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Clinical Characteristics and Outcomes of Patients with Cerebral Herniation During Continuous Lumbar Drainage

Sürekli Lumber Drenaj Sırasında Serebral Herniasyonlu Hastaların Klinik Özellikleri ve Sonuçları

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ABSTRACT

AIM: The aim of this study was to investigate the clinical characteristics and outcomes of patients who developed cerebral herniation after continuous lumbar cerebrospinal fluid (CSF) drainage.

MATERIAL and METHODS: We retrospectively reviewed eight patients who developed cerebral herniation after receiving continuous lumbar drainage between January 2009 and March 2012 in our department.

RESULTS: All eight patients were male, aged from 21 to 66 years old. All eight patients received surgical treatment and exhibited impaired consciousness before lumbar drainage, and five (62.5%) also underwent decompressive craniectomy. The average drainage speed in these patients varied from 8.3 mL/h to 20.0 mL/h, demonstrating an inverse correlation with the latency period of brain herniation after initiation of the drainage (p=0.017). Four (50.0%) patients experienced cardiopulmonary instability at the onset of cerebral herniation, requiring immediate resuscitation. After drainage clamping and supportive treatment, seven (87.5%) patients displayed complete reversal of cerebral herniation within 48 h.

CONCLUSION: Cerebral herniation induced by continuous lumbar drainage is mostly reversible if early identification and prompt management are realized. Faster drainage speed may be associated with earlier occurrence of brain herniation during lumbar drainage.

KEYWORDS: Cerebral herniation, Transtentorial herniation, Lumbar drainage, Lumbar puncture, Decompressive craniectomy

ÖZ

AMAÇ: Bu çalışmanın amacı, sürekli lumber beyin omurilik sıvısı (BOS) drenajı sonrasında serebral herniasyon gelişen hastaların klinik özellikleri ve sonuçlarını incelemekti.

YÖNTEM ve GEREÇLER: Bölümümüzde Ocak 2009 ile Mart 2012 arasında sürekli lumber drenaj yapıldıktan sonra serebral herniasyon gelişen sekiz hastayı retrospektif olarak değerlendirdik.

BULGULAR: Sekiz hastanın tümü erkekti ve hastalar 21 ile 66 yaş arasındaydı. Sekiz hastanın tümü cerrahi geçirmişti ve lumber drenaj öncesinde bilinç bozulması yaşamıştı ve beşinde (%62,5) dekompresif kraniyektomi de yapılmıştı. Bu hastalarda ortalama drenaj hızı 8,3 mL/sa ile 20,0 mL/sa arasında değişmekteydi ve drenaj başlamasından sonra beyin herniasyonunun latans dönemiyle ters bir korelasyon göstermekteydi (p=0,017). Dört (%50,0) hasta serebral herniasyon başında kardiyopulmoner instabilite yaşadı ve hemen resüsitasyon gerekti. Drenaj klempleme ve destekleyici tedavi sonrasında yedi (%87,5) hastada serebral herniasyon 48 saat içinde tamamen geri döndü.

SONUÇ: Sürekli lumber drenaj nedeniyle oluşan serebral herniasyon erken tanımlanır ve hızla tedavi edilirse büyük ölçüde geri döndürülebilir. Daha hızlı drenaj, lumber drenaj sırasında beyin herniasyonunun daha erken oluşmasıyla ilişkili olabilir.

ANAHTAR SÖZCÜKLER: Serebral herniasyon, Transtentorial herniasyon, Lumber drenaj, Lumber ponksiyon, Dekompresif kraniyektomi

INTRODUCTION

Continuous lumbar cerebrospinal fluid (CSF) drainage is a commonly used procedure in neurosurgical practice for many occasions, such as in preventing of cerebral vasospasm after subarachnoid hemorrhage (SAH) (10), treating post-traumatic CSF fistula(4), and even reducing raised intracranial pressure (ICP) (17). Complications of this procedure have been well recognized in previous studies (1, 13). Among them, cerebral herniation remains the most severe form, and may lead to an unfavorable outcome. Although previous studies have shown a relatively low incidence of cerebral herniation among patients, clinical characteristics and outcomes associated with this catastrophic event remain to be elucidated.

PATIENTS and METHODS

We retrospectively reviewed eight patients who developed cerebral herniation after receiving continuous lumbar CSF drainage between January 2009 and March 2012 in the Neurosurgical Department of Shanghai Tenth People's Hospital. The Institutional Review Board approved this study with a waiver of written consent.

The lumbar drainage kit from Medtronic Company was used according to the manufacturer's instructions. Indications of this procedure included: (1) aneurysmal SAH or traumatic SAH; (2) postoperative or posttraumatic meningitis refractory to antibiotic treatment; (3) postoperative or traumatic CSF fistula; (4) communicating hydrocephalus. Initial pressure in lumbar cistern was measured before the drainage, and those with a pressure above 26 cmH_2O were excluded from this procedure. Patients with clinical signs of impending cerebral herniation were also excluded, which included pupillary abnormalities, compression or absence of basal cisterns on computerized tomography (CT) scans.

The diagnosis of cerebral herniation was confirmed if the following criteria were met: (1) a significant decrease (≥ 2) of Glasgow Coma Scale (GCS) score after initiation of the drainage; (2) unilateral or bilateral pupillary abnormalities; (3) compression or absence of basal cisterns on CT scans. Drainage clamping and flat positioning were immediately performed at the onset of cerebral herniation. Urgent resuscitation was performed upon the occurrence of cardiopulmonary instability, including tracheal intubation, mechanical ventilation, fluid replacement, and vasoactive medicine administration. Complete reversal of cerebral herniation was defined as a full recovery of the GCS score, normal pupillary reactivity, and cardiopulmonary stability.

Continuous data were expressed as mean±standard deviation. All statistical analyses were performed with SPSS 16.0 for Windows. The *p* values were derived from the Mann–Whitney test or Pearson's correlation test. Differences were considered significant if the *p* value was below 0.05.

RESULTS

As shown in Table I, all eight patients were male, and aged from 21 to 66 years old. Three patients suffered from traumatic brain injury, two from brain glioma, two from ruptured aneurysms, and one from spontaneous intracranial hemorrhage. All eight patients underwent craniotomy before the drainage, and five (62.5%) of them were subjected to additional unilateral fronto-tempero-parietal decompressive craniectomy, with a maximum diameter of bone flap varying from 11 cm to 14 cm.

All eight patients presented with impaired consciousness before lumbar drainage, with the GCS score ranging from 7 to 13. Continuous lumbar drainage was initiated at a varying time period after surgery, from 1 day to 27 days. Initial pressure in the lumbar cistern measured prior to lumbar drainage was 13.9 ± 5.5 cmH_2O, ranging from 6 cmH_2O to 20 cmH_2O. The CSF draining speed of the eight patients was 12.8 ± 4.4 mL/h, and the time interval from the initiation of lumbar drainage to the onset of cerebral herniation was 32.5 ± 23.1 h. A significant inverse correlation was observed between them (r = -0.802, $p = 0.017$, Figure 1).

The GCS score of the eight patients saw a significant decrease at the occurrence of cerebral herniation when compared with before the drainage (5.0 ± 1.2 vs. 10.0 ± 2.4, p=0.001). Four patients also experienced cardiopulmonary instability at the onset of cerebral herniation. Immediate resuscitation was performed aside from drainage clamping and flat positioning. Cardiopulmonary function was re-stabilized within 24 h for the four patients after these procedures were implemented.

Seven (87.5%) patients displayed complete reversal of cerebral herniation within 48 h. Four patients exhibited the reversal within 24 h, and three patients showed the reversal within 24 to 48 h. One patient did not show full reversal within 48 h and remained in a vegetative state upon discharge (four weeks after admission).

ILLUSTRATIVE CASE

A 56-year-old male patient suffered from traumatic brain injury after a fall. He had a GCS score of 12 at admission with bilateral light-reactive pupils. A head CT scan showed a mild brain contusion at the left temporal lobe (Figure 2A). An intraventricular ICP probe (Codman, Johnson) was placed right after admission, and he was admitted in the neurological intensive care unit. After 8 h, the ICP increased to 35 mmHg and the GCS score decreased to 5, with dilated fixed left pupil and constricted right pupil. An immediate CT scan showed an enlarged intracerebral hematoma in the left temporal lobe (Figure 2B). Emergent surgery of hematoma evacuation plus decompressive craniectomy was performed. After the surgery, the GCS score rose to 7, and both pupils became

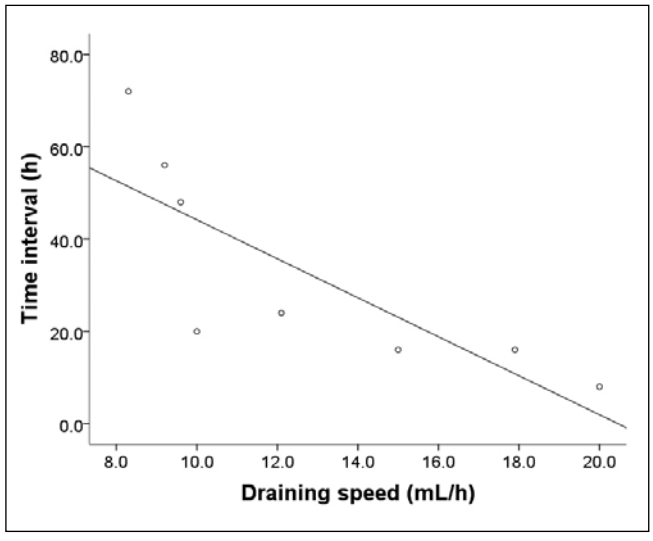

Figure 1: The inverse correlation between time interval from initiation of lumbar drainage to occurrence of cerebral herniation and the draining speed. R square = 0.644.

Table I: General Information of the Eight Patients who Developed Brain Herniation after Continuous Lumbar Drainage

No.	Age/ Gender	Diagnosis	Surgical modality	Time interval between surgery and lumbar drainage (d)	GCS score before lumbar drainage	Initial pressure in lumbar cistern (cmH_2O)	GCS score at the onset of cerebral herniation	Average draining speed before cerebral herniation (mL/h)	Time interval from drainage initiation to cerebral herniation (h)	Cardiopulmonary instability at onset of cerebral herniation	Time interval from onset of cerebral herniation to full reversal (h)
1	34/M	Brain glioma	Tumor resection	5	13	20	5	8.3	72	Yes	42
2	56/M	TBI	HE, DC	7	12	18	5	10.0	20	No	10
3	50/M	TBI	HE, DC	9	7	19	3	20.0	8	No	15
4	21/M	TBI	HE, DC	22	7	10	4	17.9	16	No	21
5	50/M	sICH	HE	6	8	16	5	12.1	24	No	12
6	51/M	Ruptured MCA aneurysm	Coiling, HE, DC	27	12	6	7	9.6	48	Yes	29
7	35/M	Brain glioma	Tumor resection	15	10	15	6	9.2	56	Yes	26
♮8	66/M	Ruptured ACA aneurysm	Clipping, HE, DC	1	11	7	5	15.0	16	Yes	-

TBI, *traumatic brain injury;* ***HE,*** *hematoma evacuation;* ***DC,*** *decompressive craniectomy;* ***sICH,*** *spontaneous intracerebral hemorrhage;* ***MCA,*** *middle cerebral artery;* ***ACA,*** *anterior cerebral artery.*

♮ *This patient did not show full reversal of cerebral herniation and remained in a vegetative state at discharge.*

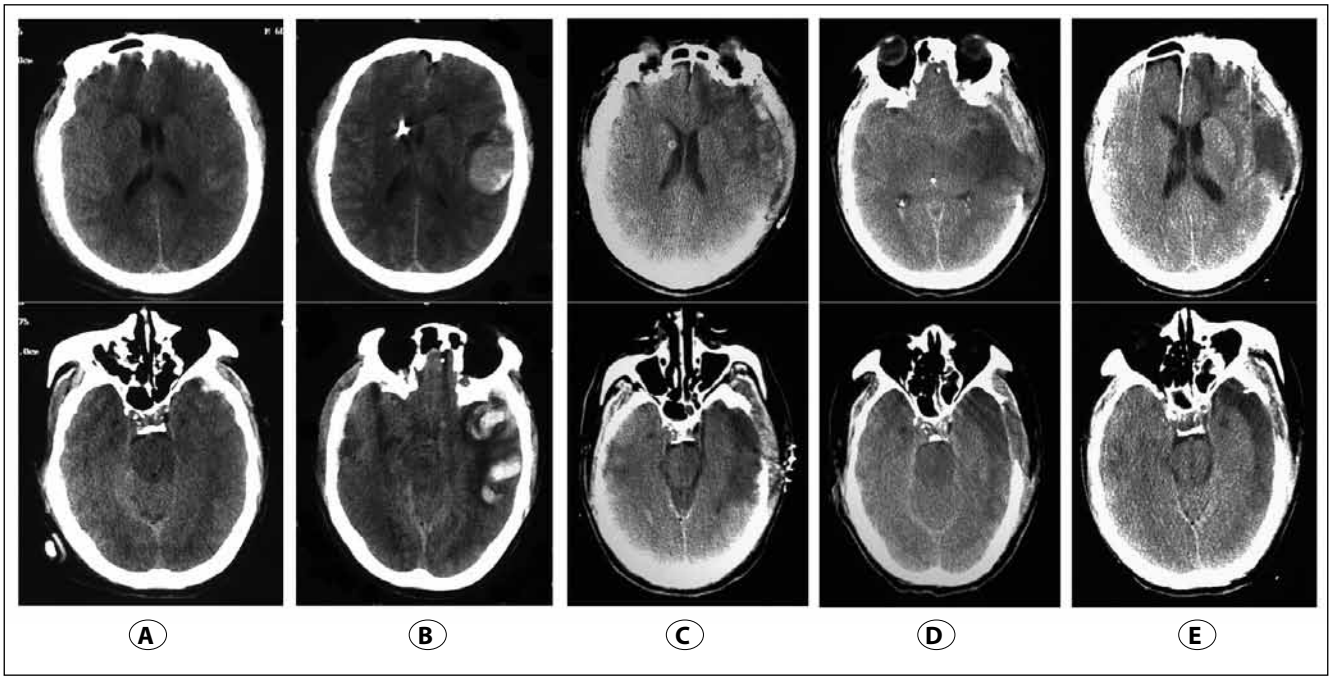

Figure 2: (column A) Head CT scans at different time points. **(column B)** They were respectively taken at admission, 8 h after admission, **(column C)** 7 days after surgery, **(column D)** 20 h after the initiation of lumbar drainage, and **(column E)** 10 h after the onset of cerebral herniation. The bright spot in the right ventricle in column B denotes the intraventricular ICP probe.

light-responsive. ICP was maintained at an acceptable range (<20 mmHg) with medical treatment and extraventricular CSF drainage throughout the first week postoperatively. On the seventh day after surgery, the GCS score increased to 12, and basal cisterns were clear on the head CT scan (Figure 2C). The intraventricular ICP probe was removed, and continuous lumbar drainage was initiated to drain blood-containing CSF to relieve central fever at a target speed of 10 mL/h. After 20 h, the GCS score decreased to 5, and both pupils became light-sluggish. The emergent CT scan showed the absence of basal cisterns (Figure 2D). Lumbar drainage was immediately discontinued and the patient was flat-positioned. After 10 h, the GCS score returned to 12, and the pupils became light-responsive. The head CT scan showed the reappearance of basal cisterns (Figure 2E). The patient regained his consciousness four weeks after the injury.

DISCUSSION

Although uncommon, cerebral herniation is the most severe form of complications related to lumbar puncture or drainage, frequently resulting in brain stem dysfunction or even death(6). Increased ICP is a well-known risk factor of cerebral herniation development following lumbar puncture (9, 15). In this study, all eight patients developed clinical manifestations of cerebral herniation after a varying time period of lumbar drainage despite of normal ICP before the drainage, which equals CSF pressure in lumbar cisterns(11). After drainage clamping and supportive treatment, seven of them displayed complete reversal of cerebral herniation within 48 h and one patient suffered from permanent neurological impairment. These findings suggest that cerebral herniation induced by continuous lumbar drainage is mostly reversible if early identification and prompt management are realized.

Cerebral herniation is defined as an abnormal movement of brain parenchyma driven by a pressure gradient between two compartments. CSF communication between these compartments is essential to avoid such a pressure gradient formation. Therefore, cerebral herniation can also be regarded as a result from insufficient CSF communication between two compartments. Cerebral herniation in this study mainly refers to descending transtentorial herniation, in which the pressure gradient across the cerebellar tentorium serves as the driving force. Because pressure gradient equals flow velocity multiplied by flow resistance, higher pressure gradient may result from faster CSF draining speed or more flow resistance. This may give some reasons to the inverse correlation between the latency period of cerebral herniation and the draining speed in this study.

CSF overdrainage is another risk factor associated with cerebral herniation during lumbar drainage(3). This condition is easy to be early suspected at the presence of discomfort complaints such as headache, nausea, and vomiting in alert patients(14). However, the diagnosis may be delayed among patients with impaired consciousness, which may result in more severe complications such as pneumocephalus or cerebral herniation(7). All eight patients in this study had impaired consciousness before lumbar drainage, which may validate closer monitoring in this group of patients.

Five of the eight patients underwent decompressive craniectomy before lumbar drainage in this study. This procedure involves removing a large piece of skull, destroys the integrity of the cranium, and transforms it from a "closed" box into an "open" box. Increasing research interest has been directed towards its complications (2, 16). Sporadic reports have shown several cases of cerebral herniation development after lumbar puncture or drainage in patients with a large skull defect(5, 8, 12). This form of cerebral herniation is termed as paradoxical herniation, which is characterized by intracranial hypotension and skin depression at the craniectomy site. In these reports, paradoxical herniation occurred at a late stage after surgery, usually more than two weeks after surgery when brain edema diminished. In the current study, three patients who received decompressive craniectomy developed cerebral herniation within two weeks after surgery. This result indicates that patients at an early stage after such a surgery can also be at a risk of developing cerebral herniation induced by lumbar drainage.

In summary, our study indicates that cerebral herniation induced by continuous lumbar drainage is mostly reversible if early identification and prompt treatment are realized. Faster draining speed may be associated with earlier occurrence of brain herniation during lumbar drainage. Patients with impaired consciousness or a large skull defect may be at high risk of developing cerebral herniation after lumbar drainage, and thus require more attention.

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