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Original article

Changes in cerebral hemodynamics in patients with posttraumatic diffuse brain swelling after external intraventricular drainage

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ABSTRACT

Purpose: To investigate the changes of cerebral hemodynamics pre- and post-ventricular drainage in patients with posttraumatic acute diffuse brain swelling.
Methods: Twenty-four cases of traumatic diffuse brain swelling were analyzed retrospectively. Patients in nonsurgical group were treated by medicine therapy. Patients in surgical group were treated by external ventricular drainage plus medicine therapy. The first CT perfusion scan was completed within 4–5 h after trauma and scanned again after 7 days. The changes of perfusion parameters in area-of-interest in two groups were analyzed and compared before and after treatment.
Results: Compared with the nonsurgical group, the value of cerebral blood volume, cerebral blood flow and mean transit time in bilateral frontal temporoparietal grey matter, basal ganglia, cerebellum, and brain stem at pre- and post-therapy were increased significantly ($p < 0.05$) in surgical group, and consequently the prognosis of patients undergoing surgery was also better than that of nonsurgical group.
Conclusion: External ventricular drainage can improve cerebral perfusion and increase survival quality for the patients with posttraumatic acute diffuse brain swelling.

1. Introduction

Posttraumatic acute diffuse brain swelling (PADBS) is a severe craniocerebral injury with a reported mortality rate of 80%.[1,2] Its pathologic mechanism is still not clear and perhaps associated with changes in cerebral hemodynamics, such as early brain hemorrhage, brain swelling, cerebral ischemia, and cerebral edema.[3] The treatment protocol for PADBS is still controversial. We used external ventricular drainage in attempting to improve the prognosis of PADBS patients, and used CT perfusion imaging (CTP) to evaluate the cerebral hemodynamics in PADBS patients without complications. We analyzed the cerebral hemodynamics of patients before and after treatment and compared the therapeutic effect of external ventricular drainage with that of conservative treatment.

2. Materials and methods

Twenty-four PADBS patients were recruited in this study who were admitted to the Department of Neurosurgery of 101st Hospital of People's Liberation Army from January 2012 to April 2012. This study was approved by the ethics committee of our hospital and consented by the patients and their relatives. The general data of the patients included in the study are shown in Table 1.

Inclusion criteria were: (1) patients aged 18–70 years; (2) stable vital signs upon admission and hospitalization; (3) CT image indicating the white matter density increased at both cerebral hemispheres, obvious pressure on the ventricular system, small or invisible ambient cistern, cerebral contusion or intracranial hemorrhage with no clear space-occupying effect, centered central line structure; (4) previous history of good health. Exclusion criteria were: (1) intracranial pressure above 35 mm Hg; (2) other

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Table 1
General data of patients upon hospitalization.

Group	n	Age (yrs)	Male/female	Mechanism of injury		Initial GCS score	
				Rotation	Deceleration	8–6	5–3
Nonsurgical	12	44.8 ± 18.2	9/3	9	3	6	6
Surgical	12	44.5 ± 17.4	10/2	8	4	7	5

There are no significant differences in the general data of patients between groups upon admission ($p > 0.05$).

severe visceral injuries, low blood pressure, hypoxemia, shock, etc.

In nonsurgical treatment group, the respiratory tract was kept unobstructed and tracheotomy was performed when necessary and oxygen saturation was maintained above 95% to prevent hypoxia. The cerebral perfusion pressure was maintained at 60–70 mm Hg.[4] The balance of water and electrolyte was maintained and the water intake volume was strictly controlled at 2000 ml/d. The patients' temperature was maintained at 35 °C to 36 °C. In surgical treatment group, patients received external ventricle drainage immediately after the first CTP measurement with the GODMAN intracranial pressure monitoring device (Johnson & Johnson Co. USA). The procedure was as follows: intracranial pressure probe was implanted under general anesthesia in the operating room. The right side of the lateral ventricle was punctured for continuous drainage and intracranial pressure monitoring. The cerebral perfusion pressure was maintained between 60–70 mm Hg after surgery. The patients were otherwise treated identically to those in the nonsurgical group.

All 24 patients received full head CTP scans using Toshiba Aquilian 320-slice/640-layer CT within 3–5 h of initial injury. The patients received a second scan seven days after treatment. The CTP images were transferred to the ADW4.2 workstation and processed using the 4D Perfusion Software. Regions of interest (ROI) were selected, including bilateral frontal temporoparietal grey matter, basal ganglia, cerebellum, and brain stem. The cerebral blood volume (CBV), cerebral blood flow (CBF), and mean transit time (MTT) of the ROIs before and after treatment were obtained from the colored CTP images.

Glasgow Outcome Scale (GOS) was used, in which GOS ≥ 3 is regarded as good prognosis, and GOS ≤ 2 as poor prognosis.

All clinical data were analyzed using SPSS 13.0 statistical software. The average ROI before and after treatment was calculated. The difference value was calculated from the following formula. ΔCBV = second CBV-first CBV, ΔCBF = second CBF-first CBF, ΔMTT = first MTT-second MTT. Student's t-test was used. The prognosis of patients was analyzed by Fisher's exact test.

3. Results

The CBF and CBV of ROIs were increased and the MTT was shortened in 18 cases after treatment, including 10 cases in surgical group and 8 cases in nonsurgical group. Six patients'CBV and CBF were partly decreased and MTT extended. The CBV, CBF and MTT in each ROI of surgical group were recovered better than that before treatment, (Figs. 1 and 2), and there is a statistically differences between two groups ($p < 0.05$, Table 2).

All of 24 cases were followed up for 6 months after treatment. Thirteen cases including 9 cases in surgical group and 4 cases in nonsurgical group made a good recovery, although 10 cases died and one case was severely disabled. There were significant differences in GOS scores between the surgical and nonsurgical groups. Compared with the nonsurgical group, patients in surgical group had a significantly better prognosis ($p < 0.05$).

4. Discussion

The mortality rate of PADBS patients is high. Its pathological mechanism is still not well understood and may be associated with changes in cerebral hemodynamics. It is currently thought that brain trauma directly or indirectly damages the pontine locus coeruleus, the midbrain reticular formation, and the thalamus, leading to malfunction or loss of function in the cerebrovascular system and rapid expansion of the cerebrovascular system, leading to increased brain blood flow[5] and brain swelling. Due to the resulting long-term high intracranial pressure, hypoxia in brain tissue, accumulation of oxygen free radicals, calcium overload, and the occurrence of other secondary brain damage, hydrocephalus does occur.[6] Hydrocephalus limits the expansion of the intracranial vascular system, causing a reduction in cerebral blood flow as well as a drop in perfusion. Low perfusion indicates that the automatic adjustment function of the cerebrovascular system is impaired and that hydrocephalus is aggravated.[7]

In the 1990s, Wu et al[8] found that in diffuse brain swelling animal models, CBF was increased within 2 min after injury and decreased progressively after 3 h. In order to avoid the influence of high perfusion that may occur in PADBS patients shortly after injury, we carried out the first CTP scan 3–5 h after injury. We observed minimal radioactive damage to the patients from whole skull CTP using 320-slice/640-layer volumetric computed tomography (VCT). In order to reduce the radioactive damage caused by CTP, we performed a second CTP scan only on the seventh day. At this time, the intracranial edema is nearly resolved and the condition of the patients is relatively stable. It is believed that the key to a successful treatment of PADBS patients is to improve cerebral perfusion, reduce intracranial pressure, and mitigate secondary damage as early as possible.[9] However, there is controversy on the specifics of the treatment method. Surgery is required if there is obvious space-occupying lesions and brain herniation. Otherwise, conservative treatment is suggested for patients with bilateral diffuse brain swelling whose central line structure is not apparently shifted. In our clinical practice, we found that conservative treatment only does not yield optimal results. Meanwhile, decompressive craniectomy often causes acute encephalocele during surgery and leads to poor prognosis. Some researchers have shown that neither surgery nor conservative treatments effectively retards PADBS.[10] In order to find a method that can reduce intracranial pressure, improve cerebral perfusion, and does not require surgery, we added external ventricular drainage to the conservative treatment. On the one hand, this method can directly release cerebrospinal fluid and reduce intracranial pressure, drain out the harmful substances such as inflammatory chemokines, leukotriene C4, and interleukin-6, and reduce secondary damage.[11] On the other hand, it allows clinicians to monitor real-time changes in intracranial pressure, prevent damage caused by sharp fluctuations in intracranial pressure. Releasing a small amount of cerebrospinal fluid can significantly lower the intracranial pressure of PADBS patients. The drainage of lateral ventricle can be implemented as long as there is lateral ventricle showed in the CT scanning images of PADBS patients.

Many methods could be used to detect cerebral hemodynamics, but digital subtraction angiography (DSA) has become the exclusive standard used in the diagnostic work-up. Its main advantage lies in its accuracy and treatment. However, this method is invasive and carries a surgical risk. Furthermore, DSA