Tension pneumocephalus: treatment with controlled decompression via a closed water-seal drainage system

Case report

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✓ The successful treatment of a patient with tension pneumocephalus by controlled decompression via external drainage is described. The advantage of the technique includes the immediate release of high pressure and the capability of maintaining constant low pressure to enable and facilitate sealing of dural tears. The method has been used in three other patients, leading to resolution of the tension pneumocephalus without recurrence or other complications.

Key Words • tension pneumocephalus • cerebrospinal fluid leak • fistula • external drainage

TENSION pneumocephalus, the entrapment of intracranial air under pressure, mimics a progressive space-occupying lesion and is a serious condition requiring prompt treatment. With increased interest in base of the skull surgery, there is a proportional increase in the incidence of tension pneumocephalus. In most surgical cases, preventive measures such as meticulous closure of the dura mater, reconstruction of the skull base, reexpansion of the intracranial compartment, placement of a drain, and nursing the patient in a head-flat position for a few days can avert the development of tension pneumocephalus. However, in some instances, this phenomenon occurs as a delayed complication and its management becomes a serious challenge.

In a series of 120 operations on the cranial base, we have encountered seven instances of giant, life-threatening tension pneumocephalus. This paper introduces a novel, but safe and effective method for decompression and long-term management of tension pneumocephalus. For brevity’s sake, we will describe only one case and its management as representative of the series.

Case Report

This 63-year-old man presented with a 3-week history of tearing and displacement of the left eye, double vision, left-sided nasal obstruction, and intermittent epistaxis. A computerized tomography (CT) scan revealed the presence of a large mass in the left maxillary antrum, extending into the ethmoid sinuses and eroding the cribiform plate and lamina papyracea of the left orbit. On examination, the left globe was displaced superiorly and anteriorly, with some limitation of upward gaze. Anterior rhinoscopy revealed a tumor obstructing the left nasal cavity, a biopsy of which showed malignant melanoma. An extent-of-disease workup was unrevealing. The patient underwent en bloc craniofacial resection of the paranasal sinus tumor including part of the basal dura, with exenteration of the left orbit. The dura was repaired primarily. The anterior skull-base defect was covered with a pedicular periosseal flap, and a split-thickness skin graft was placed on the sino-orbital defect. An epidural Jackson-Pratt drain was left in place.

During the first 3 postoperative days, the patient was nursed in the head-down position and was awake, alert, and oriented, without neurological impairment. In view of his stable condition and a minimum amount of drainage, the epidural drain was removed. On the 4th postoperative day the patient became increasingly lethargic, although afebrile and stable metabolically. A CT scan demonstrated a significant amount of air.
within the cranial cavity, with posterior displacement of the frontal lobes (Fig. 1). A 70% oxygen mixture was delivered through a non-rebreathing face mask, and the patient demonstrated marked neurological improvement within hours. Serial lateral skull radiographs over the next 2 days revealed a progressive decrease in the amount of intracranial air. Oxygen delivery was discontinued after 48 hours and the patient continued to improve.

On the 9th postoperative day, after a few hours of sitting up in a chair, the patient developed intractable hiccoughs and within hours became obtunded with signs of right-sided motor weakness. Repeat CT scan showed an increase in the amount of intracranial air. A No. 18 intravenous catheter was introduced into the aerocoele through a burr hole. The tube was connected to an intravenous extension tube which, in turn, was connected to a closed water-seal drainage system with a draining pressure of 2 cm H₂O. Within hours the patient began to improve neurologically, and continued to do so until his discharge from the hospital. The drain was left in place for 4 days until there was no further bubbling in the drainage system and serial plain lateral skull radiographs (Fig. 2) and CT scans confirmed a progressive decrease in the amount of intracranial air.

Discussion
Non-tension pneumocephalus is a common consequence of cranial surgery, and is a relatively benign complication which usually resolves spontaneously. By contrast, tension pneumocephalus mimics an expanding intracranial space-occupying lesion and may lead to rapid deterioration of the patient, requiring prompt treatment. Symptoms include restlessness, confusion, disorientation, and hiccoughs. Anisocoria, hemiparesis, and signs of meningeal irritation also can be observed. After base of the skull surgery, neurological signs and symptoms typically appear either on the 2nd to 4th postoperative day or following drain removal. The diagnosis is made based on clinical signs and symptoms, the presence of a large amount of intracranial air on the skull radiograph, and a characteristic appearance on the head CT scan.

A prerequisite for the formation of an expanding aerocoele is an intracranial pressure gradient that is favorable for the ingress of air. Usually this is created either by a persistent cerebrospinal fluid (CSF) leak or as a result of a patent intracranial shunt system. If CSF escapes and air can enter the intracranial cavity to compensate for the negative pressure (the so-called “inverted soda-pop bottle” phenomenon), then tension pneumocephalus may result. Intraoperative measures to prevent pneumocephalus include meticulous repair of the dura, tight closure of the skull-base defect with a periosseal flap, and reexpansion of the brain toward the end of surgery achieved by reduction of hyperventilation and reinsertion of CSF removed from a lumbar spinal catheter during the procedure. In addition, an epidural drain is placed and connected to a suction system set at low pressure. This drain is removed by the 3rd or 4th day when drainage has been reduced to a minimum. Postoperatively, the patients are nursed in a head-down position for the same duration of time.

If, in spite of all these measures, delayed tension pneumocephalus develops, prompt and active treatment must be instituted; several options may be considered. Simple needle aspiration of air may be the quickest way to reduce intracranial pressure but is usually only of short-lived benefit. Reinsertion of a drain is effective for immediate decompression; however, it does...
Tension pneumocephalus

Fig. 3. Diagram showing the closed water-seal drainage system for tension pneumocephalus. The first vial serves to trap fluid and mucoid material, and the second vial establishes the pressure beyond which air will be vented. The depth of immersion under the saline or water of the input tube determines the system opening pressure.

not include a mechanism to control the amount of negative pressure exercised. Fluctuations in pressure are the rule with systems such as the Jackson-Pratt drain, and may adversely affect the sealing of the cranial cavity. Excessive negative pressure will promote air entry and carries the risk of ascending infection.

Controlled decompression via a water-seal drainage system (Fig. 3) provides quick yet permanent control of tension pneumocephalus. The ability to control suction pressure permits rapid decompression and the maintenance of a constant pressure gradient that will promote sealing of dural fistulae. Since this is a closed system, ambient air cannot enter the cranial cavity, and the device can be maintained in place for days without the risk of infectious complications.

The water-seal drainage system consists of a flexible intravenous cannula (such as a No. 16 Angiocath) introduced through a burr hole after radiographic verification into the aerocele. The cannula is connected via an intravenous extension tube to the decompression system consisting of two interconnected small vials (Fig. 3). The first vial is used to trap fluids or mucoid material and is in connection with the aerocele. The second vial serves to create the desired pressure gradient. It has pressure calibration in centimeters of water and is filled with a few milliliters of water or saline. This vial has two openings connected to a respective input and output tube. The input tube is immersed in the water or saline to a depth determined by the maximum allowable intracranial pressure (for example, 2 to 3 cm). If pressure builds up within the aerocele, air will be vented through this opening. The output tube is open to the air.

Besides permitting rapid decompression and maintenance of a low and constant pressure gradient, this system allows for gauging of air pressure in the intracranial cavity by observing gas bubbling through the fluid in the vial. This is similar to the underwater seal systems used in the reexpansion of the lungs after thoracotomy.

A total of four patients with life-threatening tension pneumocephalus, which developed after drain removal, were treated with controlled decompression via the closed drainage system. The device was maintained in place for 4 to 6 days without complications, and led to the resolution of pneumocephalus in all patients.

Another treatment option for tension pneumocephalus is the administration of high (70% to 100%) inspired concentrations of oxygen via a face mask. The rationale for this is based on the fact that 80% of intracranially trapped air is nitrogen, which is inert and diffuses slowly along the pressure gradient across the pulmonary alveolar-capillary membrane. Providing a high inspired oxygen concentration to the patient creates a favorable gradient to expedite removal of nitrogen from the aerocele, thus reducing its volume and decreasing intracranial pressure. Clinical improvement may be seen shortly after initiation of oxygenation. Its administration, however, can only be continued for 48 hours because of the risk of oxygen toxicity thereafter. Hence, oxygenation (or, more properly, "denitrogenation") serves as a rapid yet, in most cases, only a temporary measure to control tension pneumocephalus.

The course we currently follow when patients develop tension pneumocephalus is as follows. When tension pneumocephalus is suspected we immediately begin delivery of high-concentration oxygen by face mask, while CT and/or skull x-ray films are obtained. By the time a radiological diagnosis is made (in approximately 45 minutes), the patient may have already responded to this conservative treatment, and it is possible to temporize by continuing with this treatment for up to 48 hours. Close observation in an intensive care unit is strongly recommended during this time. If the patient’s condition remains unchanged or deteriorates, a drain is introduced and controlled decompression begun. A CT scan or skull x-ray film is then obtained daily, while intracranial pressure is measured through the draining system until the patient is clinically and radiographically stable. The goal of treatment is to reduce the tension within the cranium rather than to eliminate the intracranial air. Pneumocephalus as such, in fact, is not dangerous and resolves spontaneously; in some cases it requires many weeks for complete reabsorption.

In conclusion, tension pneumocephalus associated with cranial-base surgery can usually be avoided. How-
ever, if it does occur, delivery of a high inspired concentration of oxygen with face mask and controlled decompression via a closed water-seal drainage system are useful procedures. While the former can only be a temporary measure, the latter provides close control of intracranial pressure and leads to a smooth resolution of tension pneumocephalus.

References


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