The Diagnosis and Surgical Treatment of Central Brain Herniations Caused by Traumatic Bifrontal Contusions

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Abstract: The objective of this study was to investigate the diagnosis and surgical treatment of central brain herniations caused by traumatic bifrontal contusions. A total of 63 patients (45 men and 18 women; mean age of 43 years with a range from 20 to 72 years) who suffered from traumatic bifrontal contusions between January 2007 and December 2012 were inspected. The clinical and imaging results were studied for all patients, and we found that swelling of the mesencephalon and a downward shift of the bilateral red nucleus were significant signs of central brain herniation in the image of magnetic resonance imaging. All patients were given a simultaneous bilateral craniotomy for balanced decompressive surgery. The Glasgow Outcome Scale was used to monitor the patients during the follow-up period, which lasted from 6 to 52 months with a mean of 22 months. At the termination of the follow-up period, the following Glasgow Outcome Scale scores were obtained: 14 patients scored 5 points, 22 patients scored 4 points, 7 patients scored 3 points, 13 patients scored 2 points, and 7 patients scored 1 point. Therefore, our study suggested that an early magnetic resonance imaging scan could result in a more timely diagnosis of central brain herniation, and simultaneous bilateral craniotomy was found to be one of the best treatments for central brain herniation to improve patient outcomes.

Key Words: Traumatic brain injury, central brain herniation, traumatic bifrontal contusions, decompressive craniectomy

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Central brain herniation, which is also referred to as bilateral tentorial herniation, commonly occurs in cases of supratentorial bilateral space-occupying lesions,[1–3] such as acute cerebral injury, diffuse cerebral edema, or lumbar cistern drainage. This condition involves the hemisphere's basal ganglion infraplacement passing through the tentorial notch and oppressing the interbrain and mesencephalon, which is also accompanied by the herniation of the temporal lobe sulcus, parahippocampal gyrus, lingual gyrus, and gyrus fornicatus into the tentorial notch. The concept of central brain herniation originated in the 1980s in various clinical reports.[4,5] Central herniation is the end result of the downward displacement of the cerebral hemispheres and the basal nuclei compressing and displacing the diencephalon and the midbrain rostrocaudally through the tentorial notch. Due to its particular pathologic process, early recognition and treatment of this type of brain herniation are vital for patient management.

Traumatic bifrontal contusions are clinically common brain injuries that are initially not serious, but they develop rapidly and often become abruptly severe and endanger the life of patients.[6,7] Moreover, this disease process has been associated with a rapid clinical deterioration from mild neurologic dysfunction to lethal midbrain compression. Therefore, the early recognition of an impending herniation is very important for traumatic bifrontal contusions. The current study[8] suggested that bifrontal decompressive craniectomy should be used as a treatment option for patients with diffuse, intractable posttraumatic intracranial hypertension. However, because of severe hypertension and further brain stem shifting, subsequent craniectomies may further the brain stem injury.[9]

Therefore, in this study, we first investigated the clinical and imaging results for all patients, specifically the magnetic resonance imaging (MRI) scan results. The results showed that swelling of the mesencephalon and a downward shift of the bilateral red nucleus, as seen by MRI, may assist neurosurgeons with an early diagnosis of impending central brain herniation and an immediate decision for decompressive craniectomy surgery. We also applied simultaneous bilateral craniotomy neurosurgery, which was performed by 2 experienced neurosurgeons simultaneously. The follow-up analysis using the Glasgow Outcome Scale (GOS) showed that 43 patients (of a total of 63 patients) recovered well after the operation.

MATERIALS AND METHODS

Subjects

This research project was approved by the institutional review boards of Shanghai Jiao Tong University. All patients who had been treated for a period of approximately 5 years at the hospital in southeast China were assessed for suitability, and a total of 63 patients who underwent simultaneous bilateral decompressive craniectomy surgery at the neuroscience center of Ren Ji Hospital (affiliated with Shanghai Jiao Tong University) between January 2007 and December 2012 were included in the study. All patients who underwent surgery with integrated medical documents were recorded before and after surgery. The study group consisted of a total of 63 patients, consisting of 45 men and 18 women ranging from 20 to 72 years old with a mean age of 43 years. The Glasgow Coma Scale value was estimated by the admitting neurosurgeon immediately after hospitalization.

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Imaging Performance Scan

All patients were examined by emergency computed tomography (CT; Sensation 16; Somatom Siemens, Germany) scan. Standard T1- and T2-weighted sequences of conventional MRI (MR Signa Excite TMHD, GE) at 1.5 T were performed for 5 conscious patients.

Simultaneous Bilateral Decompressive Craniectomy

Twenty-nine patients received operations immediately after admission, and 34 underwent emergency surgery after observation. All patients received a simultaneous bilateral craniotomy for balanced decompression. According to the hematoma distribution, either a bilateral frontal coronal approach or a lateral frontal lobe with a lateral expansion of the pterion approach was taken. A craniotomy was performed up to the margo orbitalis until the frontal pole was fully exposed to remove the bleeding and necrotic brain contusion tissue for comprehensive decompression. After surgery, the patients were treated with conventional hibernation temperature reduction, protected from infection, maintained with controlled intra cranial pressure, received nutritional support or underwent a tracheotomy in the early period, and were later treated with hyperbaric oxygenation.

Follow-Up

The follow-up assessments were conducted during face-to-face interviews. All patients (except for the 7 who died after surgery) have been followed for a period of 1 to 10 years.

RESULTS

Patients' Characteristics

A statistical analysis was performed for the data obtained from all 63 study participants. Table 1 shows the demographic and clinical characteristics for all participants.

TABLE 1. Demographic and Clinical Data of all Patients

Variable	n	%
Age, y		
20–29	2	3.2
30–39	6	9.5
40–49	12	19.0
50–59	23	36.5
60–69	11	17.5
70–79	9	14.3
Sex		
Male	45	71.4
Female	18	28.6
Cause of trauma		
Slipping	29	46.0
Traffic accident	25	39.7
Falling from high places	5	7.9
Hit	2	3.2
Explosion	2	3.2
Glascow Coma Scale, preoperation		
15–13	5	7.9
12–8	33	52.4
7–3	25	39.7

Imaging Results

All patients were examined by an emergency CT scan, and these CT images demonstrated that there were 3 cases of bifrontal contusions combined with epidural hematomas, 38 cases of subdural and intracerebral hematomas, and 12 cases with additional temporal-parietal brain contusions and extensive subarachnoid hemorrhages. Five patients were scheduled for an MRI scan while they remained conscious, and the MRI results showed the following: (1) the tentorial edge of the brain midline was largely shifted down; (2) the mesencephalon swelling had descended to the bottom of the tentorium and was accompanied by brain swelling; and (3) the basal cistern, especially the cistern surrounding the mesencephalon and suprasellar cistern, was oppilated with the mesencephalon oppressed toward the dorsum sellae, whereas the tectum mesencephali was shifted backward and the fastigial cerebellum was backwardly oppressed (Fig. 1). In addition, the bilateral red nucleus was significantly displaced to the bottom of the tentorium as compared with the normal control (Fig. 2).

Outcome After Surgery

All patients received a simultaneous bilateral craniotomy for balanced decompression, and the GOS was used to evaluate the prognosis after operation. Complications related to the simultaneous bilateral craniotomy for balanced decompression surgery were also investigated during the follow-up period (Table 2).

DISCUSSION

The concept of central brain herniation remains somewhat controversial; some scientists believe that this condition represents the end-stage behavior of tentorial herniation, involving a severe patient condition and poor prognosis,[10] whereas others propose that it differs from tentorial herniation because of clinical or pathologic differences.[11] One early indication of tentorial herniation is the dysfunction of the brain's external structure (eg, oculomotor), whereas the indication for central brain herniation is diencephalon dysfunction. The main reports on central brain herniation consist primarily of clinical reports,[2,4,11] and there is a lack of evidence concerning its characteristics, especially regarding imaging diagnosis. Therefore, our study reviewed the 10-year clinical data of patients with central brain herniations and also investigated the imaging results of these patients and the use of simultaneous bilateral craniotomy for balanced decompression surgery.

Central brain herniation demonstrates a top-down developmental process, which first involves the diencephalon and then develops toward the mesencephalon, pon, and medulla oblongata. These movements result in the infraplacement of the bilateral tentorial notch herniation with the brainstem along the axis, causing the above brainstem structure to become oppressed, pulled, and ischemic, which leads to swelling and hemorrhage.[1] The clinical

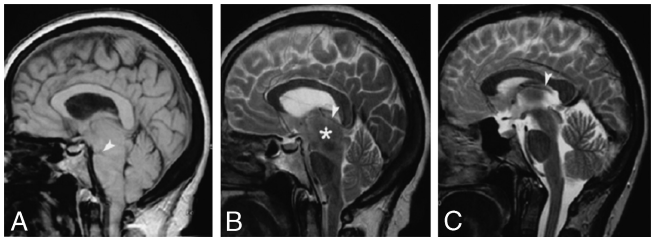

FIGURE 1. The sagittal MR image of the central brain herniation. A, The arrow shows the obviously compressed base cistern. B, The arrow indicates the great cerebral vein shifted downward significantly. The star indicates the swollen mesencephalon. C, The normal control.

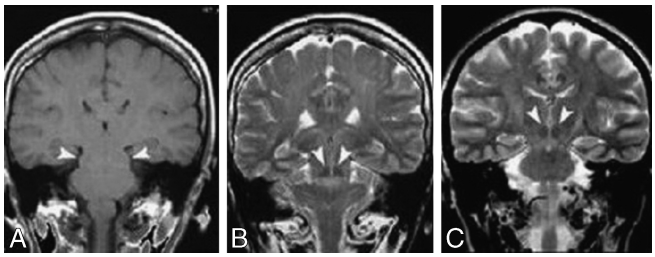

FIGURE 2. The coronal MR image of the central brain herniation. A, The arrow indicates the obviously swollen mesencephalon. B, The arrow indicates the significant downward shifting of the bilateral red nucleus. C, The normal control.

performance of central brain herniation depends on the degree of the anatomic structure's oppression and displacement; typically, this is initially demonstrated as a decrease in the patient's alertness and, subsequently, as dysfunction of the diencephalon. As the disease develops, the temporal lobe sulcus and gyrus hippocampi oppress the third cranial nerve and tectum, which results in lateral or bilateral oculomotor paralysis, failure of the bulbus oculi's ability to gaze upward, and the disappearance of the light reflex. When herniation worsens, the aqueduct of sylvius is obstructed, which leads to an increase in intracranial pressure, hydrocephalus of varied degrees, and papilledema. Moreover, the anterior choroidal artery, posterior cerebral artery, thalamus-perforating artery, and arteria superior cerebelli are oppressed by the tentorium, causing an infraction in the blood supply. In addition, ischemia of the hypophyseal portal system causes the infraction of the corpus mamillare and anterior pituitary. The mesencephalon becomes displaced and oppressed, which leads to corticospinal and corticobulbar pathway ischemia. In addition, the mesencephalon's infraplacement also causes mechanical resistance shear for perforating vessels around the pon and mesencephalon as well as Duret bleeding. The oppression of breathing, as well as the cardiovascular center in the formatio reticularis, induces irreversible coma or death.

Brain trauma is the most serious injury, and bilateral frontal lobe brain damage primarily occurs from a contrecoup injury caused by an occipital force.[14,15] Such a traumatic injury may lead to serious hydrocephalus or intracerebral hematoma formation, resulting in the rapid increase of intracerebral pressure that moves backward from the frontal pole and pushes brain tissues axially. Moreover, this directly compresses the diencephalon and brainstem, forming a central cerebral herniation. Because central cerebral herniation develops quickly with a short disease course, it is relatively difficult to diagnose. Sekula et al[2] considered central cerebral herniation to be a progressive syndrome, whereby the diagnosis depends on typical and progressive syndromes that develop from top to bottom on the brainstem. Moreover, the pupil may not change during the early period of disease, although miosis generally occurs and is followed by mydriasis. Brain CT scans show an extensive bilateral forehead brain contusion with serious brain swelling and an oppressed bilateral ventricle forehead. However, the midline brain structure does not always exhibit remarkable displacement. This typical behavior was observed by MRI in our study, as we found that, as the midline structure of the tentorial margin severely infraplaces, the mesencephalon swells and shifts to be beneath the tentorium. Moreover, this process was accompanied by brain swelling and basal cisterns, where the cistern and suprasellar cistern around the mesencephalon became obturated, the diencephalon was oppressed to the dorsum sellae, the mesencephalon tectum shifted backward, and the cerebellum head was backwardly oppressed (Fig. 1). Compared with a normal MRI image, we also found that the bilateral red nucleus had shifted significantly downward to beneath the tentorium (Fig. 2).

TABLE 2. The Prognosis of Patients After Simultaneous Bilateral Decompressive Craniotomy

Variable	n	%
GOS scale		
5	14	22.2
4	22	34.9
3	7	11.1
2	13	20.7
1	7	11.1
Major complications		
Mental disorders	25	39.7
Hydrocephalus	12	19.0
Epilepsy	11	17.5

As contrecoup bilateral frontal brain damage easily causes central brain herniation, we suggested that the surgical indications for patients with bilateral frontal brain damage should be broadened. In particular, those who demonstrate central brain herniation performance immediately after an injury should undergo emergency surgery and a decompressive craniotomy, whereas patients who do not have a significantly oppressed posterior occipital brain contusion, as judged by viewing an early emergency skull CT, should be operated on only if the following criteria are discovered subsequently during observation: (1) the patients are irritable and disturbed, excluding postural discomfort and uroschesis; (2) a bilateral myosis and a disturbance of consciousness are markedly progressive; (3) a skull CT/MRI demonstrates obturation of the cisterna ambiens, suprasellar cistern, and interpeduncular cistern and particularly if the ventricular system demonstrates a bilateral antecornu that is oppressed and oppilated (which is also a surgical indication despite that the midline does not displace significantly); and (4) the intracranial pressure exceeds 270 mmH_2O continuously. Due to the rapid development and poor prognosis of central brain herniation, the selection of surgical time is vital, as a good prognosis can be achieved with early intervention. Once central brain herniation occurs, this study suggests that the diencephalons period is critical for determining the fate of the patient. Therefore, early symmetric miosis or slight disturbances of consciousness accompanied by irritability represents the key observation regarding the decision for surgery.

To prevent the brain stem from shifting left to right or right to left, we applied a new surgical technique, where 2 practiced neurosurgeons performed the surgery simultaneously. On the basis of the degree of brain damage and the skin and bone flaps, the coronal approach or lateral forehead and lateral pterion approach should be selected, and the bone flap should be at the level of the 2 margo orbitalis. Meanwhile, the bilateral contused, necrotic and inactivated brain tissues and intracerebral hematoma should be removed for internal decompression. Bilateral decompressive craniotomy should be used for patients experiencing significant pupil changes, although the central bone bridge must be maintained to prevent damaging the sinus.

The bilateral frontal lobe is generally referred to as a "silent area," and the tissues in front of the gyrus precentralis are routinely considered unimportant functional areas. However, numerous groups have recently demonstrated that the frontal lobe is related to higher nervous activity, especially emotional activity.[16–18] Therefore, after injury, psychiatric symptoms can easily occur. In our study, 25 patients (39.7%) developed primary personality changes after surgery, including changes in abilities involving abstract thinking, calculating, reasoning, planning, and apathy, which greatly influenced the patients' quality of life during the recovery period. Hence, surgery for bifrontal contusions primarily consists of bone flap removal, intradural tension reduction, and decompression, where the removal of the frontal lobe

contusion can be viewed as supplementary and the frontal lobe should be maintained as much as possible to achieve the optimal surgical effect.

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