Long-term Outcomes After Shunt Implantation in Patients With Posttraumatic Hydrocephalus and Severe Conscious Disturbance

Huang Xin, MD, Sun Yun, MD, Xu Jun, MD, Wen Liang, MD, Cao Ye-Lin, MD, and Yang Xiao-Feng, MD

Background: Posttraumatic hydrocephalus (PTH) is a frequent complication secondary to traumatic brain injury, especially among patients keeping chronic unconscious. And effects of shunt implantation on improving outcomes among these patients are still controversial. This study was aimed to assess the long-term outcomes following shunt implantation among patients who had PTH and kept chronic unconscious.
Methods: A prospective study was performed to include patients who had PTH and remained in severe conscious disturbance from March 2010 to December 2010. All of included patients would have shunt implantation and be closely followed up at least for 2 years to assess final outcomes.
Results: Fifteen patients having PTH were identified. Before shunt implantation, 2 patients kept vegetative state (Glasgow Outcome Scale [GOS] score 2), and 13 patients kept minimally consciousness with severe disability (GOS score 3). After shunt implantation, the shunt device was removed because of intracranial infection in 1 patient, and the other patient died because of allergic shock. Among the remaining 13 patients, finally 7 patients had improvement on GOS or Modified Barthel Index (MBI) score during the 2-year follow-up, but only 1 patient achieved a good outcome (GOS score 4, independent life). Among them, 5 patients' outcomes improved as assessed by GOS or MBI score during the first 3 months following shunt implantation. During the fourth to sixth month following shunt implantation, there were 2 patients who showed first rise on GOS or MBI score. Beyond 6 months, no patient showed initial improvement. And among patients who showed improvement, most of them kept improving during a certain time.
Conclusions: A proportion of patients who had PTH and remained in severe conscious disturbance would benefit from shunt implantation, and the improvement may turn up late after this procedure.

From the Department of Neurosurgery, First Affiliated Hospital, College of Medicine, Zhejiang University, Hangzhou, Zhejiang, People's Republic of China.
Received October 10, 2013.
Accepted for publication November 14, 2013.
Address correspondence and reprint requests to Yang Xiao-Feng, MD, Department of Neurosurgery, First Affiliated Hospital, College of Medicine, Zhejiang University, No. 79 Qingchun Rd, Hangzhou City 310003, Zhejiang Province, People's Republic of China; E-mail: zjcswk@126.com
H.X., S.Y., and X.J. contributed equally to this study.
This work was supported by Science Technology Department of Zhejiang Province (2013C33160).
The authors report no conflicts of interest.

ISSN: 1049-2275
DOI: 10.1097/SCS.0000000000000583

Key Words: Traumatic brain injury, posttraumatic hydrocephalus, chronic unconscious, shunt implantation, outcomes

Abbreviations: CSF, cerebrospinal fluid, CT, computed tomography, GCS, Glasgow Coma Scale, GOS, Glasgow Outcome Scale, ICP, intracranial pressure, MCS, minimally conscious state, MBI, Modified Barthel Index, NPH, normal pressure hydrocephalus, PTH, posttraumatic hydrocephalus, TBI, traumatic brain injury, VS, vegetative state

(*J Craniofac Surg* 2014;25: 1280–1283)

Posttraumatic hydrocephalus (PTH) is a frequent complication secondary to traumatic brain injury (TBI), especially for patients with severe head trauma. According to different diagnostic criteria, the reported incidence of PTH after trauma is quite variable, ranging from 0.7% to 29%.[1] For the patients who keep severe conscious disturbance after a head trauma, especially among those in vegetative state (VS), the incidence of PTH would be much higher.[2]

Chronic unconsciousness is a quite common sequelae following head trauma as well. Posttraumatic hydrocephalus is able to prevent unconscious patients to recover after a head trauma, and academically a procedure of shunt implantation should be performed to correct PTH for better outcomes. However, actually only a proportion of patients are able to benefit from this procedure. Lumbar puncture in most of these patients commonly demonstrates normal intracranial pressure (ICP), or even low ICP, and almost all of chronic hydrocephalus secondary to head trauma indeed belong to normal pressure hydrocephalus (NPH).[1,3] Typical symptoms of NPH include dementia, gait disturbance, and psychomotor retardation. For patients who have these typical clinical presentations, the chance that they can benefit from shunt implantation is quite high. Unfortunately, a large proportion of these patients who have PTH are asymptomatic, and whether shunt implantation could improve such patients' neural functional outcomes is always unsure before the procedure, especially when patients keep unconscious. Besides considering the potential risk secondary to this shunt placement, such as intracranial infection, intracranial hematoma, and dysfunction of shunt system, the decision to perform shunt implantation is always difficult for neurosurgeons.

This study is aimed to assess long-time effects of shunt implantation on improving outcomes among patients who had chronic unconscious after TBI and suffered from PTH through a prospective study.

METHODS

This study was planned to include unconscious patients who suffered from PTH and had shunt implantation in our institute during March 2010 to December 2010. The research protocol was approved by the clinical research ethics committee of our institute. Moreover, the consent to participate in the study as well as publish the results of the

study had been signed by patients' deputies, because all of these patients were unable to make any decision by themselves.

Inclusion criteria of the study group were detailed as follows:
(1) patients who were diagnosed as PTH;
(2) before the procedure of shunt implantation, the patient remained chronic unconscious for at least 1 month after a head trauma;
(3) shunt implantation was performed for the management of hydrocephalus in this institute; and
(4) patients who had known severe neurologic deficits before the trauma were excluded from this study.

In this study, chronic unconsciousness after severe head trauma included VS and minimally conscious state (MCS). However, the diagnosis of persistent VS may have not been made.

After inclusion, the research team would develop a file for collecting each patient's information. The data about head trauma and hydrocephalus would be reviewed and recorded in detail. Besides, in this study, a neuroimaging standard was used to assess the severity of hydrocephalus. The ratio of cerebral ventricle diameter (the maximum of the transverse diameter of the middle of the ventricle in the computed tomography [CT] imaging) to biparietal diameter was used for the assessment: 26% to 40% indicated mild hydrocephalus (score 1); 41% to 60% was moderate hydrocephalus (score 2)s and 61% to 90% indicated severe hydrocephalus (score 3).[4] Higher score means more severe hydrocephalus. After shunt implantation, prognosis of patients' neurologic function and outcomes of PTH would be closely followed and recorded.

Patients' outcomes after the shunt implantation procedure would be evaluated using the Glasgow Outcome Scale (GOS) score and Modified Barthel Index (MBI) score. The research team would assess each patient's outcomes at 3, 6, and 12 months and 2 years following the procedure of shunt implantation. Follow-up would be performed through telephone or direct outpatient interviews with the patients or with family members. After shunt implantation, a rise in the GOS or MBI would be considered an improvement.

RESULTS

During January 2010 to December 2010, we identified 15 patients who met the study criteria. All of these patients were initially evaluated by the study team before the shunt implantation and followed up closely after the procedure. The patients' demographic information and trauma characteristics are shown in Table 1. In this series, there were 13 patients who also had large cranial defect because of initial decompressive craniectomy; and among them, 8 patients had cranioplasty (the procedure was performed after shunt implantation among 6 patients, before shunt implantation in 1 patient, and for the remaining one it was performed with simultaneous shunt implantation),

Each patient had been evaluated at 3, 6, and 12 months and 2 years after shunt implantation. The detailed information about PTH and outcome assessment at different times following shunt implantation is shown in Table 2.

TABLE 1. Demographic Information and Trauma Characteristics

n	15
Male/female, n	11/4
Injury mechanism	
Traffic accident	12
Falling	3
Age, y	
Range	24–66
Average	47 ± 13
No. cases with large cranial defect	13
No. cases having cranioplasty	8

All of these patients kept unconscious after a head trauma. Before shunt implantation, 2 patients kept VS (GOS score 2), and 13 patients were in MCS with severe disability (GOS score 3). Before shunt implantation, most of these patients had mild or moderate hydrocephalus evaluated by the neuroimaging standard mentioned before, and only 3 of them had severe hydrocephalus. Besides, ICP detected by lumbar puncture did not exceed 200 mm Hg among all of these patients, which was considered as an NPH. Pressure-adjustable valve was implanted among 5 patients, and median pressure valve was used among other patients. Eight patients had shunt implantation during the first to third month following initial head trauma, 5 patients during the fourth to sixth month, 2 beyond sixth month.

Intracranial infection after shunt implantation occurred in 1 patient (patient 3). The shunt device was removed at last, and the patient's relatives denied a second shunt implantation. For another patient (patient 7), allergic shock attacked after the procedure of shunt and led to the patient's death. Among other patients, there were no severe complications secondary to shunt implantation, for which a further procedure was necessary. The remaining 13 patients were followed up continually. Among them, enlarged ventricle shrunk was reduced to CT scan during the first 3 months in 8 patients, and among the remaining patients, the size of the ventricle kept stable but was not reduced.

Among the 13 patients, 5 patients' outcomes improved as assessed by GOS or MBI score during the first 3 months following shunt implantation. During the fourth to sixth month following shunt implantation, there were 2 patients who showed first rise on GOS or MBI score. Beyond the sixth month, no patient showed initial improvement. In total, 7 patients (7/13) had improvement on GOS or MBI score during the 2-year follow-up. And among patients who showed improvement, most of them kept improving during a certain time except 1 patient. Only 1 patient finally achieved a good outcome (GOS score 4, independent life).

DISCUSSION

Traumatic brain injury is always a leading cause for death and severe disability among patients younger than 35 years.[5] With the development of clinical medicine, the mortality of TBI is reduced dramatically; however, a huge proportion of these patients still survived with severe disability. Chronic unconsciousness is a common but disastrous consequence following severe TBI. Commonly chronic unconsciousness after a head trauma includes VS and MCS.[6] The main reason for severe unconsciousness is diffuse damage to subcortical white matter.[7,8] Besides, kinds of late complications are also able to cause unconsciousness after a head trauma.

Hydrocephalus is a common complication secondary to severe head trauma. As mentioned above, the reported incidence is quite variable according to different diagnostic criteria. Today, the most accepted criteria for PTH are onset within 6 months after a head trauma; dilation of ventricles not because of brain atrophy, according to a CT scan; and neurological deterioration or lack of improvement.[9] Most of PTH cases are believed to be with normal ICP, but few patients show typical symptoms of NPH. For patients developing PTH, it is frequently presented with failure to improve or with deterioration after a head trauma. Actually, PTH has a higher incidence among patients who are unconscious after a head trauma, especially for those who are in VS or MCS.[2] And hydrocephalus also is a predictive factor for chronic unconsciousness after a head trauma.[10] At present, a shunt implantation procedure is believed to be useful and also is the most popular method to correct hydrocephalus. However, the effects of this procedure on improving patients' outcomes are always unsure before it has been performed, especially when the patient also has chronic

TABLE 2. Information About PTH and Outcome Assessment

No.	Sex	Age, y	Severity of PTH	ICP	Pressure Adjustable	Time Range	Outcome*		Outcome†		Outcome‡		Outcome§		Outcome‖	
							GOS	MDI	GOS	MDI	GOS	MDI	GOS	MDI	GOS	MDI
1	M	46	2	200	−	1–3 mo	2	0	2	0	3¶	0	3	0	3	0
2	M	47	3	100	−	1–3 mo	3	0	3	0	3	0	3	0	3	0
3	M	42	1	120	−	3–6 mo	3	0	—	—	—	—	—	—	—	—
4	M	32	2	120	+	3–6 mo	3	0	3	35¶	3	65¶	3	75¶	3	75¶
5	F	61	2	120	+	1–3 mo	3	0	3	20¶	3	35¶	3	40¶	3	40
6	M	57	2	90	−	>6 mo	3	0	3	0	3	0	3	0	3	0
7	M	66	1	280	−	1–3 mo	3	0	—	—	—	—	—	—	—	—
8	M	45	1	130	−	1–3 mo	3	0	3	20¶	3	25¶	3	25	3	25
9	F	48	2	120	−	3–6 mo	3	0	3	0	3	0	3	0	3	0
10	M	28	1	160	−	1–3 mo	2	0	2	0	2	0	2	0	2	0
11	M	55	3	120	+	1–3 mo	3	0	3	0	3	15¶	3	25¶	3	25
12	M	39	2	180	+	1–3 mo	3	0	3	25¶	3	55¶	3	60¶	3	60
13	F	65	3	130	+	3–6 mo	3	0	3	0	3	0	3	0	3	0
14	M	49	1	100	−	3–6 mo	3	0	3	0	3	0	3	0	3	0
15	M	24	1	180	+	1–3 mo	3	0	3	15¶	3	70¶	3	75¶	4¶	85¶

*Patient outcomes evaluated before shunt implantation.
†Patient outcomes evaluated 3 months following shunt implantation.
‡Patient outcomes evaluated 6 months following shunt implantation.
§Patient outcomes evaluated 12 months following shunt implantation.
‖Patients outcomes evaluated 2 years following shunt implantation.
¶Increasing score of patients' outcomes.
M indicates male; F, female; Time Range, the time range from head trauma to shunt implantation.

hydrocephalus. If ICP measured by lumbar puncture is consistently greater than 200 mm H_2O or the patient has typical symptoms of NPH, the chance that patient is able to benefit from shunt implantation is high, and it is necessary to perform shunt implantation. However, for patients who keep unconscious after a head trauma, it is difficult to find any symptoms or signs of hydrocephalus. From our knowledge, only few studies focused on these patients who kept unconscious and developed PTH after severe head trauma. Tribl et al reported 48 patients who had PTH and underwent the procedure of shunt implantation. Before shunt implantation, there were 18 patients (37.5%) who lived with VS, and 30 patients kept severely disabled but conscious; at the time of 3 months following shunt implantation, the number of patients kept VS decreased to 12 (25.0%), and during the time of follow-up lasting for an average 3.52 years, 52.1% of patients showed improvement. However, the author did not detail the information of outcomes of these 18 patients who lived with VS before shunt implantation.[11] Low et al reviewed 23 patients who underwent shunt implantation because of PTH among 871 patients with severe TBI (a GCS score of ≤8 on admission or a deterioration of GCS score to ≤8 after admission due to evolving intracranial injury). Seventeen patients (74%) achieved improvement after the procedure of shunt implantation. Whereas 11 patients (48%) had GCS improvement of 2 points or more than 2 points, 6 patients (26%) had a single-point GCS improvement.[12] But we do not know the conscious state and neurological functions before the shunt implantation. Mazzini et al reported 140 patients with severe TBI (a GCS score of ≤8 in the acute phase or coma lasting for >6 hours), of whom 45% developed hydrocephalus.[13] Thirteen patients among whom hydrocephalus was assessed as severe by the neurological image criteria underwent shunt implantation, and 5 of them were in persistent VS. At last, most of these patients showed clinical improvement, including 3 of the 5 patients in VS. We also reported our retrospective study on outcomes of shunt implantation among patients who developed PTH but without atypical symptoms.[2] At the 12-month follow-up, 20 (64.5%) of the total 31 patients showed clear improvement. Licata et al reported 83 patients who underwent shunt implantation for PTH, despite severe preoperative conditions (75% in unconsciousness); the results were as follows: good recovery in 37 patients (45%), partial disability in 9 patients (11%), persistent coma in 29 patients (35%), and death in 7 cases (8%).[14] Among these studies, at least half of the patients with PTH are able to benefit from the procedure of shunt implantation, but these studies also included conscious patients before shunt implantation. In this prospective study, we focused on patients who kept unconscious after a head trauma. Except 2 patients who developed severe complications, in total 7 patients (7/13) had improvement on GOS or MBI score during the time of 2-year follow-up. The rate of patients who were able to improve after shunt implantation is also beyond 50%. From these studies, it seems the procedure of shunt implantation is worth for neurosurgeons to try.

Besides, kinds of experiments have been introduced to predict outcomes before the procedure of shunt implantation. Cerebrospinal fluid (CSF) dynamics measurements may help in formulating the diagnosis of PTH and in identifying patients who may benefit from shunt implantation, and there are several methods to perform CSF dynamics measurements. Measuring *R*(out), which is a value for resistance of CSF outflow, is a popular method of CSF dynamics evaluation. Bech-Azeddine et al performed lumbar infusion test and intraventricular assessment before shunt implantation among patients with communicating hydrocephalus or NPH.[15] Through these tests, among the selecting patients, the author reported a higher rate of patients who can improve after shunt implantation. Another popular method of CSF dynamics measurements is tap test, which assesses the clinical improvement after giving out a certain volume of CSF to predict the effects of shunt implantation.[16] These methods may be useful for those patients who have NPH but keep conscious. But for patients with chronic unconscious, it is difficult to prove clinical improvement during a short time. In addition, several neuroimging examinations, including magnetic resonance imaging, single-photon emission CT, and CT, have been introduced to help for diagnosis and prediction of outcomes after shunt implantation.[13,17] Missori et al showed that the assessment of the void in the cerebral aqueduct of patients with PTH on magnetic resonance imaging evaluation could suggest the correct diagnosis and have prognostic value.[17] Besides, the clinical status is also an important factor to predict patients' outcomes, and it can be

predicted patients in a better clinical condition before shunt implantation have better outcomes.[3,14] Though there are already lots of methods, it is still difficult to predict outcomes before shunt implantation for these patients keeping unconscious following severe head trauma through these exiting methods. And the guidelines for NPH are not suitable for these patients either, because of the severe conscious disturbance.

Nevertheless, for patients who have hydrocephalus and keep unconscious following severe head trauma, shunt implantation is just a part of the whole treatment. The rehabilitation and long-time follow-up after shunt implantation is quite important. In our series, some patients' clinical improvements were presented after 3 months following shunt implantation, and some of them kept improving during the whole time range of follow-up.

In conclusion, from this prospective study, more than half patients who developed PTH and kept chronic unconscious were able to improve after shunt implantation. But the clinical improvement may be presented late, and the continuous rehabilitation and long-time follow-up after shunt implantation are important for these patients. At present, it is still difficult to predict outcomes before shunt implantation for these patients. For patients who developed PTH and kept chronic unconscious, the shunt implantation is worthy to try, but considering the unpredictable outcomes and patients' poor conditions, the decision should be cautious.

REFERENCES

1. Guyot LL, Michael DB. Post-traumatic hydrocephalus. *Neurol Res* 2000;22:25–28
2. Jennett B, Adams JH, Murray LS, et al. Neuropathology in vegetative and severely disabled patients after head injury. *Neurology* 2001;56:486–490
3. Wen L, Wan S, Zhan RY, et al. Shunt implantation in a special sub-group of post-traumatic hydrocephalus—patients have normal intracranial pressure without clinical representations of hydrocephalus. *Brain Inj* 2009;23:61–64
4. Hong Z, Ping P, Xinwei Q. Clinical observation of ventriculoperitoneal shunt for traumatic hydrocephalus [in Chinese]. *Chin J Neuromed* 2006;5:1238–1239
5. Chua KS, Ng YS, Yap SG, et al. A brief review of traumatic brain injury rehabilitation. *Ann Acad Med Singapore* 2007;36:31–42
6. Bernat JL. Current controversies in states of chronic unconsciousness. *Neurology* 2010;75(18 suppl 1):S33–S38
7. Kinney HC, Samuels MA. Neuropathology of the persistent vegetative state. A review. *J Neuropathol Exp Neurol* 1994;53:548–558
8. Adams JH, Graham DI, Jennett B. The neuropathology of the vegetative state after an acute brain insult. *Brain* 2000;123(pt 7):1327–1338
9. Miki T, Nakajima N, Wada J, et al. Cause of post-traumatic hydrocephalus because of traumatic aqueduct obstruction in two cases. *J Trauma* 2006;61:985–989
10. Laureys S, Owen AM, Schiff ND. Brain function in coma, vegetative state, and related disorders. *The Lancet Neurology* 2004;3:537–546
11. Tribl G, Oder W. Outcome after shunt implantation in severe head injury with post-traumatic hydrocephalus. *Brain Inj* 2000;14:345–354
12. Low CY, Low YY, Lee KK, et al. Post-traumatic hydrocephalus after ventricular shunt placement in a Singaporean neurosurgical unit. *J Clin Neurosci* 2013;20:867–872
13. Mazzini L, Campini R, Angelino E, et al. Posttraumatic hydrocephalus: a clinical, neuroradiologic, and neuropsychologic assessment of long-term outcome. *Arch Phys Med Rehabil* 2003;84:1637–1641
14. Licata C, Cristofori L, Gambin R, et al. Post-traumatic hydrocephalus. *J Neurosurg Sci* 2001;45:141–149
15. Bech-Azeddine R, Gjerris F, Waldemar G, et al. Intraventricular or lumbar infusion test in adult communicating hydrocephalus? Practical consequences and clinical outcome of shunt operation. *Acta Neurochir (Wien)* 2005;147:1027–1035
16. Meier U, König A, Miethke C. Predictors of outcome in patients with normal-pressure hydrocephalus. *Eur Neurol* 2004;51:59–67
17. Missori P, Miscusi M, Formisano R, et al. Magnetic resonance imaging flow void changes after cerebrospinal fluid shunt in post-traumatic hydrocephalus: clinical correlations and outcome. *Neurosurg Rev* 2006;29:224–228
18. Mazzini L, Campini R, Angelino E, et al. Posttraumatic hydrocephalus: a clinical, neuroradiologic, and neuropsychologic assessment of long-term outcome. *Arch Phys Med Rehabil* 2003;84:1637–1641
19. Povlishock JT, Jenkins LW. Are the pathobiological changes evoked by traumatic brain injury immediate and irreversible. *Brain Pathol* 1995;5:415–426