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Original Article

# Lumbar-peritoneal shunt for idiopathic normal pressure hydrocephalus and secondary normal pressure hydrocephalus

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## Abstract

**Objectives:** Normal-pressure hydrocephalus is a clinical syndrome consisting of dilated cerebral ventricles with the clinical triad of gait disturbance, cognitive impairment and/or urinary dysfunction. Lumbar-peritoneal (LP) shunt could improve idiopathic normal pressure hydrocephalus (iNPH) while its effectiveness on secondary NPH (sNPH) is elusive. We compared the clinical results of the patients who received LP shunt surgery between iNPH and sNPH. **Materials and Methods:** We retrospectively analyzed the patients who received LP shunt surgery in a single center from January 1, 2017, to June 30, 2017. Patients selected for LP shunt placement had at least two of three cardinal symptoms of iNPH. The symptoms should persist for more than 3 months with compatible brain magnetic resonance imaging findings. All patients were followed up with iNPH grading scale (iNPHGS) and Modified Rankin Scale (MRS) for evaluation. **Results:** Thirty-three patients (23 male and 10 female patients) with mean age 76-year-old completed follow-up in this study, and 17 patients received lumbar drainage tests and intracranial pressure measurements. Both iNPH ($n$ = 22) and sNPH ($n$ = 11) groups did not have major complications such as infection, nerve root injury, or shunt failure. Both groups have significant improvement in iNPHGS and MRS. Interestingly, we found the correlation between both opening intracranial pressure and pressure gradient difference to the improvement percentage from LP shunt. **Conclusion:** The safety and effectiveness for sNPH patients who received LP shunt placement are equivalent to the iNPH patients. Lumbar drainage test provides prerequisite outcome prediction and should be considered to identify NPH patients planned to receive LP shunt.

**Keywords:** *Lumbar-peritoneal shunt, Normal pressure hydrocephalus, Outcome*

## Introduction

Idiopathic normal-pressure hydrocephalus (iNPH) is a clinical syndrome consisting of dilated cerebral ventricles with the clinical triad of gait disturbance, cognitive disturbance, and urinary dysfunction. Cerebrospinal fluid (CSF) diversion through a surgically placed shunt is currently the standard method of treatment however the effectiveness is variable and reported to be around 50%–80%. It is usually identified by CSF pressure in the range of 5–20 cm$H_2O$. Most centers used ventriculoperitoneal shunt (VP) for patients and the clinical outcome could reach more than 50% improvement [1,2]. However, VP shunt still bears the risk of intracranial hemorrhage [3].

Lumbar-peritoneal (LP) shunt has been reported to be an alternative surgical strategy for iNPH in many studies [4,5]. The LP shunt operation has become increasingly used in recent years in Asia because it has the advantage of being an extra-cranial operation. Many recent reports suggest that a LP shunt provides an alternative choice to the VP shunt in communicating hydrocephalus due to better safety. However, there was no idea that the LP shunt had the same benefit for secondary normal pressure hydrocephalus (sNPH) [6]. sNPH is characterized by patients with communicating hydrocephalus secondary to previous cerebral incidences such as stroke or traumatic brain injury. Patients with sNPH usually have similar normal range CSF pressure as iNPH. We compared the clinical results of the patient who received LP shunt surgery between iNPH and sNPH. In addition, how to identify patients with

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NPH, who will get the most improvement after shunt surgery, is a prerequisite. One recent meta-analysis concluded that the lumbar drain test still is not conclusive on the prediction of better clinical outcome [7].

The standard treatment for iNPH usually relies on shunt surgery. Since the etiology and its related pathophysiology for sNPH are various, the treatment outcome might be different from iNPH and needs to be evaluated. This study aims to compare those patients with sNPH to iNPH and the safety and the extent to which they benefit from LP shunt implantation.

## Materials and Methods

### Patient eligibility

We included the NPH patients (including iNPH and sNPH) who received PS Medical Strata NSC LP shunt from January 1, 2017, to June 30, 2017 and completed follow-up at neurosurgical clinics. Data were obtained from medical charts, follow-up examinations, and neuroimaging studies of the patients. The patients who underwent LP shunt placement all had at least two of three cardinal symptoms of NPH for more than 3 months and enlarged ventricles on preoperative intracranial imaging. There were 17 patients who had external lumbar drainage tests before the permanent CSF diverting surgery. In our studies, we defined the open pressure as the initial CSF pressure when lumbar puncture was accessed. Moreover, we make the definition of close pressure as the pressure which was measured at the time just after tapping 20 mL CSF. Initial adjustable valves settings, shunt revisions and indications, complications, and duration of follow-up were also recorded.

### Surgical technique

We pretest the valves before implantation with the initial setting 1.5. All the patients underwent the procedure with general anesthesia and in a lateral decubitus position, with routine skin preparation and draping. Two incisions were made: A 1.5 cm paramedian lumbar incision exposing the lumbar fascia, a 3 cm lateral transverse abdominal incision. The subcutaneous pouch was made through the abdominal incision to lodge the valve, and the abdominal wall was dissected in layers to open the peritoneum. The Tuohy needle was used to introduce 25 cm of lumbar catheter into the thecal sac, and checked the tip level under c-arm fluoroscopy. The tube was then tunneled subcutaneously to the abdominal incision, where it was secured to the proximal end of the valve. We connected the enlarged end of the peritoneal catheter to the distal end of the valve. After free flow of CSF was confirmed, we introduced the distal end of the abdominal intraperitoneally. Proximal and distal catheters were secured to the surrounding fascia, and the plastic base of the valve was also sutured to abdominal fascia to prevent eversion. Wounds were closed in layers.

To prevent an inadvertent injury of neuronal roots, preoperative lumbar X-ray was necessary, and lumbar spine magnetic resonance imaging (MRI) may be an option for those patients who have a high risk of spinal stenosis.

C-arm fluoroscopy is used during operation to make sure the intrathecal catheter is placed through the appropriate level, and check if any kinking site whether the abdominal or lumbar catheter. In addition, we usually will arrange a lumbar drainage test before the shunt surgery, especially sNPH patients. Postoperative lumbar and abdominal X-ray is also important to confirm the position of LP shunt.

### Follow up and outcome measures

In the follow-up period, brain computed tomography (CT) or MRI was repeated 6 months after shunt surgery. The Modified Rankin Scale (MRS) and iNPHGS were used to measure the degree of disability or dependence in the daily activities as well as cognitive functions of our patients. These measurements were performed at baseline and at 6 months after surgery. The details of evaluation and surgical intervention are summarized in Figure 1.

### Ethics declaration

Ethical approval for this study (Research Ethics Committee, REC No. IRB 110-064-B) was provided by the Research Ethics Committee of Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, on March 30, 2021. Informed written consent was waived because the study was a retrospective data analysis.

## Results

### Clinical characteristics of patients

A total of 36 patients received LP shunt during the study. Three of these 36 patients did not complete postoperative follow-up. We performed the lumbar drainage test before shunt surgery in 17 of these 33 patients receiving LP shunt [Table 1]. The mean age was 76 years (standard deviation [SD] = 13). The mean age is older in patients who were diagnosed with iNPH compared with sNPH patients (77 years vs. 64 years, $P$ = 0.096). The gender was also not significantly different between the two groups. The etiology of sNPH patients

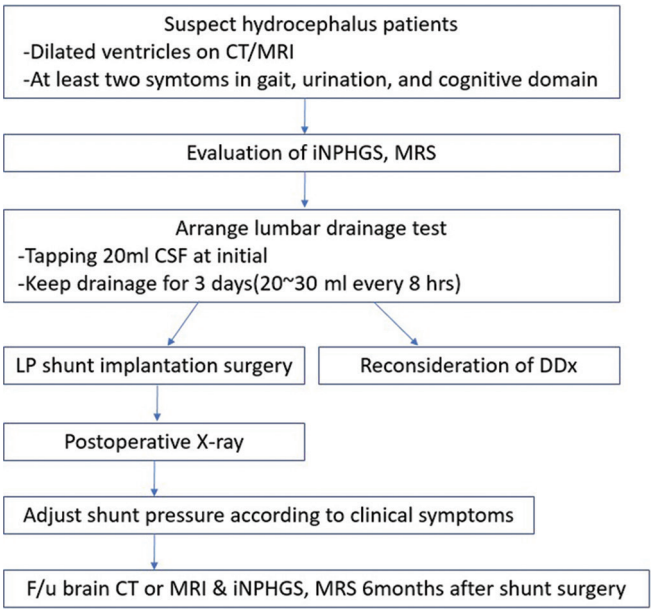


**Figure 1:** Flow chart demonstration of the evaluation and treatment protocol for both idiopathic normal pressure hydrocephalus and secondary normal pressure hydrocephalus patients

included posttraumatic hydrocephalus patients ($n$ = 5), cerebral vascular accidents ($n$ = 5), and brain tumor ($n$ = 1).

### Lumbar drainage test

After 20 mL CSF was drained, we checked the intracranial pressure again and placed one intrathecal catheter for continual drainage of CSF. We would observe the clinical improvement during the 3-day period. The median opening pressure measured at the time of lumbar drainage test was 13.5 $cmH_2O$ (SD = 6) in the iNPH group and 10 $cmH_2O$ (SD = 4) in the sNPH group and these pressures were not significantly different according to NPH type. These 17 patients (iNPH group: 14; sNPH group: 3) finished the lumbar drainage test. All of the 17 patients did feel either subjective or objective improvement during the lumbar drainage test.

### Clinical improvement

After shunt installation, no matter what groups they were, both of the patients got significant improvement according to the pre-OP and post-OP iNPHGS scoring system. The median preoperative iNPHGS in iNPH group was 5, and postoperative score was 3. In the sNPH group, the preoperative iNPHGS score was 5, and postoperative score was 4. Both groups improved significantly after shunt surgery and the extent of improvement between groups after shunt surgery were comparable. There was no significant difference in terms of the degree of clinical improvement from shunt surgery based on NPH type. In addition, the MRS score also improved for all the patients (preoperative: 4 vs. postoperative: 3). In detail, the difference between the proportions of patients who experienced improvement was not statistically significant between the iNPH group and sNPH group after correcting with age, gender, preoperative score.

### Correlation between intracranial pressure and shunt outcome

We also correlated the intracranial opening pressure level and pressure difference with the iNPHGS and MRS scores. In those patients, who received lumbar drainage tests and recorded the outcome, we found that higher opening pressure significantly correlated with better MRS score [Figure 2]. For those patients with NPH having higher pressure difference during lumbar drainage test, their iNPHGS get better improvement.

Though we considered the LP shunt surgery was safe, few patients found some complications. One patient was found overshunting, and the symptoms improved after adjusting the valve setting. Moreover, one patient was found to have wound dehiscence over the lumbar area due to CSF leakage,

**Table 1: Subject characteristics between groups of idiopathic normal pressure hydrocephalus and secondary normal pressure hydrocephalus**

| | Hydrocephalus type | | *P* |
|---|---|---|---|
| | iNPH ($n$=22) | sNPH ($n$=11) | |
| Age | 77 (8) | 64 (34) | 0.096 |
| Gender, male (%) | 17 (77.3) | 6 (54.5) | 0.240 |
| Open pressure | 13.5 (6) | 10.0 (4) | 0.143 |
| Close pressure | 7.0 (6) | 7.0 (5) | 0.530 |
| iNPHGS_preoperative | 5 (3) | 5 (3) | 0.984 |
| iNPHGS_postoperative | 3 (3) | 4 (3) | 0.421 |
| MRS_preoperative | 3 (1) | 4 (1) | 0.318 |
| MRS_postoperative | 3 (1) | 4 (2) | 0.073 |

Data are presented as $n$ (%) for gender and median (IQR) for other numerical data. MRS: Modified Rankin scale, NPH: Normal pressure hydrocephalus, iNPH: Idiopathic NPH, iNPHGS: iNPH grading scale, sNPH: Secondary NPH

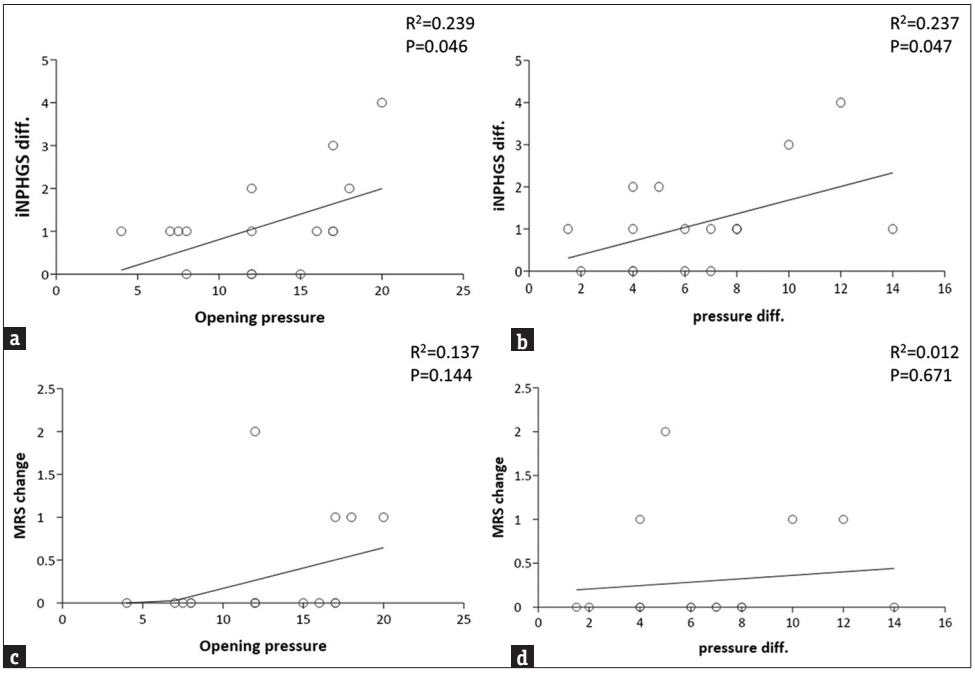


**Figure 2:** The results of linear regression analysis between different pressure measurement and clinical improvement after shunt surgery. (a and c): Correlation between opening pressure and neurological improvement (iNPHGS: Idiopathic NPH grading scales); (b and d): Correlation between intracranial pressure difference and neurological improvement

which may result from subcutaneous CSF accumulation due to inadequate drainage rate. The other patient was accidentally found to have gastric cancer complicated with perforated peptic ulcer and needs shunt removal.

### Case illustration

#### *Case one: Idiopathic normal pressure hydrocephalus*

A 77-year-old male patient with past medical history of DM and HTN was found to have progressive lower limbs weakness for months. His family also found that patients had worse memories. The MRI showed ventriculomegaly [Figure 3a], and the clinical symptoms met the criteria of iNPH. The LP shunt (Strata® NSC LP valve, initial pressure setting: 1.5) procedure was performed. The postoperative MRI images were followed at 6 months after operation [Figure 3b]. Significant radiological improvement was found, and the FH/ID ratio was 0.316 preoperatively and 0.301 postoperatively.

#### *Case two: secondary normal pressure hydrocephalus*

A 39-year-old female patient had a past medical history of HTN, and she suffered from traumatic SAH due to a traffic accident. Frequency of urination and deterioration of memory were noted about 6 months after trauma, and the brain CT showed ventriculomegaly. Post-traumatic hydrocephalus was impressed, and she received LP shunt operation after lumbar drainage test showing remarkable clinical improvement. Otherwise, the opening pressure showed 15 $cmH_2O$, and the closing pressure was 8 $cmH_2O$ during the lumbar drainage test. The postoperative MRI images were also followed at 6 months after operation, and the FH/ID ratio improved from 0.346 to 0.305 [Figure 3c and d].

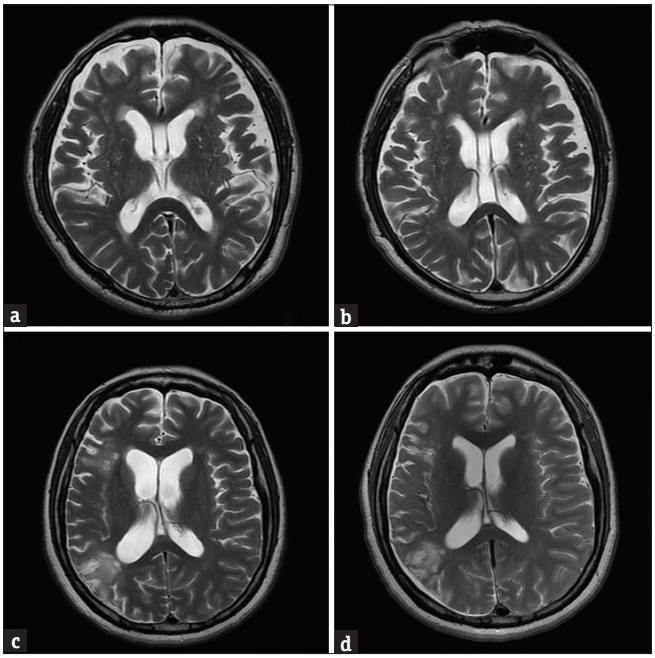


**Figure 3:** The brain magnetic resonance imaging before the shunt surgery revealed ventriculomegaly. (a and c) The ratio of FH/ID was 0.316 in case one and 0.346 in case two. The FH/ID (FH: Largest width of frontal horns; ID: Internal diameter from inner table of skull to inner table at this level) ratio decreased after surgery, 0.301 in case one and 0.305 in case two respectively. (b and d) Both of the two cases got obvious decreased ventricle size, and postoperative magnetic resonance imaging also revealed remission of periventricular lucency

## Discussion

Our results showed significant improvement for patients with iNPH after they underwent LP shunt surgery and the sNPH group reached a similar outcome as the iNPH group. Although the benefit of LP shunt for iNPH patients was reported for times, there were no previous studies to confirm its effectiveness for sNPH patients. In addition, the external lumbar drainage test as well as the measurement of intracranial pressure in the beginning of tapping or after drainage not only predicts the effectiveness of LP shunt for iNPH but also facilitates the identification of patients with sNPH who will benefit from the surgery also. The adverse effects confirm the safety of doing LP shunt implantation for patients with both iNPH and sNPH.

Diagnosis for the sNPH may be not as difficult as iNPH since it is usually associated with a prior history of a cerebral event before the appearance of NPH related symptoms and ventriculomegaly identified from brain imaging as well [6]. Thus, to confirm the hydrocephalus type; communicating or noncommunicating, is the first step and very important for sNPH patient selection. Although the clinical symptoms and severity of ventriculomegaly between iNPH and sNPH might be similar, the pathophysiology and mechanism might be different. These would lead to different outcomes and improvement from shunting surgery for both groups. However, one study that examined neuroinflammatory biomarkers in CSF from patients with iNPH or with post-subarachnoid hemorrhage-induced hydrocephalus showed that both groups have comparable levels [8]. Our results showing a similar outcome between both groups after undergoing LP shunt suggest that sNPH patients, under strict selection criteria, would benefit from shunt implantation as well [9].

Previous studies have demonstrated the sensitivity and reliability of using external lumbar drainage tests to predict the outcome of VP shunt [10,11]. Wu *et al*. showed that subjective improvement could help alleviate the possibility of underestimation of referring patients with only objective improvement of symptoms to receiving VP shunt surgery [12]. Therefore, our results further confirm the reliability of lumbar drainage tests before planning LP shunt surgery for both iNPH and sNPH groups [13]. In addition, the predictive value is not only good for iNPH patients but also for those patients with sNPH as well.

Although a patient's responsiveness after surgery relies on accurate diagnosis, the clinical symptoms and brain imaging characteristics of NPH might only predict the postoperative outcome for only 64% [14]. This might be due to the coexistence of Alzheimer's disease or parkinsonism-like neurodegenerative neuropathology, which has been shown to offset the benefit of clinically suspicious iNPH from shunting [5,15,16]. These studies suggest that the preoperative assessment with lumbar drainage test provides a high predictive value of postoperative improvement of CSF shunt surgery [17]. In addition to the transient improvement from the drainage test, we could also record several neurophysiological parameters and CSF dynamics, including opening pressure, pressure difference after tap test, and CSF

resistance [11,18,19]. We had found that the higher opening pressure and the more pressure difference may anticipate better outcomes, and some previous studies reported the same opinion [20]. As a matter of fact, we combine the CSF tapping test and lumbar drainage test for preoperative evaluation in our protocol. Despite most patients get a rapid response from initial CSF tapping, identifying those patients who had gradual improvement during the continual drainage test was also important. Making observations about the side effects during the test period could also help the decision of shunt diversion surgery.

There were several studies indicating that LP shunt showed almost the same benefits as VP shunt for patients with iNPH [21]. However, the LP shunt might have some advantages over the VP shunt, such as avoidance of intracranial procedures. Without the intracranial insertion of ventricular, lower rate of intracranial hemorrhage and seizure risks were shown before. Low infection rates were also reported in LP shunt cases than VP shunt cases by several studies, and these situations may be due to bacteria being much less prevalent on the back skin than on the scalp hair follicles [22-24]. Some studies compared the revision rate and infection rate between VP shunt and LP shunt, and the latter also showed better results. Our experience was also in favor of this outcome during the study period. However, our study might need future randomized design of trials with the inclusion of more patients with iNPH and sNPH to confirm the results.

## Conclusion

The application of LP shunt for iNPH and sNPH patients was safe and effective and a low side effect rate was found in our study. In addition, the lumbar drain test was a useful and minimal invasive procedure which could help identification of suitable candidates for shunt diversion surgery. Hence, to construct a proper preoperative observation course for sNPH patients is very important. Studies to enroll more patients with iNPH and sNPH in the future are warranted and might improve the postoperative care and valve setting.

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### Conflicts of interest

Dr. Shinn-Zong Lin, an editorial board member at *Tzu Chi Medical Journal*, had no role in the peer review process of or decision to publish this article. The other authors declared no conflicts of interest in writing this paper.

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