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Original Article

Application value of ventricular ICP monitoring for traumatic bifrontal contusions

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Abstract: Objective: The goal of this study was to assess the application value of ventricular intracranial pressure monitoring (VICPM) for patients diagnosed with traumatic bifrontal contusions. Methods: Clinical data of 85 patients who were diagnosed with traumatic bifrontal contusions between June 2014 and June 2015 at Shandong Provincial Hospital was retrospectively analyzed. All patients were divided into groups A (n=38) and B (n=47). In group A, patients received VICPM and their counterparts in group B did not undergo VICPM. Multiple parameters, such as clinical efficacy, decompression craniotomy (DC) rate, bifrontal craniotomy rate, length of hospital stay, and medical expenses were statistically compared between two groups. Results: At 6 months after traumatic injury, assessment outcomes of clinical efficacy did not significantly differ between two groups according to the Glasgow Coma Scale (GCS) scores ($P>0.05$). Compared with the non-VICPM group, the success rate of conservative treatment was significantly higher, the bifrontal craniotomy rate was considerably decreased, and the surgical trauma after craniotomy was dramatically mitigated in the VICP monitoring group (all $P<0.05$). Moreover, the length of hospital stay and medical expenses in the VICPM group were significantly less compared with those in the non-VICPM group (both $P<0.05$). Conclusion: Perioperative delivery of VICPM is beneficial for patients diagnosed with traumatic bifrontal contusions, which enhances the clinical efficacy, shortens the length of hospital stay, and reduces the medical expenses.

Keywords: Traumatic bifrontal contusions, intracranial pressure, decompression craniotomy, clinical efficacy, ventricular monitoring

Introduction

Traumatic brain injury (TBI) is one of the most severe public health issues, which can exert negative effects upon the physical and emotional life of the patients and their family members. In addition, TBI can also inflict heavy economic burden to the family and society [1, 2]. According to the U.S. Centers for Disease Control and Prevention, the overall incidence rate of TBI-related hospitalization, emergency department visit and mortality is estimated to be 823.7 per 100,000 in 2010 [3].

Traumatic bifrontal contusions (TBC), primarily caused by traffic accidents or falls, are frequently encountered in clinical practice [4]. Initial computed tomography (CT) scan immediately after TBC may be merely indicative of slight frontal contusions and no obliteration of the ambient cistern. Consequently, the severity of these TBC patients tends to be ignored and seldom monitored by physicians. Nevertheless, the conditions of certain TBC individuals can be rapidly and sharply aggravated due to central herniation. If not treated in a proper and timely manner, the clinical prognosis of the TBC patients might be extremely poor. At present, there are no standard guidelines which indicate whether TBC patients require surgical interventions and what type of surgical strategies should be performed. Currently, surgical options for TBC mainly consist of unilateral or bilateral craniotomy and decompressive craniotomy

(DC) in clinical settings. To provide professional and standard guidelines, an explicit and widely-accepted guideline for the treatment of TBC is urgently required.

Intracranial pressure (ICP) monitoring has been widely used in the intensive care and clinical management for patients with neurological disorders, especially for those with TBI. However, ICP monitoring has not been recommended as a routine intervention for patients with mild to moderate head injury with a rating score of 9-15 on the Glasgow Coma Scale (GCS). Current guidelines support that certain types of patients may obtain clinical benefits from ICP monitoring [5].

In this study, we retrospectively analyzed clinical data of 85 patients diagnosed with TBC who were admitted to our hospital. This investigation aimed to investigate the application value of ventricular ICP monitoring (VICPM) for TBC patients.

Material and methods

Baseline data

From June 2014 and June 2015, a total of 217 patients diagnosed with acute head trauma with a GCS score ranging from 3 to 15 were admitted to our hospital. Among them, 85 (3.9%) patients suffered from bifrontal contusions determined by CT scan. There were 58 (68.2%) male and 27 (31.8%) female, aged 45 years on average (range: 25-72 years). Thirty-eight patients with TBC underwent V-ICPM and 47 TBC patients did not receive V-ICPM. The three most common causes of head trauma were as follows: motor vehicle crashes (n=52), falls (n=20) and violence (n=6). Injury mechanisms included contrecoup injury (n=71) and coup injury (n=14). GCS assessment was performed in all patients within 24 h after injury: GCS score of 3-8 in 8 patients (severe TBI), 9-12 (moderate TBI) in 35 and 13-15 (mild TBI) in 42 cases, as shown in **Table 1**.

Exclusion criteria

(1) Multiple serious injuries (more than 2 organs); (2) Multiple organ dysfunction syndromes (MODS); (3) CT showed TBC combined with epidural hematoma greater than 30 cm^3, acute subdural hematoma with thickness greater than 10 mm, a midline shift greater than 5 mm, or any parenchymal mass lesions, except frontal contusions, greater than 20 cm^3 in volume [9].

Inclusion criteria

(1) The time of injury to admission was less than 8 hours; (2) First CT examination confirmed TBC, or first CT examination found no TBC but a second CT re-examination within 4 hours confirmed TBC; (3) No obstacles to emergency operation [10].

Imaging examination

All patients received CT scan upon admission. Fifty-six cases were diagnosed with TBC at the first CT scan, while another 29 patients were diagnosed with unilateral brain contusion or showed no contusions at the first CT scan but had confirmed TBC 4 hours later upon second CT scan. Typical characteristics of contusions on CT scan were as follows: punctiform or sheet high-density shadow in the frontal lobe and the frontal base, associated or not associated with subarachnoid hemorrhage, subdural hemorrhage, epidural hemorrhage and skull fracture. CT scans revealed disappearance of the ambient cistern, a midline shift or ventricle compression in certain cases.

Therapeutic plan

After admission to the neurosurgery intensive care unit (NICU), clinical data were recorded and clinical scores were evaluated by one neurosurgeon and one NICU physician. All patients received routine blood test, arterial blood gas analysis, serum electrolytes, liver and renal function tests and clotting mechanism. Cranial CT (CCT) scan as performed every 3-8 hours for the first 24 hours. All patients received identical therapeutic plan consisting of dehydration, sedation and analgesia with the only difference of surgical ICP probe implantation for patients undergoing VICPM. Of 85 patients, 38 cases underwent ICP monitoring. All 38 patients who received ICP monitoring were punctured into the lateral ventricle. If the initial ICP was higher than 25 mmHg, then a craniotomy was performed. If the initial ICP was lower than 25 mmHg, patients were sent to the NICU and received conservative treatment as the ICP monitoring group. These patients were moni-

Table 1. Baseline data of the enrolled patients

Parameter	N (%)
Sex	
Male	58 (68.2%)
Female	27 (31.8%)
Age (m ± SD, year)	45.4 ± 5.7
Causes	
Motor vehicle crashes	52 (61.2%)
Falling from a height	20 (23.5%)
Violence	6 (7.1%)
Mechanisms	
Contrecoup	71 (83.5%)
Coup	14 (16.5%)
TBI severity	
Mild TBI	42 (49.4%)
Moderate TBI	35 (41.2%)
Severe TBI	8 (9.4%)

tored for the following signs suggestive of the need for an emergency craniotomy: whether the ICP continued to increase and was higher than 25 mmHg and did not respond to mannitol dehydration treatment, properly released CSF by external drainage, or sedation and analgesia; whether the GCS score decreased by more than 2 points; or if a CT re-examination showed the enlargement of contusions and hematomas, the ambient cistern had disappeared, or a midline shift had occurred. If both bilateral hematomas and contusions were too large to be removed, then a bilateral craniotomy was performed. Intraoperatively, hematoma and contusions were thoroughly eliminated. DC was carried out if the ICP was high and severe brain swelling occurred.

Even though the original conditions did not significantly differ between the two groups, the pathogenetic condition of the VICPM group was worse than that of the non-VICPM group evaluated by a neurosurgeon. All patients in the non-VICPM group were directly transferred to the NICU and did not receive VICPM, whereas other treatments and routine monitoring were performed the same as the VICPM group. The indications of need for a craniotomy were as follows: ① GCS score decreased by more than 2, if the GCS score decreased quickly and was less than 8; ② Mydriasis and various physiological reflexes disappeared; ③ CT re-examination showed enlargement of contusions and hematomas, absence of ambient cistern, a midline shift, or ventricle compression. Two neurosurgeons collectively determined whether the operation was performed or not and propose the surgical plans in details. Patients in both groups received similar surgeries by two neurosurgeons.

Outcome evaluation

Neurological outcomes of GOS scores at postoperative 6 months were assessed by two neurosurgeons via telephone consultation or face-to-face interview. The rating grades were divided into the following 5 levels: Grade 5 indicated a good recovery with resumption of normal life and independent living, despite mild neurological or pathological defects; Grade 4 denoted mild disability with the ability to live independently and work or study with assistance; Grade 3 suggested severe disability, requiring care from others in daily life and presenting severe mental and physical disabilities, while nonetheless retaining consciousness; Grade 2 represented persistent vegetative state or a long-term coma with just with minimal responses; and Grade 1 was death. Grades 4 and 5 indicated good outcomes, Grades 3 and 2 were severe disability and Grade 1 was suggestive of poor outcomes. The success rate of conservative treatment, DC rate, bifrontal craniotomy rate, LOS, intracranial infection rate and medical expenses were statistically compared between the two groups.

Statistical analysis

All continuous variables are presented as the mean ± standard deviation. SPSS 19.0 statistical software (SPSS Inc., Chicago, USA) was used for statistical analysis. Independent two-sample *t*-tests and Spearman correlation analysis were performed for categorical data. A Chi-square test or Fisher's exact test was used for categorical variables. Ranked data between two groups were evaluated using a rank-sum test. No statistical significance was noted in the baseline data between two groups. A value of $P<0.05$ was considered as statistical significance.

Results

Baseline data

There were over 217 TBI patients admitted to our hospital between June 2014 and June

Table 2. Comparison of therapeutic outcomes between two groups

Factor	VICPM	Non-VICPM	*P*
Operation			0.046
Yes	12 (31.58%)	25 (53.19%)	
No	26 (68.42%)	22 (46.81%)	
DC			0.124
Yes	1 (2.63%)	6 (12.77%)	
No	37 (97.37%)	41 (87.23%)	
Bilateral craniotomy			0.174
Yes	2 (5.26%)	8 (17.02%)	
No	36 (94.74%)	39 (82.98%)	
Outcome			0.679
Good	31 (81.58%)	37 (78.72%)	
Severe disability	7 (18.42%)	8 (17.02%)	
Poor	0 (0%)	2 (4.26%)	
LOS (day, m ± SD)	13.2 ± 1.8	18.5 ± 5.1	<0.001
Medical expenses (m ± SD)	7.7 ± 1.3	9.1 ± 2.9	0.01

DC: Decompression craniotomy; LOS: Length of stay; Medical expenses: Ten thousand CNY.

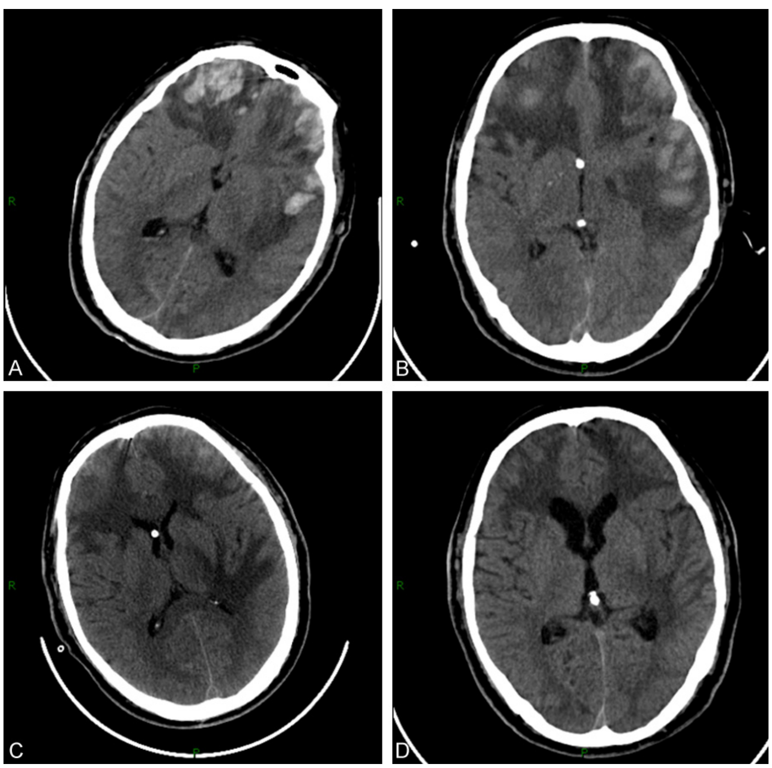

Figure 1. Case 1. Male, 62 years, motor vehicle crashes, GCS was 10 upon admission. A: CT scan confirmed TBC after brain injury for 2 hours, then ICP was monitored in the first day and ICP was 8-10 mmHg. B: 7 days after ICP monitoring, CT scans showed brain edema was aggravated, ventricles and cisterns were pressed and occluded, but ICP was 12-15 mmHg. C: 14 days after ICP monitoring, CT scans showed intracerebral hematoma absorbed and brain edema relieved, ICP was 10 mmHg. D: 21 days after injury, CT scans indicated the absorption of bifrontal contusion, intracerebral hematoma and brain edema, the patient obtained complete recovery without neurological dysfunctions.

2015. Among them, 85 eligible patients were enrolled in this study. There were 58 (68.2%) male and 27 (31.8%) female with an average age of 48 years. Thirty-eight TBC patients (44.7%) underwent VICPM and 47 (55.3%) patients with TBC did not undergo VICPM. The most common causes of head trauma were as follows: motor vehicle crashes (52/85, 61.2%), falls (20/85, 23.5%) and violence (6/85, 7.1%). Injury mechanisms included 71 (83.5%) cases of contrecoup injury and 14 (16.5%) of coup injury. Eight cases (9.4%) had GCS scores of 3-8 (severe TBI), 9-12 (moderate TBI) in 35 (41.2%) and 13-15 (mild TBI) in 42 (49.4%), respectively (**Table 1**).

Therapeutic plan

Among 85 patients, 38 cases received VICPM. In the VICPM group, 26 patients successfully received conservative treatment, whereas merely 12 patients were operated as their conditions became worsened. Among these 12 patients, 2 cases received bifrontal craniotomy and the remaining 10 underwent unilateral craniotomy with just one patient receiving unilateral DC. In the non VICPM group, 25 of 47 patients successfully received conservative treatment, whereas 22 patients received operation as their conditions were worsened. Fourteen patients received bifrontal craniotomy and 8 underwent unilateral craniotomy. Four patients received unilateral DC and two underwent bifrontal DC, as demonstrated in **Table 2** and **Figures 1**, **2**. No significant

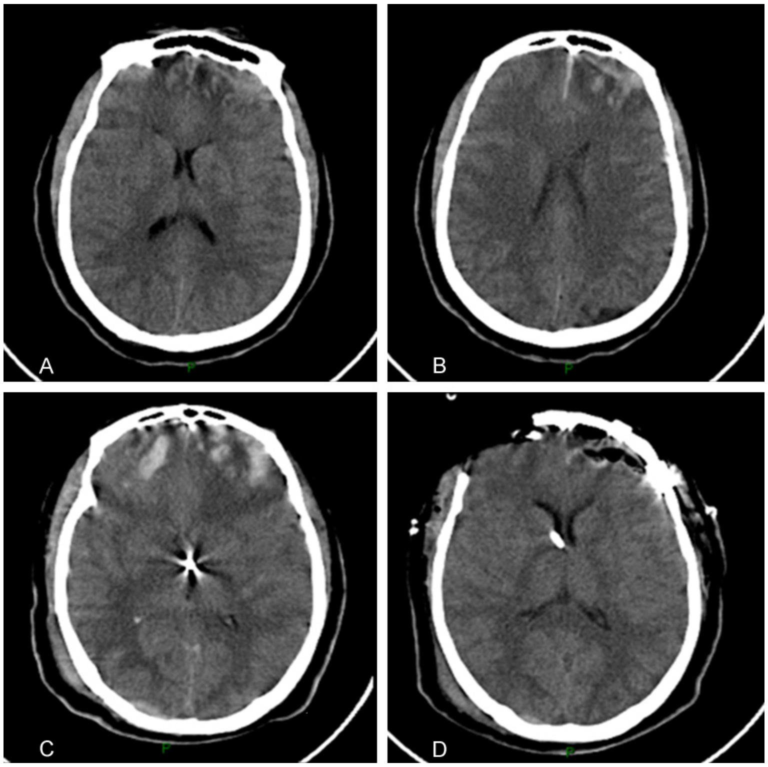

Figure 2. Case 2. Female, 47 years, falls, GCS was 13 upon admission. A and B: CT scan confirmed mild TBC after brain injury for 4 hours, then ICP was monitored in the first day and ICP was 12-16 mmHg. C: 8 hours after ICP monitoring, ICP increased to 25 mmHg, CT re-examination showed brain contusion was aggravated. Even brain contusion was not larger than case 1, but ICP was higher, so this patient received unilateral craniotomy. D: Postoperative CT showed brain contusion was completely removed, the patient obtained complete recovery without neurological dysfunctions.

Table 3. Comparison of catheter insertion-related complications between two groups

Factor	VICPM	Non-VICPM	*P*
Intracranial infection			0.695
Yes	4 (10.5%)	3 (6.4%)	
No	34 (91.5%)	44 (93.6%)	
Epilepsy			0.685
Yes	2 (5.3%)	4 (8.5%)	
No	36 (94.7%)	42 (91.5%)	
Hydrocephalus			0.625
Yes	1 (2.6%)	3 (6.4%)	
No	37 (97.4%)	44 (93.6%)	
Hemorrhage			0.447
Yes	1 (2.6%)	0	
No	37 (97.4%)	47 (100%)	

difference was noted in the DC rate and the bifrontal craniotomy rate between the two groups (both *P*>0.05). In the VICPM group, the DC rate was 2.63% and the bifrontal craniotomy rate was 5.25%, lower than 12.77% and 17.02% in the VICPM group.

Outcome evaluation

All 85 cases were contacted and no patients were lost to postoperative follow-up, and the GOS score at postoperative 6 months was evaluated by two neurosurgeons. No significant difference was observed in the GOS scores between two groups (*P*>0.05) (**Table 2**). However, the recovery rate (81.6%, 31/38) in the V-ICPM group was higher compared with (78.7%, 37/47) in the non-ICPM group. None in the VICPM group obtained poor outcome and 2 (4.3%) patients in the non-VICPM group. The mean length of stay (LOS) was (13.2 ± 1.8) days in the VICPM group, significantly shorter compared with (18.5 ± 5.1) days in the non-VICPM group (*P<0.001*). The mean overall hospital cost in the V-ICPM group was just 84000 RMB, significantly less than 95000 RMB in the non-ICPM group (P=0.01), as demonstrated in **Table 2**.

Postoperative complications

Postoperative complications, such as hydrocephalus, epilepsy and intracranial infection were assessed. Of 38 patients who received VICPM, 1 patient (2.6%) displayed hydrocephalus and 2 (5.3%) suffered from epilepsy during hospitalization, and 3 (6.4%) and 4 (8.5%) in the non-VICPM group with no statistical significance between two groups (both *P*>0.05). Intracranial infection was present if the outcomes of cerebrospinal fluid culture were positive after surgery. There were 4 (10.5%) patients in the VICPM group with intracranial infection during hospitalization, which was slightly higher compared with 3 (6.4%) in the non-VICPM group with no statistical significance between two groups (*P*=0.695). In addition, catheter insertion-related hemorrhage was identified in 1 (2.6%) patient, who was recovered after conservative treatment (**Table 3**).

Discussion

TBI is one of the most common diseases with a high morbidity and mortality rate [11]. Bifrontal contusions commonly occur in coup or contrecoup injuries and primarily affect the cortical tissues with specific features [12]. Many awake TBC patients (mild TBI) present with rapid deterioration and brain herniation in the advanced clinical stage, with the characteristics of "talk and die" syndrome. The potential causes may be progressive hemorrhage, contusion, encephaledema, or enlargement of intracranial and cerebral herniation [13]. In this study, there were 38 (44.7%) patients in the VICPM group and 47 (55.3%) patients in the non-VICPM group who experienced rapid deterioration and ultimately required surgery. However, many patients have mild injury and their consciousness remains clear. Some of these patients had multiples complications, which may be ignored by nurses and doctors. Therefore, development of the best practice for the diagnosis and treatment of TBC patients is a goal to obtain favorable clinical prognosis.

Imaging examination is a conventional diagnostic tool for TBC in clinical settings. However, neither CCT nor MRI can continuously monitor or provide real-time dynamic information of the TBC patients. Therefore, it is challenging to provide a timely early warning before the patient's condition deteriorates by means of imaging tools. Additionally, imaging examination fails to reflect the actual circumstances of intracranial environment as accurately as ICP. Some patients appeared to need surgical intervention based on their outcomes by CCT evaluation, but the ICP was not high enough to undergo surgery (**Figure 1**). Therefore, the operative rate would be unnecessarily increased if the surgeons solely depended upon the outcomes of CT examination. Alternatively, certain patients do need operation as the ICP is high, whereas the CCT shows no indication of the need for surgical intervention (**Figure 2**). This may severely delay the appropriate timing of clinical treatment, leading to the deterioration of diseases. Kouvarellis et al. [14] have also reported that ICP frequently increases despite open basal cisterns, as shown by examinations from 104 patients. Therefore, the status of basal cisterns should not be used as a sole criterion to evaluate intracranial conditions. Alternatively, VICPM can provide accurate and real-time information of intracranial conditions. Consequently, it can offer accurate reference and evidence for neurosurgeons to determine whether surgery should be performed or not for TBC patients.

It is efficacious and safe to perform surgery to establish VICPM, which can be easily mastered by almost every neurosurgeon. There are many clinical options and pressure detecting technologies available, as ICP can be measured in the epidural space, subdural space, parenchyma, ventricles and lumbar cistern [15]. However, most neurosurgeons believe that the ICP from the parenchyma is a local measurement of a regional phenomenon [16]. Therefore, VICPM is more accurate as it can reflect the real ICP more accurately than intra-parenchymal ICP monitoring. VICPM can not only monitor ICP, but also allow for drainage of CSF to decrease ICP, which is a highly effective method to control ICP.

In this study, ICP was utilized for goal-directed therapy in the VICPM group as recommended by the Brain Trauma Foundation Guideline [17]. TBC patients received operation if the ICP was higher than 25 mmHg continuously if the sedation and dehydration treatment were not effective. Eventually, the success rate of conservative treatment in the VICPM group was higher, and no patient developed cerebral hernia before the operation, whereas 6 patients suffered from cerebral hernia before the operation in the non-VICPM group. Two patients died following receiving bilateral craniotomy and DC.

ICP monitoring can assist neurosurgeons to select an appropriate surgical method and minimize secondary brain injury. Even though bilateral craniotomy can allow for complete removal of bilateral brain contusions, it takes longer and may result in more hemorrhage. Although unilateral craniotomy has a lower risk of hemorrhage and injury, it cannot completely remove contralateral brain contusions and hematomas, which makes it difficult to select an appropriate surgical plan for TBC patients. ICP monitoring can give neurosurgeons more information, and the confidence to select unilateral craniotomy to manage TBC when appropriate. Because we can use ICP monitoring to evaluate the ICP after unilateral brain contusion is removed, it is evident that if the ICP increases, then the contralateral brain contusion must be eliminated. If the ICP is normal and the contralateral brain contusion is not severe, then the contralateral brain contusion does not need surgery. In the present study, 2 patients received bifrontal craniotomy and 10 underwent unilateral craniotomy in the VICPM group, whereas 14 cases received bifrontal craniotomy and 8 underwent unilateral craniotomy in the non-VICPM group. Therefore, the rate of bifrontal craniotomy was significantly reduced in the VICPM group.

DC has been used for the management of patients with high ICP or herniation syndrome. Following ischemic or TBI, ICP may be increased due to a delayed hemorrhage or brain swelling inside the fixed volume of the skull. In DC, a large portion of the skull is removed to relieve ICP and allow the swollen brain to herniate outward rather than compress normal structures [18, 19]. Hemorrhagic complications, infectious and inflammatory complications, and disturbances of the CSF compartment were found to occur in more patients after undergoing DC. In addition, when a patient undergoes DC, a second surgery must be planned to repair the iatrogenic skull defects [18]. Cranioplasty carries its own risk of postoperative complications, and some of these may require additional surgery. Many patients may not be able to afford the costs of these procedures [18, 20, 21]. DC surgical procedures should be reduced if ICP is utilized and the patients' condition permits conservative treatment after the operation. In our study, one in the VICPM group patient received DC, whereas six patients received this intervention in the non-VICPM group, prompting that VICPM probably contributes to reduce the DC rate.

ICP monitoring in this study was a technique for goal-directed therapy while part of the management protocol for TBI patients. Nonetheless, the complications associated with VICPM worried many neurosurgeons because all ICP-monitoring techniques have significant drawbacks [22]. The most frequent complications reported in the literature were infection, hemorrhage, and epilepsy, which were also analyzed in this study. There were 4 (10.5%) patients in the VICPM group who developed intracranial infection, whereas 3 (6.4%) patients in the non-VICPM group suffered from intracranial infection, and the infection rate with ICP monitoring was similar to those reported previously [22]. The infection rate in the VICPM group was higher than that in the non-VICPM group with no statistical significance. A previous study has recommended that antimicrobial-impregnated external catheters and silver-coated catheters might decrease the infection rate [22]. Another frequent VICPM-induced complication is device-related hemorrhage. In the present study, one (2.6%) patient appeared to experience catheter insertion-related hemorrhage, who recovered after receiving conservative treatment, which was consistent with previous findings [23]. Aswin et al. [24] also reported that ICP monitoring is safe routine protocol to manage complex hydrocephalus after retrospective follow-up for 338 cases over 10 years.

Conclusion

Taken together, VICPM can be used as a useful method for monitoring TBI patients, especially for those diagnosed with TBC. TBC patients undergoing intraventricular ICP monitoring yield shorter LOS, less medical expense, lower DC rate, lower surgical rate, and decreased doses of osmotic drugs, even if they fail to obtain better outcomes at postoperative 6 months compared with their counterparts without ICP monitoring. It is of significant necessity to precisely determine the medical care afforded by ICP monitoring for TBC patients.

Disclosure of conflict of interest

None.

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