Novel Method for Emergency Craniostomy for Rapid Control and Monitoring of the Intracranial Pressure in Severe Acute Subdural Hematoma

—Technical Note—

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Abstract

Acute subdural hematoma (ASDH) is a critical condition following the onset of traumatic brain injury, and it is essential to immediately reduce elevated intracranial pressure (ICP). Single burr hole surgery/twist drill craniostomy is commonly performed in patients with ASDH as an emergency surgical intervention, usually preceding decompressive craniotomy. A novel method using a cerebrospinal fluid (CSF) drainage catheter kit for rapid drainage of ASDH is described. Percutaneous twist drill craniostomy using a CAMINO® micro ventricular bolt pressure-temperature monitoring kit was performed in the emergency room in 12 patients with severe ASDH. The kit contained a closed-system CSF drainage and pressure-temperature monitoring catheter, which allowed aspiration of the hematoma and monitoring of the ICP. The tip of the catheter was inserted into the hematoma from the forehead. The mean initial ICP was 61 mmHg, with a range of 31 to 120 mmHg. The liquid hematoma was aspirated, and the ICP was temporarily controlled to the normal range. Pupil dilation recovered immediately after aspiration of the hematoma in 3 patients. No complications occurred either during or after the operation. This new method for craniostomy is easy, safe, and effective to monitor and rapidly control ICP in the emergency room. This technique also offers the possibility of evaluating the patient’s prognosis and determining indications for further decompressive craniectomy by the continuation of ICP control under ICP monitoring and evaluation of the reversibility of pupillary findings in ASDH patients.

Key words: acute subdural hematoma, intracranial pressure, emergency craniostomy, single burr hole surgery, traumatic brain injury

Introduction

Severe acute subdural hematoma (ASDH) is often a fatal result of head injury, and the mortality rate ranges between 60% and 90%.22,30) Primary traumatic brain injury is a consequence of the biomechanics of the injury process.30) Therefore, one of the main goals of treatment is to minimize the secondary injury processes of hypoxemia and/or hypotension.16,23,30) Surgical intervention for ASDH includes drainage of the hematoma and decompressive craniotomy, which is performed primarily to reduce the increased intracranial pressure (ICP).5–7,21,23) Single burr hole surgery/twist drill craniostomy for ASDH was previously performed to diagnose subdural hematoma,12) and then to aspirate the hematoma. Currently, the procedure is performed for temporary ICP reduction in the emergency room preceding decompressive craniectomy.5,6,10,11,14,20,31,32) However, the effectiveness of emergency craniostomy for ICP reduction is still controversial. Therefore, decompressive craniectomy is often performed routinely even in the absence of indications. Continuous ICP elevation, despite successful aspiration of the hematoma, is an indication of diffuse brain swelling that can lead to irreversible damage of the brain tissue.9,19,27,33) In contrast, in the absence of brain contusion or brain swelling, craniostomy and aspiration of the hematoma would improve ICP and further surgery would be unnecessary.6,31,32) Therefore, monitoring of the
ICP during craniostomy in patients with ASDH might provide a method to determine the indications for further surgery.

The present study developed a novel method and technique for twist drill craniostomy using a cerebrospinal fluid (CSF) drainage catheter kit, a CAMINO® micro ventricular bolt pressure-temperature monitoring kit (Model 110-4HMT; IntegraTM Neurosciences, Plainsboro, N.J., U.S.A.; purchased from Tokibo Co., Ltd., Tokyo). The CAMINO® monitoring kit was originally developed to monitor ICP in the lateral ventricle of the brain. The kit consists of a sterile transdural-tipped pressure monitoring catheter with a thermistor and accessory items that can access the cerebral ventricles for CSF sampling, drainage, fluid injection, and continuous monitoring of ICP and brain temperature. We inserted the CSF drainage catheter into the hematoma, which allowed rapid aspiration of the hematoma with simultaneous monitoring of the ICP.

### Materials and Methods

Twelve patients with severe ASDH, 7 men and 5 women aged 16 to 79 years (mean 54 years), who suffered either road-traffic injury or fall were transported to Showa University Hospital Emergency Center between 1999 and 2002 (Table 1). Patients with evidence of multiple injuries in addition to the head injury or who were already in a state of cardiopulmonary arrest at the time of admission were excluded from the study.

Every patient was initially resuscitated according to the Advanced Trauma Life Support® guidelines.1) All patients were intubated and given oxygen or artificially ventilated. Lactated Ringer’s solution was infused continuously. The diagnosis of ASDH was based on computed tomography (CT). After diagnosis, emergency craniostomy was immediately performed in the emergency room.

The CAMINO® micro ventricular bolt pressure-temperature monitoring kit was used to perform the craniostomy and aspirate the hematoma. One CT slice showing the hematoma was selected, and the size and the location of the hematoma were measured on this selected slice. The point of perforation was determined on the frontal side of the long axis of the hematoma (Fig. 1). The vertical distance between the selected slice and the orbitomeatal (OM) line (arrow A), and the distance between the midline and the point of perforation (arrow B) were measured. In most cases, the point of perforation was located in the forehead, 4 to 5 cm lateral to the midline, 6 to 7 cm superior to the OM line, and just medial to the superior temporal line. The direction

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<th>Hematoma thickness on brain CT (mm)</th>
<th>ICP before craniotomy (mmHg)</th>
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CT: computed tomography, D: death, GCS: Glasgow Coma Scale, GOS: Glasgow Outcome Scale, ICP: intracranial pressure, n: no, y: yes, VS: vegetative state.
of perforation (degree \( C \)) was determined to be parallel to the long axis of the hematoma. The craniostomy was performed percutaneously under local anesthesia using a twist drill contained in the kit. A bolt was fixed to the skull, and the CSF drainage catheter was inserted into the subdural cavity with a stylet. The depth of the catheter (arrow \( D \)) was determined to be the same length as the long axis of the hematoma. The initial ICP was monitored, and then the hematoma was aspirated with a syringe. During and after aspiration, the ICP and the neurological findings were monitored (Fig. 2). If the ICP exceeded 30 mmHg, the hematoma was aspirated repeatedly.

After craniostomy, decompressive craniotomy was performed in the operating room in 6 patients within 6 hours of the injury. All patients were admitted to the intensive care unit (ICU) postoperatively and received general management of respiratory and cardiovascular conditions. The CAMINO® catheter remained in the subdural cavity and the ICP was monitored continuously.

Results

The mean Glasgow Coma Scale (GCS) score at the time of admission was 4 (3–4 in 9 patients and 5–7 in 3 patients). All patients had unilateral or bilateral dilated pupil(s) caused by transtentorial herniation. The mean time interval from injury to craniostomy was 94 minutes (range, 71–156 minutes). Craniostomy was performed on all patients without major complications. The mean initial ICP was 61 mmHg (range, 31–120 mmHg). After craniostomy and hematoma evacuation, the dilated pupils recovered in 3 patients (Cases 1, 2, and 3).

Further decompressive craniotomy was performed in 6 patients whose ICP was controlled after hematoma evacuation (Cases 1, 3, 4, and 5) or whose dilated pupils recovered after the craniostomy (Cases 1, 2, and 3), and also whose family had a strong desire for intervention despite a bad prognosis (Case 6). After decompressive craniotomy, ICP was monitored in the ICU and ranged from 6 to 48 mmHg (data not shown in Case 6). The ICP was controlled below 15 mmHg soon after decompressive craniotomy, but the brain swelling deteriorated within several days in Cases 1, 3, and 5. Acute epidural hematoma occurred in the contralateral site of the subdural hematoma after decompressive craniectomy, and surgery was performed again in Case 2. Bleeding from the injured brain could not be stopped during decompressive craniectomy in Cases 4 and 6. The ICP decreased temporarily after craniostomy and aspiration of the hematoma, but increased again and could not be controlled and no indication was determined for further surgery in Cases 7 through 12. After 6 months, 2 patients (Cases 1 and 2) remained in a vegetative state, and the other 10 patients (Cases 3–12) had died of elevated ICP.

Discussion

Single burr hole surgery/twist drill craniostomy for ASDH was first performed as a method to quickly diagnose subdural hematoma before CT.\(^{12}\) Burr hole exploration for the diagnosis of intracranial hematomas was performed before CT in patients with head injuries with clinical signs of tentorial herniation or upper brain stem dysfunction, and craniotomy was performed if hematoma was discovered.\(^{2}\) Hemato-
ma irrigation with trephination therapy was performed for ASDH, in which patients underwent a small craniotomy with a diameter of about 3 cm for hematoma evacuation and irrigation. Recently, craniostomy for ASDH has been performed to aspirate the hematoma and control the ICP rapidly in the emergency room preceding decompressive craniectomy. However, without ICP monitoring, the effect of the operation and the indication of further decompressive craniectomy are difficult to estimate. In addition, over-evacuation often leads to acute epidural hematoma in the opposite site.

The new method of craniostomy for ASDH has many advantages in comparison with the conventional method. The new method uses a closed-system CSF drainage and pressure-temperature monitoring kit, which permits monitoring of ICP before and after aspiration of the hematoma. Evaluation of the ICP is essential for estimating the severity and prognosis of head injuries. Various criteria have been proposed for evaluating the severity of ASDH, including preoperative neurological status (GCS), time interval from injury to surgery, and CT parameters such as hematoma thickness and midline shift, but none has adequately defined the severity of the primary brain injury. In this study, the severity of the brain CT did not always reflect the initial ICP. In Cases 8, 9, 11, and 12, the initial ICP was elevated above 60 mmHg even though the size of the hematoma thickness was not greatly increased (10–15 mm). This observation suggested that the combination of diffuse brain swelling and the hematoma would have raised the ICP in these patients. The outcome of ASDH associated with diffuse brain swelling was poor, even when treated with surgical aspiration. On the other hand, in Cases 1, 3, 4, and 5, the parameters on CT scanning were the same or worse (hematoma thickness 15 or 20 mm), but the initial ICP was not greatly increased compared with other cases (range, 31–38 mmHg). Therefore, the initial ICP may be an important prognostic factor.

This study also evaluated the improvement of pupillary findings after ICP reduction. Pupil dilation without reactivity to light signifies severe brain stem compression and is often the only available neurological sign in comatose patients. The dilated pupil(s) recovered after evacuation of the hematoma in 3 patients (Cases 1, 2, and 3). Although the initial ICP increased to 54 mmHg, the dilated pupil recovered after craniostomy, and the patient remained in the vegetative state after 6 months in Case 2. In contrast, although the initial ICPs were 35 and 38 mmHg, the dilated pupils did not recover, and the patients died in Cases 4 and 5. Therefore, assessment of the reversibility of the pupillary findings, with ICP determination, might be another important prognostic factor.

The new method is also suitable for aspiration of the hematoma. Craniostomy for chronic subdural hematoma is associated with surgical complications including inadequate drainage and catheter obstruction. However, the main purpose of the emergency craniostomy in ASDH is to decrease the ICP rapidly, not to remove the whole hematoma. In this study, the catheter was thinner than that used in the conventional method, but could aspirate the liquid component of the hematoma, and the elevated ICP was temporarily controlled to within the normal range.

This procedure is much easier, safer, and less invasive than the conventional method. The entire procedure required only about 5 to 10 minutes. The size of the burr hole is smaller than the usual burr hole, so the perforation can be performed within 1 minute. However, we had to pay careful attention to the point and direction of the perforation because the direction of the drainage catheter was fixed by the direction of the first perforation. The point of the perforation was located on the forehead and the direction was determined to be parallel to the long axis of the hematoma, so that more effective hematoma evacuation was possible by sliding the tip of the catheter. The cosmetic effect was negligible because the incision on the forehead was small.

The disadvantage of this method is that the CAMINO® micro ventricular bolt pressure-temperature monitoring kit is more expensive than the usual catheter. In addition, inadequate drainage can occur because the catheter is thinner than that for the usual method.

The limitation of this preliminary study is that the patients enrolled had severe injuries with bad prognoses, making the advantages and disadvantages of the new method difficult to clarify. Further investigations are needed to determine the potential benefit of this new craniostomy technique.

In conclusion, the new method for craniostomy for severe ASDH using a CAMINO® micro ventricular bolt pressure-temperature monitoring kit to aspirate the hematoma and monitor ICP was easier, safer, and less invasive than the conventional method of craniostomy. The new method allowed rapid aspiration of the hematoma and monitoring of ICP from the acute phase of the injury. In addition, the new method may be suitable to evaluate the prognosis and determine any indications for further decompressive craniectomy by continuation of ICP control under ICP monitoring and evaluating the reversibility of pupillary findings in ASDH patients.
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