Subdural tension pneumocephalus following surgery for chronic subdural hematoma

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The computerized tomography (CT) findings were analyzed in five cases of subdural tension pneumocephalus following surgery for chronic subdural hematoma. They were compared with CT scans in 14 cases of asymptomatic subdural pneumocephalus. In this study, two new CT findings were identified that suggest increased tension of the subdural air. Subdural air separates and compresses the frontal lobes, creating a widened interhemispheric space between the tips of the frontal lobes that mimics the silhouette of Mt. Fuji. The presence of air between the frontal tips associated with massive air inclusion over the frontal lobes presumably indicates increased tension of the subdural air. The "Mt. Fuji sign" was seen in four of the five cases with subdural tension pneumocephalus. The other finding was the presence of multiple small air bubbles scattered through several cisterns ("air bubble sign"). It is postulated that these air bubbles enter the subarachnoid space through a tear in the arachnoid membrane caused by increased tension of air in the subdural space. This finding was seen in four cases with subdural tension pneumocephalus. These two CT findings are helpful in making a diagnosis of subdural tension pneumocephalus following surgery for chronic subdural hematoma.

KEY WORDS □ pneumocephalus □ chronic subdural hematoma □ subdural hematoma □ computerized tomography

INTRACRANIAL air is often seen after operations for chronic subdural hematoma (SDH), but there is seldom enough mass effect to cause neurological deterioration. Although subdural tension pneumocephalus has been reported in increasing numbers of cases since the advent of computerized tomography (CT) scanning, there are only a few reports in which the CT findings are discussed in relation to the mechanism of increased tension of the subdural air. To make a diagnosis of subdural tension pneumocephalus, increased tension of the subdural air must be proved, but this is often speculative based on clinical evidence of increased intracranial pressure (ICP). Subdural air produces an artifact of increased volume on CT scans, which makes it difficult to assess the mass effect of the air.

The purpose of this paper is to describe two CT findings characteristic of increased tension of the subdural air and to discuss the possible mechanisms by which these phenomena are created. For this purpose, "true" subdural tension pneumocephalus was compared with asymptomatic subdural pneumocephalus. The former condition was confirmed when air spouted through burr holes at reoperation; patients with the latter condition showed no neurological deterioration in spite of large accumulations of intracranial air after operation for chronic SDH.

Clinical Material and Methods

Among 196 patients with chronic SDH who were treated between 1981 and 1984 in Yokohama City University Hospital and affiliated hospitals, there were only five cases of "true" subdural tension pneumocephalus that were confirmed at reoperation. These were compared with the cases of 14 patients with asymptomatic subdural pneumocephalus who did not deteriorate neurologically in spite of large accumulations of air detected on at least four serial CT slices, each 1 cm wide. A summary of the five cases with subdural tension pneumocephalus is presented in Table 1. The following aspects were studied: 1) the volume, location, and shape of the main air mass, which was observed on at least four serial CT slices; 2) the distribution of small air...
Postoperative tension pneumocephalus

**FIG. 1.** Computerized tomography appearance in Cases 1 to 5 (A to E, respectively) with subdural tension pneumocephalus. The Mt. Fuji sign is seen in all cases except Case 2 (B), which presents subdural air in a niveau formation. A typical Mt. Fuji sign is seen in Case 3 (C).

**TABLE 1**

Clinical summary in five patients with subdural tension pneumocephalus

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Postop Neurological Status</th>
<th>Postop Time of Symptom Onset</th>
<th>Shape of Main Air Mass</th>
<th>Cisterns With Small Air Bubbles</th>
<th>Results of Air Evacuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>70, M</td>
<td>reduced level of consciousness; decerebrate rigidity</td>
<td>2 days</td>
<td>Mt. Fuji sign</td>
<td>suprasellar, quadrigeminal, ambient</td>
<td>immediate improvement</td>
</tr>
<tr>
<td>2</td>
<td>78, M</td>
<td>reduced level of consciousness</td>
<td>1 day</td>
<td>niveau formation</td>
<td>none</td>
<td>gradual improvement</td>
</tr>
<tr>
<td>3</td>
<td>86, F</td>
<td>reduced level of consciousness; anisocoria</td>
<td>1 day</td>
<td>Mt. Fuji sign</td>
<td>suprasellar</td>
<td>gradual improvement</td>
</tr>
<tr>
<td>4</td>
<td>71, M</td>
<td>reduced level of consciousness; anisocoria</td>
<td>6 hrs</td>
<td>Mt. Fuji sign</td>
<td>suprasellar</td>
<td>immediate improvement</td>
</tr>
<tr>
<td>5</td>
<td>77, M</td>
<td>reduced level of consciousness</td>
<td>16 hrs</td>
<td>Mt. Fuji sign</td>
<td>suprasellar</td>
<td>immediate improvement</td>
</tr>
</tbody>
</table>

bubbles distant from or near the main air mass; and 3) the change in the midline shift after operation for chronic SDH. The operation for relief of subdural tension pneumocephalus consisted of releasing the air through burr holes and filling the subdural space with saline.

**Results**

**Main Air Mass**

The main air mass was seen on at least four serial CT slices in all five cases of subdural tension pneumocephalus. Furthermore, in four of these cases and in seven cases of asymptomatic subdural pneumocephalus air was seen on more than six CT slices. There was no definite difference in the air volume between both types of pneumocephalus.

The main air mass was located bilaterally over the frontal and temporal lobes in four of the subdural tension pneumocephalus cases and over both frontal lobes in the fifth. Of the 14 asymptomatic cases of pneumocephalus, the air mass lay over one frontal lobe in five cases, over both frontal lobes in four, and unilaterally over the frontal and temporal lobes in five. All five patients with subdural tension pneumocephalus had bilateral accumulations of air, probably because they all had bilateral chronic SDH's. The main air mass was located unilaterally in all cases of unilateral chronic SDH and bilaterally in all cases of bilateral hematoma.

Subdural air with increased tension separated and compressed the frontal lobes. The collapsed frontal lobes with widened interhemispheric space between the tips of the frontal lobes resembles the silhouette of Mt. Fuji; thus, this CT finding was termed the “Mt. Fuji sign” (Fig. 1). This appearance was seen in four of the subdural tension pneumocephalus cases; the fifth case exhibited a niveau formation on CT scans, in which air and residual subdural fluid formed a fluid level. Nine of the asymptomatic subdural pneumocephalus cases showed a niveau formation, two had a crescent appearance in which the shape of the air-fluid level formed a crescent between the skull and the surface of the brain, two had a biconvex appearance, and one had a “peaking sign” (Fig. 2). In brief, the Mt. Fuji sign was most frequently seen in cases of subdural tension pneumocephalus, and the niveau formation was most common in the asymptomatic condition.

**Small Air Bubbles**

Small air bubbles (the “air bubble sign”) were seen in four cases of subdural tension pneumocephalus and
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FIG. 2. Computerized tomography scans showing the types of subdural air collection in cases with asymptomatic subdural pneumocephalus: niveau formation (A, nine cases); crescent shape (B, two cases); biconvex shape (C, two cases); and peaking sign (D, one case). A typical peaking sign was not seen in any of our cases with subdural tension pneumocephalus.

in nine cases of asymptomatic subdural pneumocephalus. They tended to occur more frequently in the former than in the latter type. Judging from the CT appearance, the small air bubbles were located in the cisternal subarachnoid space and the cortical subarachnoid or subdural space. It was not possible to identify exactly whether these small air bubbles on the surface of the brain were in the subarachnoid or the subdural space. In subdural tension pneumocephalus, small air bubbles were seen in the suprasellar cistern in four cases, in the quadrigeminal cistern in one case, in the ambient cistern in one case, and in the cortical subarachnoid or subdural space in four cases (Fig. 3). In asymptomatic subdural pneumocephalus, small air bubbles were trapped in the cortical subarachnoid or subdural space in nine cases and in the suprasellar cistern in one case. Small air bubbles tended to spread diffusely into a variety of cisterns in tension pneumocephalus cases while those associated with asymptomatic pneumocephalus tended to gather in the cortical subarachnoid or subdural space.

Postoperative Midline Shift Change

No patient with subdural tension pneumocephalus showed a midline shift on CT scans either before or after surgery for chronic SDH. However, midline shift was observed in eight of 14 patients with asymptomatic pneumocephalus, all of whom had unilateral hematomas. Postoperatively, the midline shift decreased in seven of these cases and no change was observed in the eighth.

Discussion

Tension pneumocephalus is a relatively rare complication of neurological surgery, and many causes have been suggested for this phenomenon. Burr-hole irrigation of the subdural space for chronic SDH is one of the most common causative operations. Bremer and Nguyen reported a 16% incidence of subdural tension pneumocephalus in 19 operations for chronic SDH, which appears to be an unacceptably high rate compared to our experience of a 2.5% incidence in 196 such operations.

FIG. 3. Computerized tomography scans showing the presence of small air bubbles in the suprasellar cistern (A); ambient cistern (B, arrowhead); quadrigeminal cistern (C, arrows); and cortical subarachnoid and/or subdural space (D).
To establish a definitive diagnosis of subdural tension pneumocephalus, a causal relationship between clinical deterioration and increased tension of the subdural air must be shown. This correlation is not always possible, however, and there are no reports of ICP measurements in these cases. Computerized tomography provides useful information about ICP in the presence of a mass effect produced by subdural air, but evaluation of this effect is difficult because the brain may remain distorted after surgery for chronic SDH. Few workers have reported on the mass effect of subdural air. Monajati and Cotanch stated that midline shift, if present, was often indicative of a mass effect in unilateral subdural tension pneumocephalus, but that it was difficult to assess a mass effect if the condition was bilateral. They cautioned that the presence of more than 65 ml of air could result in tension pneumocephalus. Measuring the exact volume of air is very difficult because of the "partial volume phenomenon," which is caused by the marked difference of attenuation values between air and bone. In this series, there was no significant difference in the volume of air found in tension compared with asymptomatic pneumocephalus. Furthermore, no midline shift was observed in cases with subdural tension pneumocephalus, although it was found in eight of 14 patients with the asymptomatic type. This was probably because all our patients with tension pneumocephalus had bilateral accumulations of air.

A peaking sign is a well-known unique CT finding indicative of increased tension. In this sign, the frontal lobes form a peak in the midline (Fig. 2C). Pop, et al., thought that the peak was formed by bridging veins entering the superior sagittal sinus. In our series, a typical peaking sign was observed in one case with asymptomatic pneumocephalus but was not found in the tension pneumocephalus cases. On the other hand, the Mt. Fuji sign was revealed in four of five cases with subdural tension pneumocephalus: this sign is caused by the presence of air between the frontal tips and of a massive air inclusion over the anterolateral aspects of the frontal lobes. The presence of air between the frontal tips indicates that the tension of the air exceeds the surface tension of the cerebrospinal fluid between the frontal lobes. This Mt. Fuji sign appears to suggest higher subdural pressure than the peaking sign does; however, in our experience, the absence of the Mt. Fuji sign does not necessarily rule out subdural tension pneumocephalus. Even partial replacement of fluid by air (niveau formation) may cause deterioration because vulnerability of the brain to subdural air is quite variable from patient to patient. Niveau formation has not been reported before in subdural tension pneumocephalus, but was observed in one of our cases.

Another interesting finding was the presence of small air bubbles in the cisternal subarachnoid space: this was seen in four of the five cases of subdural tension pneumocephalus. Location of the air in the subarachnoid space was confirmed on CT by the characteristic features described by Osborn, et al. We propose that these air bubbles entered the subarachnoid space through a tear in the arachnoid membrane which had been ruptured easily by the tense air in the subdural space. The patient’s head movement might have precipitated the tear in the arachnoid membrane. Small air bubbles in a variety of cisterns were seen more often and were more widespread in the tension than in the asymptomatic cases. Only one asymptomatic case had small air bubbles in the cistern, and the others had them only in the cortical subarachnoid or subdural space. Case 1 was interesting because the small air bubbles in the ambient cistern may have contributed to the neurological deterioration.

The CT appearance of the Mt. Fuji sign and the small air bubbles in the cisternal subarachnoid space are particularly helpful in making the diagnosis of subdural tension pneumocephalus following surgery for chronic SDH.

References

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