotracheal intubation. Anesthesia was maintained with nitrous oxide (60 per cent) and halothane (0.5–0.75 per cent) in a semiclosed circuit. Respiration was controlled using an Ohio model Series 300/DO ventilator. Arterial blood pressure fluctuated between 160/100 and 110/70 torr, and pulse, 70–85 beats/min. We monitored vital signs as in Case 1. Ninety minutes into the surgical procedure, the distal prostheses were inserted into the femur. Mill-wheel murmurs appeared within 2–3 minutes. Arterial blood pressure and pulse remained stable at 110/70 torr and 80 beats/min, respectively. Nitrous oxide was discontinued. The murmurs disappeared in 5 minutes. The patient received 1,500 ml of whole blood, 1,000 ml of Ringer’s lactate solution, and 500 ml of 5 per cent dextrose in water during the operation. Recovery was uneventful.

**Case 3.** A 70-year-old woman who had severe rheumatoid arthritis was scheduled to have a total hip arthroplasty on the left. She had anemia (hemoglobin 9.2 g/100 ml), corrected with transfu-
sions. Immediately prior to anesthesia, hemoglobin concentration reached 11.8 g/100 ml. Induction of anesthesia with thiopental (275 mg) and endotracheal intubation were accomplished without difficulty. We administered nitrous oxide (60 per cent) and meperidine in divided doses to maintain anesthesia and pancuronium (0.01 mg/kg, repeated four times) for muscular relaxation. Positioning of the patient and monitoring were the same as in Cases 1 and 2. Arterial blood pressures during the first two hours of operation ranged 140–90/70–55 torr. pulse 55–85 beats/min. Four to five minutes following the insertion of the distal prosthesis, typical mill-wheel murmurs were heard through the esophageal stethoscope and precordially. Systolic pressure fell from 130 torr immediately prior to the episode to 100 torr. Nitrous oxide was discontinued. The murmurs lasted approximately 10 minutes. The patient received 1,500 ml of whole blood, 1,000 ml of Ringer’s lactate solution, and 500 ml of 5 per cent dextrose in water. Her postoperative course was uneventful.

DISCUSSION

As of July 1973, 1,014 total hip arthroplasties have been performed at the Columbia-Presbyterian Medical Center. There has been no cardiac arrest during anesthesia and operation in this series. Significant hypotension occurred infrequently. Our anesthetic management consists of light general anesthesia with nitrous oxide–oxygen supplemented with halothane, enflurane or narcotics. Close monitoring of the cardiovascular status is the rule. We stress adequate fluid and blood replacement. Blood loss is estimated grossly by visual inspection of surgical pads and blood in the suction bottle. The acrylic cement is "cured" for approximately 4–6 minutes before application to the previously prepared acetabulum and femoral shaft.

In the cases reported here we did not vent the medullary cavity of the femur with a catheter or with drill holes in the femoral shaft. Upon insertion of the distal prosthesis, pressure in the medullary cavity can reach 2–3 atmospheres absolute (Eftekhar, N.S., Columbia University, personal communication). It is conceivable then that air trapped in the medullary cavity could find its way into the freshly opened venules. The volume of air entering the venous circulation would vary considerably, depending upon the pressure and the volume of air entrapped within the cavity. We do not consider other sources of air embolism possible, as the patients are always kept supine. Entrapment of air through open veins, frequently occurring during craniotomy, cervical laminectomy and radical neck dissection, would not occur here. It is not likely that the amount of methylmethacrylate monomer absorbed could form gas pockets in the blood; the highest blood level of the monomer reported was 1.1 mg/100 ml.9

We do not have absolute proof that air embolism did indeed occur. However, the typical murmurs heard, and the close temporal relationship between the insertion of the femoral prosthesis and the onset of murmurs is strongly suggestive. In Case 1, the murmurs disappeared in 8–10 minutes, only to reappear when nitrous oxide was added to the anesthetic mixture. We believe that the gas expanded in volume as nitrous oxide diffused into the bubbles trapped in the heart.10

In all probability, the phenomenon reported here does not present a serious threat to the patients’ cardiovascular functions. The volume of air within the femoral medullary cavity is limited. All three episodes resolved spontaneously upon discontinuation of nitrous oxide. Significant hypotension necessitating therapy occurred in Case 1 only. However, we suggest that the medullary cavity be routinely vented, as proposed by Kepes et al.9 Meticulous attention to fluid and blood replacement, along with continuous monitoring of circulatory status, would contribute much to the well-being of patients undergoing total hip arthroplasties of the hip or the knee.

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Ketamine Anesthesia in a Hydranencephalic Infant

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It has been proposed that ketamine produces anesthesia by dissociating the cerebral cortex from the limbic system. It has also been observed in cats that during maximal ketamine effect seizure-like activity occurs in the limbic system and cortex, with suppression of the EEG response to sensory stimuli. The following case report of a hydranencephalic infant with no cortex who was successfully anesthetized with ketamine suggests that the precise mechanism has not yet been elucidated.

REPORT OF A CASE

A full-term male infant weighing 9 lb, 6 oz, was delivered by cesarian section because of cephalopelvic disproportion. Macroecephaly and hypospadias were found on physical examination. The circumference of the head was 42 cm, the fontanelles were open, and there was almost complete transillumination of the cranial vault. The baby appeared completely normal on routine newborn neurologic examination. It was later observed that the child did not extinguish responses to stimuli. He responded in a stereotyped way to repeated nonpainful stimuli. A normal newborn infant "learns" that the stimulus is not injurious and will extinguish his response. The infant's body temperature was normal and he responded normally to pain and hunger. He had a diffusely abnormal low-voltage electroencephalogram (EEG).

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Received from the Department of Anesthesia, University of California at San Diego, 225 West Dickinson Street, San Diego, California 92103. Accepted for publication October 15, 1973.

Pneumoencephalography and cerebral angiography were performed at the ages of 4 and 12 days, respectively. General anesthesia was necessary for these procedures, since the patient was large and active. The reasons for the studies were threefold. If the diagnosis were hydrocephalus, some operative correction would be feasible. Second, if hydrocephalus were diagnosed a prognosis could be established from the amount of cerebral cortex present. Third, it was important to distinguish between hydrocephalus and hydranencephaly in order to counsel the parents. Hypospadias and hydrocephaly can occur together as an inheritable defect.

Prenesthetic medication for both procedures was atropine, 0.1 mg. im. Pulse rate and ventilation were monitored throughout with a precordial stethoscope. Blood pressure monitoring was not practical in this infant, who was completely swaddled in elastic bandages, and whose body position was frequently changed. On the first occasion, ketamine, 5 mg, was given intravenously for induction of anesthesia. The mouthing movements, searching eye movements and salivation typical of ketamine anesthesia followed. The baby was immobilized in a modified infant seat, and 15 minutes after induction a lumbar puncture needle was inserted into the subarachnoid space. Anesthesia was deemed adequate since he did not move or cry. One and a half hours were required for the pneumoencephalography, and a total dose of 10 mg of ketamine was used. Pulse rates ranged from 120 to 160 beats/min. The infant "awoke" suddenly about 45 minutes after the procedure, and cried until he was fed.

Eight days later cerebral arteriography was performed using ketamine, 40 mg, iv, and 20 mg, im. The intravenous infusion set became nonfunctional during the procedure, and it is not clear how much of the iv dose was delivered. Pulse rates ranged from 140 to 150 beats/min during the procedure, which lasted 3½ hours. Recovery was slower after