

Accuracy and safety of 1-day external lumbar drainage of CSF for shunt selection in patients with idiopathic normal pressure hydrocephalus

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OBJECTIVE Three to five days of external lumbar drainage (ELD) of CSF is a test for ventriculoperitoneal shunt (VPS) selection in idiopathic normal pressure hydrocephalus (iNPH). The accuracy and complication rates of a shorter (1-day) ELD procedure were analyzed.

METHODS Data of patients with iNPH who underwent 1-day ELD to be selected to undergo VPS placement with a programmable valve in the period from 2005 to 2015 were reviewed. Patients experiencing VPS complications, valve malfunctioning, or with less than 1 year of follow-up were excluded. The ability of 1-day ELD to predict VPS outcome at 1- and 12-month follow-up was assessed by calculating sensitivity, specificity, and positive and negative predictive values.

RESULTS Of 93 patients who underwent 1-day ELD, 3 did not complete the procedure. Of the remaining 90 patients, 2 experienced transient nerve root irritation. Twenty-four patients had negative test outcomes and 66 had positive test outcomes. Nine negative-outcome patients had intraprocedural headache, which showed 37.5% sensitivity (95% confidence interval [CI] 19.5%–59.2%) and 100% specificity (95% CI 93.1%–100%) as predictors of negative 1-day ELD outcome. Sixty-eight patients (6 with negative and 62 with positive outcomes) underwent VPS insertion, which was successful in 0 and 58 patients, respectively, at 1-month follow-up. Test sensitivity and specificity in predicting surgical outcome at 1-month follow-up were 100% (95% CI 92.3%–100%) and 60% (95% CI 27.4%–86.3%), respectively, with 94.1% accuracy (95% CI 85.6%–98.4%). Among the 1-day ELD–positive patients, 2 showed no clinical benefit at 12 months follow-up. Test sensitivity and specificity in predicting surgical outcome at 12-month follow-up was 100% (95% CI 92.5%–100%) and 75.0% (95% CI 35.6%–95.5%), respectively, with 97.1% (95% CI 89.8%–99.6%) accuracy.

CONCLUSIONS One-day ELD is a reliable tool in iNPH management, with low complication risk and short trial duration. The test is very consistent in predicting who will have a positive outcome with VPS placement, given the high chance of successful outcome at 1- and 12-month follow-up; negative-outcome patients have a high risk of unsuccessful surgery. Intraoperative headache is prognostic of 1-day ELD negative outcome.

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KEYWORDS external lumbar drainage; headache; idiopathic normal pressure hydrocephalus; screening test accuracy; ventriculoperitoneal shunt

CEREBROSPINAL fluid shunting is the treatment of choice for idiopathic normal pressure hydrocephalus (iNPH) with a 75%–82% rate of successful outcome¹⁸ and 11% risk of serious adverse events.¹¹ Not all patients diagnosed with iNPH are likely to benefit from shunt, and preoperative “supplemental prognostic tests” with intracranial pressure recording or CSF infusion/sub-

traction are recommended.¹⁶ External lumbar drainage (ELD) of CSF has gained wide acceptance among neurosurgeons^{16,17} as the best predictor of successful shunt surgery.¹⁵ The hypothesis underlying ELD is that prolonged drainage of a relatively large amount of CSF, more than with the spinal tap test,²⁸ mimics a shunt effect.² However, the amount of CSF drained and the duration are different

ABBREVIATIONS ELD = external lumbar drainage; iNPH = idiopathic normal pressure hydrocephalus; MMSE = Mini-Mental State Examination; VPS = ventriculoperitoneal shunt.

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in these studies, perhaps resulting from arbitrary choices.²⁷ Since its first description,⁶ prolonged ELD has been used to continuously or intermittently drain 100–500 ml/day of CSF over variable periods (3–5 days).^{4–6,8,10,14,15,17,21,27,29} Prolonged ELDs have exhibited variable accuracy and complications.^{5,10,15,17,21,27,29} However, as observed by Marmarou et al.,¹⁶ no studies have assessed whether better or equivalent outcomes may result from shorter ELD. A shorter ELD could offer advantages in terms of healthcare costs, and for patients who often present with limited compliance with hospitalization and bed constraint due to cognitive impairment. Furthermore, it was believed that reduced infection risk correlated with the number of drainage days.²³ According to Silverberg et al.,²⁵ CSF production in iNPH is 15 ± 5 ml/hr (360 ± 120 ml/day). Therefore, a subtraction of 300 ml/day would involve a momentary reduction of CSF volume, already mimicking a postshunt state after 24 hours. Previous experience has demonstrated that this daily amount of CSF could be safely drained in iNPH.¹⁰ Moreover, we anecdotally observed that in patients in whom the drain was accidentally removed from its placement after approximately 24 hours, shunt responsiveness was predicted anyway.

Given all these data, since 2005 we have systematically followed a protocol in which ELD was intended to last 24 hours (1-day ELD) for ventriculoperitoneal shunt (VPS) selection in iNPH. In this paper, the accuracy and complications of 1-day ELD are analyzed and, in light of our 10-year experience with this approach, implications for clinical practice are discussed.

Methods

Data Collection

In September 2017 we reviewed the records of all patients who were consecutively admitted between 2005 and 2015 with signs/symptoms of iNPH (at least two disruptions of Hakim's triad,¹ and an Evans ratio > 0.30) to undergo 1-day ELD for VPS selection, according to a standardized protocol.²⁴ All procedures received patient consent. In addition, patients gave proper consent to use their anonymized data for research purposes.

One-Day ELD Procedure

Anticoagulant and/or antiplatelet medications were stopped before admission, according to indications from the prescribing physicians. Patients were admitted early in the morning on the day of CSF drainage. Before beginning the procedure, the patient's cognitive functions were assessed via Mini-Mental State Examination (MMSE),⁷ urinary disorders were scored according to a urinary incontinence scale (four categories from normal urinary function to complete incontinence), and gait disorders were evaluated by means of a gait scale (four categories ranging from normal gait to inability to walk independently). One-day ELD was performed at the bedside by a neurosurgical resident or physician assistant with the patient in a sitting position and less frequently in the lateral decubitus position. With a Perifix R kit (B. Braun Medical), a 20-gauge closed-tip catheter was introduced through an 18-gauge Tuohy needle in the lumbar (L4–5/L5–S1) subarachnoid

space. The drain was fixed to the skin of the back with a double layer of 100×12 -mm polypropylene sterile strip film (Steri-Strip, 3M) overlaid by a third layer of polyacrylate adhesive dressing (Fixomull, BSN medical). The drain was connected to a 500-ml CSF drainage system (EDS3, DePuy Synthes, Johnson & Johnson). Patients remained supine, with the trunk and head raised about 30° . The drain was then opened and the collection system was positioned so that CSF drained continuously at a velocity of 12–15 ml/hr for 24 hours (approximately 1 drop every 12 seconds). A nurse checked the drain hourly and adjusted the height of the collection system drip chamber to ensure a constant flow. All patients received a daily single intravenous dose of 400 mg of teicoplanin and every 8 hours a dose of 2 g of ceftazidime. Patients were able to move in the bed during drainage and allowed to sit in a chair, with the drainage system closed transiently (for approximately 30 minutes) for meals. A physician recorded any adverse event occurring during the test. After removing the drainage, checking the correct closure of its insertion point and the absence of CSF leak, a small compressive dressing was applied to cover the point of drainage insertion. Patients remained supine for 30 minutes and then received an initial clinical examination. Patients were discharged early in the afternoon and returned to the clinic 1 week later for final assessment, in the same manner as prior to drainage and performed by the same resident or physician who performed the initial assessment. A gain of at least 2 points by combining the urinary incontinence and gait scales, or when the patient obtained a gain of 1 point in urinary incontinence scale or gait scale and at least 3 points on the MMSE was considered a positive response (i.e., clearance for surgery). VPS insertion was performed within 1 month after 1-day ELD, positioning a catheter in the frontal horn of the nondominant hemisphere, connected through interposition of a programmable valve to a second catheter whose distal end was positioned in the suprahepatic space. The same criteria used to assess 1-day ELD response were used to assess surgical outcome.

Outcome Variables

For our purposes, exclusion criteria were previous CSF diversions, VPS complications, valve malfunctioning, and less than 1 year of follow-up. For each included patient, demographic and clinical information, duration of ELD, amount of drained CSF, and complications were recorded. Furthermore, for those patients who underwent VPS placement, valve opening pressure settings (at surgery and during follow-up), and outcome at 1 and 12 months after VPS placement were recorded. One-day ELD predictions were matched with 1- and 12-month surgical follow-up outcomes, and true positives, true negatives, false positives, and false negatives were identified. Sensitivity, i.e., the ability of the 1-day ELD to identify patients who would benefit from a VPS, was calculated as (true positives)/(true positives + false negatives). Specificity, or the ability of the test to identify those who would not benefit from surgery, was calculated as (true negatives)/(true negatives + false positives). The positive predictive value, i.e., the percentage of 1-day ELD-positive patients who were true positives, was calculated as (true positives)/(true positives

+ false positives). And the negative predictive value, i.e., the percentage of 1-day ELD–negative patients who were true negatives, was calculated as (true negatives)/(true negatives + false negatives). Accuracy, or the proportion of patients who were correctly identified by the test, was calculated as (true positives + true negatives)/(true positives + false positives + true negatives + false negatives).

Statistical Analysis

Univariate analysis was performed using the Mann-Whitney U-test for quantitative data. All analyses were performed by an experienced epidemiologist using Stata

(version 14, StataCorp LP). All statistical tests were 2-sided, and a p value < 0.05 was considered significant. Approval by the Ethics Committee was not required because this study involved a retrospective analysis of routine data without any intervention.

Results

Results are summarized in Fig. 1. Ninety-three patients met the selection criteria. In 2 patients (2.2%) drain placement was not accomplished due to procedural difficulties (related to obesity in 1 patient and spinal stenosis in the other). In 1 case (1.1%) the procedure was interrupted be-

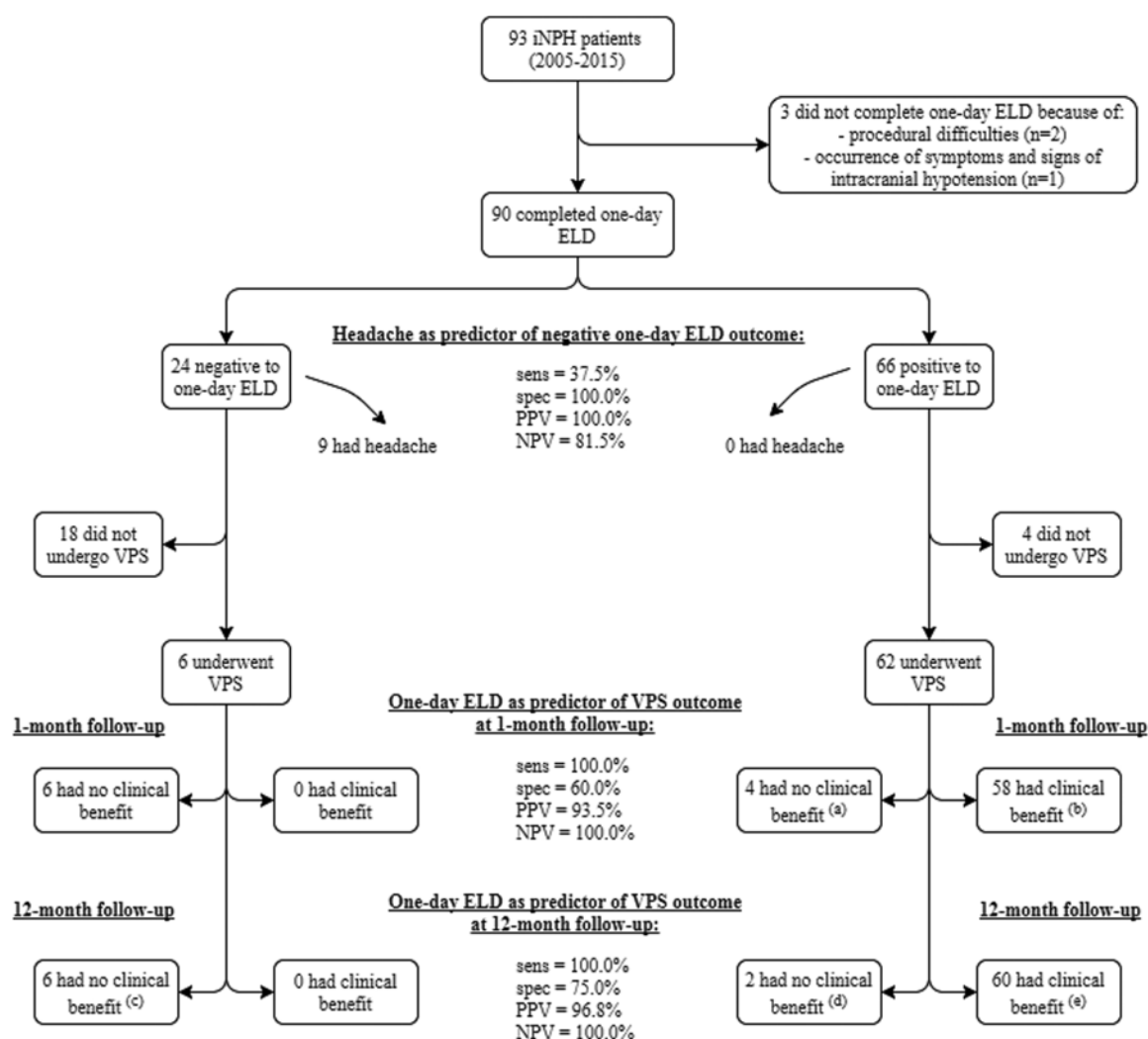


FIG. 1. Stratification of 93 patients with iNPH who underwent 1-day ELD as a test for VPS selection: accuracy of headache occurrence during the procedure as a predictor of test outcome, and accuracy of the test as a predictor of shunt surgery outcome.

^(a)One of these patients received downward opening pressure valve adjustment between shunt surgery and 1-month follow-up.

^(b)One of these patients received upward valve resetting between shunt surgery and 1-month follow-up of headache.

^(c)Between 1- and 12-month follow-up, 5 of these patients received downward opening pressure valve resetting, while in 1 patient the valve was reset at the implantation value after downward adjustments because of subdural fluid collection.

^(d)Both of these patients received downward opening pressure valve adjustment between 1- and 12-month follow-up.

^(e)Between 1- and 12-month follow-up, 28 patients received downward opening pressure valve adjustment. Because of the occurrence of symptoms of overdrainage, 4 patients (in addition to one who already had received valve adjustment to a higher value than that at implantation [see note (b)]) received upward opening pressure valve adjustments. NPV = negative predictive value; PPV = positive predictive value; sens = sensitivity; spec = specificity.

cause of headache, nausea, emesis, and neck pain stiffness followed by a brief state of consciousness deterioration, which occurred after 45 ml of drained CSF. The patient rapidly and spontaneously recovered without sequelae after drainage interruption and recumbent positioning. Ninety patients completed 1-day ELD; 62 were men and 28 women; age at the time of the procedure ranged between 65 and 86 years (median 76 years); MMSE score ranged between 10 and 30 (median 23); urinary incontinence scale score ranged between 0 and 3 (median 2); and gait scale score ranged between 1 and 3 (median 2). Two patients (2.2%) experienced transient nerve root irritation that was resolved by the crouched lateral decubitus position. Nine patients (10.0%) experienced headache after 20–180 ml (median 40 ml) of drained CSF and drainage time in the range of 2–15 hours (median 3 hours). Headache resolved within 10–20 minutes while lying in bed after transiently closing the CSF collection system. In patients who experienced headache, the total volume of drained CSF ranged between 120 and 350 ml (median 300 ml) during a drainage time ranging between 10 and 36 hours (median 24 hours). In those patients without headache, total volume of drained CSF ranged between 110 and 450 ml (median 300 ml), and CSF drainage time ranged between 10 and 48 hours (median 24 hours). No significant differences were observed in the total amount of drained CSF and duration of drainage between headache and nonheadache groups.

One-Day ELD Outcome

Twenty-four (26.7%) of the 90 patients had a negative outcome to 1-day ELD. In these patients, volume drained ranged between 120 and 350 ml (median 300 ml) and 1-day ELD lasted between 10 and 36 hours (median 24 hours). Sixty-six (73.3%) of the 90 patients had a positive to 1-day ELD. In these patients, volume drained ranged between 110 and 450 ml (median 300 ml) and the duration ranged between 10 and 48 hours (median 24 hours). The amount of drained CSF and duration of drainage did not vary by test outcome. Because all 9 patients with headache were among 1-day ELD–negative patients, we aimed to assess the accuracy of headache as an index to predict a negative outcome of the test: sensitivity (37.5%, 95% CI 19.5%–59.2%), specificity (100%, 95% CI 93.1%–100%), positive predictive value (100%, 95% CI 62.9%–100%), negative predictive value (81.5%, 95% CI 71.0%–88.9%), and accuracy (83.3%, 95% CI 74.0%–90.4%) were determined.

One- and 12-Month Follow-Up

Six of the 24 1-day ELD–negative patients demanded surgery for VPS placement despite awareness of only a 1-in-5 chance of improvement,¹⁷ while 18 did not receive shunt placement. Four of the 66 1-day ELD–positive patients refused VPS. Overall, 68 patients underwent surgery. Valve setting at surgery ranged between 90 and 130 cm H₂O (median 110 cm H₂O). At 1-month follow-up, the 6 negative 1-day ELD patients with shunts had negative outcomes. Outcome remained negative at 12-month follow-up. Among the 62 1-day ELD–positive patients with shunts, at 1-month follow-up 4 patients had negative out-

comes, while 58 showed positive surgical outcomes. At the 12-month follow-up, there were 60 patients with positive VPS outcomes, while 2 patients remained negative.

Therefore, at the 1-month follow-up, 58 patients were classified as true positives, 4 false positives, 6 true negatives, and zero false negatives. This translated into the following performance parameters: sensitivity = $58/(58+0) = 100\%$ (95% CI 92.3%–100%); specificity = $6/(6+4) = 60\%$ (95% CI 27.4%–86.3%); positive predictive value = $58/(58+4) = 93.5\%$ (95% CI 83.5%–97.9%); negative predictive value = $6/(6+0) = 100\%$ (95% CI 51.7%–100%); and accuracy = $(6+58)/68 = 94.1\%$ (95% CI 85.6%–98.4%).

At the 12-month follow-up, 60 patients were classified as true positives, 2 false positives, 6 true negatives, and zero false negatives. Accordingly, after 12-month follow-up we observed: sensitivity = $60/(60+0) = 100\%$ (95% CI 92.5%–100%); specificity = $6/(6+2) = 75.0\%$ (95% CI 35.6%–95.5%); positive predictive value = $60/(60+2) = 96.8\%$ (95% CI 87.8%–99.4%); negative predictive value = $6/(6+0) = 100\%$ (95% CI 51.7%–100%); and accuracy = $(60+6)/68 = 97.1\%$ (95% CI 89.8%–99.6%).

The above values might be biased by the low proportion of 1-day ELD–negative patients who underwent surgery. To account for this possible bias, we aimed to determine the range of actual performance parameters (sensitivity and specificity) that were compatible with the observed data. The likelihood that none of the 6 patients benefited from surgery was compatible (binomial distribution, $\alpha \geq 0.05$) with the likelihood that up to 9 of the 24 1-day ELD–negative patients would have benefited from surgery, had they chosen to undergo it. In other words, the observed data were compatible with an actual proportion of false negatives (i.e., 1-day ELD–negative patients benefiting from surgery) ranging between a minimum of 0 of 24 and a maximum of 9 of 24. We replaced these values in the calculations, and concluded that the observed data were compatible with an actual sensitivity ranging between 86.6% and 100.0%, and an actual specificity ranging between 78.9% and 85.7%, at 1-month follow-up, and with an actual sensitivity ranging between 87.0% and 100.0%, and an actual specificity ranging between 88.2% and 92.3%, at 12-month follow-up.

All results were largely maintained when limiting the analysis to patients with no more than 24 hours of test duration and no more than 300 ml of drained CSF (data not shown).

Discussion

One-day ELD is a reliable way to predict positive outcomes for patients offered VPS placement, having a low complication risk and requiring a short duration. Negative-outcome patients have a high risk of unsuccessful surgery. Intraoperative headache is prognostic of 1-day LD negative outcome.

One-Day ELD Prognostic Value

Most of the papers analyzing the effectiveness of prolonged ELD as a screening tool in INPH have demonstrated high sensitivity and positive predictive value,^{5,10,15,21,29} with the exception of the Walchenbach et al.²⁷ series in

which possible biases in patient selection were admittedly introduced. The largest prospective study on prolonged ELD reported 95% sensitivity and 90% positive predictive values.¹⁷ Consistent with those results, our study demonstrates that ELD, even if performed over a shorter time, is a highly reliable tool supporting the decision to address 1-day ELD–positive patients to VPS. Positive prediction of the test correlated correctly with positive surgery outcome at 1- and 12-month follow-up. However, in almost 50% of 1-day ELD–positive patients with shunts, downward adjustment of valve opening pressure was needed to obtain/maintain the clinical benefit (Fig. 1). Exclusion of patients with fixed valves from the study allowed us to avoid underestimation of the test performance at 12-month follow-up. Likewise, the high negative predictive value (100%) suggested that a patient who has a negative outcome to our test has a high chance of negative shunt outcome: none of the six 1-day ELD–negative patients who underwent VPS placement had favorable surgical outcome, even after valve resetting to lower values (Fig. 1).

However, specificity was not high, meaning that the tool was not completely reliable in identifying all patients who did not benefit from surgery. Low specificity is consistent with the study of Marmarou et al.,¹⁷ who reported a value of 64%. In their report, 51 of 151 patients tested negative to ELD, and of those, only 18 (35.3%) underwent surgery.¹⁷ Also in our study, only a minority of 1-day ELD–negative patients underwent operations (6 of 24, 25%). The low proportion of 1-day ELD–negative patients undergoing surgery (in comparison with positive-outcome patients) is reasonably due to stringent preliminary selection based on the clinical experience. Although justified by routine clinical practice, this selection may have affected the observed performance of 1-day ELD as a predictor of shunt placement outcome. In theory, a better estimate of the 1-day ELD specificity could only be achieved by subjecting all of the test-negative patients to VPS insertion, which would raise ethical concerns given the low probability of clinical improvement. Our simulation (based on simple probabilistic calculations, see *Results*) suggests that the actual specificity of 1-day ELD, and therefore overall performance, might be better than observed. Therefore, from a clinical standpoint, we believe it appropriate to not direct patients to VPS placement if they lack improvement following a correctly performed drainage, also taking into account the risk of adverse events¹¹ and costs.^{12,26} Moreover, clinical, imaging, and laboratory findings are not sufficiently reliable predictors of shunt outcome¹¹ and cannot be used to enhance identification of possible false negatives when faced with 1-day ELD–negative patients. In this regard, the value of cognitive deterioration during CSF drainage as a predictor of negative shunting outcome¹⁵ remains to be fully determined. Finally, with 1-day ELD–negative patients, resorting to intracranial monitoring or a lumbar infusion test does not provide higher negative prognostic power against further risks inherent to these procedures.¹⁵

Although the length of hospitalization was not quantitatively assessed in our patients, the shorter duration of the trial and fewer days spent in the hospital intuitively suggest substantial cost savings. The cost-effectiveness of prolonged ELD in iNPH has been previously analyzed.³ Only

a screening test providing the minimal 0.95 sensitivity at 80% specificity would improve expected outcomes, compared with results of direct shunting in cases of suspected iNPH.³ In the absence of such a test, all patients with suspected iNPH should automatically receive a VPS without further investigation.³ Studies on the overall performance and costs of 1-day ELD might help understand whether the required cost-effectiveness threshold is reached.

One-Day ELD Complications

Governale et al.,⁸ who retrospectively analyzed complications of prolonged ELD on 233 patients, distinguished procedural complications from those related to drainage itself, which were classified as minor and significant.

Procedural complications involved difficulties in drain positioning in 4.3% of their patients.⁸ In fact, drain positioning can be difficult in patients with spinal arthrosis or in obese patients, as in the 2 patients (2.1%) of our series. Impossibility of drain positioning was also observed in 3 (4.6%) of 65 patients by Mahr et al.¹⁵ and 1 (6.7%) of 15 patients by Lenfeldt et al.¹⁴ Walchenbach et al.²⁷ reported drain disruption/displacement in 5 (13.2%) of 38 patients, and Haan and Thomeer¹⁰ in 4 (18.2%) of 22 patients. Marmarou et al.¹⁷ reported accidental drain removal in 4 (2.6%) of 151 patients. In Chotai et al.,⁵ 1 (1.5%) of 66 patients removed the drain prematurely because he became agitated. No removal of drains was reported in the study of Governale et al.,⁸ who secured the catheter with 3 sutures. Our technique allowed us to reliably secure the spinal catheter, avoiding sutures, and no drain removal occurred among our patients. A shorter time in bed results in better compliance, especially for patients with cognitive deterioration, and this may also explain the absence of accidental drain removal in our study.

In the study of Governale et al.,⁸ minor and significant drainage complications were 5.2% and 3.0%, respectively. Among minor complications, 6 of their patients (2.6%) experienced nerve root irritation, which required premature drain removal in 3 patients.⁸ Root irritation was also observed in 13.6% of patients in the study of Haan and Thomeer¹⁰ and in 9% of cases in the investigation by Chotai et al.,⁵ who withdrew the catheter by 5–10 mm and administered pain medication. In our series, root irritation occurred in 2 patients (2.2%), for whom pain was alleviated by repositioning them to reduce stretching of the lumbar spinal root. This simple expedient step helped patients tolerate the drainage and complete the trial, thanks to its short duration.

In this study, 1 patient experienced signs and/or symptoms suggestive of intracranial hypotension²² during drainage, which is thought to be caused by the downward displacement of the brain due to a reduction of the buoyant action of CSF.¹⁹ This unpredictable occurrence did not involve significant consequences. However, because of its potential danger, close monitoring is advised in the first hours of the procedure, even with standard CSF drainage speed.

Governale et al.⁸ reported 1.7% of patients with headache required early drain removal; Marmarou et al.¹⁷ described this in 2.6% of patients. Compared to our study, headache was noted in the literature when a smaller daily

amount of CSF was drained at slower speed,⁸ while it did not appear when larger amounts were drained more quickly.^{4,21} Moreover, headache was observed independent of continuous⁸ or intermittent modality of CSF drainage.^{14,17} The percentage of headache (9.9%) in the present study was higher than that in the literature. No procedural differences in drainage were found between patients in our series who experienced headache or did not, to account for its occurrence. The reasons behind the difference between our study and previous reports remain unclear.

In our series, headache occurred significantly more frequently in 1-day ELD–negative patients, which is a novel finding. Experimentally, headache occurs when approximately 10% of the estimated total CSF volume is withdrawn.¹³ Moreover, it has been reported that hypovolemia is the essential cause of headache in these conditions, rather than intracranial hypotension.²⁰ It may be hypothesized that headache occurs in 1-day ELD–negative patients rather than in positive-outcome patients because their CSF volumes are in the normal range and are more likely to experience CSF hypovolemia. Thus, headache might not be considered a complication of the drainage, but rather a response to reduction of CSF volume in patients with other conditions mimicking iNPH. Indeed, headache was a perfect predictor of negative outcome to 1-day ELD, although not all the negative-outcome patients developed headache during the procedure. If confirmed in further studies, intraprocedural headache occurrence could allow anticipated conclusion of drainage. On the other hand, absence of headache strengthens the prediction of a positive test outcome.

Among significant complications of ELD, Governale et al.⁸ reported catheter retention in 1 patient that led those authors to verify complete catheter removal by the presence of the marked distal tip. In prolonged ELDs for iNPH, meningitis was observed at a rate ranging from 5.2%²⁷ to 9%¹⁰ in the earliest studies; the meningitis rate declined in later studies. In a study aimed to assess infectious complications from spinal catheter insertion in 419 patients with iNPH, Greenberg and Williams⁹ found a 3.6% rate, with 1 death. Infections were reduced to 1.8% when chlorhexidine topical antiseptics was performed.⁹ In other reports, meningitis ranged from 0% to 1.3%.^{5,8,17} With the limitation that we did not perform microbiological analyses, no meningitis was observed in our study. Because a nil/low rate of meningitis was reported in studies (including ours) in which antibiotic prophylaxis was performed,^{8,9} and in studies in which it was not,^{5,17} the use of antibiotics remains questionable. Moreover, the absence or low rate of meningitis in both prolonged ELDs and 1-day ELDs would suggest that procedural duration has no role in its occurrence.

Governale et al.⁸ reported a 1.3% rate of symptomatic subdural collection (2 hematomas, 1 hygroma), and a 0.4% rate of traumatic subarachnoid hemorrhage. The occurrence of subdural fluid collection was not observed in the other prolonged ELD experiences. Specifically, none of the patients in a study in which CT was systematically performed after drain removal¹⁷ showed subdural fluid collections. With the limitation that we did not perform systematic imaging, none of our patients experienced neu-

rological signs or symptoms suggestive of subdural fluid collection. Therefore, considering our experience and the data in the literature, the occurrence of this complication may be considered rare and systematic postdrainage CT unnecessary, but performed prudentially in those patients who become symptomatic.

Overall, 1-day ELD demonstrated a 2.1% rate of procedural complications, 3.2% rate of minor drainage-related complications (including nerve root irritation and intracranial hypotension), and no significant complications. A higher rate of complications was reported in prolonged ELDs^{5,8–10,17,27} with the exception of headache, which occurred more frequently in this study. However, it is debatable whether this latter occurrence is to be considered a true complication.

Conclusions

One-day ELD is a safe tool for VPS selection in patients with iNPH, with shunting recommended only if results of the test are positive. Because 1-day ELD has good performance and a low overall complication rate, and it appears more appealing for patients and offers healthcare cost savings, it should be considered one of the main options among supplemental tests in shunt selection in iNPH.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Porfirio, Gallina, Di Lorenzo, Scollato. Acquisition of data: Lastrucci, Scollato. Analysis and interpretation of data: Lastrucci, Caini, Scollato. Drafting the article: Porfirio, Gallina, Lastrucci, Caini. Critically revising the article: Porfirio, Gallina, Di Lorenzo. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Porfirio. Statistical analysis: Caini. Study supervision: Gallina, Di Lorenzo.

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