Critical Classification of Craniostomy for Chronic Subdural Hematoma; Safer Technique for Hematoma Aspiration

—Technical Note—

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Abstract

Chronic subdural hematoma (CSDH) is generally treated by twist drill, and one and two burr-hole craniostomy. We proposed new classification of the intraoperative condition of CSDH, and present a safer technique for aspiration of CSDH in one burr-hole surgery. The intraoperative condition of CSDH was classified according to the connections between the hematoma cavity and the extracranial space as follows. The “closed condition” represents only a single route consisting of a tube inserted intraoperatively connecting the extracranial space to the hematoma cavity. The “open condition” includes another route or space, which can freely pass air, saline, or old hematoma fluid, in addition to the tube inserted intraoperatively. Twist drill craniostomy and two burr-hole craniostomy clearly involve the intraoperative closed and open conditions, respectively. One burr-hole craniostomy may involve either condition due to the operative procedure. Aspiration and irrigation of the hematoma is basically free and safe in the open condition, but risky in the closed condition. All of the hematoma can be aspirated through one burr hole under certain open conditions with temporary replacement of the hematoma cavity with air followed by replacement of air with saline. Twenty-seven patients with symptomatic CSDH underwent one burr-hole craniostomy by the above mentioned aspiration technique. There were no special complications. The recurrence rate was average. The substitution of saline after complete aspiration of hematoma carries little risk only under the “open condition,” shortens the operation time, and achieves good irrigation of the hematoma.

Key words: chronic subdural hematoma, burr hole, twist drill, craniostomy

Introduction

Chronic subdural hematoma (CSDH) is generally treated by surgical evacuation, usually resulting in great improvements in neurological condition, but also sometimes causing critical side effects.7,21,23) Craniotomy is generally not performed because of the invasiveness of the procedure. Craniostomy is the main method of surgical treatment,23) and is performed by twist drill craniostomy (diameter less than 5 mm),6,7,13,19,23) one burr-hole craniostomy (8–15 mm),5,7,18,20) and two burr-hole craniostomy.15,23) Twist drill craniostomy was introduced as a less invasive method for the treatment of CSDH, and is used worldwide.13,19) The two burr-hole method is also widely used,15,21) and was introduced to achieve sufficient irrigation, which could reduce the rate of recurrence of CSDH.3,12) One burr-hole craniostomy with or without irrigation may be the most important surgical method and the most widely used in Japan.5,6,11,24

Previous studies, using these three types of craniostomy and these applications, have focused on surgical methods, recurrence, prognosis, supportive technique, and complications to CSDH. However, the effect of the intraoperative condition of hematoma cavity during the surgery on CSDH remains unknown. We designed a new classification of the intraoperative condition of the hematoma cavity in patients with CSDH.
Fig. 1  Upper row: Closed condition. Operative photograph showing only a silicone tube connects the hematoma to the extracranial space, without another route in one burr hole (left). Schematic of the intraoperative condition showing aspiration of hematoma causes hyperextension of the brain (center). Photograph showing the effect of aspirating liquid from a soft package in the closed condition (right).  Lower row: Open condition. Operative photograph showing another route (or space) in addition to the silicone tube (left). Schematic of the intraoperative condition showing internal pressure of the hematoma cavity is equal to the external pressure during aspiration of the hematoma (center). Photograph showing the effect of aspirating liquid from a soft package in the open condition (right).

Critical Classification of Intraoperative Conditions in Craniostomy for CSDH

The intraoperative condition of the hematoma cavity was classified according to the connections between the hematoma cavity and the extracranial space as follows. The closed condition represents only a single route consisting of a tube (silicone tube or others) inserted intraoperatively connecting the extracranial space to the hematoma cavity. The open condition includes another route or space, which can freely pass air, saline, or old hematoma fluid, in addition to the tube (silicone tube or others) inserted intraoperatively (Fig. 1).

In the closed condition, aspiration of old liquefied blood will cause the volume of intra-arachnoid components (brain, cerebrospinal fluid [CSF], blood) to be extended, and injection of saline into the hematoma cavity will cause the volume of intra-arachnoid components to be compressed (Fig. 1). Therefore, rapid aspiration of hematoma, and rapid injection of saline or air is dangerous in the closed condition. Twist drill craniostomy clearly involves the intraoperative closed condition. Consequently, aspiration of blood and injection of saline is contraindicat-
ed. One burr-hole craniostomy usually uses simple drainage without irrigation. Surgeons who dislike air collection in the hematoma cavity will select this method, and usually use a small burr hole and small dural incision. Therefore, the intraoperative closed condition is achieved, and resembles that of twist drill craniostomy. Consequently, aspiration of blood and injection of saline is also contraindicated (Figs. 1 and 2).

Irrigation requires another route to the extracranial space to allow escape of the mixture of hematoma and saline in addition to the irrigation tube. Therefore, the hematoma cavity with two independent routes to the extracranial space is classified as the open condition. Two burr-hole craniostomy involves insertion of the catheter tube into one burr hole, so the other burr hole provides another route to the outer space, and is classified as the open condition. One burr-hole craniostomy can also provide two independent routes, the tube and a dural gap, and so can be classified as the open condition (Fig. 1). Aspiration of the hematoma is basically safe in the open condition. The pressure inside the hematoma cavity should not become negative in the presence of another route, so the internal pressure of the hematoma cavity will remain equal to the external pressure during the operation (Figs. 1 and 2, Table 1).

In one burr-hole craniostomy, two independent routes must exist in one burr hole to maintain the open condition, so any instability in conditions may lead to establishment of the closed condition. For example, if the burr hole and dural opening is not sufficiently large, the drainage tube is relatively thick, or the other root is very small or obstructed by clot, the open condition can change to the closed condition, and aspiration or irrigation becomes risky (Fig. 1). Aspiration in the closed condition may be related to hemorrhagic complications such as intracerebral
hemorrhage and others. Therefore, the surgeon should ensure the presence of another route, thus allowing free aspiration of the hematoma. We have developed a safer technique for aspiration of CSDH using the one burr-hole method.

Materials and Methods

Hematoma evacuation was performed through a one burr-hole craniostomy made over the area of maximal hematoma width. The patient’s head position was controlled to position the burr hole at the highest level in the operative field. The dura and outer membrane were extensively incised in cruciate fashion to provide the maximum size in the burr hole. The edge of the dura was coagulated adequately. During this procedure, old hematoma spontaneously flowed out. A silicone tube was then inserted in the posterior direction so that the top of the tube was positioned at the lowest point of the hematoma cavity. The hematoma was aspirated using a syringe. Maintenance of the open condition was strictly confirmed throughout the procedure. The dural gap (route other than the tube) was sometimes secured using tweezers to ensure the open condition. Sometimes the silicone tube was reinserted in several directions, so that the hematoma could be completely aspirated. All of the hematoma cavity was temporarily replaced with air under the open condition. Saline was injected through the silicone tube until saline flowed out from the other route in the burr hole. The silicone tube was connected to a closed drainage bag, and the skin incision was closed. Brain computed tomography (CT) was routinely performed on the next day, and the drainage tube was removed.

This retrospective study included 27 consecutive patients with CSDHs who underwent the above technique for one burr-hole craniostomy between January 1 and December 31, 2008 in the Fuji Neurosurgical Hospital. Informed consent was obtained from each patient or authorized guardian. The 27 patients were 13 men and 14 women aged from 38 to 93 years (mean 74.4 ± 14.5 years). Six patients underwent simultaneous bilateral craniostomies for bilateral CSDHs at the initial operation (total 33 sides). Data sources included patients’ hospital records and preoperative CT scans or magnetic resonance (MR) images, and postoperative CT scans. Evaluation of the hematoma thickness and density on initial CT was necessary for 31 sides because MR images were not available. The hematoma collection was classified as hypodense, isodense, hyperdense, or mixed, on the basis of the density of the hematoma relative to the brain tissue. The air correction on postoperative CT was estimated according to the criteria reported before. Patients were neurologically classified according to the Markwalder grading.

Results

The etiology of CSDH was head trauma in 11 patients and unknown in 16. Among the patients with known history of head trauma, 3 patients received anticoagulation therapy. The CSDH was located on the right in 9 patients (33.3%), the left in 12 patients (44.4%), and bilaterally in 6 patients (22.2%). On admission, neurological score with Markwalder grading scale was grade 1 in 6 patients (22.2%), grade 2 in 17 (63.0%), grade 3 in 3 (11.1%), and grade 4 in 1 (3.7%). The procedure was performed by M.T. or K.S. Mean duration of the operation was 20.1 ± 2.8 minutes for one side (n = 20) and 40.5 ± 8.0 minutes for two sides (n = 6), less than half of the time reported previously. The radiological findings of the surgical procedure are shown in Table 2. The four recurring CSDHs were treated from 7 to 64 days after the initial procedure (14.8%). One of these patients suffered from decreased platelet concentration and coagulopathy due to severe liver cirrhosis and had to be re-operated on day 7 after the initial procedure. She underwent a third operation on day 9 after the second procedure, and recovered. Repeated aspiration and substitution with saline through the previous burr hole with closed system drainage was done in the other three patients. They were successfully treated with one re-evacuation. On discharge, neurological score with Markwalder grading scale was grade 0 in 17 patients (63.0%), grade 1 in 5 (18.5%), and grade 2 in 5 (18.5%). There were no complications such as infection, subdural empymes, acute intracerebral or cerebellar hemorrhage, and postoperative epilepsy. Symptomatic

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Two intended intraoperative conditions during craniostomies for chronic subdural hematoma</th>
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<tbody>
<tr>
<td>Irrigation</td>
<td>Air collection</td>
</tr>
<tr>
<td>Open condition</td>
<td>sufficient (priority)</td>
</tr>
<tr>
<td>Closed condition</td>
<td>risky</td>
</tr>
</tbody>
</table>

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Air collection

Densities of subdural space
rigated satisfactorily (Table 2).6) The postoperative and postoperative CT showed the hematoma was irre- patient. Duration of the operation was shortened, and relatively thin silicone tube are optimal. The advantage that little subdural air remains. In the one burr-hole procedure without irrigation (simple drainage), minimum dural incision and rapid insertion of the drainage tube may reduce air collection in the hematoma cavity (Table 1).5,10) The Monro-Kellie doctrine is important only to the “closed condition,” but is not related to the “open condition.” Rapid aspiration of hematoma via the tube has little risk theoretically in the open condition. The most general procedure of irrigation of the hematoma by one burr-hole craniostomy is repeated irrigation of the hematoma cavity with saline (or Ringer-acetate solution, etc.) through a silicone tube inserted in several directions until the irrigation return is clear.10) This method needs large amounts of saline, and much time until the irrigation return is clear. The most rapid method of irrigation may substitute saline after complete aspiration of hematoma (a few minutes to complete). Confirmation of opening of another route (open condition) enables the aspiration of hematoma. We were able to shorten the operation time by this method.9) Low density subdural cavity was observed in 77.4% of cases on postoperative CT, compared to 16.1% on preoperative CT. These findings indicate that sufficient irrigation of hematoma was achieved (Table 2). To maintain the open condition, a large dural incision and relatively thin silicone tube are optimal. The surgeon should confirm the presence of the two routes in one burr hole (Fig. 1, Table 1).

The theoretical explanation for the higher recurrence rate after one burr-hole craniostomy is that the residual hematoma fluid contains large concentrations of vasoactive cytokines, inflammatory mediators, and fibrinolytic factors. Complete evacuation of hematoma seems to be directly linked to the success of the surgical procedure. Therefore, two burr-hole craniostomy is more efficient to flush out subdural fluid collections.14,15,21) The two burr-hole method maintains the open condition by design, because the other route is secured by the second burr hole (Fig. 2). The two burr holes are generally 7 cm apart.15) A large part of the hematoma is discharged spontaneously. However, similar hematoma removal may be possible with one burr-hole craniostomy using the method of substitution of saline after complete aspiration of hematoma, excluding the separated type of CSDH. Therefore, the sec-

Table 2 Head computed tomography (CT) findings before and after the surgical procedure*

<table>
<thead>
<tr>
<th>Thickness of subdural space (mm)</th>
<th>Before surgery (mean ± standard deviation)</th>
<th>After surgery (mean ± standard deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean ± standard deviation</td>
<td>20.1 ± 5.1</td>
<td>6.4 ± 4.0</td>
</tr>
<tr>
<td>range</td>
<td>8—31</td>
<td>0—14</td>
</tr>
<tr>
<td>Densities of subdural space</td>
<td></td>
<td></td>
</tr>
<tr>
<td>hypodense</td>
<td>5 (16.1)</td>
<td>24 (77.4)</td>
</tr>
<tr>
<td>isodense</td>
<td>12 (38.7)</td>
<td>0</td>
</tr>
<tr>
<td>hyperdense</td>
<td>4 (12.9)</td>
<td>1 (3.2)</td>
</tr>
<tr>
<td>mixed dense</td>
<td>10 (32.3)</td>
<td>3 (9.7)</td>
</tr>
<tr>
<td>no visible subdural space</td>
<td>—</td>
<td>3 (9.7)</td>
</tr>
<tr>
<td>Air collection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>large</td>
<td>—</td>
<td>3 (9.7)</td>
</tr>
<tr>
<td>moderate</td>
<td>—</td>
<td>13 (41.9)</td>
</tr>
<tr>
<td>small</td>
<td>—</td>
<td>15 (48.4)</td>
</tr>
</tbody>
</table>

*Two cases with no preoperative CT were excluded. **Postoperative CT was performed on the day after surgery.

Discussion

Aspiration and irrigation via a tube are not invasive under the open condition, but are contraindicated under the closed condition during craniostomy for CSDH. Our present modified aspiration and irrigation technique applies this concept. No complications associated with this method occurred in any patient. Duration of the operation was shortened, and postoperative CT showed the hematoma was irrigated satisfactorily (Table 2).5) The postoperative rate of recurrence was almost equal to those report-
ed.6,14,15,16,23)

The Monro-Kellie doctrine holds that the skull is a rigid compartment housing three components, the brain, blood, and CSF, and if the volume of one component becomes decreased, the volumes of the other components must enlarge accordingly.9) In the closed condition of surgery for CSDH, the intracranial components are the brain, circulating blood, CSF, and old hematoma (modified elements of the Monro-Kellie doctrine). Aspiration of the hematoma via the drainage tube may be compensated by the brain, blood, and CSF in the closed condition, resulting in overextension of the brain, and possibly cerebral or cerebellar hemorrhage. Rapid aspiration or irrigation of hematoma via the tube is dangerous in the closed condition.

During twist drill craniostomy, irrigation or aspiration is risky because the closed condition is maintained during the procedure. No theoretical ex-
Hematoma aspiration to treat CSDH under the open condition is theoretically safe. In the open condition, the tip of the tube may be free and not exert torque pressure on the internal capsule of the hematoma. However, the location of the tip of the tube may not be confirmed by the operator. This type of blind procedure requires careful attention and gentle manipulation technique. The inner membrane should never be injured. Residual air collection may be relatively large after our procedure under the open condition (Tables 1 and 2). The patient’s head position should be chosen to position the burr hole at the highest level in the operative field.

Maintenance of the open condition may be the essential technical point in one burr-hole surgery with irrigation. If the surgeon selects the one burr hole and irrigation method, the dura must be opened extensively, and the edge of the dura coagulated sufficiently to secure the tube space and the other route, and the other route confirmed and maintained intraoperatively. Aspiration and irrigation of the hematoma are theoretically safe under the open condition. The substitution of saline after complete aspiration of hematoma carries little risk, shortens the duration of the operation, and achieves good irrigation of the hematoma.

**Conflicts of Interest Disclosure**

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices in the article. All authors who are members of The Japan Neurosurgical Society (JNS) have registered online Self-reported COI Disclosure Statement Forms through the website for JNS members.

**References**

19) Sucu HK, Gökmen M, Ergin A, Bezircioğlu H, Gök-


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