

## Case Report



# A Case of Traumatic Pneumocephalus on the Opposite Side of the Injury Site

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### Conflict of Interest

The author has no financial conflicts of interest.

## ABSTRACT

Pneumocephalus is defined as an abnormal presence of intracranial air or gas. Traumatic pneumocephalus (TP) typically occurs on the injured side and is in communication with the external environment. This report presented an extremely rare case of TP that occurred on the opposite side of the injured site, even with the absence of any traumatic injury. The patient sustained injuries, including linear skull fracture, acute epidural hematoma, fractures in the clavicle and scapula, and subcutaneous emphysema, on the left side of the body. However, TP occurred on the right side. Although the exact underlying pathogenic mechanism remains unclear, the condition might be attributed to the migration of air bubbles or negative pressure on the opposite side caused by side-to-side closed head injury.

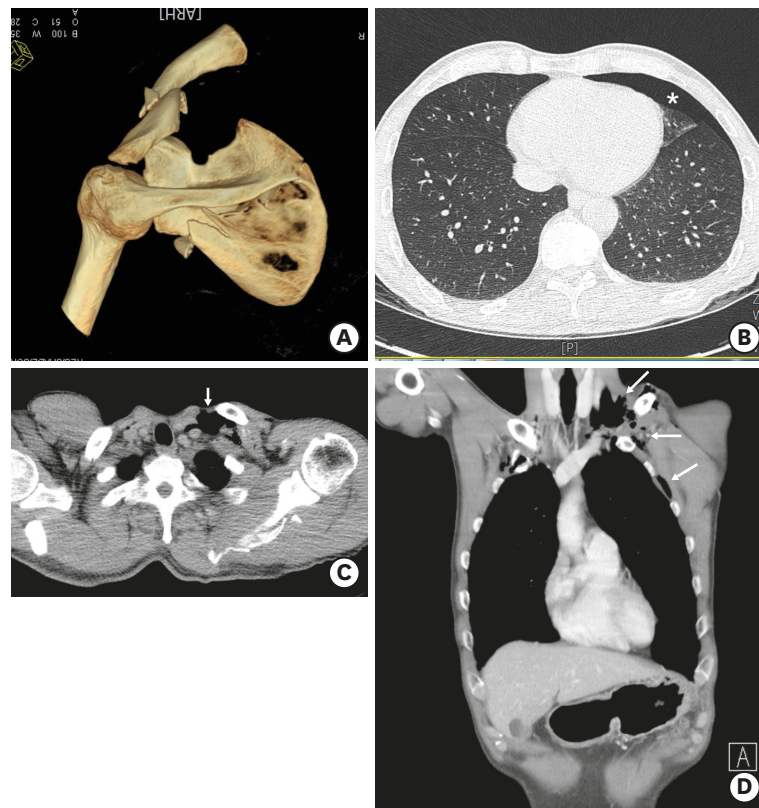
**Keywords:** Traumatic pneumocephalus; Skull fracture; Closed head injury

## INTRODUCTION

Pneumocephalus is defined as an abnormal presence of intracranial air or gas. Moreover, it can occur spontaneously or after trauma or cranial surgeries, and it is usually associated with damage in the skull. Craniofacial trauma is the most common etiologic factor. That is, approximately 7–9% of patients with this type of trauma present with traumatic pneumocephalus (TP) on computed tomography (CT) scan.<sup>10</sup> TP indicates a communication between the intracranial cavity and the air-containing structures during or after trauma. Therefore, it typically occurs on the injured side and is in communication with the outside. This report presented a rare case of TP that occurred on the opposite side of the injured site.

## CASE REPORT

A 52-year-old man was admitted due to headache and pain in the left shoulder and chest. He fell from a height of about 2 m and hit the left side of his head and body against the floor. Physical examination revealed swelling in the left temporal area and multiple contusions in the left hemi-body. Leakage of cerebrospinal fluid (CSF) was not observed, and the neurological examination findings were unremarkable. Three-dimensional (3D) shoulder

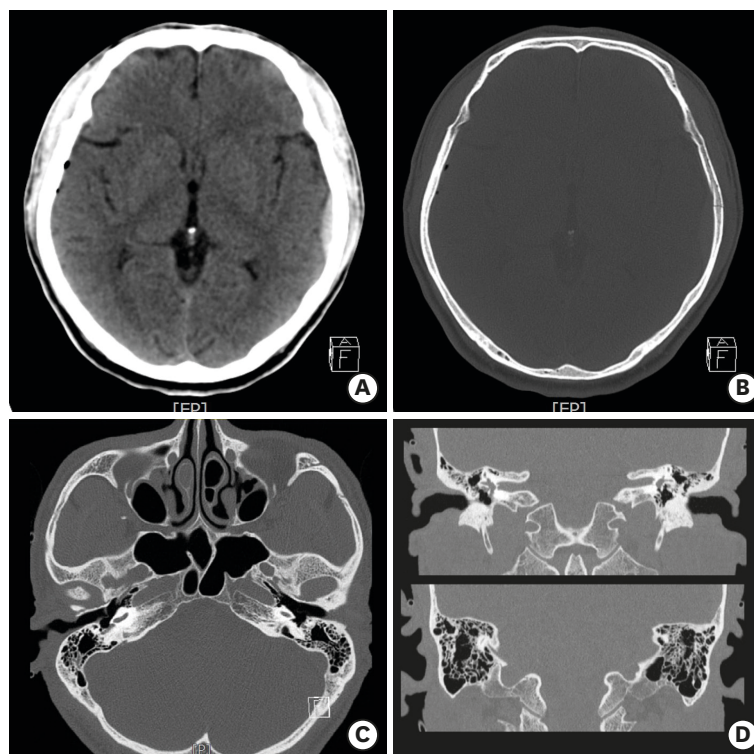


**FIGURE 1.** (A) Three-dimensional shoulder CT scan images showing comminuted fractures in the left clavicle and scapula. (B-D) CT scan of the chest revealed multiple fractures in the left rib and small amount of left pneumothorax (\*). Multiple subcutaneous emphysema was observed around the fractured clavicle and scapula (white arrows). CT: computed tomography.

CT revealed comminuted fractures in the left clavicle and scapula (**FIGURE 1A**). CT scan of the chest revealed multiple fractures in the left rib and small amount of left pneumothorax. Multiple subcutaneous emphysema was observed around the fractured clavicle and scapula (**FIGURE 1B-D**). Brain CT scan revealed a small acute epidural hematoma (about 10 mm in maximum thickness) and an overlying linear fracture in the left temporal region. Moreover, the presence of air bubbles indicated TP in the right temporal region (**FIGURE 2A & B**). However, based on temporal bone CT scan and thin-slice CT scan of the head, there were no fractures and injuries in the right side except TP (**FIGURE 2C & D**). Thus, the patient received conservative treatment, including figure-of-eight bandage for the fracture in the left clavicle. Brain CT scan was again performed 7 days after the injury, and results showed complete disappearance of TP. The patient is doing well without any complications for 2 years after discharge from hospital. This report was approved by the Institute Ethical Committee of Wonkwang University Hospital (WKUH) and in compliance with institute's requirements (WKUH 202002006).

## DISCUSSION

TP indicates a communication between the intracranial cavity and extracranial regions or air-containing structures, and it is most commonly caused by trauma, including craniofacial bone fracture, which allows communication via an injury to the dura.<sup>4,7)</sup> Based



**FIGURE 2.** (A, B) Brain CT scan images showing a small acute epidural hematoma and an overlying linear fracture in the left temporal region, and the presence of air bubbles indicated traumatic pneumocephalus in the right temporal region. (C, D) No fractures and injuries were noted on thin-slice CT scan images of the base of the skull. CT: computed tomography.

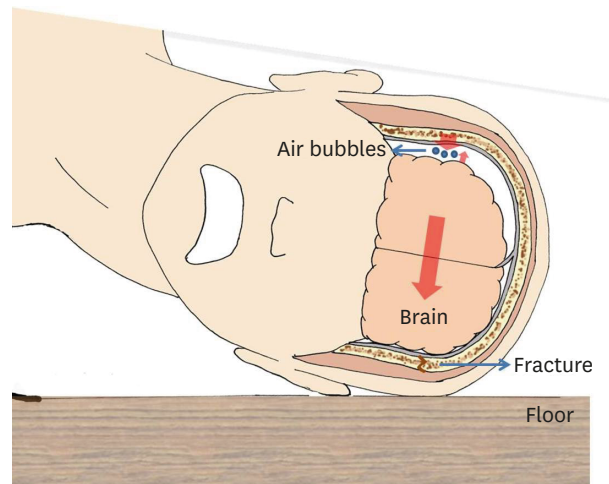
on 2 hypotheses, the ball valve and inverted bottle mechanisms have been implicated in the development of TP.<sup>3,4,6,11</sup> In the ball valve mechanism, air enters through the fractures or foramen of the bone of the skull base adjacent to the air-containing space, and when there is force, air is pushed into the intracranial cavity and is then trapped. Next, seals are made by the arachnoid membrane, brain parenchyma, or ventricles. Meanwhile, according to the inverted bottle mechanism, negative pressure develops within the intracranial cavity as CSF flows out of the skull. This phenomenon occurs when the CSF leaks from the skull until the air enters the area and equilibrates the pressure difference. Most cases of TP involve low pressure and resolves spontaneously within a few days. In the current case, the ball valve mechanism can be considered because there was no leakage of CSF.

A fracture involving the pneumatic bone of the cranial base indicates the entry of air. Other routes of air entry include skull fracture with an overlying deep scalp laceration or fracture of the mastoid cells or paranasal sinus. Less than 3% of all skull fractures have been associated with TP.<sup>6</sup> However, about 8% of fractures of the skull base and paranasal sinus and 41% of fractures of the sella turcica are associated with TP.<sup>6</sup> In addition, the dura of these regions is at risk of tearing because it is thin and tightly attached to the bone in these regions. Ultra-thin CT scan of these regions should be performed to detect such fractures.<sup>6</sup> Although TP develops in the absence of skull fracture, this phenomenon is rare and the mechanism remains unknown. Two mechanisms describing the occurrence of TP in the absence of skull fracture have been proposed, both of which involve low intracranial pressure that results in the sucking of air through a dural defect.<sup>4,9,11</sup> The first mechanism involves vertical pressure

that develops a pressure gradient within the CSF system. Meanwhile, the second involves the ball valve effect, which allows air to enter the cranial base through the foramen or the craniocervical junction pathway. Ultimately, a transcranial pressure gradient favorable for the ingress of air causes the development of TP.

TP can also develop due to an air path via the intracranium.<sup>4)</sup> Choi et al.<sup>4)</sup> have presented a case of multiple TP that occurred in the absence of skull fracture, and it may have developed by the entry of air into the brain parenchyma, subarachnoid space, and ventricle system via the retropharyngeal space and internal carotid artery canal pathway. They concluded that the brief pressure gradient between the intracranial and extracranial spaces associated with subcutaneous emphysema or pneumothorax allows air to be canalized through a subcutaneous tract in the patient's body. The common routes of air formation generally include a weak entry point, such as the basal cistern, carotid canal, cavernous sinus, foramen ovale and lacerum, choroidal fissure, jugular foramen, and thecal sac of the thorax.<sup>4,12)</sup> Based on the patient's risk factors and the anatomical structure of the cranial base foramen, both intracranial and extracranial pneumocephalus can be develop. Moreover, in rare cases, TP can occur after lumbar spinal surgery, epidural procedure, blunt musculoskeletal trauma, and chemoradiation.<sup>1,2)</sup>

In the current case, the patient presented with injuries, including linear skull fracture, acute epidural hematoma, fractures of the clavicle and scapula, and subcutaneous emphysema, in the left side of the body. However, TP occurred in the right side even though there was no evidence of injury, including fractures or contusion. The author has considered that other mechanisms can explain this rare phenomenon. The first possibility is that air bubbles move to the upper portion of the intracranial spaces when the patient was lying on the side. Although this mechanism is most likely to be common sense, there was no communication with extracranial space through the damaged left head, and the possibility of TP moving from the injured head until beyond the midline to the right head is low due to the presence of the falx cerebri. Therefore, the second possibility considered whether TP originated from the multiple subcutaneous emphysema around the fractured clavicle and scapula. Malca et al.<sup>8)</sup> have reported that the development of pneumocephalus in the absence of skull fracture is caused by a fistula between the thoracic cavity and subarachnoid space after thoracotomy. Hwang et al.<sup>5)</sup> have revealed the occurrence of massive cerebral air embolism after cardiopulmonary resuscitation (CPR). Moreover, they explained that massive cerebral air embolism can occur if air enters the circulatory system via ruptured pulmonary vessels during CPR even without pneumothorax or extravascular pneumocephalus. However, in this case, the risk of left subcutaneous emphysema migrating to the right temporal lobe through the connection of the circulatory system is extremely low because there is no evidence of air bubble movement, as previously described in previous cases. Although no fractures were found in the axial, coronal, and sagittal view of the facial bone and brain CT and craniofacial 3D CT scan, the third possibility is that an extremely small skull fracture may have been missed between thin-slices of CT, thereby resulting in failure detection. Finally, the author assumed that TP was attributed to a side-to-side closed head injury, which causes the brain to move to the left side. This phenomenon creates an instantaneous negative pressure in the right cranial cavity, which is assumed to have caused air to escape from the small skeletal pneumaticity in the right side of the skull or defective arachnoid membranes (**FIGURE 3**). Because most TPs are often accompanied by dural tears, further imaging studies include the whole neural axis from skull base to whole spinal canal are needed to identify tear points. In this case, additional imaging studies should have been conducted to find the dural tear point,



**FIGURE 3.** Side-to-side closed head injury caused the brain to move to the left side, thereby creating an instantaneous negative pressure in the right cranial cavity, which is assumed to have caused air to escape from the small skeletal pneumaticity in the right side of the skull or defective arachnoid membranes.

but the whole spine evaluations were omitted because there were no symptoms associated with spines.

## CONCLUSION

The author presented a rare case of TP that occurred on the opposite side of the injured site. Although the exact underlying pathogenic mechanism remains unclear, the author has considered that several mechanisms can explain this rare phenomenon. This phenomenon might be attributed to the migration of air bubbles or negative pressure on the opposite side caused by side-to-side closed head injury. Further studies must be conducted to identify the mechanism associated with this rare phenomenon.

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