NEUROLOGIA I NEUROCHIRURGIA POLSKA 51 (2017) 286–289

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.elsevier.com/locate/pjnns

Original research article

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

ARTICLE INFO

Article history:
Received 26 December 2015
Accepted 26 April 2017
Available online 11 May 2017

Keywords:
Tension pneumocephalus
Sitting craniotomy
Children

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).
http://dx.doi.org/10.1016/j.pjnns.2017.04.006
0028-3843/

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.

4. Discussion

The first report on TP in a living person was by Walter Dandy in 1926 [1]. Adoption of a sitting position for posterior fossa surgery and it's widespread use contributed to accumulation of a large body of data concerning various phenomena associated therewith, including TP, air emboli, etc. [2–5]. However, TP is not associated solely with sitting position. There are anecdotal reports on TP developing after prone craniotomy [6], lumbar drainage for aneurysm surgery in supine position [7], conservative treatment of rhinorrhea [8], scuba diving [9], traffic accident [10], etc. A role of nitrous oxide in the development of TP has also been postulated [11], as well as that of hyperbaric oxygen therapy [12]. In spite of a considerable progress in neurosurgery, TP still poses a considerable clinical challenge.

Presence of intracranial air is common after sitting craniotomy and of itself is not a problem [13,14], confirmed by our material where most patients with CT-confirmed postoperative pneumocephalus did not develop clinical signs requiring emergency intervention. It appears that these occur only above certain threshold quantity of intracranial gas combined with individual susceptibility, favored by reduced elasticity of brain, compromised cerebral perfusion, hypoxia, immaturity, etc. [15]. Both in our material and according to literature data, the incidence of symptomatic TP is low (7% of cases in our material, 2–5% in other authors' reports), although when it does happen, it is fairly well remembered by all concerned. We did not notice the influence of age, gender, or type of anesthesia on the incidence of TP. Some authors highlight a possible role of nitrous oxide in the development of TP [11]. As already mentioned, we do not use this agent for intracranial procedures.

Hydrocephalus is common in children with posterior fossa tumors, occurring in 71–90% of pediatric patients [2]. In our material, TP developed significantly more often in children with pre-existing long-lasting ventriculomegaly associated with low-grade slow-growing tumors than in those without hydrocephalus or with only a short history of hydrocephalus associated with high-grade, fast growing tumor. This would suggest a possible role of prolonged ventriculomegaly and reduced brain elasticity in the development of TP, as opposed to children with high-grade tumors, presenting with a short history of acute hydrocephalus, relatively narrow ventricles, preserved brain elasticity and it's superior pressure-absorbing properties. In our material, distribution of histological types of tumors was similar to that commonly reported in the literature, so such a suggestion appears viable [4,16].

Symptoms usually develop within the first few hours after surgery, warranting close monitoring, diagnostic vigilance and rapid intervention, if necessary. Decompression of TP usually provides an immediate relief, but external drainage must be maintained for a few days to enable evacuation of air, it's replacement by CSF and restoration of normal intracranial pressure–volume balance. If CSF absorption deficit persists indicating active hydrocephalus and no infection is present, external drainage must be replaced by a permanent CSF shunt system. While among all patients with posterior fossa tumor, the percentage of persons requiring implantation of a CSF-shunt after tumor excision is estimated at 10–40% [16,17], the respective proportion of TP-patients is as high as 57% in our material. This may be caused by pre-existing long-lasting severe hydrocephalus, or permanent obstruction of arachnoid granulations by gas, permanently blocking CSF-absorption capacity.

We try to prevent excessive intraoperative loss of CSF by temporary occlusion of the aqueduct by a cottonoid, by as complete as possible replacement of lost CSF by warm physiological saline and watertight dural closure, but such apparently obvious measures are not 100% effective in preventing TP. Given the actual rarity of TP (7% in our material) and paucity of recruited patients both in ours and in other authors' reports, at the moment any generalizations and firm conclusions appear premature. Nevertheless, ''preventive'' routine placement of external ventricular drainage during suboccipital sitting craniotomy, as well as renouncement of sitting position as such on purely principal grounds appears unjustified. What remains, is meticulous surgical technique, close postoperative monitoring and timely intervention, if necessary.

Misquoting Hamlet, ''prone or sitting position – that is the question!''[18]. Both have their adherents, based mainly on personal experience and standards of a particular center, because hard evidence- and randomized controlled trials-based data are lacking. Sitting position provides an unobstructed and ''anatomical'' approach, reduced venous congestion, gravitational drainage of blood and CSF, providing access for the entire posterior fossa, including the pineal region. It's opponents emphasize the risk of pneumocephalus and air embolism, delayed hematoma formation (inactive bleeding when sitting may become active upon putting the patient in a horizontal position), not to mention surgeon's fatigue. On the other hand, prone or ''concorde'' position prevents pneumocephalus and air embolism (the latter to a certain extent only), potential bleeders that can be dealt with on the spot and is more comfortable for the surgeon. It's main draw backs include: work in blood- and CSF-filled field, more venous congestion, more difficult orientation in the ''upside down'' setting. Last but not least, anatomic considerations should also be taken into account (tumor location, configuration of the tentorium, position of the vein of Galen complex, etc.). In our institution, children under 3, as well as mid-line, low-lying and peripheral posterior fossa tumors and patients with a flat more horizontal tentorium (when standing) are approached in the prone position. Older patients and pineal region tumors, as well as patients with a more vertical tentorium (when standing) are operated on in the sitting position. To sum up, each case should be dealt with on an individual basis. The best position and surgical corridor should be chosen, according to current clinical situation and surgeon's preference.

5. Conclusions

Due to a small number of TP cases, we may only highlight our most relevant findings:

- TP was a relatively rare but potentially serious complication of suboccipital sitting craniotomy;

- at-risk population includes children harboring low-grade tumors and established ventriculomegay;
- TP required emergency decompression by temporary external drainage;
- TP patients often required a permanent CSF shunt.

Conflicts of interest

None declared.

Acknowledgement and financial support

The work was prepared on the basis of funds for the statutory activities of the Institute.

Ethics

The work described in this article has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans; Uniform Requirements for manuscripts submitted to Biomedical journals.

REFERENCES

[1] Fullick P. Physics Heinemann 1994;141–2.
[2] Dandy WE. Pneumocephalus (intracranial pneumatocele or aerocele). Arch Surg 1926;12:949–82.
[3] Korkmaz Dilmen O, et al. The sitting position in neurosurgery for children. Br J Anaesth 2002;88(1):12–7.
[4] White YS, Bell DS, Mellick B. Sequelae to pneumoencephalography. J Neurol Neurosurg Psychiatry (BMJ Group) 1973;36(1):146–51.
[5] Bonner K, Siegel KR. Pathology, treatment and management of posterior fossa brain tumors in childhood. J Neurosci Nurs 1988;20(2):84–93.
[6] Matjasko J, Petrozza P, Cohen M, Steinberg P. Anesthesia and surgery in the seated position: analysis of 554 cases. Neurosurgery 1985;17:695–702.
[7] Porter JM, Pidgeon C, Cunningham AJ. The sitting position in neurosurgery: a critical appraisal. Br J Anaesth 1999;82:117–28.
[8] Standefer M, Bay JW, Trusso R. The sitting position in neurosurgery: a retrospective analysis of 488 cases. Neurosurgery 1984;14:649–58.
[9] Wroński M, Ferber J, Wroński J. Acute tension pneumocephalus as a complication of surgical procedures of the posterior cranial fossa in prone position, Case Reports, English Abstract. Neurol Neurochir Pol 1987;21 (2):167–70.
[10] Saito K, Inamasu J, Kuramae T, Nakatsukasa M, Kawamura F. Tension pneumocephalus as a complication of lumbar drainage for cerebral aneurysm surgery – case report. Neurol Med Chir (Tokyo) 2009;49:252–4.
[11] Mirza S, Seed SR, Ramsdenn RT. Extensive tension pneumocephalus complicating continuous lumbar CSF drainage for the management of CSF rhinorrhea. ORL J Otorhinolaryngol Relat Spec 2003;65:215–8.
[12] Zeba I, Barcovic I, Knezevic S, Lender CM, Bralic M, Bulat-Kardum L. Pneumocephalus after an uneventful scuba diving. Aviat Space Environ Med 2010;81(5):511–3.
[13] Komolafe EO. Tension pneumocephalus – a rare but treatable cause of rapid neurological deterioration in traumatic brain injury. A case report. Afr J Neurol Sci 2010;29(2):88–91.
[14] Artru AA. Nitrous oxide plays a direct role in the development of tension pneumocephalus intraoperatively. Anesthesiology 1982;57:59–61.
[15] Lee Ch, Chen WC, Hsia TC. Tension pneumocephalus: a rare complication after hyperbaric oxygen therapy. Am J Emerg Med 2009;27(2). 257.e1-3.
[16] Di Lorenzo N, Caruso R, Floris R, Guerrisi V, Bozzao L, Fortuna A. Pneumocephalus and tension pneumocephalus after posterior fossa surgery in the sitting position: a prospective study. Acta Neurochir (Wien) 1986;83:112–5.
[17] Toung TJ, McPherson RW, Ahn H, Donham RT, Alano J, Long D. Pneumocephalus: effects of patient position on the incidence and location of aerocele after posterior fossa and upper cervical cord surgery. Anesth Analg 1986;65:65–70.
[18] Kitahata LM, Katz JD. Tension pneumocephalus after posterior-fossa craniotomy, a complication of the sitting position. Anesthesiology 1976 May;44(5):448–50.