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ORIGINAL ARTICLE - BRAIN TRAUMA

Application of neuro-endoscopic target aspiration of the necrotic core for cerebral contusion with delayed progression: technical note

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Abstract
Background The optimal management strategy for cerebral contusion remains controversial, especially when standard craniotomy could not be used. We performed neuro-endoscopic target lesionectomy for the delayed progression of cerebral contusion in order to aspirate the necrotic core, which is the primal source of contusional edema.
Methods The present study included 10 consecutive patients (2 women and 8 men, with a mean age of 67 years old) with traumatic brain injury presenting with delayed deterioration of cerebral contusion where standard craniotomy could not be used. Neuro-endoscopic aspiration of the necrotic core was prospectively performed for all patients. We assessed the computed tomography findings after surgery to evaluate the efficacy of this procedure.
Results Endoscopic surgery was performed promptly after neurological deterioration, with a mean interval between trauma and surgery of 7 days, ranging from 2 to 16 days. During the operation, the centers of contusions comprised serous liquid components in all 10 patients and were easily aspirated by endoscopy. Contusional edemas were markedly decreased in all within 3 days after surgery.
Conclusions Progression of contusional edema can be caused by the accumulation of water into the necrotic core due to the rapid increase in osmolality. In light of the highly liquefied demarcated characteristics of the necrotic core, neuro-endoscopic aspiration could be an optional treatment strategy for cerebral contusion with delayed progression in a minimally invasive manner.

Keywords Cerebral contusion · Endoscopic · Intracranial pressure · Edema

Introduction

The surgical indications for cerebral contusion have been proposed in several guidelines [1, 8] such as deterioration of the neurological status and uncontrollable increase of intracranial pressure (ICP). However, as the clinical features of cerebral contusion vary with location, multiplicity, or accompanied intracranial injuries including acute subdural or epidural hematoma, the optimal surgical procedure for each state is unclear. Several surgical procedures are recommended, including evacuation of intracerebral hematoma, resection of damaged brain, cerebrospinal fluid drainage, decompressive craniectomy, and combinations of these procedures [1, 8], but the strategies differ among institutions [4] and the operative methods of each procedure are not specifically defined.

One advocated pathophysiology of cerebral contusion is considered to be edema caused by focal accumulation of fluid into the hyperosmolar necrotic tissue located in the core of the contusion accompanied by the deposition of blood cells [2–5, 7]. Based on this observation, we attempted neuro-endoscopic target lesionectomy for the delayed progression of cerebral contusion in order to aspirate the necrotic core, which is the primal source of contusional edema. We initially intended this endoscopic procedure for the emergent palliative treatment when standard craniotomy was considered to be much invasive because of patients' age or lost opportunity of surgery in the acute phase, while consequently, neuro-endoscopic aspiration of the necrotic core promptly ameliorated brain edema in all patients without subsequent large craniotomy. Our

This article is part of the Topical Collection on *Brain Trauma*

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Table 1 Summary of 10 cases of cerebral contusion treated by endoscopic surgery

Case	Age (years), sex	Location of contusion treated by endoscope	GCS on admission	GCS before surgery	Interval between trauma and surgery (days)	Other intracranial lesions	ICP monitoring	Blood-fluid interface in contusion	Remission of mass effect	Reduction of ICP < 15 mmHg	GOS 1 month after trauma
1	71, M	Rt. temporal lobe	4	4	16	Contusion in Rt. frontal lobe Traumatic SAH	Yes	Yes	Yes	Yes	D
2	58, F	Rt. temporal lobe	14	12	11	Contusion in Rt. Frontal lobe Rt. ASDH	Yes	No	Yes	Yes	GR
3	70, M	Rt. frontal lobe	12	9	10	–	No	Yes	Yes	–	SD
4	85, M	Lt. frontal lobe	4	5	6	Lt. ASDH	Yes	Yes	Yes	Yes	SD
5	74, M	Lt. frontal lobe	13	7	2	Contusion in Rt. Frontal lobe	No	Yes	Yes	–	SD
6	39, M	Lt. temporal lobe	12	12	5	Contusion in Lt. Frontal lobe Lt. ASDH	No	Yes	Yes	–	MD
7	63, F	Lt. temporal lobe	13	10	14	Lt. ASDH	No	No	Yes	–	MD
8	85, M	Lt. frontal lobe	13	7	2	Skull Fx, Pneumocephalus	No	Yes	Yes	–	SD
9	69, M	Lt. temporal lobe	12	10	2	Lt. ASDH	No	Yes	Yes	–	MD
10	58, M	Blt. Temporal lobes	5	5	2	Contusion in Frontal lobes Hydrocephalus	Yes	Yes	Yes	Yes	VS

Rt right, Lt left, Blt bilateral, SAH subarachnoid hemorrhage, ASDH acute subdural hematoma, GCS Glasgow Coma Scale, Fx fracture, ICP intracranial pressure, GOS Glasgow Outcome Scale, GR good recovery, MD moderate disability, SD severe disability, VS vegetative state, D dead

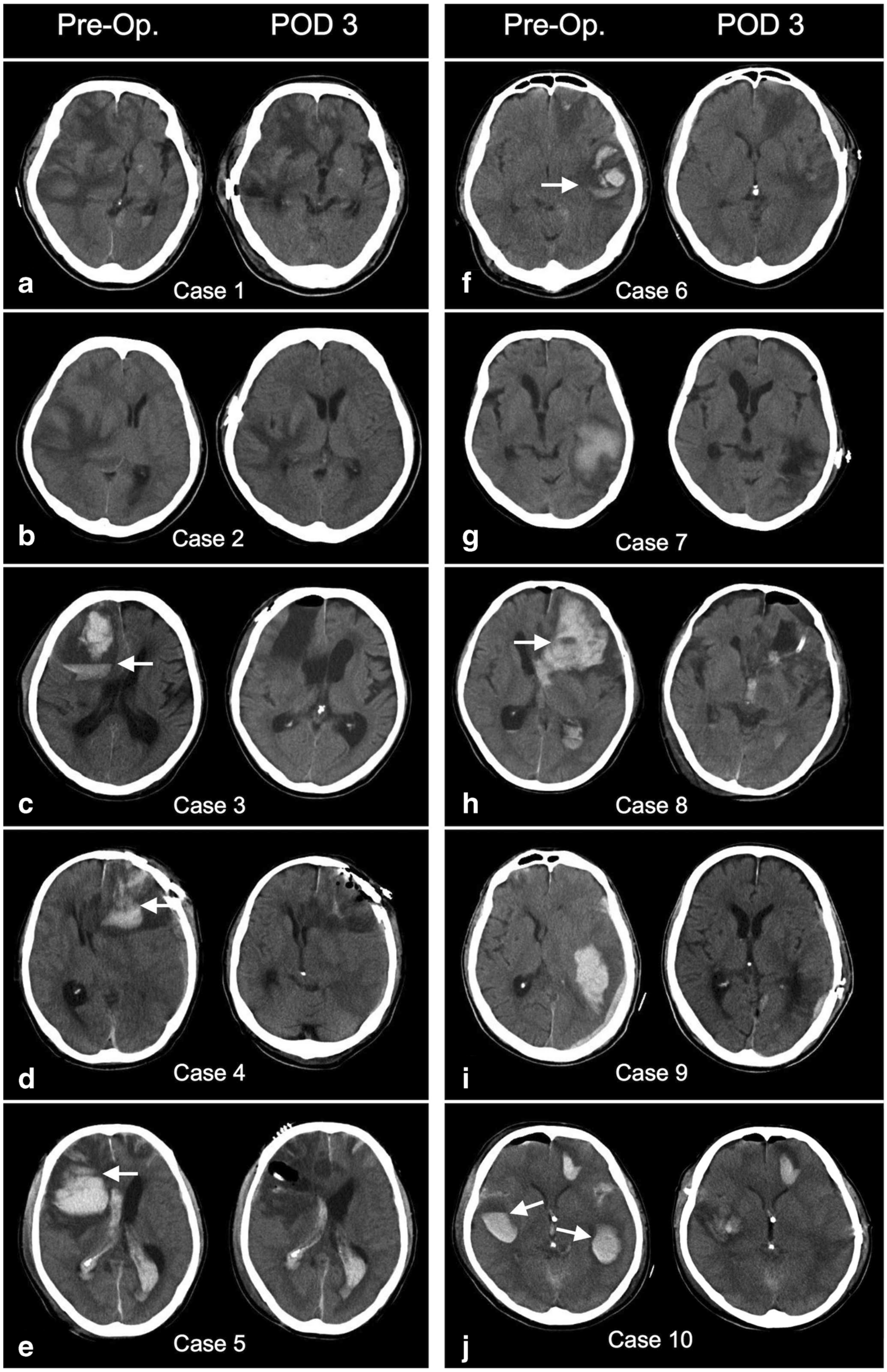

Fig. 1 Computed tomography (CT) scans for our present patients taken preoperatively (left) and 3 days after endoscopic surgery (right). Arrows show the blood-fluid interfaces. Sufficient reduction in contusional edema was obtained within 3 days after neuro-endoscopic surgery. **a** Case 1, a 71-year-old man with right temporal lobe contusion, and surgery at day 16 after trauma. **b** Case 2, a 58-year-old woman with right temporal lobe contusion, and surgery at day 11 after trauma. **c** Case 3, a 70-year-old man with right frontal lobe contusion, and surgery at day 10 after trauma. **d** Case 4, an 85-year-old man with left frontal lobe contusion, and surgery at day 6 after trauma. **e** Case 5, a 74-year-old man with left frontal lobe contusion, and surgery at day 2 after trauma. **f** Case 6, a 39-year-old man with left temporal lobe contusion, and surgery at day 5 after trauma. **g** Case 7, a 63-year-old woman with left temporal lobe contusion, and surgery at day 14 after trauma. **h** Case 8, an 85-year-old man with left frontal lobe contusion, and surgery at day 2 after trauma. **i** Case 9, a 69-year-old man with left temporal lobe contusion, and surgery at day 2 after trauma. **j** Case 10, a 58-year-old man with bilateral temporal lobe contusion, and surgery at day 2 after trauma

procedure could be an optional treatment strategy for cerebral contusion with delayed deterioration in a minimally invasive manner, where standard craniotomy could not be used.

Materials and methods

Between January 2014 and December 2016, 11 contusions in 10 patients (2 women and 8 men, aged 39 to 85 years) presented delayed increase of the mass effect and were indicated for surgical treatment in the present series. Table 1 shows the characteristics of the patients. After admission, all contusions were initially managed conservatively. The reason why we did not perform immediate craniotomy was slight consciousness disturbance in cases 2 (Fig. 2), 3, 5, 6, 7, 8, and 9. The patient in case 1 was in deep coma on admission without notable contusional edema, and underwent continuous monitoring of intracranial pressure. The patient in case 4 underwent emergent trepanation for acute subdural hematoma and intracranial pressure was reduced. The patient in case 10 underwent emergent ventricular cerebrospinal fluid drainage for acute hydrocephalus (Fig. 3). Operation-indicated contusions were located in the temporal lobe in 6 patients and in the frontal lobe in 4 (Fig. 1).

Surgical indication was based on one of the following: (1) development of new neurological symptoms, (2) deterioration of consciousness level by more than 2 points on the Glasgow Coma Scale (GCS), or (3) increase of intracranial pressure over 25 mmHg due to the cerebral contusion. The mean interval between head injury and surgery was 7 days, ranging from 2 to 16 days. In all the cases, we prepared microscopic evacuation of the hematoma/necrotic tissue by large craniotomy, and the neuro-endoscopic surgery was attempted for the purpose of emergent reduction of the ICP prior to large craniotomy.

Operation

Neuro-endoscopic surgery was performed according to the procedure for endoscopic evacuation of intracerebral hematoma under general anesthesia for all patients. We targeted the niveaus in the contusional lesion (blood-fluid interfaces; Fig. 1) and planned the best trajectory with the shortest pathway to the target via the edematous cerebral cortex. Single burr hole was made at the frontal region for the frontal lobe contusion in the supine position, and at the temporal region for the temporal lobe contusion in the supine-lateral position. In all, the fronto-temporo-parietal regions were draped to allow subsequent large craniotomy, to perform microscopic evacuation or external decompression. We introduced a 9-mm endoscopic transparent sheath (Neuroport® regular size; Olympus Corp., Tokyo, Japan) via the planned trajectory and aspirated the liquid component with suction device for endosope (FUJITA Medical Instruments Co., Ltd., Tokyo, Japan) under observation by a rigid endoscope (GAAB®; Karl Storz, Tuttingen, Germany). We did not persist in the evacuation of the solid hematoma and only aspirated the liquid component in the contusion. Hemostasis was obtained by the electrical coagulation via the suction device. In light of the absence of coagulation abnormality in our patient series, we did not use thrombolytic agents.

Efficacy of the neuro-endoscopic surgery was evaluated by the CT scan taken 3 days after surgery, by the disappearance of mass lesion and remission of the mass effect including midline shift and deformation of the ventricles.

Results

During the operation, the centers of the contusions comprised serous liquid components in all cases and were easily

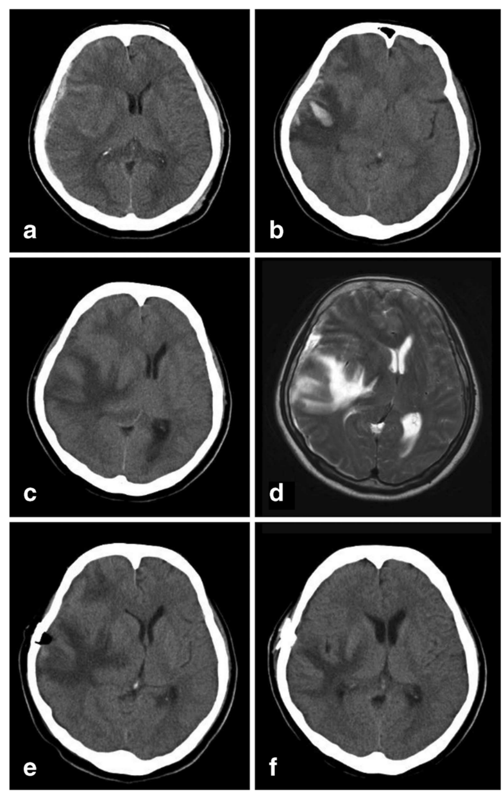

Fig. 2 CT scans and MRI-T2 weighted image for case 2, a 58-year-old woman with fall accident from stairs. **a** CT scan on admission showing thin subdural hematoma in the right temporal region. **b** CT scan 1 day after trauma showing cerebral contusion in the right temporal lobe, conservatively managed because of the absence of neurological symptoms. **c** CT scan 10 days post-trauma after development of left hemiparesis showing increased contusional edema. **d** MRI-T2 weighted image showing fluid accumulation at the contusional lesion. **e** CT scan immediately after endoscopic aspiration of the contusion tissue. **f** CT scan 3 days after surgery showing marked decrease of the mass effect of cerebral contusion, with the intracranial pressure under 15 mmHg and improved hemiparesis

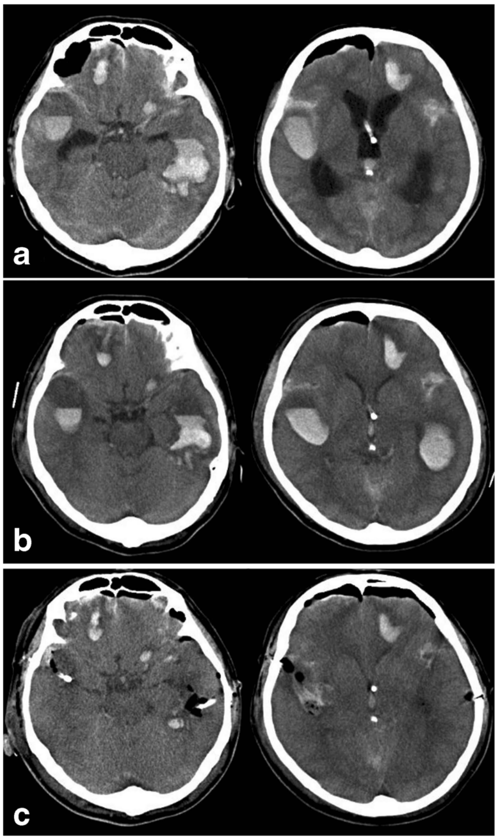

Fig. 3 CT scans of case 10, a 58-year-old man with fall accident. **a** CT scan taken the next day of trauma revealed manifestation of multiple cerebral contusions in his bilateral temporal lobes and bilateral frontal lobes. He underwent ventricular drainage for acute hydrocephalus. **b** CT scan taken 2 days after trauma, showing increased contusional edema. The blood-fluid interfaces were observed in contusions. Lateral ventricles were collapsed with the increasing intracranial pressure to 30 mmHg. **c** Postoperative CT scan revealed the disappearance of the blood-fluid interfaces in both temporal lobes, with the successful reduction of intracranial pressure under 10 mmHg

aspirated by endoscopy (Fig. 4). Pulsatile hemorrhage from arteries was not observed and there were no difficulties in hemostasis in any patient. In our present series, none of the patient required subsequent large craniotomy in light of the conformation of decreased ICP by endoscopic procedures.

Postoperatively, one patient who was admitted with GCS 4 died of pneumonia (case 1). The patients who were comatose on admission and older patients had poorer outcomes. Although it was difficult to evaluate the prognostic benefit of the contusion surgery because of other intracranial lesions, the contusional edemas on CT scans were sufficiently reduced in all patients within 3 days after surgery (Figs. 1, 2, 3, and 4). In patients undergoing intracranial pressure monitoring, the pressure markedly decreased immediately after surgery without recurrent increase over 15 mmHg (Table 1). There were no surgical complications, including postoperative bleeding or infection. Postoperative regrowth of contusional edema was not observed by serial CT scans.

Discussion

Although the generally recommended surgical strategy for cerebral contusion is large craniotomy or craniectomy (evacuation of hematoma and external decompression), our result suggests that reduction of the mass effect can be achieved by less invasive manner by neuro-endoscopic surgery, in a selected group of cases. Our results may suggest that neuro-endoscopic target aspiration of the necrotic core could be an optional treatment strategy for cerebral contusion with delayed progression in a minimally invasive manner, where standard craniotomy could not be used.

In 1957, Freytag and Lindenberg reported that the core of cerebral contusions is composed of necrotic tissues with cellular disintegration and homogenation, and named it the *contusion necrosis proper* [7]. Katayama and colleagues observed a rapid increase in osmolality within the contused brain tissue, and reported that the cause of early massive edema is accumulation of water into the contusion necrosis due to hyperosmolality [3]. The contusion necrosis proper is a well-

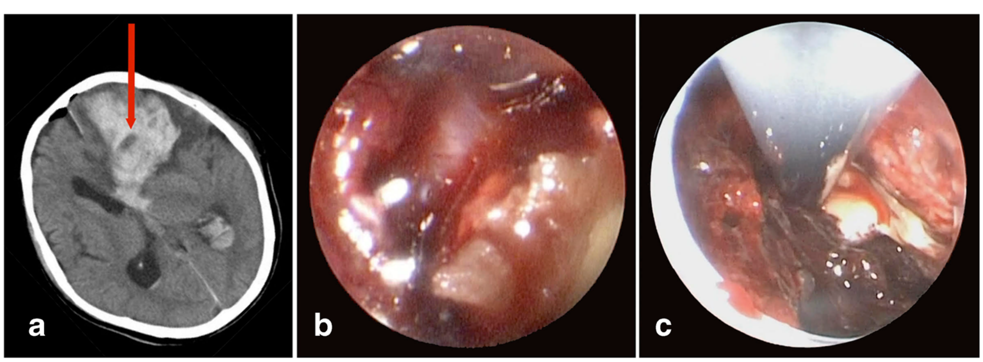

Fig. 4 CT scan and intraoperative endoscopic views of case 8, an 85-year-old man. **a** The red arrow indicates the planned trajectory for neuro-endoscopic aspiration, targeting the blood-fluid interface in the cerebral contusion. **b** Edemotous brain surface observed from the burr hole. **c** After the sprout of dark-red fluid, there remained only a small space for endoscopic observation. Aspiration of the hematoma-like tissue exposed normal brain tissue in its circumference

demarcated area that develops within 12–48 h after trauma [7], and surgical excision of the contusion necrosis can provide satisfactory control of increased ICP, without decompressive craniectomy [5]. Although these theories do not explain all of the mechanisms underlying the delayed progression in cerebral contusion, the successful reduction of the contusional edema in our present cases can be obtained by the aspiration of the contusion necrosis, the primal cause of contusional edema. Katayama et al. examined the blood-fluid interface frequently observed on CT/MRI in the center of the contusion necrosis, and considered that these lesions are formed by the permeation of red blood cells into the highly liquefied center of contusion necrosis [2]. Thus, the existence of the blood-fluid interface can be a considerable finding for the indication of neuro-endoscopic target aspiration. Kawamata and Katayama suggest excision of the contusion necrosis by large craniotomy within 48 h during the period when the demarcation plane between the contusion necrosis and peripheral edema is distinctly visible in order to prevent early massive edema [5]. However, neurological deterioration after cerebral contusion can occur much later (cases 1, 2, 3, 4, 6, and 7), and endoscopic surgery can be smoothly performed for such cases, for multiple lesions or multiple times.

The problems of this study include the unclear applicability of this procedure for patients in more acute phases of trauma. The marked hemorrhage detectable in more acute phases may be pure "hematoma" due to laceration of cortical arteries, and in such cases, extraction of the clots can cause further bleeding, for which hemostasis can be difficult endoscopically, especially in the hyper-acute phase of severe injury when the congealing fibrinogenolysis system often deteriorates [6]. Although not included in the present series, patients with coagulation disorder could need more measured approaches. The purpose of neuro-endoscopic surgery should be limited to the aspiration of the watery material, not persisting to the removal of hard clots.

Although further investigations are necessary to define the best indication of this procedure, neuro-endoscopic surgery can be an optional treatment in those patients where standard craniotomy should not be used (our study includes relatively high-age patients), as a minimally invasive treatment tool.

Conclusion

Progression of contusional edema can be caused by the accumulation of water content into the necrotic core due to the rapid increase in osmolality. Based on the highly liquefied demarcated nature of the necrotic core, neuro-endoscopic target aspiration of the necrotic core can be used as an optional treatment for cerebral contusion with delayed progression as the minimally invasive management strategy, especially when standard craniotomy could not be used.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in this study were in accordance with the ethical standards of the institution and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study formal consent is not required.

Informed consent Informed consent was obtained from individual participants included in the study, when the patient was alert and had enough understanding. When the patient was in coma, informed consent was obtained from her/his families.

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