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Extended lumbar drain trials for diagnostic evaluation of idiopathic normal pressure hydrocephalus with the Berg Balance Scale

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OBJECTIVE Idiopathic normal pressure hydrocephalus (iNPH) is characterized by impaired gait, cognitive impairment, and urinary incontinence. Idiopathic NPH is treated with insertion of a ventriculoperitoneal shunt (VPS), but response to VPS placement varies. Extended lumbar drain (ELD) trials over a 3-day period can predict VPS success. Patients undergoing ELD trials are evaluated for gait improvement after lumbar drain (LD) placement using the Berg Balance Scale (BBS). This study examines changes in BBS scores in iNPH patients undergoing an ELD trial to determine the optimal trial length.

METHODS This single-center, retrospective analysis included iNPH patients from 2007 to 2023 who underwent an ELD trial. Daily BBS scores were compared along with frequency of achieving the minimal detectable change (MDC), the threshold for clinical improvement, which varies between 4 and 7 points depending on the baseline score. Billing data were used to calculate the average daily charges of admission for ELD trials, excluding the LD procedure cost.

RESULTS Eighty iNPH patients were included. The mean BBS score difference from baseline improved by 3.7 points on day 1, 7.19 points on day 2, and 8.38 points on day 3. MDC thresholds were met by 31% of patients on day 1, 77% on day 2, and 82% on day 3. The increase in MDC achievement from day 1 to day 2 was significant ($p < 0.0001$), while the change from day 2 to day 3 was not ($p = 0.3428$). The average total admission charge was $31,168.14 (standard error of the mean $994.61), with a per diem charge of $9756.05 after subtracting the LD procedure charge ($1900).

CONCLUSIONS While daily improvements in BBS score are seen during the ELD trial, achievement of MDC thresholds primarily happens by day 2. These data suggest that for patients who meet the MDC, limiting the ELD trial to 2 days could reduce costs without compromising the diagnostic utility of the ELD.

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KEYWORDS Berg Balance Scale; cost analysis; idiopathic normal pressure hydrocephalus; lumbar drain trial

IDIOPATHIC normal pressure hydrocephalus (iNPH) is a syndrome caused by the abnormal accumulation of CSF in the brain's ventricles, leading to ventriculomegaly.[1] Although its pathophysiology is unknown, iNPH is characterized by a well-documented triad of symptoms including gait disturbances, cognitive impairment, and urinary incontinence.[2,3] Idiopathic NPH poses significant challenges in diagnosis and management due to its insidious presentation and overlapping symptoms with other neurodegenerative disorders.[4]

Idiopathic NPH is treated with CSF diversion, typically with a ventriculoperitoneal shunt (VPS).[5] However, response to VPS placement is variable and predictive factors for shunt success are not well established.[6,7] Careful patient selection and preoperative evaluation of suspected iNPH can improve VPS response and patients' symptoms.

ABBREVIATIONS BBS = Berg Balance Scale; CPT = Current Procedural Terminology; EDW = Enterprise Data Warehouse; ELD = extended LD; iNPH = idiopathic normal pressure hydrocephalus; LD = lumbar drain; LOS = length of stay; MDC = minimal detectable change; PT = physical therapist; SEM = standard error of the mean; VPS = ventriculoperitoneal shunt.

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Lumbar drain (LD) trials are one way to diagnose iNPH and predict the response to VPS placement.[8] During an LD trial at our institution, CSF is continuously drained through a lumbar subarachnoid drain for 3 days, simulating the effects of a shunt. This temporary drainage allows clinicians to assess the patient's response to CSF diversion by tracking subsequent improvements in gait, cognition, and urinary symptoms. A favorable response to an LD trial is used to identify patients who might benefit from VPS placement.[9]

In evaluating the effectiveness of LD trials, objective measures such as the Berg Balance Scale (BBS) are utilized.[10,11] The BBS is an extensively studied and validated clinical assessment of functional balance used as an outcome measure in conditions characterized by balance impairment, including iNPH.[12,13] The BBS is a 14-item measure that assesses balance and fall risk in adults.[14] Scores range from 0 to 56, where lower scores indicate an increased fall risk. The BBS has been utilized to identify improvements in gait and balance function after CSF diversion in patients undergoing workup for iNPH.[15] BBS has been shown to be significantly lower in patients with iNPH when compared with age-matched healthy subjects and has been validated as a useful outcome measure in evaluating iNPH improvement.[16] In 2009, Donoghue and Stokes proposed a minimal detectable change (MDC) stratified by baseline BBS score to determine a clinically significant true improvement (i.e., the minimum increase in BBS score necessary based on the baseline BBS score) in older patients after an intervention.[17] Patients scoring between 0 and 24, 25 and 34, 35 and 44, and 45 and 56 at baseline should increase in BBS score by ≥ 5, ≥ 7, ≥ 5, and ≥ 4 points, respectively, to meet the minimal clinically significant improvement. By tracking changes in BBS score from baseline during an LD trial with the proposed MDC thresholds, clinicians can quantify clinically significant improvements in functional balance due to CSF diversion.

Recent literature has reported the use of extended lumbar drain (ELD) trials to provide a longer evaluation of patients admitted for suspected iNPH.[18,19] These extended trials, typically lasting at least 3 days, allow for a longer duration of CSF diversion. However, ELD trials require longer hospital admissions and greater resource allocation for the evaluation of suspected iNPH.[20] Few studies have evaluated whether daily improvements in balance during the trial justify the increased length of stay (LOS).[21] The purpose of this study was to evaluate the day-by-day effectiveness of ELD trials in improving BBS scores among patients with iNPH and predicting response to VPS placement.

Methods

This study was granted approval by our institutional review board. We identified patients diagnosed with iNPH at our tertiary academic center through our institution's Enterprise Data Warehouse (EDW) from 2007 to 2023 using ICD-9 code 331.5 and ICD-10 code 91.2 and filtered this set for ELD trials. Per the literature, we defined an ELD trial as at least 3 consecutive days of inpatient admission following LD placement. Patients at our institution are admitted, receive a baseline BBS assessment, and then undergo LD placement. They undergo drainage for 3 days and their BBS score is assessed daily by a physical therapist (PT). To be included in the analysis set, patients had to have BBS scores recorded for each day of inpatient admission along with a baseline BBS score prior to LD placement for comparison. We collected the time of day that the PT's evaluation was reported in the medical records. Gait and balance testing occurred consecutively every day following baseline BBS evaluation and LD placement. We compared the difference in time to assessment between each BBS evaluation (baseline to day 1, day 1 to day 2, and day 2 to day 3) for the entire cohort. We then repeated this analysis for each of the subsequent subgroups, recording the interval duration between baseline assessment, LD placement, and daily BBS evaluations.

Minimal Detectable Change

For each patient, we calculated the difference between their BBS score on each day of inpatient admission and their baseline BBS score. We then categorized these values based on the 95% confidence thresholds for MDC based on prior literature. We repeated this analysis across subgroups defined by MDC achievement, where MDC achievement was defined as meeting the MDC threshold at least once across the 3-day ELD trial.

Predicting VPS Success

To determine if MDC achievement predicts VPS success, we identified patients who had undergone VPS placement in this cohort with the Current Procedural Terminology (CPT) code 62223. We included patients who had a follow-up after VPS placement of at least 3 months. We defined VPS success as clinician-noted gait improvement during the standard physical examination at any follow-up visit between 3 and 6 months and between 6 and 12 months after VPS placement. Patients were determined to be late VPS responders if their gait did not improve between 3 and 6 months but did improve between 6 and 12 months. For this analysis, patients who did not undergo VPS placement were excluded. Similar to the MDC analysis, we conducted a subgroup analysis of the day-by-day BBS score differences and MDC achievement rates of VPS responders and VPS nonresponders.

Cost Analysis

Additionally, we conducted a cost analysis to understand the per diem charges associated with admission during the 3-day ELD trial. All recorded billing information was pulled from our institution's EDW for all patients in our cohort. From the averaged billed amount per patient, we subtracted the cost of the LD procedure as reported in our institution's standard charge report based on CPT code 62272 ($1900) and divided the remaining average charge by the 3 days of admission. The result was attributed to be the per diem charge associated with the ELD trial. We further categorized this per diem amount into a room and board cost versus the cost of any other services using the daily cost of a surgical bed reported in our institution's standard charge report.

Statistical Analysis

For the overall cohort as well as within each subgroup of interest (VPS responders, VPS nonresponders, MDC achievers, and MDC nonachievers), we compared the mean BBS score difference from baseline between consecutive days using paired 2-tailed Welch t-tests, as well as the frequency of MDC threshold achievement between consecutive days using the McNemar test. Between subgroups, BBS scores and MDC threshold achievement were compared for each day using unpaired 2-tailed Welch t-tests and Fisher exact tests, respectively. The t-test was used throughout this analysis based on the appropriate sample size according to the central limit theorem.[22] For all analyses, statistical significance was defined a priori as a p value < 0.05.

Results

Cohort Characteristics

Eighty iNPH patients met our inclusion criteria and were included in the analysis. The average time between assessments was 24.59 hours (standard error of the mean [SEM] 0.373 hours) from baseline to day 1, 24.39 hours (SEM 0.310 hours) from day 1 to day 2, and 22.99 hours (SEM 0.321 hours) from day 2 to day 3. The time to assessment from day 2 to day 3 was significantly lower than that from baseline to day 1 ($p = 0.0043$) as well as from day 1 to day 2 ($p = 0.0073$). The time between assessments from baseline to day 1 and from day 1 to day 2 was not significantly different ($p = 0.7497$). While there is a shorter interval from day 2 to day 3, the timing difference was < 2 hours and not clinically meaningful. Only 5 patients had ELD trials extending to an inpatient LOS of 4 days with an LD in place. The average patient age was 74 years (SEM 0.685 years), with a slight male predominance (56%). The average BBS score prior to LD placement was 34.03 (SEM 1.305) (Table 1).

TABLE 1. Cohort characteristics (n = 80)

Variable	Value
Age at diagnosis, yrs	74.33 (0.685)
Male sex	45 (56.3)
BMI	28.63 (0.619)
Comorbidities	
Diabetes	16 (20.0)
Hypertension	62 (77.5)
CHF	17 (21.3)
MI	9 (11.3)
COPD	13 (16.3)
BPH	21 (26.3)
Presenting symptoms	
Gait impairment	79 (98.8)
Cognitive impairment	71 (88.8)
Urinary incontinence	52 (65.0)
Procedure characteristics	
Baseline BBS score	34.03 (1.305)
VPS placement	62 (77.5)
Time to VPS placement from LD trial, mos	8 (1.968)
Length of follow-up from LD trial, mos	86 (9.816)

BPH = benign prostatic hyperplasia; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; MI = myocardial infarction.
Values are given as number of patients (%) or mean (SEM).

MDC Results

For the total cohort, the average change from baseline to day 1 was 3.7 (SEM 0.506); from baseline to day 2, 7.19 (SEM 0.804); and from baseline to day 3, 8.38 (SEM 0.504). The changes from day 1 to day 2 and from day 2 to day 3 were statistically significant ($p < 0.0001$ and $p = 0.0006$, respectively). MDC thresholds were first met for 25 (31%), 34 (43%), and 7 (9%) patients on days 1, 2, and 3, respectively. When adjusting for overall MDC achievement status, 25 (31%) patients achieved this threshold on day 1, 58 (73%) achieved or maintained it on day 2, and 62 (78%) achieved or maintained it on day 3. The difference between day 1 and day 2 was significant ($p < 0.0001$), while the difference between day 2 and day 3 was not ($p = 0.3428$) (Table 2).

In the subgroup analysis, 66 patients achieved an MDC, while 14 patients never achieved an MDC during the trial. There was no statistically significant difference in duration at any interval between BBS assessments for MDC achievers and nonachievers, respectively (baseline to LD placement: 2.02 and 1.83 hours, $p = 0.4299$; LD placement to day 1 to day 2: 22.71 and 22.10 hours, $p = 0.6062$; baseline to day 1: 24.73 and 23.92 hours, $p = 0.4782$; day 1 to day 2: 24.18 and 25.38 hours, $p = 0.1442$; day 2 to day 3: 22.80 and 23.86 hours, $p = 0.2646$). Of the 66 patients who achieved an MDC during the trial, 4 patients met their MDC threshold on day 1 or day 2 but did not meet it on day 3. For the MDC achievers, the average change from baseline was 4.29 (SEM 0.581) on day 1, 8.21 (SEM 0.542) on day 2, and 9.48 (SEM 0.510) on day 3. The changes from day 1 to day 2 and from day 2 to day 3 were statistically significant ($p < 0.0001$ and $p = 0.0019$, respectively). For each day, the frequencies of MDC achievement were 25 (38%), 58 (88%), and 62 (94%), respectively. The frequency of MDC achievement from day 1 to day 2 was significant ($p < 0.0001$), but it was not from day 2 to day 3 ($p = 0.3427$), reflecting the same trend as the overall cohort.

For the 14 MDC nonachievers, the average change from baseline was 0.93 (SEM 0.486) on day 1, 2.36 (SEM 0.289) on day 2, and 3.14 (SEM 0.390) on day 3. The difference in BBS score improvement from day 1 to day 2 was significant ($p = 0.0077$), while that for day 2 to day 3 was not ($p = 0.0595$).

When comparing the daily improvements in BBS score from baseline between MDC achievers and nonachievers, a significant difference ($p < 0.0001$) was demonstrated every day during the trial. The trend of BBS score improvement from baseline across all three groups (MDC achievers, MDC nonachievers, and total cohort) is represented in Fig. 1.

Predicting VPS Success Results

Of the patients who underwent an ELD trial, 62 patients

TABLE 2. BBS scores and MDC achievement frequency across each inpatient admission day for total cohort, MDC achievers, and MDC nonachievers

	Overall (n = 80)	MDC Achievers (n = 66)	MDC Nonachievers (n = 14)
Day 1			
BBS score change	3.70 (0.506)	4.29 (0.581)	0.93 (0.486)
MDC	25 (31)	25 (38)	0 (0)
Day 2			
BBS score change	7.19 (0.804)	8.21 (0.542)	2.36 (0.289)
Day 1 to day 2 BBS score change p value	**<0.0001**	**<0.0001**	**0.0077**
MDC	58 (73)	58 (88)	0 (0)
Day 1 to day 2 MDC p value	**<0.0001**	**0.0077**	
Day 3			
BBS score change	8.38 (0.504)	9.48 (0.510)	3.14 (0.390)
Day 2 to day 3 BBS score change p value	**0.0006**	**0.0019**	0.0595
MDC	62 (78)	62 (94)	0 (0)
Day 2 to day 3 MDC p value	0.3428	0.3427	

Values are given as number of patients (%) or mean (SEM) unless otherwise indicated. Boldface type indicates statistical significance.

underwent VPS placement and met our inclusion criteria. Of these patients, 48 had a successful VPS outcome, while 14 did not. Of the 48 patients who had a successful VPS outcome between 3 and 12 months, 44 (92%) responded between 3 and 6 months and 4 (8%) first responded between 6 and 12 months postoperatively.

Comparing BBS assessment intervals, there was a significant difference from day 1 to day 2 between VPS responders and nonresponders (23.95 and 25.64 hours, respectively; $p = 0.0438$). However, there was no significant difference between VPS responders and nonresponders, respectively, at all other assessments (baseline to LD placement: 2.00 and 1.93 hours, $p = 0.0898$; LD placement to day 1 to day 2: 23.37 and 21.08 hours, $p = 0.1024$; baseline to day 1: 25.28 and 23.01 hours, $p = 0.0705$; day 2 to day 3: 22.85 and 22.53 hours, $p = 0.7166$). While there was a significant difference in the interval hours between VPS responders and nonresponders from day 1 to day 2, this was not clinically meaningful as the difference was < 2 hours.

For the 62 patients who had a VPS placed, the average BBS score improvement from baseline was 3.81 (SEM 0.612) on day 1, 7.81 (SEM 0.591) on day 2, and 9.05 (SEM 0.578) on day 3. The changes from day 1 to day 2 and from day 2 to day 3 were statistically significant ($p < 0.0001$ and $p = 0.0014$, respectively). For each day, the rates of MDC achievement were 31% (n = 19), 77% (n = 48), and 82% (n = 51), respectively. The frequency of MDC achievement

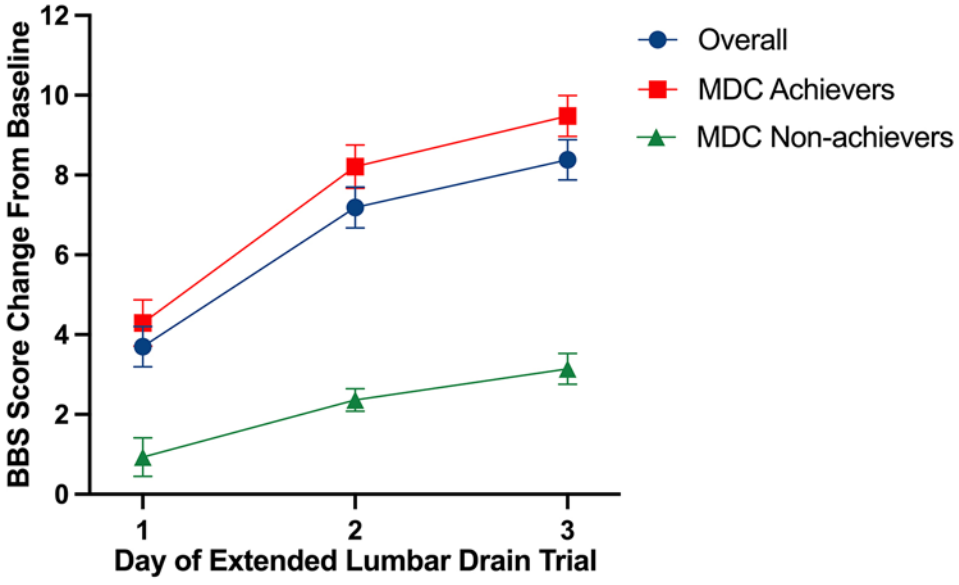

FIG. 1. BBS score improvement in overall cohort (n = 80), MDC achievers (n = 66), and MDC nonachievers (n = 44). Figure is available in color online only.

TABLE 3. BBS scores and MDC achievement frequency across each inpatient admission day for overall patients with VPS, VPS responders, and VPS nonresponders

	Overall (n = 62)	VPS Responders (n = 48)	VPS Nonresponders (n = 14)
Day 1			
BBS score change	3.81 (0.612)	4.40 (0.735)	1.79 (0.847)
MDC	19 (31)	18 (38)	1 (7)
Day 2			
BBS score change	7.81 (0.591)	8.33 (0.686)	6.00 (1.045)
Day 1 to day 2 BBS score change p value	**<0.0001**	**<0.0001**	**0.0029**
MDC	48 (77)	40 (83)	8 (57)
Day 1 to day 2 MDC p value	**<0.0001**	**<0.0001**	**0.0233**
Day 3			
BBS score change	9.05 (0.578)	9.75 (0.663)	6.64 (0.965)
Day 2 to day 3 BBS score change p value	**0.0014**	**0.0009**	0.4874
MDC	51 (82)	41 (85)	10 (71)
Day 2 to day 3 MDC p value	0.5050	>0.999	0.6171

Values are given as number of patients (%) or mean (SEM) unless otherwise indicated. Boldface type indicates statistical significance.

from day 1 to day 2 was significant ($p < 0.0001$), but that from day 2 to day 3 was not ($p = 0.5050$) (Table 3).

Among the 48 patients who had an improvement in gait after VPS placement, the average BBS score improvement from baseline was 4.40 (SEM 0.735) on day 1, 8.33 (SEM 0.686) on day 2, and 9.75 (SEM 0.663) on day 3. The improvement in BBS score from day 1 to day 2 was significant ($p < 0.0001$), as was that from day 2 to day 3 ($p = 0.0009$). Comparing BBS scores between the 44 early (3–6 months) and 4 late (6–12 months) VPS responders, there was no significant difference at any time point between the early and late responders, respectively (day 1: 4.09 and 7.75, $p = 0.2652$; day 2: 8.16 and 10.25, $p = 0.3077$; day 3: 9.64 and 11.00, $p = 0.4458$). For each day, the rates of MDC achievement for VPS responders were 38% (n = 18), 83% (n = 40), and 85% (n = 41), respectively. Only 3 (6%) patients who responded positively to VPS placement first achieved the MDC threshold on day 3. The frequency of MDC achievement from day 1 to day 2 was significant ($p < 0.0001$), while that from day 2 to day 3 was not ($p > 0.9999$). There was no significant difference in MDC achievement between early and late VPS responders, respectively (day 1: 34% and 75%, $p = 0.1415$; day 2: 82% and 100%, $p > 0.999$; day 3: 84% and 100%, $p > 0.999$).

Of the 14 patients who did not have a successful outcome after VPS placement, the average BBS score improvement from baseline was 1.79 (SEM 0.847) on day 1, 6.00 (SEM 1.045) on day 2, and 6.64 (SEM 0.965) on day 3. The improvement in BBS score from day 1 to day 2 was significant ($p = 0.0029$), but that from day 2 to day 3 was not ($p = 0.4874$). For each day, the rates of MDC achievement were 7% (n = 1), 57% (n = 8), and 71% (n = 10), respectively. The frequency of MDC achievement from day 1 to day 2 was significant ($p = 0.0233$), while that for day 2 to day 3 was not ($p = 0.6171$).

When comparing daily BBS score improvements between VPS responders and nonresponders, day 1 and day 3 showed a statistically significant difference ($p = 0.0258$ and $p = 0.0132$, respectively), but day 2 did not ($p = 0.0742$). However, when comparing MDC achievement between the two subgroups, day 1 showed a statistically significant difference ($p = 0.0459$), but day 2 and day 3 did not ($p = 0.0656$ and $p = 0.2493$, respectively) (Table 4). The trajectories of BBS score improvement from baseline and MDC threshold achievement across all three groups (VPS responders, VPS nonresponders, and VPS total cohort) are represented in Fig. 2.

Cost Analysis Results

The average total admission charge of the ELD trial was $31,168.14 (SEM $994.61). After subtracting the cost of the LD procedure ($1900), the remaining average charge was $29,268.14. The per diem charge associated with admission was $9756.05. The cost associated with a surgical bed is $2674 per day. The remaining per diem charge is $7082.05, representing the daily cost of PT testing, neuropsychiatric assessments, laboratory testing, and medications.

Discussion

This study examined the relationship between ELD trials and daily improvement in patient BBS scores reflecting improvements in functional balance and gait after CSF drainage. Studies utilizing the BBS for evaluating improvement in balance and gait have reported numeric improvement after CSF diversion but have not analyzed

TABLE 4. Comparison of daily BBS scores and MDC achievement trajectories between VPS responders and nonresponders

	p Value		
	Day 1	Day 2	Day 3
BBS mean change	**0.0258**	0.0742	**0.0132**
MDC comparison	**0.0459**	0.0656	0.2493

Boldface type indicates statistical significance.

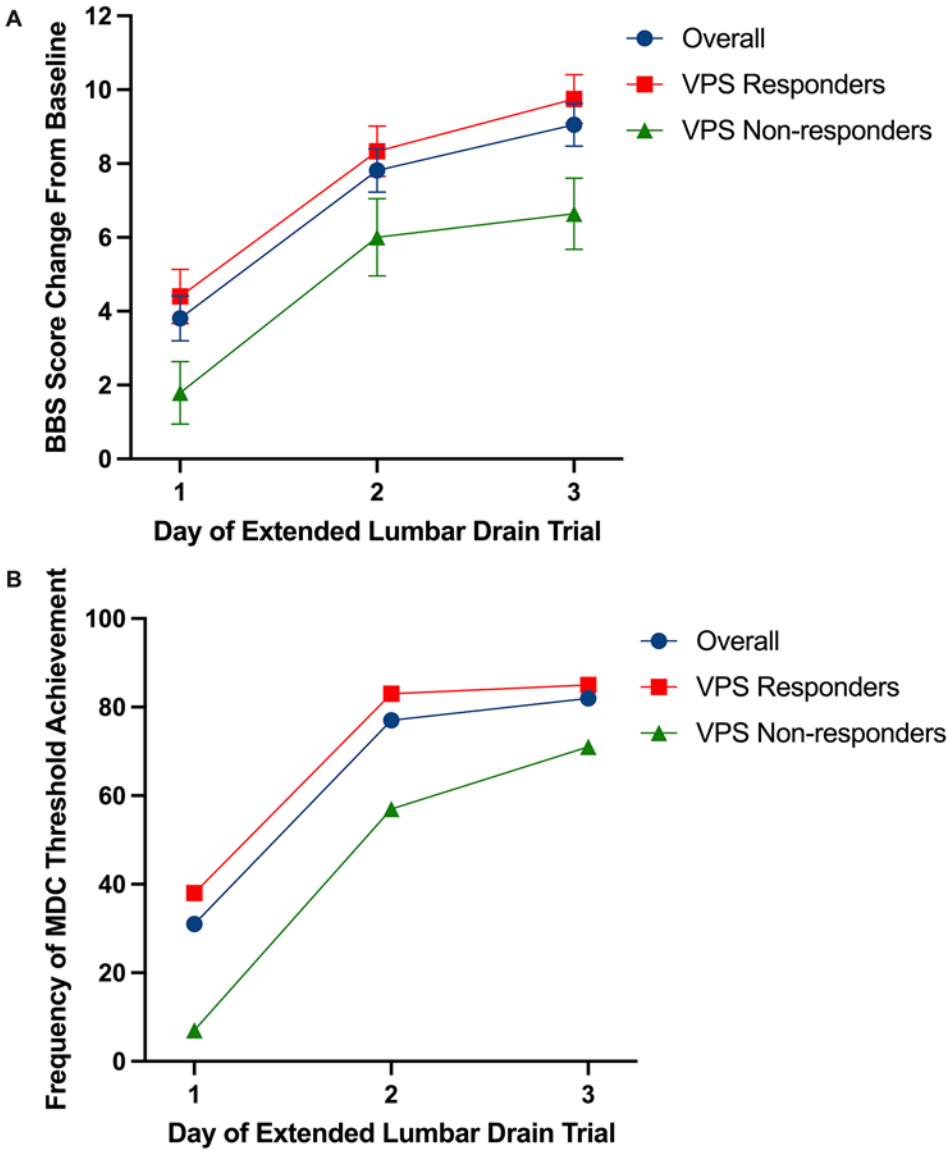

FIG. 2. BBS score improvement (**A**) and frequency of MDC threshold achievement (**B**) in overall patients with VPS (n = 62), VPS responders (n = 48), and nonresponders (n = 14). Figure is available in color online only.

daily changes using the MDC thresholds as proposed by Donoghue and Stokes for clinically significant improvement.[17]

The reported utility of the ELD in the evaluation of iNPH is the extended period of CSF drainage and further outcome measurement in improvements of gait, incontinence, and cognition.[18,23] However, to our knowledge, there have not been studies reporting daily changes in outcomes to justify the increased LOS required of an ELD trial or to determine the optimal length of these trials.

In this presented study, there was no clinically significant improvement in BBS score according to MDC thresholds from day 2 to day 3 of the ELD trial. These results indicate that while scores in the BBS improve numerically every day of the ELD trial, there is a plateau in true clinical improvement between day 2 and day 3. This held true within a subgroup analysis defined by MDC achievement.

This study also showed that patients who experience improvements in their gait after VPS placement do not have clinically significant improvements in their BBS scores from day 2 to day 3 of the ELD trial. Patients who do not respond to VPS placement also do not experience increases in BBS scores after day 2, nor do they achieve MDC thresholds after day 2. During an LD trial, any differences between probable VPS responders and nonresponders will manifest between day 1 and day 2. This suggests that clinicians can determine LD trial response within 2 days rather than 3 days if MDC thresholds are met by the 2nd day.

While 7 patients in our cohort first achieved an MDC on day 3, the frequency of MDC achievement from day 2 to day 3 was insignificant. Only 3 of these 7 patients ex-

perienced improvement in gait following VPS placement. These data indicate that there is a potential benefit to the 3rd day of the trial for patients who have not met the MDC during the first 2 days, although these changes are not significant across the cohort. To increase the sensitivity for the trial, clinicians can proceed with a 3-day ELD trial for patients who have not achieved MDC thresholds by day 2. However, for the majority of patients who achieve an MDC by day 2, the addition of a 3rd day to the LD trial increases the LOS and does not correlate with a significant improvement in functional balance in patients who will benefit from VPS insertion.

In the present study, we conducted a cost analysis and found that the per diem charge associated with the ELD trial is $9756.05. This daily cost represents a significant financial burden for patients and resource allocation by hospitals. The increased LOS can negatively impact patients' fiscal well-being with minimal benefit to the diagnostic validity of the LD trial. Conversely, decreasing the length of LD trials for patients who meet MDC thresholds by day 2 can result in significant savings for this subset of patients. The cost-effectiveness of ELD trials is a significant concern reported in the literature.[9,24] Efforts should be made to reduce unnecessary inpatient stays to improve healthcare efficiency.

The major limitation with this study is its retrospective nature and small cohort size drawn from a single institution. Additionally, the results of this study are specific for LD trials requiring inpatient admission and cannot be generalized to outpatient, large-volume CSF lumbar punctures for the diagnosis of iNPH. Future large-cohort, prospective, and randomized studies with sufficient power should be conducted to further determine the degree of improvement of a 2-day versus 3-day LD trial as well as the predictive power of both in determining response to VPS placement.

Conclusions

The primary conclusion of this study is that LD trials for diagnostic evaluation of iNPH can be limited to 2 days for patients who meet MDC thresholds by day 2 after LD placement. The extension of LD trials to 3 days for this subset of patients does not correlate with increased functional gait and balance improvement. However, if MDC thresholds are not achieved by day 2, the LD trial can continue to 3 days to increase its sensitivity. Decreasing the duration of LD trials for iNPH evaluation will decrease the financial burden for patients without compromising their diagnostic validity. Future large prospective studies should be conducted to compare the effectiveness of 2-day versus 3-day LD trials in assessing balance and gait improvement in suspected iNPH.

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Disclosures

Dr. Rosenow reported personal fees from Boston Scientific Neuromodulation, Stryker, Monteris, and AiM Medical Robotics outside the submitted work. Dr. Lesniak reported being a stockholder in Calidi Biotherapeutics.

Author Contributions

Conception and design: Magill, Sadagopan, Houskamp. Acquisition of data: Sadagopan, Houskamp, Nandoliya, Chaliparambil, Govind, Alwakeal, Cannone, Grivas, Kennedy, Rosenow, Chandler, Tate. Analysis and interpretation of data: Magill, Sadagopan, Khazanchi, Lesniak, Potts. Drafting the article: Magill, Sadagopan, Khazanchi, Nandoliya, Govind. Critically revising the article: Magill, Sadagopan, Khazanchi, Houskamp, Nandoliya, Chaliparambil, Govind, Rosenow, Potts, Tate. Reviewed submitted version of manuscript: Magill, Sadagopan, Khazanchi, Nandoliya, Chaliparambil, Govind, Cannone, Grivas, Kennedy, Rosenow, Potts, Tate. Approved the final version of the manuscript on behalf of all authors: Magill. Statistical analysis: Khazanchi, Zhang. Study supervision: Magill, Sadagopan, Lesniak.

Supplemental Information

Previous Presentations

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