Surgical Treatment of Traumatic Bifrontal Contusions: When and How?

Lu Zhaofeng¹, Li Bing¹, Qiao Peng¹, Jiang Jiyao²

OBJECTIVE: The study aimed to investigate optimal surgical timing, methods, and clinical efficacy of bifrontal decompression craniotomy (BDC) on traumatic bifrontal contusions (TBC).

METHODS: A retrospective analysis was performed of 98 patients with TBC who underwent BDC of 2510 patients with traumatic brain injury. The operation-timing score was used to determine surgical timing.

RESULTS: Ninety-eight cases (19%) underwent amended BDC. Initial Glasgow Coma Score was 13–15 in 52 cases (61%). Initial computed tomography showed hematoma volumes of 15.1 ± 5.2 mL in 73 cases (74%). Preoperative hematoma (80.2 ± 20.5 mL; P < 0.05) was significantly enlarged. Fluctuation in the surgery-timing curve is timing for surgery. Average operation time was 4.5 ± 3.4 days after admission. Hematoma was totally evacuated and Glasgow Coma Score significantly increased (P < 0.05) in all cases. In the follow-up Glasgow Outcome Score, 79 patients (81%) recovered well.

CONCLUSIONS: TBC progressed gradually and deteriorated rapidly; this should be strictly and dynamically observed, and patients should be operated on in a timely manner. Changing the operation-timing score is the gold standard for surgery. Amended BDC can significantly improve the prognosis of patients.

INTRODUCTION

Traumatic brain injury (TBI) constitutes a major health and socioeconomic problem throughout the world. It is the leading cause of mortality and disability among young individuals in high-income countries, and globally, the incidence of TBI is increasing sharply, mainly because of increasing motor-vehicle use in low-income and middle-income countries. Occipital impact leading to frontal contrecoup injury is common. The secondary brain injury (ischemia and hypoxia) deteriorates gradually. Multimodal individual monitoring (eg, intracranial pressure [ICP]) as soon as possible is necessary to determine individual treatment. The application of sedative drugs, the mechanism of injury, and other factors limit Glasgow Coma Score (GCS) application.

Decompressive craniectomy (DC) performed for the management of intracerebral hemorrhage alone is more controversial in light of the DECRA trial (DC in Diffuse TBI), which was associated with more unfavorable outcomes. Studies showed that obvious brain contusions could be seen in computed tomography (CT) scans of 70% of patients with severe brain injuries. CT scans based on GCS examination could be used as a criterion in patients who need surgery. Combined evaluation of multi-indicators (including injury mechanism, size of hematoma and edema, neurologic impairment, and so on) is still the most important indication for therapy strategies. The Brain Trauma Foundation evidence-based guidelines have defined threshold values for volume and thickness of hematomas that require evacuation (class II and III evidence). However, traumatic bifrontal contusions (TBC) have the characteristics of gradually progressing hematoma/edema and rapid deterioration as a result of central herniation, even if the patient is...
conscious at the time of admission. The state of consciousness, dynamic and timely CT, and even ICP monitoring after admission should be closely observed and analyzed. To reduce mortality and improve outcomes, timely identification of patients who need surgical intervention is important. However, there are still controversies regarding TBC timing and treatment method.4

We retrospectively analyzed the clinical features of 98 patients with TBC in our department and the timing of operation, the operation method, and the prognosis.

METHODS

General Data
Clinical data of 2510 patients with TBI admitted to the surgical intensive care unit (ICU) from January 2000 to June 2015 were collected. Ninety-eight patients with TBC underwent surgical treatment by neurosurgeons. Sixty-two patients were male and 36 were female. Average age was 44.5 years, with the youngest patient being 13 years old and the oldest being 76 years old. Causes of injury were as follows: 36 cases of falling from height, 20 cases of accidental injury, 78 cases of injury caused by ground level falls. Injury mechanisms included 82 cases of contrecoup injury and 16 cases of coup injury. Occipital bone fracture was present in 70 cases, and forehead fracture was present in 12 cases. Sixty-six cases presented with occipital subcutaneous hematoma, and 11 cases presented with forehead subcutaneous hematoma. On admission, GCS was 6–8 in 9 cases, 9–12 in 38 cases, and 13–15 in 51 cases.

Exclusion Criteria
The exclusion criteria were multiple serious injuries (injury to 2 or more organs and undergoing abdominal surgery or chest surgery); heart, lung, liver, kidney, or other organ function failure; pregnancy or lactation; admission or rescue after bilateral pupil scattering, ventilator application; patients with cerebral rigidity; TBC combined with other types of hematoma; and admission GCS less than 5.

Clinical Manifestation and Imaging Data
After the patients were admitted to the ICU, clinical data were recorded by 2 neurosurgeons. Cranial CT (CCT) scans were performed every 4–6 hours for 48 hours according to the patient’s condition. Subsequent CT scans depended on clinical manifestations, such as aggravated disorder of consciousness, enlarged hematoma/edema (CT scan), midline structure shift, ambient cisterns not clear, bilateral anterior horn of lateral ventricle compressed and having become small, the suprasellar cistern, quadrigeminal cistern, or the third ventricle compressed or having disappeared. The volume of hematoma and edema was calculated by 2 radiologists using the Coniglobus formula (A × B × C/2).

Timing of Operation
All patients with TBC were closely observed and measured by 2 neurosurgeons. The change curve of the timing of operation score was drawn and recorded every 2 hours.

The score is divided into 4 grades:

I (1 point): there was no significant change in GCS or no significant change in the volume of hematoma and edema;

II (2 points): GCS decreased to 9–12 or the volume of hematoma and edema increased significantly;

III (3 points): GCS decreased to 6–8 or the volume of hematoma and edema increased significantly;

IV (4 points): GCS decreased to below 6 or hematoma and edema volume increased significantly; bilateral mydriasis and vital signs were not stable.

Figure 1. The changing curve type of operation-timing score. (A) Flat type curve, O + Co; (B) Mountain type curve, O + Co; (C) Hillside type curve I, II, OP; (D) Hillside type curve II, OP. O, observe; Co, conservative; OP, operation.
The score curve is divided into 4 categories; if it reaches the latter 2, emergency bifrontal decompression craniotomy (BDC) should be carried out immediately (Figure 1).

**Surgical Methods**

All patients with TBC who met the surgical criteria underwent a modified BDC. Patients were placed in the supine position, with their heads fixed by a headstock system (DORO Headrest System, Freiburg, Germany) or head rest. The head of the bed was elevated 15°–20° (reverse Trendelenburg position). A modified bifrontal coronal incision was used, and the preferential craniotomy side was selected according to hematoma and edema volume.

**Skin Incision.** The bicoronal skin incision runs from 1.5 to 2 cm above the bilateral zygomatic arch, pretragal 0.5–1.0 cm, walking within the hairline. Total length of incision was about 22.1 ± 3.1 cm.

**Skin Flap.** Skin was raised in 1 flap to the forehead. The temporalis muscle was kept intact on both sides. Only the keyhole and temporal line were exposed totally. The periosteotomy ran respectively 0.5 cm apart from the midline and along the skin edge to each temporal line.

**Burr Holes.** Four burr holes in each side were located along the exposed range of the periosteum, with the first burr hole located in the keyhole. The medial margin of each bone flap was about 0.5 cm from the midline, the lower margin was about 0.5 cm from the superior orbital, and the lateral margin was located on the temporal line. The anterior skull base was fully exposed. Each bone flap was about 4 cm × 6 cm, leaving a strip of midline bone bridge covering the superior sagittal sinus.

**Dural Incision and Suture.** The dura mater was cut along the edge of the bone window in the direction of the superior sagittal sinus. The periosteum was applied to relaxation suture dura mater posthematoma evacuation. The bone flap was removed for decompression. Biological glue was used to temporal muscle flap-gelatin sponge-periosteum consisted of sandwichlike structure to seal the opened frontal sinus (Figure 2).

**Postoperative Assessment and Treatment**

Changes in vital signs were observed by neurosurgeons every 2 hours. Routine postoperative CCT scans were performed to detect the patient’s intracranial condition. Whether or not tracheotomy was performed depended on the patient’s condition of...
consciousness. All patients were routinely conservatively treated with mannitol, furosemide, and antiepileptic drugs.

**Outcome**

Three months of patient follow-up was recorded by 2 neurosurgeons according to the Glasgow Outcome Score (GOS). The rating grade was 5) good recovery and return to normal life, despite the slight defect; 4) mild disability, but can live a life of independence; can work under protection; 3) severe disability awake, requires care in daily life; 2) patients survive in a vegetative state, with only a minimal response (such as with the sleep/wake cycle) and eyes open; and 1) the patient died.

**Statistical Analysis**

Continuous variables were presented as mean or median and standard deviation. We considered a confidence interval of 95%, and a Student t test was used to make comparisons. A P value less than or equal to 0.05 was considered to be significant. Data analyses were performed in SPSS Statistics 18.0 (SPSS, Chicago, Illinois, USA).

**RESULTS**

**Clinical Data Analysis**

Among the 98 TBC cases, there were 62 male patients (63%) and 36 female patients (37%). Thirty-six cases (37%) were caused by falling from height, 20 cases (20%) were caused by traffic accident injury, and 42 cases (43%) were caused by ground level falls. Eighty-two cases (84%) showed contrecoup injury and 16 cases (16%) showed coup injury. Occipital bone fracture was present in 70 cases (71%) and frontal bone fracture in 12 cases (12%). There were 66 cases (67%) with occipital subcutaneous hematoma, and 11 cases (11%) with frontal subcutaneous hematoma. The GCS was 6–8 in 9 cases (9%), 9–12 in 38 cases (39%), and 13–15 in 51 cases (52%) on admission.

After injury, coma occurred in 10 cases (10%), headache in 82 cases (84%), vomiting in 36 cases (37%), irritability in 45 cases (46%), apathy in 11 cases (11%), and obvious mental symptoms, such as hallucinations, in 23 cases (23%). Hemorrhagic cerebrospinal fluid leakage was present in 18 patients (18%) and subarachnoid hemorrhage (SAH) in 52 patients (53%). Seizures occurred in 5 cases (5%). In 2 cases (2%), 1 pupil was dilated and the eyelid was drooping on admission. The first CCT scan immediately on admission showed patchy and tiny contusions (spotted contusions) in 17 cases (17%), with a hematoma volume of 15.1 ± 5.2 mL in 73 cases (75%) and 30.2 ± 5.1 mL in 8 cases (8%). Patients stayed in the ICU for a period of 12.3 ± 3.2 days (Table 1, Figures 2 and 3).

**Timing of Operation**

Average operation timing was 4.5 ± 3.4 days after admission. Among these, 8 (8%) patients were operated on within 1 day of admission to the ICU, 20 patients (20%) within 2 days, 31 patients (32%) within 3 days, 32 patients (33%) within 4 days, 6 patients (6%) within 7 days, and 1 patient (1%) within 10 days (Table 2).

**Assessment of Efficacy**

Dynamic CCT showed satisfactory removal of hematoma in 98 patients (Figure 4). At 3 days after surgery, the GCS was 13 in 92 cases (94%) (P < 0.05), 6 in 6 cases (6%), and 14 in 93 cases (97%) (P < 0.05). The GCS was 6 in 5 cases (5%) at 7 days after operation. Two patients had cerebrospinal fluid rhinorrhea and underwent repair surgery 1 month later. At the 3 months follow-up, the GOS score was 5 in 79 cases (81%), 4 in 14 cases (14%), 3 in 2 cases (2%), and 2 in 1 (1%) case. (2%) patients died (Table 3).

**DISCUSSION**

TBCs have unique features compared with contusions in other locations. Awake TBCs often lead to rapid deterioration late in the clinical course, with the characteristics of talk and die. The patients with TBC present with mild head injury (GCS 13–15) and then deteriorate and die abruptly from intracranial causes. This accounts for 2.6% of overall TBC, and the annual incidence did not significantly alter over the 10-year period. A combination of high GCS and benign clinical course for several days made aggressive management of these patients difficult to justify. For the first time, in this study, we examined when and how to treat this subgroup timely and appropriately. The primary finding of this study is that the pathologic process could be controlled with timely BDC and that good recovery outcomes are possible.

**General Clinical Features**

Research showed that the causes of TBI have changed from traffic accidents to falls or falling from heights with the aging and

<table>
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<th>Table 1. General Data</th>
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<tr>
<td>Characteristic</td>
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<tr>
<td>Sex</td>
</tr>
<tr>
<td>Male</td>
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<tr>
<td>Female</td>
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<tr>
<td>Cause</td>
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<tr>
<td>Traffic accident</td>
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<tr>
<td>Falling</td>
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<tr>
<td>Falling from a height</td>
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<tr>
<td>Mechanism</td>
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<tr>
<td>Contrecoup</td>
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<tr>
<td>Coup</td>
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<tr>
<td>Glasgow Coma Score on admission</td>
</tr>
<tr>
<td>6–8</td>
</tr>
<tr>
<td>9–12</td>
</tr>
<tr>
<td>13–15</td>
</tr>
<tr>
<td>Fracture</td>
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<tr>
<td>Occipital</td>
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<tr>
<td>Frontal</td>
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<tr>
<td>Hematoma</td>
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<tr>
<td>Occipital subcutaneous</td>
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<td>Frontal subcutaneous</td>
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developing of society. Average age also increased from 25 to 48 years. This study showed that 78 patients (80%) with falling injury were an average age of 44.5 years old, which was similar to the previous study. Despite the relatively low risk of a GCS of 15 in patients with brain contusion, Smits et al.6 found that 14% of patients with TBI with a GCS of 14 had intracranial lesions. Patel et al.7 unequivocally showed a 2.15 times increase in the odds of death (adjusted for case mix) for patients with severe head injury treated in nonneurosurgical centers versus neurosurgical centers. In our study, 98 patients (98/2510, 3.9%) were admitted to the surgical ICU and underwent operations. Santiago et al.8 found a statistically significant association between frontal traumatic intracerebral hemorrhage and impact sites located on the anterior area of the head. The contrecoup represents a risk factor independently associated with hemorrhagic progression. Forehead contrecoup injury is often associated with fracture of the occipital bone. It was found that the incidence of skull fracture was 64% in patients with craniocerebral injury.9 This study showed that 82 cases (84%) had contrecoup injury, with 16 cases (16%) of coup injury. Skull fracture is an important risk factor for brain injury, and it is closely related to the prognosis.10 Seventy cases (71%) presented with occipital bone fracture, and 12 cases (12%) presented with forehead fracture. The high incidence of fractures in this group was a result of the injury mechanism. We also had the experience of conservative treatment of frontal contusion with occipital bone fracture, which reminded us that much attention should be paid to frontal contusions with occipital fractures.

Figure 3. Surgical incision and image before and after operation. (A) Bifrontal contusion (8 hours after injury); (B) bifrontal contusion (1 day after injury); (C) bifrontal contusion (2 days after injury); (D) skin incision (right view); (E) skin incision (anterior view); (F) skin incision (left view); (G) anterior view after operation.
Cerebrospinal fluid leakage was found in 15% of frontal depression fractures, and the incidence of intracranial inflammation as a result of fracture was 15%–30%. The cerebrospinal fluid leakage was 18% (88/48) in this group, which was similar to that of the former report. Postoperative cerebrospinal fluid leakage was repaired in 2 patients (who recovered well) 1 month after surgery. Scholsem et al.11 reported that intracranial gas (70%) and SAH (82.5%) were more common in patients with TBI with skull fractures. It is believed that intracranial gas accumulation is also an important cause of intracranial infection. Eight cases (8/12) of intracranial gas and no intracranial infection occurred in this group. This might be associated with good environment and early antibiotic treatment in the ICU. Studies have shown that the incidence of SAH was 42.5%. The incidence of SAH in this group was 52.1% (52/98), which may be not related to the initial overall GCS. We believe that the difference is caused by the mechanism of injury and that SAH might be a risk factor for TBC.

Bokhari et al.12 showed GCS of 9–12 (92%), and 13 (8%) for cases of admission for bifrontal contusion. Our study showed a GCS of 6–8 in 9 cases (9%), 9–12 in 38 cases (39%), and 13–15 in 51 cases (52%). Eight patients who had lower GCS were operated on within 1 day. Gao et al.13 showed GCS of 13–14 in 53 cases (42%), 9–12 in 38 (39%) cases, and 13–15 in 30 (28%) TBC cases. We postulate that the difference is mainly caused by rapid and timely transport and a named green channel for trauma in the emergency department. The time from injury to admission was more appropriate for initial injury judgment.

Studies have indicated that the frontal pole and medial and lateral frontal lobe lesions correspond to a series of behavioral, will, and affective syndromes, respectively, even pseudopsychopathic syndromes.14 Bifrontal contusions manifest common symptoms, such as coma in 9 cases (9%), headache in 82 cases (84%), and vomiting in 36 cases (37%), that are also found in other types of TBI; psychiatric symptoms, such as irritability in 45 cases (49%), indifference in 11 cases (11%), and hallucination and delusion in 23 cases (23%) in this group. These are all alleviated or disappear after operation.

Wang et al.15 reported that the incidence of epilepsy in severe, moderate, and mild brain injury was 19.0%, 10.3%, and 6%, respectively. Seizures in 5 cases (5%) in this group, all occurred within 1 week after injury. This might be associated with low mechanism of injury and most are categorized as mild. TBI and prophylactic intravenous infusion of sodium valproate are administered on admission.

Two of our patients (2%) showed primary injuries of the oculomotor nerve, with ptosis and dilated pupils from traffic accidents, which were related to the fracture of the anterior skull base. This is similar to the previously reported 1.2%. In our study, conservative treatment was implemented in these cases.

TBCs occurred in up to 8.2% of all TBI. The occurrence of traumatic parenchymal mass lesions reached 13%–35% in TBI, representing as much as 20% of all surgical intracranial lesions in published series. The first CT scans on admission showed tiny and patchy injuries in 18 cases (18%), a hematoma volume of 15.1 ± 5.2 mL in 73 cases (74%), and a hematoma volume of 30.2 ± 5.1 mL in 8 cases (8%). Dynamic CT showed that preoperative hematoma (80.2 ± 20.5 mL; P < 0.05) was significantly enlarged. Peterson et al.16 found 8.5% of TBCs (13/153) with hematoma volumes no less than 30 mL, and 54% (7/13) underwent surgery. This difference indicated that we had taken a more active and practical approach to assessing the patient’s condition, such as using the operation-timing score and its changing trends.17

### Timing of Operation

The main focus of TBCs is the development of trends and the treatment process. This evolution related to many factors, such as hemorrhagic expansion, increasing pericontusional edema, and the appearance of delayed lesions. Twenty-five to forty-five percent of patients with cerebral contusion deteriorated in as few as 2 hours after injury.18 Dynamic CT reflected dynamic changes and further deterioration after TBI. Newcombe et al. pointed out that penumbra exists in TBC, which is closely related to hematoma and edema expansion. Peterson et al. also showed that 54% of patients with bifrontal contusion underwent surgical treatment because of the delayed worsening.

The temporal pattern of TBI progression has been widely reported, which relates to an early evolution phase, within 12–24 hours from injury, mainly as a result of hematoma expansion, and to a late phase, lasting 5–10 days after injury, as a result of increased pericontusional edema. Surgery timing has so far been the most disturbing problem to resolve.19 Serial neurologic examinations are the first and most widely used indicators.

### Table 2. Timing of Operation

<table>
<thead>
<tr>
<th>Number of Cases (%)</th>
<th>Glasgow Coma Score</th>
<th>Initial Hematoma Edema Volume (mL ± SD)</th>
<th>Timing (days)</th>
<th>Timing Score</th>
</tr>
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<tbody>
<tr>
<td>8 (8)</td>
<td>8–8</td>
<td>30.2 ± 5.1</td>
<td>≤1</td>
<td>3</td>
</tr>
<tr>
<td>20 (20)</td>
<td>8–10</td>
<td>15.1 ± 5.2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>19 (19)</td>
<td>10–12</td>
<td>15.1 ± 5.2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>34 (35)</td>
<td>13</td>
<td>15.1 ± 5.2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>16 (16)</td>
<td>14</td>
<td>Tiny and patchy</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>3 (3)</td>
<td>15</td>
<td>Tiny and patchy</td>
<td>10</td>
<td>2</td>
</tr>
</tbody>
</table>

SD, standard deviation.
However, they are not reliable in deeply comatose or sedated patients. Emergency operation (within 24 hours after injury) mainly depended on radiologic results. Timing of delayed surgery consisted of 1) hematoma or edema size expansion, 2) clinical manifestation deterioration, or 3) significant increase in ICP. Intracranial hypertension develops in up to 77% of cases, and increased ICP is related to poorer outcome. The effectiveness of ICP monitoring in TBI has been questioned; however, no monitoring technique can improve outcomes unless it can drive an appropriate intervention. ICP monitoring carries a 0.5% risk of hemorrhage and a 2% risk of infection. This has been our motivation to look for a simpler and more

Table 3. Data for 2 Patients

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age (years)</th>
<th>Mechanism</th>
<th>GCS on Admission</th>
<th>Hematoma/Edema Volume (mL)</th>
<th>Tracheotomy</th>
<th>Timing of Operation (days)</th>
<th>Cause of Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>55</td>
<td>Contrecoup</td>
<td>10</td>
<td>30</td>
<td>Yes</td>
<td>4</td>
<td>Renal failure (5 days)</td>
</tr>
<tr>
<td>Male</td>
<td>76</td>
<td>Contrecoup</td>
<td>13</td>
<td>25</td>
<td>Yes</td>
<td>3</td>
<td>Pulmonary embolism (7 days)</td>
</tr>
</tbody>
</table>
effective indicator. GCS of 9–13 made up 91% (89/98) of cases in this group. Physical examinations and CT showed mild disturbances and awakened states. Despite the existence of psychiatric symptoms, routine sedative use is not recommended in our ICU. ICP monitoring is also not routinely performed in these patients. The optimal timing of surgery because of the talk and die characteristic proved to be important in this study.

In view of this, we created a simple and practical TBC score with the following characteristics:

1) The score is divided into 4 grades; all patients with TBC admitted to the ICU were closely observed and recorded by neurosurgeons.

2) The changing curve was drawn as the main basis for judging the patient’s condition.

3) The score curve is divided into 4 categories; if it reaches the last 2, emergency BDC should be implemented without further waiting.

The advantage of this approach is that it was not only timely and accurately monitored the patient’s condition to select the optimal timing of surgery but it also helped to avoid the influence of subjective factors. This is helpful for treatment, especially in TBCs. Thus, we are also able to avoid premature surgery in most cases. Some investigators reported that early surgery (≤1 days) did not significantly improve the prognosis in frontal injury. However, we believe that it is the most appropriate solution, especially for awake cases in the ICU. Among these cases, 8 patients (8%) were operated on within 1 day, 20 patients (20%) within 2 days, 31 patients (31%) within 3 days, 32 patients (32%) within 4 days, 6 patients (6%) within 7 days, and 1 case (1%) within 10 days after admission to the ICU. Studies showed the average hematoma development time for frontal lobe contusions (including unilateral and bilateral) to be approximately 5 days after admission. A previous study showed that the timing of the operation in TBCs was 4.5 days after injury. These are basically the same results found in our study. Our results indicated that operations occurred 4.5 ± 3.4 days after injury. Based on the concept of optimal operation timing, we were able to achieve more accurate results. This is also consistent with the view that time from clinical deterioration to operation should be kept to a minimum, which plays a vital role in improving the outcomes of patients with TBI.

Operating Methods

BDC is used primarily for the treatment of posttraumatic refractory brain edema. It was initially described by Miyazaki in 1966 and popularized by Kjellberg and Prieto in 1971.22 It is also used in other diseases, such as aneurysms, tumors, and subdural empyema, which lead to increased ICP and swelling of the brain.23 DC has been recommended as a second-tier treatment for intracranial hypertension in severe TBI. Delayed DC is increasingly used as a salvage procedure for intractable intracranial hypertension in patients with diffuse bilateral swelling. Complications such as hematoma, subdural hygroma, and hydrocephalus occurred frequently after DC.24 The DC (DECR) trial (a randomized trial of early bifrontotemporoparietal DC for patients with severe TBI with diffuse brain swelling) unexpectedly showed a significantly worse outcome at 6 months in patients in the craniectomy group compared with those in the standard care group. When and how to adopt DC remains a source of controversy. In this group, all patients underwent a modified BDC.

Shorter Skin Incision. Full coronal skin incision runs from 1.5 to 2 cm above bilateral zygomatic arch, 0.5–1.0 cm pretragal, walking along the hairline, for a total incision length of about 22.1 ± 3.1 cm. If there is no hairline, the skin incision runs approximately 3 cm to the front of the coronal suture.

Amended Skin Flap. Skin was raised in flap to the forehead. The temporalis muscle was kept intact on both sides, with only the keyhole and temporal line exposed totally. Periosteotectomy runs respectively apart from the midline 0.5 cm and along the skin edge to each temporal line.

Smaller Bone Flap. The medial margin of the bone flap was about 0.5 cm from the midline, and the lower margin was about 1.0 cm from the superior orbital margin. The lateral margin is located in the temporal line, fully exposing the anterior skull base. The bilateral size is about 4 cm × 6 cm, leaving a strip of midline bone called the bone bridge covering the superior sagittal sinus.

Dural Cut and Suture. The dura mater is cut along the edge of the bone window toward the superior sagittal sinus. The periosteum was applied to relaxation suture dura mater after hematoma evacuation. Previous surgical experience emphasized that the incision should be large enough from the bilateral zygomatic arch extension to the coronal suture and the incision of temporal muscle. The bone flap should extend to the temporal region and middle cranial fossa, forming an extensive resection of the bilateral frontotemporal skull, while at the same time ligation of the superior sagittal sinus is ligated and the falx cerebri is cut. No patient experienced complications, and 81% (79/98) recovered well. In this group of patients with bilateral frontal hematoma and edema, we found that improved operation methods not only effectively reduced ICP but also offered fewer complications, less risk of injury, and ease of cranioplasticity.

Outcome

In our study, patients in this group were admitted to the ICU for 12.3 ± 3.2 days. Further treatment was carried out in the general ward. The investigators reported that 39 cases of bifrontal contusion stayed in the ICU for 15.67 ± 8.72 days. This difference might be associated with the different treatment methods in this group and other studies. This treatment method required timely detection of patients requiring surgery and improved surgical methods.

The good BDC outcomes ranged from 7% to 70% in different reports. Elwatidy25 believed the variation could be caused by many factors, including the operation timing and methods. Whitfield et al.26 reported good outcomes in 69% of patients with BDC, 8% with severe disabilities, and 23% mortality in a series of 26 patients with posttraumatic refractory intracranial hypertension. BDC significantly reduced intracranial hypertension. Because of its limitations, the study was unable to show the relationship between the timing of surgery and the prognosis. Polin et al.27
showed 57% (12/21) favorable outcomes in patients with posttraumatic intracranial hypertension who underwent BDC within the first 48 hours of injury.

In our study, dynamic CT scans showed satisfactory removal of hematoma in 86 patients. At discharge, the GCS was 6 in 93 cases (94%) (< 0.05), 6 in 6 cases (6%), 14 in 93 cases (93%) (< 0.05), and 6 in 5 cases (5%) at 7 days after operation. Two patients with postoperative cerebrospinal fluid rhinorrhea underwent repair surgery 1 month later. At 3 months follow-up, the GOS score was 5 in 79 patients (81%) who recovered well, 4 in 14 patients (14%) with mild disability, 3 in 2 patients (2%) with severe disability, and 2 in 1 patient (1%) with vegetative survival. Two patients (2%) died.

Two (2%) patients died in our study. One patient suffered from renal insufficiency after operation and underwent hemofiltration after 7 days, 1 patient (76 years old) presented with sudden respiratory failure and oxygen saturation decreased. After consultation with the respiratory department, a diagnosis of pulmonary embolism was reached. Although the patient received application of a respirator and thrombolytic therapy (heparin), he died 5 days after operation. This study showed that the multiparameter analysis of dynamic CT combined with GCS was the decisive factor for treatment and prognosis. The good results we have achieved are because we have used a comprehensive trend score rather than a simple threshold determining the optimal treatment. This experience is worthy of further research and promotion.

REFERENCES