

- 9) Maintain low airway pressures. Anesthesia by mask with spontaneous or assisted ventilation is preferable to endotracheal intubation and mechanical ventilation because of potential orolaryngotracheal hematomas and pneumothoraces.
- 10) Avoid hypertension. This may exacerbate blood loss or cause rupture of occult aneurysms.
- 11) To avoid esophageal damage, try to keep the patient from vomiting while cricoid pressure is applied.
- 12) Use adequate doses of muscle relaxant for ease of endotracheal intubation without trauma or bucking.
- 13) Extreme gentleness is indicated for endotracheal intubation or passage of nasogastric tubes.

Ehlers-Danlos syndrome may be present in various degrees of severity. In severely affected individuals tissue fragility and the potential for hemorrhage can present management problems during anesthesia. These two cases illustrate many of the problems, and recommendations are made for anesthetic management.

REFERENCES

1. Beighton P, Price A, Lord J, et al: Variants of the Ehlers-Danlos syndrome. *Ann Rheum Dis* 28:228-245, 1969
2. McKusick VA: Mendelian inheritance in man. Fifth edition. Johns Hopkins University Press, 1978
3. Pope FM, Martin GR, McKusick VA: Inheritance of Ehlers-Danlos type IV syndrome. *J Med Genet* 14:200-204, 1977
4. Dalton ML Jr., Bricker DL, Nannini L: Spontaneous rupture of the subclavian artery and innominate vein. *Arch Surg* 109:552-554, 1974
5. Scully RE, Galdabini JJ, McNeely BU: Case records of the Massachusetts General Hospital. *N Engl J Med* 300:129-135, 1979
6. Schofield PF, MacDonald N, Clegg JF: Familial spontaneous rupture of the colon: Report of two cases. *Dis Colon Rectum* 13:394-396, 1970
7. Beighton PH, Murdoch JL, Votteler T: Gastrointestinal complications of the Ehlers-Danlos syndrome. *Gut* 10:1004-1008, 1969
8. Shemwell RE, Weed JC: Ehlers-Danlos syndrome and pregnancy: Report of a case in a Negro. *J Louisiana State Med Soc* 128:225-229, 1976
9. Barabas AP: Vascular complications in the Ehlers-Danlos syndrome. *J Cardiovasc Surg* 13:160-167, 1972
10. Cabeen WR, Reza MJ, Kovick RB, et al: Mitral valve prolapse and conduction defects in Ehlers-Danlos syndrome. *Arch Intern Med* 137:1227-1231, 1977
11. McKusick VA: Heritable disorders of connective tissue. Fourth edition. St. Louis, C.V. Mosby, 1972
12. Cavanaugh MJ, Cooper DM: Chronic pulmonary disease in a child with the Ehlers-Danlos syndrome. *Acta Paediatr Scand* 65:679-684, 1976
13. Beighton P: Obstetric aspects of the Ehlers-Danlos syndrome. *Br J Obstet Gynaecol* 76:97-101, 1969

Anesthesiology
52:269-271, 1980

Subdural Pneumocephalus Resulting from Drainage of Cerebrospinal Fluid during Craniotomy

BETTY L. GRUNDY, M.D.,* AND ROBERT F. SPETZLER, M.D.†

Uncontrolled drainage of cerebrospinal fluid (CSF) during craniotomy can produce ventricular collapse and neurologic damage. Pneumocephalus is a possibility whenever the cranial vault is open and a free path for gravity drainage of CSF exists. While anesthesiologists are attuned to the need for close observation and control of lumbar CSF drainage instituted to facilitate operations on the brain, they may be less aware of risks posed by the presence of other pathways for dependent escape of CSF. We have observed two instances of subdural air collection during craniotomy in patients with treated hydrocephalus.

* Assistant Professor of Anesthesiology.

† Assistant Professor of Neurosurgery.

Received from Case Western Reserve University, Cleveland, Ohio. (This work was done at University Hospitals of Cleveland.) Accepted for publication September 11, 1979.

Address reprint requests to Dr. Grundy at her new address: Department of Anesthesiology, 1060 E Scaife Hall, University of Pittsburgh, Pittsburgh, Pennsylvania 15261.

REPORT OF TWO CASES

Patient 1. A 23-month-old 10-kg hydrocephalic boy with treated lumbar myelomeningocele, hypotonia, and seizure disorder was admitted with recurrent fever and dysfunction of his ventriculoperitoneal (VP) shunt. The proximal end of the shunt was converted to external ventriculostomy drainage and the child was prepared for placement of a new VP shunt. Ventriculostomy drainage was kept open and the reservoir bottle placed on the operating table with the patient during induction of anesthesia with nitrous oxide, oxygen, and halothane. The rate of CSF flow increased noticeably with administration of halothane. Vital signs were stable during placement of a left parietal burr hole, but with opening of the dura systolic pressure rose from 80 to 105 torr and heart rate decreased from 140 to 120 beats/min. When the underlying ventricle was tapped CSF flow was sluggish. At this point the reservoir bottle attached to the external ventriculostomy catheter was noticed to be on the floor, the tubing open. A 170-ml volume of CSF had been drained acutely, a volume greater than 20 per cent of the child's estimated blood volume. Roentgenograms of the skull revealed a large left subdural pneumocephalus with ventricular collapse and inversion of the cortical mantle (fig. 1). Subdural air was evacuated and the ventricles were refilled with lactated Ringer's solution. Physiologic saline solution, 250 ml, was given intra-



FIG. 1. Patient 1. Intraoperative pneumocephalus.

venously. The child awoke with a right hemiparesis that partially cleared during the next several weeks.

Patient 2. An 18-year-old boy with von Recklinghausen's syndrome and multiple intracranial masses was scheduled for excision of a large symptomatic acoustic neuroma. He had since infancy undergone several shunt procedures for hydrocephalus and currently had in place a functioning valved ventriculoperitoneal shunt. Posterior fossa craniotomy and excision of the tumor were performed uneventfully with the patient in the sitting position. Routine postoperative roentgenograms of the skull revealed a huge collection of subdural air bilaterally (fig. 2). The patient's VP shunt was externalized and used to refill the ventricles partially with saline solution after bilateral shunt tubes had been placed into subdural air collections. The patient was comatose for 24 hours, with a marked left hemiparesis evidenced by responses to noxious stimuli. The ventricles were allowed to re-expand over 72 hours by clamping the ventricular catheter and allowing the subdural catheters to be open. Thus, the patient's own CSF production was used to re-expand the ventricles gradually. The patient made a complete recovery over a three-week period.

DISCUSSION

Patients who have undergone CSF shunting or drainage procedures for treatment of hydrocephalus are particularly apt to experience subdural pneumocephalus if free gravity drainage of CSF is permitted while the cranial vault is open. In patients with marked hydrocephalus the cerebral mantle is thin and easily collapsible. When negative ventricular pressure

exists, as from the siphon effect through a shunt tube, an opening of the skull outside the cerebral mantle will result in excessive CSF drainage and collapse of the ventricles. Special care must be taken to minimize the possibility of rapid or excessive loss of ventricular CSF in these susceptible individuals.

Our first patient had an external ventriculostomy. Subdural pneumocephalus and ventricular collapse developed because the position of the ventriculostomy reservoir was inadequately monitored, and when the skull was opened, the cerebral mantle collapsed as air entered the subdural space. Though it may be desirable to maintain open ventriculostomy drainage during induction of anesthesia with agents such as halothane that are known to increase intracranial blood volume, ventriculostomy tubing should be kept clamped except when drainage is clinically indicated. Certainly all members of the operating room team must be aware of the critical importance of positioning ventriculostomy reservoirs properly and checking them frequently.

Our second patient had a functioning VP shunt, which was not disturbed at the time of craniotomy. We failed to recognize the risk introduced by subjecting a patient with noncommunicating hydro-



FIG. 2. Patient 2. Postoperative pneumocephalus with complete ventricular collapse. Notice the ventricular catheter and "high-pressure" shunt valve.

cephalus to craniotomy in the sitting position while that patient had a functioning VP shunt. When the posterior fossa was opened, air entered the subdural space, allowing the ventricles to drain and to collapse completely.

Even with the skull intact, the shunted hydrocephalic patient lives with a constant potential risk of subdural hematoma.^{1,2} Although the negative pressure due to the siphoning effect of the shunt is equally distributed through the skull, any slight head trauma may rupture a small dural-cortical blood vessel and lead to subdural hematoma, whereas in most patients such small bleeding sources are adequately tamponaded by the higher intracranial pressure. Valves opening at "high" (60–110 mm H₂O) or "medium" (40–60 mm H₂O) pressures are incorporated into shunts to minimize such complications. Antisiphoning devices have been developed,³ but it is not clear that these devices reduce the incidence of subdural hematoma.²

Dependent loss of CSF during craniotomy may also occur in patients without shunts or ventricular catheters. Lunsford *et al.*⁴ reported two cases of subdural tension pneumocephalus in patients who

underwent posterior fossa craniotomy in the sitting position. They postulated a mechanism for air entry analogous to entry of air into an inverted bottle, referring to the "inverted pop-bottle syndrome."

The risk of subdural pneumocephalus due to uncontrolled CSF drainage during craniotomy can be minimized by: 1) identification of patients at risk; 2) vigilant observation of ventricular or lumbar CSF drainage catheters and reservoirs; 3) externalization of functioning shunts prior to craniotomy with the patient in the sitting or head-up position.

REFERENCES

1. Driesen W, Elies W: Epidural and subdural hematomas as a complication of internal drainage of cerebrospinal fluid in hydrocephalus. *Acta Neurochir (Wien)* 30:85–93, 1974
2. Milhorat TH: Hydrocephalus, *Pediatric Neurosurgery*. Philadelphia, F. A. Davis, 1978, pp 91–135
3. Portnoy HD, Schutte RR, Fox JL, et al: Antisiphon and reversible occlusion valves for shunting in hydrocephalus and preventing postshunt subdural hematomas. *J Neurosurg* 38:729–738, 1973
4. Lunsford LD, Maroon JC, Sheptak PE, et al: Subdural tension pneumocephalus: Report of two cases. *J Neurosurg* 50:525–527, 1979

Anesthesiology
52:271–273, 1980

Hemodynamic Effects of Prosthesis Insertion during Knee Replacement without Tourniquet

KAMRAN SAMII, M.D.,* EDITH ELMELIK, M.D.,† DANIEL GOUTALIER, M.D.,‡ PIERRE VIARS, M.D.,§

During recent total knee replacement operations in which bone cement was used, release of the tourniquet was followed by an acute and significant pulmonary vascular obstruction,¹ which may explain the reported complications of hypotension and cardiac arrest.^{2,3,4} Although a tourniquet decreases hemorrhage and facilitates the surgical procedure, this operation may also be performed without a tourniquet.

In this study we observed the intraoperative hemodynamic changes during total knee replacement performed without a tourniquet.

METHODS

Eight patients (mean age 70 years, range 60–78 years) without cardiorespiratory disease were studied. All received a so-called Guepar prosthesis, which requires insertion with acrylic bone cement. Mean duration of the operations was 125 min.

Premedication with atropine, 0.5 mg, im, and diazepam, 10 mg, im, was followed by spinal anesthesia to T10 with tetracaine. Diazepam was infused during operation at a rate of approximately 0.02 mg/min. The patients were drowsy and breathed ambient air to which oxygen was added at 3 l/min. The estimated blood loss was replaced with whole blood and averaged 1,260 ml. Lactated Ringer's solution was administered in a mean volume of 740 ml.

* Chef de Clinique Assistant in Anesthesiology and Intensive Care.

† Assistant in Anesthesiology and Intensive Care.

‡ Professor of Orthopedic Surgery.

§ Professor of Anesthesiology and Intensive Care.

Received from the Department of Anesthesiology and Intensive Care of the Pitie-Salpetriere Hospital, Paris, France, and the Departments of Anesthesiology and Intensive Care and Orthopedic Surgery of the Henri-Mondor Hospital, Cretiel, France. Accepted for publication September 19, 1979.

Address reprint requests to Dr. Samii: Departement d'Anesthesie-Reanimation, Hospital Bicetre, 78, rue du General Leclerc, 94270 Le Kremlin Bicetre, France.