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Tension pneumocephalus following suboccipital sitting craniotomy in the pediatric population

P. Daszkiewicz [a,*], D. Dziedzic [b]

[a] Department of Pediatric Neurosurgery, The Childrens' Memorial Health Institute, Warsaw, Poland
[b] Faculty of Medicine, Warsaw Medical University, Warsaw, Poland

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ABSTRACT

Background: Sitting craniotomy often results in entrapment of air in fluid-filled intracranial cavities. Gas under pressure exerts a deleterious effect on adjacent nervous tissue, resulting in clinical deterioration.
Aim of study: To assess the incidence of tension pneumocephalus (TP) and to define risk factors associated therewith.
Material and method: Analysis included 100 consecutive patients (57 boys, 43 girls, mean age 9.7 y) undergoing suboccipital sitting craniotomy since 2012 to 2014.
Results: In our material ($n = 100$) TP was seen in 7 cases, asymptomatic pneumocephalus (AP) in 77 and no pneumocephalus (NP) in 16. Tumor types encountered were typical for pediatric population. In the TP group ($n = 7$) the ratio of low-grade to high-grade tumors was 5:2, in the AP group ($n = 77$) 2:1 and in the NP group ($n = 16$) 1:1. Preoperative hydrocephalus was present in 21 cases (21%, mean incidence), thereof 3 in the TP group (3/7; 42.8%), 12 in AP group (12/77; 15.5%) and 6 in the NP group (6/16; 37.5%). All TP patients received an emergency external drainage, thereof 4 required a permanent ventriculo-peritoneal shunt (57.1%), while AP and NP patients combined ($n = 93$) required a permanent shunt in 4 cases only (4.3%). TP-associated morbidity ($n = 2$) consisted in a significant deterioration of neurological condition.
Conclusions: TP is a relatively rare but potentially serious complication of suboccipital sitting craniotomy. Risk factors for TP are low-grade tumor and pre-existing long-standing hydrocephalus. TP requires emergency decompression by temporary external drainage. TP patients significantly more often require a permanent CSF shunt.

1. Introduction

Tension pneumocephalus (TP) is a phenomenon where gas (usually air) exceeding atmospheric pressure accumulates in the intracranial cavity, either in the subdural space, ventricles or arachnoid cisterns. Based on a physical laws discovered by Jacques Charles in 1787 and further developed by Joseph Gay-Lussac in 1802 (thus Charles' and Gay-Lussac Law) [1], heating of intracranial gas from ambient temperature (about 20 °C) to internal body temperature (37 °C) will cause an increase of it's volume and, consequently, pressure it exerts on adjacent

* *Corresponding author at*: Klinika Neurochirurgii, Al. Dzieci Polskich 20, 04-730 Warszawa, Poland.
E-mail address: neurochirurgia@czd.pl (P. Daszkiewicz).
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structures. This results in compression of nerve tissue and elevation of intracranial pressure with potentially serious consequences. In the past, such a situation was common in patients undergoing pneumoencephalography, a radiological technique, currently obsolete, devised by Walter Dandy in the '30s, enabling visualization of cerebral ventricles [2]. At present, air may enter incracranial space as a consequence of open cranio-cerebral trauma with uncontrolled egress of cerebro-spinal fluid or in the setting of sitting craniotomy for posterior fossa pathology, where surgical field is located below CSF-filled intracranial compartments. CSF escapes through the surgical wound and is replaced by air.

Sitting suboccipital craniotomy is commonly performed to treat posterior fossa pathology in patients over 3 y.o., where calvarial bone thickness allows for a safe and secure fixation of the patient's head. Sitting position provides good access to the entire posterior fossa including pineal region, facilitating spontaneous gravitational evacuation of blood and CSF, providing the surgeon with a slack and relatively dry field. It's main draw-backs include TP, air embolism and fatigue associated with ''hands-up'' working position [3].

Intracranial air under pressure (TP) may cause headache, vomiting, altered sensorium, focal neurological deficits, in extreme cases brainstem dysfunction and death [2,4]. There are many theories concerning pathogenesis of TP and iatrogenic risk factors associated therewith including use of nitrous oxide, significant ventriculomegaly prior to surgery, loss of elasticity and reduced volume of neural tissue due to preoperative dehydration, intracranial hypotension caused by hyperventilation or evacuation of CSF by pre-existing ventriculo-peritoneal shunt or external drainage, prolonged surgery, dural CSF leak (e.g. dural laceration after epidural lumbar analgesia). All of these tend to reduce intracranial pressure with subsequent aspiration of air [4].

TP has already been extensively analyzed in the '70s and '80s but despite overall progress in neurodiagnostics, neuroanesthesia and neurosurgery, it remains a significant clinical challenge. The aim of this study is to analyze the frequency of this phenomenon in everyday clinical practice, it's management and to determine risk factors which may help to select patients at-risk for this complication.

2. Material and method

Analysis included 100 consecutive patients undergoing suboccipital sitting craniotomy for posterior fossa pathology, treated since 2012 to 2014. Study population includes 57 boys and 43 girls aged 4–17 y. (mean age: 9.7 y.). Retrospective analysis of medical records was the employed study method.

Patients were operated on under general anesthesia; no halothane neither nitrous oxide were used. Normotension and normocapnia were maintained throughout the procedure. Short-term hyperventilation and intravenous infusion of mannitol were used ''on demand'' to reduce intracranial pressure and facilitate dural opening. Surgery as such was performed by experienced neurosurgeons observing standard protocols and techniques. External ventricular drainage in the setting of sitting craniotomy is not used at our center.

Clinical signs suggesting a TP induced an emergency CT-scan. If confirmed, temporary external drainage was placed (ventricular or subdural, depending on location of intracranial air). Volume and morphology of drained CSF were monitored and intracranial air volume was controlled by CT scan. If after 5–7 days drainage volume did not exceed 100 ml and intracranial gas disappeared, the patient was gradually weaned from the drainage. If daily drainage volume exceeded 100 ml and no infection was present, external drainage was replaced by a permanent ventriculo-peritoneal shunt.

3. Results

In the entire study population ($n = 100$), intracranial air after surgery was seen in 84 cases, thereof in the ventricles in 9 patients, in the subdural space – in 29 cases and in ventricular AND subdural space combined – in 46 patients. In the entire group, tension pneumocephalus (TP) developed in 7 cases (4 boys and 3 girls), asymptomatic pneumocephalus (AP) in 77 (43 boys and 34 girls) and no pneumocephalus (NP) developed in 16 (10 boys and 6 girls). Mean age of SP-, AP- and NP subgroups was 10.14 y, 9.92 y and 8.63 y, respectively.

In terms of histopathology, the entire group included 47 cases of pilocytic astrocytoma, 32 cases of medulloblastoma, 7 cases of ependymoma, 3 cases of schwannoma and 11 cases of other types of posterior fossa pathology. TP group ($n = 7$) included 5 low grade (WHO I and II) and 2 high grade tumors (WHO grade III and IV) (ratio 5:2), the AP group ($n = 77$) – 50 and 27 (ratio 2:1) and the NP group ($n = 16$) – 8 and 8 cases (ratio 1:1).

In the entire study population, preoperative hydrocephalus was present in 21 cases, thereof 3 in the TP group (3/7; 42.8%), while in AP and NP groups combined ($n = 93$), it was present in 19.3%, thereof 12/77 in AP group (15.5%) and 6/16 in the NP group (37.5%). Analysis of effect of preoperative hydrocephalus and tumor type on subsequent development of TP revealed, that TP patients with hydrocephalus harbored 1 high-grade and 2 low-grade tumors (1:2); AP patients with hydrocephalus harbored 6 high-grade and 6 low-grade tumors (6:6); NP patients with hydrocephalus harbored 4 high-grade and 2 low-grade tumors (4:2). This would attest to a direct ''protective'' role of tumor malignancy on pneumocephalus as such and development of TP (exactly opposite ratios of high-grade to low-grade tumors in TP and NP groups).

All TP patients received an emergency external drainage. In this group ($n = 7$), 4 subsequently required a permanent ventriculo-peritoneal shunt (57.1%), while AP and NP patients combined ($n = 93$) required a permanent shunt in 4 cases only (4.3%).

In our study, no TP-associated mortality was noticed, while TP-associated morbidity ($n = 2$) included a significant deterioration of neurological condition (disturbed consciousness, bulbar syndrome, hemiparesis), resulting in prolonged hospital stay and long-term rehabilitation.

Unfortunately, small numbers of patients in particular subgroups preclude formal statistical analysis and unequivocal conclusions based on our material.