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Lumboperitoneal shunts for the treatment of post-traumatic hydrocephalus

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ABSTRACT

Objective: To assess the effectiveness and safety of lumboperitoneal shunt for treatment of post-traumatic hydrocephalus (PTH). **Methods:** A retrospective analysis of medical records of patients with lumboperitoneal shunts admitted in Shanghai Tenth People's Hospital from January 2014 to March 2017 was done. Experience with lumboperitoneal shunt placement for PTH was reviewed. The diagnosis of PTH was based on ventricular enlargement with the Evans' index (EI>0.3) before shunt implantation. Patients were evaluated for improvements in Glasgow Coma Scale (GCS), Glasgow Outcome Scale (GOS), and EI after shunt placement. **Results:** Totally, the study included 34 PTH patients with the average age of 49.32 years (range: 9–67 years). The average follow-up period was (3.9±3.5) months. Before lumboperitoneal shunt, the GOS score was (4±1), the GCS score was (8.53±3.38), and the EI score was (0.40±0.08). After shunt implantation, the GOS score was (3±1), the GCS score was (10.29±3.15), and the EI score was (0.34±0.13), respectively ($P<0.05$). Before lumboperitoneal shunt, 24 (70.58%) patients had a GOS score of 4 (vegetative state), and 10 (29.42%) patients had a GOS score of 3 (severe disabled). After lumboperitoneal shunt, 18 (52.94%) patients had improvement in GOS (11 patients improve from GOS 4 to GOS 3, 5 patients from GOS 3 to GOS 2 and 2 patients from GOS 3 to GOS 1), 22 (64.71%) patients achieved improvement in their GCS (14 patients GCS improvements ≥ 2 and 8 patients GCS improvement=1), 21 (61.76%) patients had EI improvement (18 patients with EI<0.3). There was no complication in this study. **Conclusion:** Lumboperitoneal shunt placement is safe and effective for PTH, and serious complications are not observed.

1. Introduction

Post-traumatic hydrocephalus (PTH) is a common complication secondary to traumatic brain injury (TBI), the incidence of PTH has been reported to be between 0.7% and 51.4%, and this wide variation is probably due to different evaluation criteria[1-3]. It may be attributed with the disorder of cerebrospinal fluid (CSF) circulation and malabsorption characterized by symptoms of increased intracranial pressure, papilledema, hydrocephalus, focal

neurologic deficits, or coma in the setting of ventricular dilatation[4]. Among these, hydrocephalus is present in approximately 45% of the cases and associated with the worst intellectual outcomes[5]. Post-traumatic ventriculomegaly was most frequent in patients with moderate to severe TBI and has been proposed as an index of brain damage[6].

The treatment of PTH primarily involves CSF diversion through

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shunting. Ventriculoperitoneal shunt placement is the standard of care for patients presenting with PTH. However, ventriculoperitoneal shunt complications are still a significant problem, with an overall rate exceeds 30% [7]. Lumboperitoneal shunts with horizontal-vertical valves is an alternative to ventriculoperitoneal shunts for CSF diversion that avoid or minimize secondary cerebral injury and may decrease the risk of overdrainage [8]. Lumboperitoneal shunt is associated with lower incidence of failure in the treatment of normal pressure hydrocephalus [9].

In this study, data was retrospectively analyzed for PTH patients with lumboperitoneal-horizontal-vertical valves shunt placement and the outcomes and complication rates were evaluated for this procedure.

2. Materials and methods

2.1. Patient demographics

We retrospectively reviewed the electronic medical records of all patients undergoing lumboperitoneal shunt placement for PTH at the Department of Neurological Surgery at the Shanghai Tenth People's Hospital from January 2014 to March 2017. All selected patients had at least one symptoms of deteriorating conscious or enlarged ventricles on preoperative intracranial imaging, and a positive improvement in symptoms with a large volume lumbar puncture or extended lumbar drainage. All patients had lumboperitoneal shunts placed with horizontal-vertical valves (Medtronic, Inc.). Specifications for the available valves are given in parentheses: 0.5 mm H₂O (0–30 mm H₂O), 1.0 mm H₂O (1–60 mm H₂O), 1.5 mm H₂O (55–115 mm H₂O), 2.0 mm H₂O (105–170 mm H₂O), and 2.5 mm H₂O (155–225 mm H₂O).

Inclusion criteria are as follows: (i) Only patients with PTH undergoing initial lumboperitoneal shunt placement were included. (ii) Patients with an Evans' index (EI) ≥ 0.3 . Exclusion criteria are as follows: (i) Patients with secondary PTH, obstructive hydrocephalus, communicating hydrocephalus, previous ventriculoperitoneal shunts or lumboperitoneal shunts placed at other institutions. (ii) Patients had neurologic deficits before the trauma.

2.2. Radiologic assessment

Findings on computed tomography (CT) scans were reviewed for intracranial pathology. EI and the frontal horn to internal diameter ratio were measured on CT scans performed before or after lumboperitoneal shunting. Additional features such as the enlargement of ventricles and ventricular size were also reviewed.

2.3. Outcome assessment

The Glasgow Coma Scale (GCS) [10], Glasgow Outcome Scale (GOS) [11] and EI were recorded at admission. All patients with PTH underwent diagnostic CSF removal (either large volume lumbar puncture and/or extended lumbar drainage) before shunting and showed a positive improvement in GCS or EI. Response to shunting

was assessed by subjective reports from patients as well as objective testing. All the patients were evaluated in the clinic at 1 month post-operatively. Improvement in GCS score of ≥ 2 points was classified as "significant" and one point as "slight improvement". Patients were followed for 1–24 months.

2.4. Statistical analysis

The results are presented primarily as simple descriptive statistics. Continuous data are expressed as the mean \pm standard deviation (SD), whereas categorical data are expressed as median value interquartile \pm range (IQR). A paired-point Student's *t*-test or Wilcoxon test was used to comparing GOS, GCS, and EI pre-operatively and post-operatively patients, with $P < 0.05$ significance.

3. Results

Thirty-four patients (12 women and 22 men) underwent lumboperitoneal shunt placement for PTH. The average age of these patients was 49.32 years (range 9–67 years). The average length of follow-up was (3.9 \pm 3.5) months (range 1–24 months) (Table 1). The mean duration from injury to shunt implantation was (4 \pm 3) months (range, 1–48 months). Twenty-five patients (73.53%) underwent large volume lumbar puncture and nine patients (26.47%) underwent 3- or 7-day trial of lumbar drainage. Operations before shunt implantation and types of TBI in the total group are displayed in Table 1.

Table 1

Demographics of patients with post-traumatic hydrocephalus treated with lumboperitoneal shunts ($n=34$).

Patients	Data [n(%)]
Male	22 (64.71)
Female	12 (35.29)
Causes of TBI	
Traffic accident	23 (67.65)
Fallen	8 (23.53)
High falling	3 (8.82)
Types of TBI (Primary GCS)	
Mild TBI (GCS 13–15)	2 (5.88)
Moderate TBI (GCS 9–12)	5 (14.71)
Severe TBI (GCS 3–8)	27 (79.41)
Any operation before shunt implantation	
Decompressive craniectomy	
Hematoma removal	29 (85.29)
Intracranial pressure monitoring	29 (85.29)
Cranioplasty	7 (20.59)
Conservative treatment	9 (26.47)
Pre-shunt testing	1 (2.94)
Large volume lumbar puncture	9 (26.47)
Lumbar drainage	25 (73.53)

TBI: traumatic brain injury; GCS: Glasgow Coma Scale.

Before shunt implantation, the mean presenting GOS score was (4 \pm 1), GCS score was (8.53 \pm 3.38), and EI score was (0.40 \pm 0.08), respectively. After shunt implantation, the mean GOS score was

(3±1), GCS score was (10.29±3.15), and EI score was (0.34±0.13), respectively ($P<0.05$). Neurological scale showed significant improvement post-operatively when compared with pre-operatively (Table 2).

Twenty-four patients with GOS 2 before shunt implantation, 11 patients achieved improvement (32.35%) after shunt implantation, and 13 patients (38%) had no significant change. Ten patients with GOS 3 before shunt implantation, 7 patients (20.59%) had improvement after shunt implantation, and the remainder did not. Meanwhile, a similar result was obtained when other variables were omitted. Fourteen patients (41.18%) had GCS improvements of ≥ 2 points; 8 patients (23.53%) had a single-point GCS improvement. The remaining 12 patients (35.29%) had no improvement post-shunting.

CT scans were performed after shunt placement for all 34 patients. Twelve patients had $EI>0.4$ and twenty-two patients had $0.3\leq EI<0.4$ before shunt implantation. Twenty-one patients (61.76%) had improvements in their EI after shunt implantation, among which 18 patients (52.94%) with $EI<0.3$.

Lumboperitoneal shunt complications, such as infection, obstruction, and disconnection with the fractured fragment migrating in the peritoneal cavity, were not found. Also, there were no instances of subdural hematoma and hygroma, intraparenchymal hematoma and Chiari malformation caused by over-drainage of fluid.

A healthy 53-year-old male was involved in a vehicle accident and was transported to the emergency department 120 min after injury and had a GCS 4 at admission. The right pupil diameter was 4.5 mm, the left pupil diameter was 3 mm, and direct and indirect light reflex disappeared. An emergency brain CT scan showed a right-sided epidural hematoma, a left-sided thin-layer hematoma, traumatic subarachnoid hemorrhage and a right scalp hematoma. He underwent surgery for intracranial hematoma, decompressive craniectomy, and CT scan. He was transferred to the neurosurgical ICU for medical treatment and close monitoring. One and a half months later, the brain CT showed subdural hygroma, ventriculomegaly ($EI=0.31$). He had a GCS 4 and GOS 4 with normal-sized light-reactive pupils and underwent the lumboperitoneal shunt surgery. He was transferred to the rehabilitation center with a GCS of 10. Six months later, he underwent cranioplasty, and CT showed that the ventricle was obviously smaller ($EI=0.29$), with a GCS of 15 and GOS of 3.

4. Discussion

PTH is one of the most common and devastating complications after TBI. It can cause brain metabolism disturbances and oxidative dysfunction, which leads to ongoing ventricular enlargement and characteristic clinical deterioration[12]. Previous studies have shown that post-traumatic ventriculomegaly is frequently seen on CT[13]. Lumboperitoneal shunt placement has been demonstrated to be effective in the treatment of communicating hydrocephalus[14,15]. However, the outcomes of the procedure are always uncertain. To our knowledge, very few studies focused on these patients who developed PTH after trauma.

Tribl and Oder reported 48 PTH patients who underwent shunt implantation[16]. Eighteen patients kept vegetative state ($GOS=4$) before shunt implantation, 6 patients (12.5%) had improvement on GOS after shunt implantation, and the other 12 patients (25%) did not. Thirty patients kept minimally consciousness with severe disability ($GOS=3$) before shunt implantation, 19 patients (39.58%) had GOS improvements after shunt implantation, and the remainder did not. Totally, 52.08% of patients showed improvement. Our researchers showed 18 patients (52.94%) of 34 achieved improvement after lumboperitoneal shunt. Twenty-four patients with GOS 2 before shunt implantation, 11 (32.35%) had improvement after shunt implantation, 13 (38.24%) patients had no improvement. Ten patients with GOS 3 before lumboperitoneal shunt, in which seven patients (20.59%) improved and three patients (8.82%) did not after lumboperitoneal shunt. Generally speaking, patients who experienced improvement after shunt implantation exceeded 50%.

Low *et al.* reviewed 23 patients who underwent shunt implantation[17]. Seven patients (30.43%) achieved improvement after shunt insertion, eleven patients (47.83%) had improvements in their GCS score of ≥ 2 points, while six patients (26.09%) had a single-point GCS improvement in their GCS score. In our study, 22 of 34 (64.71%) patients achieved improvement after lumboperitoneal shunt, in which 14 (41.18%) patients had GCS improvements of ≥ 2 points and 8 patients (23.53%) had a single-point GCS improvement. These results compare favorably with other studies.

Hydrocephalus induced enlarged ventricles may influence the poor neurological outcome of head injury[18]. In the present study, $EI>0.3$ was a consistent finding indicating the presence of PTH in 34 patients. In term of EI, 21 patients (61.76%) had improvements in their EI after shunt implantation, among which 18 patients (52.94%)

Table 2

Outcomes in patients with post-traumatic hydrocephalus treated with a lumboperitoneal shunt

Time	Glasgow Coma Scale (GCS)				Evans' index (EI)				Glasgow Outcome Scale (GOS)				
	Mean±SD	3-8	9-12	13-15	Mean±SD	$EI>0.4$	$0.3\leq EI<0.4$	Median±IQR	GOS 1	GOS 2	GOS 3	GOS 4	GOS 5
Pre-shunt	8.53±3.38	21	6	7	0.40±0.08	12	22	4±1	0	0	10 (29.42%)	24 (70.58%)	0
Post-shunt	10.29±3.15	14	11	9	0.34±0.13	11	5	3±1	2 (5.88%)	5 (14.71%)	14 (41.18%)	13 (38.23%)	0
P value	$P<0.05$				$P<0.05$				$P<0.05$				

GOS 1: Death; GOS 2: Persistent vegetative state (including minimal responsive state); GOS 3: Conscious but disabled; GOS 4: Disabled but independent; GOS 5: Good recovery, resumption of normal life, there may be minor neurological and psychological deficits.

with $EI < 0.3$. The results are corresponding to above findings. Patients who experienced improvement after shunt implantation exceeded 50%. Our success with lumboperitoneal shunts for the treatment of PTH, making the procedure a reasonable alternative to cure this difficult disease.

The main drawback to this procedure was the need for frequent revisions in a few patients, regardless of the indication for the placement [19,20]. Infection remains a common complication of lumboperitoneal shunting, and the lower rates for lumboperitoneal shunts have been reported in various studies [21,22]. In our series, we did not find the revision, and no patient developed an infection. Overdrainage is another concern, patients who had a ventriculoperitoneal shunt placement with valves had a lower frequency of overdrainage than those whose shunts did not have valves [22]. In our study, all patients had lumboperitoneal shunts placed with horizontal-vertical valves, and we did not find overdrainage related complications. Despite its efficacy and the very low complication rates, many surgeons remain hesitant to use lumboperitoneal shunts for the treatment of hydrocephalus because of historically high failure rates and difficulty assessing function [23]. In our research, no patient shunt failure.

Our experience suggests that when surgical candidates have chosen appropriately, lumboperitoneal shunts are effective for the treatment of PTH. The clinical results after shunt insertion suggest significant improvement in nearly 50% of patients diagnosed with PTH. Our study also demonstrates complications is significantly less than that of the ventriculoperitoneal shunt. Lumboperitoneal shunt is a safe treatment modality with lower rates of complication and can be a practical and effective alternative treatment for PTH. A large-scale study is needed to support our results in the future.

Conflict of interest statement

The authors have declared that they have no conflict of interest.

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