

# Tension Pneumocephalus

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**Abstract:** *Pneumocephalus, air in the cranial cavity, is a common occurrence following cranial surgery. However, tension pneumocephalus, accumulation of air trapped in the cranial cavity causing a mass effect and abnormal neurological signs, is uncommon. Knowledge about conditions that contribute to tension pneumocephalus, a potentially fatal complication, including the related signs and symptoms, is imperative. Immediate collaboration with a physician allows for timely treatment and patient recovery. Treatment measures include preoperative teaching, immediate removal of intracranial air, supine positioning, administration of 100% oxygen, repair of the bony and dural defect, and, if indicated drain placement into the air cavity, temporary tracheotomy, and antibiotics.*

Nursing knowledge about a tension pneumocephalus complication related to dural or bony compromise is needed for early diagnosis and immediate life-saving intervention. For as common and benign a pneumocephalus is, the opposite can be said of a tension pneumocephalus. Pneumocephalus occurs in all craniotomy patients and usually resolves spontaneously in about 2 days. Although the incidence of a tension pneumocephalus is low (approximately 0.1% to 2% of all craniotomies), it can cause death if not treated immediately (Sprague & Poulgrain, 1999; Wanamaker, Mehle, Wood, & Lavertu, 1995).

## Definition

Pneumocephalus is defined as intracranial air (Clevents, Marentetten, Esclamado, Wolf, & Ross, 1999). It is a common effect of cranial surgery and may occur at anytime when the bone and dura are compromised (Sprague & Poulgrain, 1999; Uemura, Megura, & Matsumura, 1997). The openings allow air to accumulate in the subdural, subarachnoid, epidural, and intraventricular spaces (Cunningham, 1984; Laviola, Kirvela, Spoto, Tschuor, & Alon, 1999; Uemura et al.). Small amounts of air are usually metabolized by the body and resorbed over several days (Ijelikciogler, Bek, Bekmaz, & Basock, 2003; Sprague & Poulgrain; Wanamaker et al., 1995). This article discusses theories and causes of tension pneumocephalus and provides an overview of treatment.

Tension pneumocephalus is an uncommon and life-threatening problem (Sprague & Poulgrain, 1999; Uemura et al., 1997). Intracranial air can increase in amount over a

few minutes or several days or weeks. Tension pneumocephalus can contain as little as 25 cc of air (Gozur, 1987; Sprague & Poulgrain, 1999; Wanamaker et al., 1995; Zasler, 1999). Because the air cannot escape or be resorbed quickly, it causes a mass effect and increases intracranial pressure (ICP). If left untreated, progressive brain compression results in a deteriorating mental status due to decreased oxygen supply to the brain, displaced ventricles, tentorial herniation, brain stem herniation, and death. Tension pneumocephalus is an emergency situation and requires immediate attention to prevent fatal complications (Clevenger, 1990; Laviola, Kirvela, Spoto, Tschuor, & Alon, 1999; Uemura et al., 1997).

## Theories

Two theories have been proposed to explain the development of a tension pneumocephalus (Clevents et al., 1999; Sprague & Poulgrain, 1999; Suri, Mahapatara, & Singh, 2000; Wanamaker et al., 1995; Zasler, 1999). The first mechanism is the *inverted soda-pop bottle phenomenon*. When the bottle is inverted, soda pours out, leaving an empty space of negative pressure above the fluid level. This air is trapped at the top of the bottle. The same effect can occur when cerebrospinal fluid (CSF) is siphoned out in the sitting position. Positive pressure air rushes into the subdural, subarachnoid, epidural, or intraventricular space via the bony and dural defect to ascend, fill, and collect in the negative pressure space created by the loss of CSF. A tension pneumocephalus begins to develop when a patient's normal CSF volume is restored and the air volume remains the same.

The second mechanism is the *ball-valve mechanism*. It is hypothesized that air enters a bony or dural defect into the intracranial spaces due to high pressure created during ambu-bag resuscitation (Van Heerden, Pinder, & Cameron, 1999), severe sneezing (Ayala, Watkins, & Deschler, 2002; Wein & Gans, 1999), coughing (Ayala et al.) and the Valsalva maneuver (Ayala et al.; Schrijver & Berendse, 2003). The ball-valve mechanism does not allow air to escape since the brain's soft tissue becomes the "ball" that blocks the "valve" defect on the exhalation cycle, creating a mass effect from tension pneumocephalus.

## Causes

All patients with craniotomies have the potential to develop tension pneumocephalus. Situations or procedures that pose an increased risk for accumulation of intracranial air include surgical interventions, such as burr holes (Gozur, 1987), posterior fossa surgery (Suri et al., 2000), craniofacial surgery (Clevents et al., 1999;

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Wanamaker et al., 1995; Sprague et al., 1999), transphenoidal hypophysectomy (Iplikcioglu et al., 2003), ventricular peritoneal shunt, and lumbar drain placement (Clevenger, 1990). The sitting position during and following the cranial surgery increases the risk for air being trapped above the brain tissue (Schrijver & Berendse, 2003; Wanamaker et al.; Wein & Gans, 1999).

Fractures of the fragile bony structures of the facial paranasal sinuses and orbital roof, as well as gun shot wounds, malplacement of nasotracheal/nasogastric tubes, and ambu-bag resuscitation also have the potential to cause a tension pneumocephalus (Alder, Graeb, & Nugent, 1992; Baskaya, 1999; Ferreras, Junquera & Garcia-Consuegra, 2000; Sprague & Poulgrain, 1999). The anatomy of the frontal region predisposes the patient to a pneumocephalus. The dura mater adjoining the frontal and paranasal sinuses is thin and tightly attached to bone along the olfactory cranial nerve; it is easily torn (Aferzon, & Spektor, 2001). Neoplasms (Bramley & Ghosh, 2001) or inflammation (Ayala et al., 2002) of the frontal and paranasal sinuses that progress to erosion of the dura mater and bony structures can cause pneumocephalus (Ayala et al.; Sprague & Poulgrain). Raised external pressure during frequent and severe nose-blowing (Ayala et al.), sneezing (Wein & Gans, 1999), coughing (Wanamaker et al., 1995) or Valsalva maneuver (Schrijver & Berendse, 2003) have been identified as contributing to tension pneumocephalus. Thoracic vertebral fractures have also been associated with pneumocephalus (Uemura et al., 1997). Nitrous oxide anesthesia may potentiate a tension pneumocephalus; it diffuses from the blood into an air-filled cavity more quickly than it diffuses out of the cavity, thereby causing a tension pneumocephalus (Sprague & Poulgrain).

## Prevention

Preoperative or preprocedure prevention of a tension pneumocephalus begins when consent is obtained. The nurse then has the opportunity to educate the patient and family about potential complications. This may allow the patient to identify problems early and provide for patient compliance, thereby limiting complications (Giraudet-Le Quintrec et al., 2003; Scott, 2004).

Teach the patient and family about signs and symptoms of a CSF leak and rationale for reporting clear, watery, nonsticky fluid draining from the nose and/or ear. Educate them about the purpose of a drain in the head, if used, as well as the purpose of activity restrictions. Also, discuss the rationale for no coughing, nose-blowing, or Valsalva maneuver. Use of C-Pap or Bi-Pap should be discontinued. Medications may be given to aid compliance with these restrictions, such as a cough suppressant, stool softener, or decongestant.

Perioperative and postoperative prevention includes an absolute water and air-tight repair of the dural defect (Aferzon et al., 1999) and flat (supine) patient positioning (Sprague & Poulgrain, 1999). Following hematoma

removal or craniotomy, neuroscience nurses need to monitor the patient so that the incisional drain vents air and is free of possible obstructions (Sprague & Poulgrain; Wanamaker et al., 1995). Also, assess for a delay in "waking-up" during the recovery room period if nitrous oxide anesthesia was used. This patient will not be arousable (Clevens et al., 1999; Suri et al., 2000). If a craniofacial approach is used, a short-term tracheotomy may be necessary to decrease airway pressure and the potential for a tension pneumocephalus (Wanamaker et al.). When facial trauma exists, use an orogastric tube to decompress the stomach, thereby preventing inadvertent brain placement (Ferreras et al., 2000). At discharge, direct the patient with a partially resorbed pneumocephalus to refrain from traveling by airplane and avoid activities that include exposure to changing air pressure (Schrijver & Berendse, 2003).

## Diagnosis and Management

Computed tomography (CT) is the "gold standard" diagnostic tool for tension pneumocephalus (Sprague & Poulgrain, 1999; Wanamaker et al., 1995). The CT is used to identify the presence of air via the density differences between air, fluid, tissue, and bone. Air-filled cavities are darkest, almost black. Fluid-filled areas are dark gray, and tissue is light gray. Bone is very light, almost white. (See Figs 1–3 for these density differences.) The CT is also used to identify the amount and location of air and fluid, presence of a defect, and the effect of trapped air on the brain.

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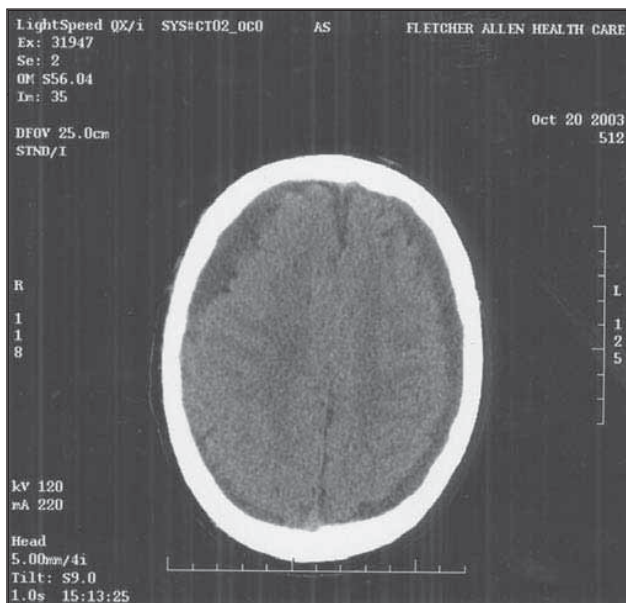
***As soon as tension pneumocephalus is confirmed, all efforts are directed toward reducing the mass effect and intracranial pressure.***

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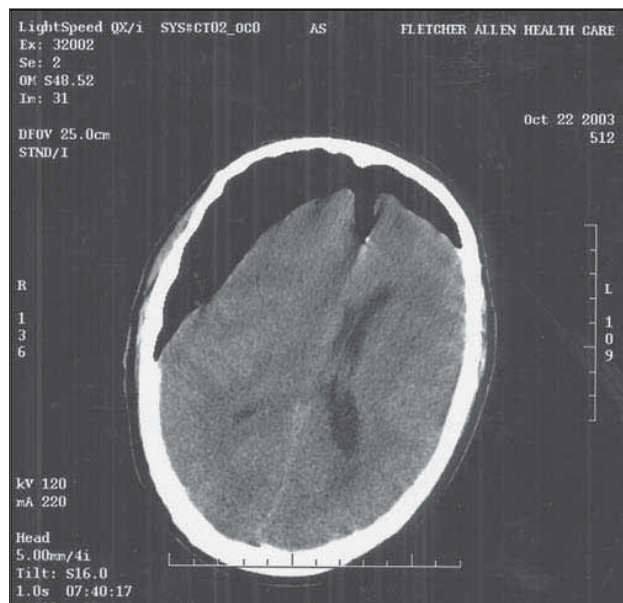
After tension pneumocephalus is diagnosed, 100% oxygen is administered via a non-rebreather mask. One hundred percent inspired oxygen hastens the resorption of air (Clevens et al., 1999; Sprague & Poulgrain, 1999; Wanamaker et al., 1995; Zasler, 1999). If a CSF leak is the cause or a lumbar drain is in place, clamp or remove the drain, and place the patient in a supine position. A sitting position allows for continued inflow of air via the dural defect. As treatment is administered, neuroscience nurses monitor the patient's response.

As soon as tension pneumocephalus is confirmed, all efforts are directed toward reducing the mass effect and intracranial pressure. A tension pneumocephalus is an emergency. Needle and syringe aspiration or catheter drainage of the air usually produces immediate patient improvement. A closed water seal system has been shown to be very effective in decompressing the trapped air (Sprague & Poulgrain, 1999; Wanamaker et al., 1995).

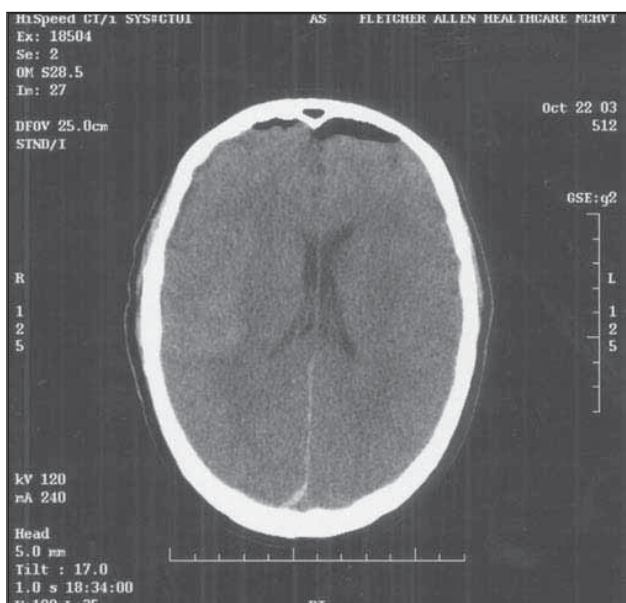
For the patient with evacuation of a chronic subdural hematoma or excision of a brain tumor where the brain



**Fig 1.** The subdural hematoma with blood over right and left hemispheres.



**Fig 2.** The tension pneumocephalus showing a mass effect and compression of a ventricle.



**Fig 3.** Following air aspiration of the tension pneumocephalus with a small amount of residual frontal air.

tissue does not immediately expand to fill the space, a drain may remain in place and the patient may be placed supine until the brain tissue rebounds, thereby reducing the risk of recurring tension pneumocephalus (Gozur, 1987; Wood, Mirvis, & Shanmuganathan, 1996). While the drain remains in place, an antibiotic may be administered for 48 hours to prevent infection (Levine, 1991; Sprague & Poulgrain; Stankiewicz, 1991).

After air aspiration, medication such as mannitol may be ordered to reduce brain edema, thereby aiding in the reduction of the mass effect and lowering the intracranial pressure (Stankiewicz, 1991). An elective tracheotomy may be suggested for upper airway diversion to reduce the airway resistance and pressure for those patients requiring a craniofacial approach thereby preventing reoccurrence of a tension pneumocephalus (Clevers et al., 1999; Sprague, & Poulgrain., 1999; Wanamaker et al., 1995; Yates, Hamill, Borel, & Toung, 1994). After removal of air, the patient often demonstrates immediate improvement but requires close monitoring since reaccumulation can occur in as few as 10 minutes (Sprague & Poulgrain).

Identifying and repairing the bony and/or dural defect is imperative and is the objective. It can be accomplished endoscopically or via craniotomy. An endoscopic or extracranial approach is preferred for the patient with multiple comorbidities and who may not survive an open craniotomy. A craniotomy approach is used when the defect cannot be viewed with the endoscope, the approach would be difficult, or a previous endoscopic repair was unsuccessful (Stankiewicz, 1991). The open craniotomy approach allows for clear visibility and improved access to the defect. Both methods have about equal success rates in terms of defect closure (Dodson, Gross, Swerdloff, & Gustafson, 1994). However, the intracranial approach is often accompanied by increased operative and anesthetic time, increased morbidity, and a longer hospital stay (Aferzon et al., 2001; Dodson et al.; Stankiewicz).

## Patient Case Review

J. D., a 60-year-old male, was involved in an auto accident while on vacation in Florida. At the time of the accident, his head hit the windshield. He was unconscious at the scene when paramedics arrived, but regained consciousness en route to the emergency department (ED). J. D. had two forehead lacerations that were sutured in the ED. While in the ED, J. D. complained of neck pain. Emergent radiographs and CT scans were negative for major cervical vertebra fractures, dislocation, or intracranial bleeding. His Glasgow Coma Scale (GCS) score was 14–15. The neurological exam was normal. Since J. D. continued to have neck pain, he was placed on spine precautions and ordered to wear a cervical collar, and neurological vital signs were monitored every 2 hours. The repeat head CT scan, done the following day, was again negative for intracranial bleeding. Repeat neck radiographs were scheduled for day 3. These also were negative for fracture. J. D. was discharged on day 4 with a GCS score of 15 and directions to schedule an appointment with his primary care physician for removal of his forehead stitches. J. D., and his wife drove home to New England. Three weeks after the auto accident, J. D.'s family noted that he had balance problems and generalized weakness. J. D. complained of increasingly severe headaches, dizziness, lethargy, and some memory difficulty along with delayed response to commands. His speech was clear and appropriate. He was admitted to a hospital near his home.

A CT scan showed bilateral frontal subdural hematomas (Fig 1). J. D. was taken to surgery. With the patient in a 15° head-up position, bilateral burr holes were performed. Within 24 hours, J. D. improved and was appropriately responsive to his family. The postoperative orders included maintaining the 15° head-up position. Forty hours following the burr hole procedure, the nurse noted that he became somnolent, difficult to arouse, and responded to painful stimuli. His right pupil was round and 4 mm in size with a sluggish response to light. His left pupil was round and 3 mm in size with brisk response to light. On the way for a repeat CT scan, he had a seizure. His respiratory status was deteriorating. He was intubated and ventilated. The scan showed a tension pneumocephalus (Fig 2). A total of 75 cc of air was immediately aspirated via burr holes using an intravenous access catheter and syringe while J. D. was in the CT department. He was taken to the operating room, and a penrose drain was placed in each burr hole. J. D.'s mental status immediately improved. He opened his eyes on command; his pupils were equal at 3 mm with a brisk response to light.

Eight hours following the placement of the penrose drains, J. D. was extubated. Over the next hour he continued to improve. The postprocedure orders included 100% oxygen via a non-rebreather mask for 48 hours and a full supine position for 72 hours. The patency of

the penrose drains and the neurological vital signs were monitored. He was given a cough suppressant and stool softener and directed to refrain from blowing his nose. Cefazolin 1 gram every 8 hours was initiated intravenously at the time of insertion of the penrose drains and discontinued in 48 hours. A postoperative CT scan (Fig 3) showed resolution of the tension pneumocephalus. This antibiotic was followed by oral administration of cephalexin 500 mg every 6 hours for 7 days. The penrose drains were removed 72 hours after insertion. During the following week, J. D. had significant improvement. The residual effects included some left leg and arm weakness and balance problems. J. D. was discharged to an acute rehabilitation unit. After 4 weeks, he recovered to the point of being able to care for himself with minimal assistance and returned to his home.

## Summary

A tension pneumocephalus creates a mass effect and constitutes an emergency. It presents with a variety of neurological changes and causes an altered mental status. It can occur with as little as 25 cc of air and can take as few as 10 minutes or days to weeks to develop. Immediate air aspiration is required to prevent permanent neurological deficits. For those patients with a mass effect, placement of a drain prevents recurrence of the tension and allows the brain tissue to reexpand. Prevention is recommended. Nursing management priorities should focus on identifying those patients at high risk for a tension pneumocephalus, close monitoring of the neurological vital signs, and immediately reporting neurologic deterioration.

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