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The Incidence of Pneumocephalus after Supratentorial Craniotomy

Observations on the Disappearance of Intracranial Air

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Background: Pneumocephalus occurs in a variety of clinical settings and has important anesthetic implications, particularly if N₂O is used. One common cause of pneumocephalus is a craniotomy or craniectomy, and therefore patients undergoing these neurosurgical procedures may be at increased risk for the development of tension pneumocephalus if N₂O is used during a subsequent anesthetic. However, because the rate at which a postoperative pneumocephalus resolves has not been well defined, the duration of this risk period is unknown.

Methods: Department of Anesthesia billing codes were used to identify all patients undergoing supratentorial craniotomy between 1986 and 1990. This list was cross-indexed with Department of Radiology data to generate a list of patients who had had a computed tomographic scan of the head performed on or after the day of their surgery. From this list, 240 scans were examined for the presence of intracranial air. The magnitude of pneumocephalus, if present, was ranked as large, moderate, small, or trace.

Results: Air was seen in all scans obtained in the first 2 postoperative days. Sixty-six percent of these pneumocephali were judged to be moderate or large. The incidence of pneumocephalus decreased to 75% by postoperative day 7. During the 2nd and 3rd postoperative weeks, the incidence of pneumocephalus decreased to 59.6 and 26.3%, respectively. The size of the pneumocephali also decreased. Still, 11.8% of the scans obtained during the 2nd postoperative week had pneumocephali that were judged to be moderate or large.

Conclusions: These data indicate that all patients have pneumocephalus immediately after a supratentorial craniotomy. Although the incidence and size of pneumocephali decrease over time, a significant number of patients have an intracranial air collection large enough to put them at risk for complication if N₂O is used during a second anesthetic in the first 3 weeks after the first procedure. This information

should be considered in the evaluation of the patient and in the selection of anesthetic agents. (Key words: Anesthesia: neurosurgical. Anesthetics, gases: nitrous oxide. Brain: intracranial pressure. Complications: pneumocephalus. Neuroanesthesia.)

PNEUMOCEPHALUS occurs in a variety of clinical settings. It can be produced by trauma¹⁻³ or infection⁴⁻⁶ or can occur after the ventriculostomy^{7,8} or even after spinal or epidural anesthesia.⁹⁻¹¹ It is also, of course, seen after diagnostic pneumoencephalography.^{12,13} More commonly, however, it is found in patients who have recently undergone a craniotomy or craniectomy.^{14,15}

The presence of intracranial air in a patient requiring surgery is of special concern to the anesthesiologist because of the possible iatrogenic development of a *tension* pneumocephalus secondary to the use of N₂O.^{16,17} Because of the differences in blood-gas solubility between N₂O and N₂/air, N₂O administration can lead to an expansion of any trapped air bubble, thereby increasing intracranial pressure.^{12,13,18} To avoid this complication, it is important to identify patients at risk and alter anesthetic technique. It is likely that the patients at highest risk for N₂O-induced tension pneumocephalus are those who have recently undergone a neurosurgical procedure and who then must be returned to the operating room for a second operation. The neurosurgical literature indicates that as many as 1-2.5% of patients undergoing intracranial surgery must be returned on an emergency basis to the operating room, for reasons such as the evacuation of a hematoma.¹⁹⁻²¹ The multiply injured trauma patient who has had a neurosurgical procedure as a part of his or her acute management may return to the operating room many times in the following weeks, for orthopedic procedures, wound debridement, or skin grafting, for instance. Other neurosurgical patients may

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be returned for elective reasons, such as the implantation of radioactive material.

The reabsorption of intraventricular gas has been described for patients undergoing pneumoencephalography.²² Although previous observations indicate that a large percentage of patients have intracranial air in the first few hours after surgery,^{15,17,23} there are few data concerning the time required for a postoperative pneumocephalus to resolve. Therefore, the period of potential risk for the development of an inadvertent N₂O-induced tension pneumocephalus is unknown. To begin to define this period, we examined a large number of postoperative computed tomographic (CT) scans of the head from patients who had recently undergone intracranial surgery.

Materials and Methods

To identify patients at the University of Iowa Hospitals and Clinics who had undergone a head CT scan after an intracranial procedure, computerized Department of Anesthesia billing records were searched to identify patients undergoing a supratentorial craniotomy between 1986 and 1990. This list of patients was then compared with the Department of Radiology's database to generate a set of approximately 700 patients who had undergone a head CT scan on or after the date of surgery. From this set, 134 patients (who had undergone a total of 240 scans) in whom a CT scan had been obtained within 1 yr after the date of surgery were randomly selected.

Each scan was then reviewed by a single individual (DKR) who knew the films had been taken after craniotomy but who was blinded to the actual postoperative day. More than 10 scans were reviewed at each sitting. Pneumocephalus was determined to be present if a characteristic air density (an area of very low attenuation) was present within the cranium as viewed on routine axial sections.²⁴ In addition, the amount of air was subjectively estimated by examining all axial sections for each scan. Each scan was then assigned to one of the following categories: no air or a trace (tiny bubble seen one section), small, moderate, or large (air approximately 10% or more of intracranial contents as observed in one section) amount of air. Examples of the scans are shown in figure 1.

The percentage of patients with intracranial air on any given postoperative day was then calculated. The percentage of patients in whom the pneumocephalus was judged to be moderate or large also was calculated.

Results

The overall incidence of pneumocephalus *versus* postoperative day and the percentage of scans in which the volume of air was scored as moderate or large is shown in figure 2. All scans obtained on the day of surgery (postoperative day 0) or on the first 2 postoperative days had evidence of intracranial air; in 40 of 61 scans (66%) the volume of air was ranked as either moderate or large. The incidence of pneumocephalus remained greater than 90% until the 7th postoperative day, when it decreased to 75%. There was a further, progressive decrease thereafter. In the 2nd week (postoperative days 8–14), 31 of 52 scans demonstrated intracranial air (59.6%); 6 (11.8%) were described as moderate or large. During the 3rd postoperative week (postoperative days 15–21), only 5 of 19 (26.3%) had intracranial air, and in only 1 of these was air volume ranked as moderate or large. No scan showed evidence of moderate or large pneumocephalus after the 3rd week.

Discussion

It is clear from our work and that of others that pneumocephali are common in the immediate postoperative period after craniotomy. Toungh *et al.*¹⁵ observed intracranial air in 77 of 100 patients who had undergone posterior fossa or upper cervical cord procedures. Their patients had had postoperative skull x-rays taken within 120 min after the end of their surgery. These authors noted that patient position did influence the measured incidence of pneumocephalus; 100% of the patients undergoing surgery in the sitting position had radiographic evidence of intracranial air, whereas those undergoing procedures in the "Park Bench" and prone positions had a lesser incidence of pneumocephalus. Dash *et al.*,[§] using fluoroscopy, also demonstrated postoperative intracranial air, this time in 77 of 79 sitting craniotomy patients. Both of these studies used relatively insensitive techniques to detect pneumocephalus.

In our study, by contrast, we used head CT scanning, which can detect as little as 0.5 ml air.²⁴ Using this

§ Dash HH, Bithal PK, Muley S, Mishra NK, Saini SS, Tandon PN: Fluoroscopic imaging for monitoring tension pneumocephalus. *ANESTHESIOLOGY* 71:A1133, 1989.

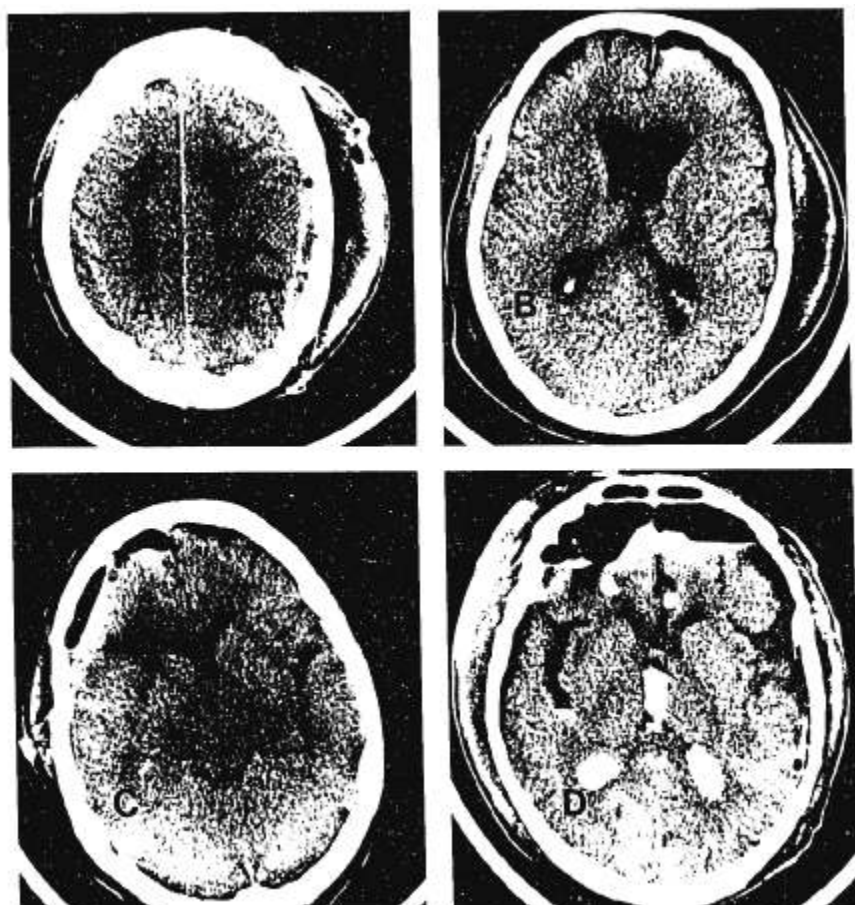


Fig. 1. Typical computed tomographic scans illustrate the scoring system used to assess the size of observed pneumocephali. A = trace; B = small; C = moderate; D = large.

technique, we detected a very high incidence of postoperative pneumocephalus, even though all of the patients in our study had undergone supratentorial craniotomies in nonsitting positions. This finding is consistent with the report of Domino *et al.*, who, using head CT imaging, detected intracranial air in all of their patients (24 of 24) immediately after craniotomy.²³ However, they only looked at patients immediately after surgery, and thus did not provide any data concerning the resolution of aerocele.

Although some information with regard to the reabsorption of pneumocephalus after pneumoencephalography has been published,²² information concerning the resolution of intracranial air after craniotomy is lacking. In fact, our inability to locate such data was a major reason for undertaking this project. In addition to confirming the high incidence of intracranial air in the immediate postoperative period, we found evidence that these pneumocephali persisted both into and after the 2nd postoperative week. In fact, the in-

cidence of moderate or large pneumocephalus still was greater than 20% at postoperative day 7. Unless there is some mechanism for continued air entry (which is most unlikely in supratentorial craniotomy), this finding suggests that air is only poorly absorbed in the postoperative setting.

It should be clear that this was not a "random survey" of all postcraniotomy patients. We studied only patients who had had head CT performed for clinical indications after a neurosurgical procedure. Because most patients do not require CT scans of the head, we may have selected a subset of patients who were having a poor or worsening clinical course. It is possible that these patients are more likely to have residual air than is the general neurosurgical population. Even if so, however, this would not lessen the importance of our findings, because this subset probably is the group most likely to be returned to the operating room (for reasons such as clot removal, burr hole, or lobectomy). One other limitation of the study is that the individual reviewing

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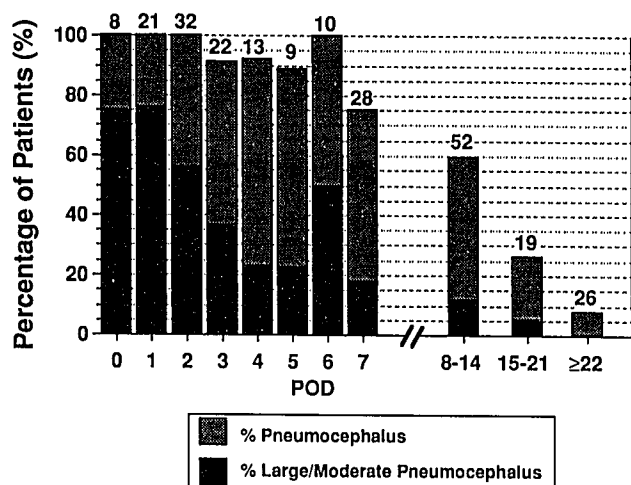


Fig. 2. The incidence of pneumocephalus versus postoperative day. The total bar height (black and gray) represents the total incidence; the black portion of the bar represents the proportion of scans in which the volume of air was scored as moderate or large. The number at the top of each bar is the number of scans reviewed for each postoperative interval. Because of the limited number of scans reviewed after the 1st week, data are combined into week-long blocks.

the scans was not blinded and knew that the scans were from patients who had undergone a supratentorial craniotomy. However, large numbers of scans were reviewed at each session; scans were not reviewed in sequential order; and the reviewer was not aware of the number of days after surgery that scans had been performed (although the scan date was known). We therefore believe that the potential likelihood of bias is small. Moreover, because air is so distinctive on CT scans, the potential for bias should be particularly small with respect to the simple "yes or no" detection of air.

There is obviously a greater chance of error in our assessment of the magnitude of pneumocephalus than in more sophisticated techniques, such as computer aided image analysis volume determinations. However, the purpose of this report is to describe the changes in pneumocephali in a clinically useful manner, and not precisely to define the rate of air absorption in, for example, milliliters per day.

How should the clinician respond to these data? Is the presence of pneumocephalus important, and if so, how should we change our practice? We suggest that preoperative knowledge of the existence of pneumocephalus is important because we can alter our practice to avoid tension pneumocephalus secondary to the use of N₂O. N₂O has been associated with, if not firmly

linked to, the development of tension pneumocephalus in a number of cases.^{14,16,17,25-27} Whether the use of N₂O was indeed the critical factor in each of the aforementioned cases is a matter of debate. However, there is little question that the addition of N₂O to the inspired gas mixture experimentally increases intracranial pressure in the presence of intracranial air.^{12,13,18} Furthermore, a small clinical study has demonstrated an increase in intracranial pressure when N₂O was introduced after dural closure in patients who had undergone posterior fossa craniotomy in the sitting position,²⁸ presumably by expanding an intracranial air collection. Despite a case report purporting to link the continuation of N₂O past dural closure with an increase in intracranial pressure,¹⁶ controlled clinical trials indicate that continuing N₂O past dural closure does not affect intraoperative intracranial pressure, and may, in fact, reduce postoperative intracranial pressure once N₂O is withdrawn.^{23,28} It seems likely that most intracranial gases rapidly equilibrate at the time of closure and that the resulting pneumocephalus already contains a significant amount of N₂O (such that there is little to no diffusion gradient).

Given our findings on the incidence of pneumocephalus after craniotomy and the persistence of significant pneumocephalus into the 2nd week (and sometimes the 3rd week), the following guideline can be offered. For any patient coming to the operating room in the first 3 weeks after an open intracranial procedure, N₂O should probably be avoided until the dura is opened, unless accurate intracranial pressure monitoring is in place or the presence of pneumocephalus has ruled out by a preoperative head CT scan.

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