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Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) as a Cognitive Evaluation Tool for Patients with Normal Pressure Hydrocephalus

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Abstract

External lumbar drainage (ELD) is recognized as a screening method for ventriculo-peritoneal shunting (VPS) candidacy for possible normal pressure hydrocephalus (NPH). This study focused on the ELD predictability of the cognitive outcome after VPS for NPH. In addition, Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) was examined in ELD cognition screening. ELD results were considered positive with any improvement in gait and/or cognition. Among 36 patients examined for possible NPH, 26 underwent VPS because of positive ELD. Cognitive outcome after VPS was assessed at 6-month follow-up. The RBANS scores, examined pre- and post-ELD, were evaluated statistically to identify consistency with the neuropsychologist judgment and the predictability of cognitive outcome after VPS. Among 26 shunted patients, gait was improved in 24. Cognitive improvement was rated in 19, and there were 9 false negative and 5 false positive in ELD cognition screening. The neuropsychologist judgment in ELD cognition screening is most consistent with the RBANS score in delayed memory. The patients rated as improved in cognition after VPS had significantly lower RBANS scores pre-ELD in immediate memory and delayed memory. If both scores at pre-ELD were ≤ 80 (13 patients), all were rated as improved in cognition after VPS. ELD screening was highly predictive of clinical gait improvement but not of cognitive improvement after VPS for possible NPH. Particularly among patients with a positive ELD gait response, pre-ELD low RBANS scores in memory predicted cognitive improvement after VPS. RBANS seems effective in evaluating cognition for NPH.

Key words: cognition, external lumbar drainage, normal pressure hydrocephalus, Repeatable Battery for the Assessment of Neuropsychological Status

Introduction

Typical symptoms of normal pressure hydrocephalus (NPH) include the "triad" of impaired gait, cognitive impairment, and urinary incontinence. The efficacy of surgical procedures, most commonly ventriculo-peritoneal shunting (VPS) or endoscopic third ventriculostomy for selected cases,[1,2] is evaluated by clinical improvement in this triad of symptoms. However, clinical improvement may not occur in all symptoms. Individual patients vary in the importance placed on change in each symptom (i.e., one patient may only be concerned with cognitive improvement, while another may only care about improvement in gait). It is not sufficient to determine that a surgery is effective by observing improvement in any preoperative clinical symptom, although several former reports have done so.[3–5] It is important to be able to predict the degree of expected improvement in each symptom in order to counsel patients appropriately.

Temporary continuous slow cerebrospinal fluid (CSF) diversion through external lumbar drainage (ELD) is regarded as a reliable predictive evaluation

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for VPS candidacy.[6,7] However, the predictive value of the ELD screening, specifically in terms of cognitive improvement, has not been adequately studied. There is no consensus regarding the prediction of cognitive improvement after VPS for NPH; some believe cognitive outcome can be predicted[8–10] and some doubt preoperative prediction is possible.[11,12]

One of the reasons for the difficulty in analyzing cognitive improvement in patients with possible NPH is the discordance between the neuropsychological examinations and patients and/or families' impression. In fact, some patients may not feel any cognitive improvement even with the increase in the examined scores; on the contrary, others may believe their symptoms have improved without any objective evidence. Patients and/or families' impression should be respected, although that does not necessarily indicate the reality. Unfortunately, the patients at the clinic for the postoperative evaluation after VPS tend to be reluctant to undergo further cognitive evaluations, since the postoperative detailed evaluation itself does not bring any symptomatic improvement, and moreover, we do not have sufficient evidence on any neuropsychological examinations to justify them as postoperative standard tests. Considering such a clinical setting, in this study, the outcome of cognition after VPS was rated as "improved" and "unimproved" based on the physician's clinical judgment by reference to patients and/or families' impression and several objective postoperative examinations, if performed, used as supportive measures. This grouping method in cognition is at risk of the physician's "subjective" contamination; however, this method of determining outcome has been frequently used in the literature and in actual clinical practice as a standard procedure.

We still recognize the importance of establishing objective neuropsychological examinations that accord closely with the impressions of the professional clinicians. In this report, the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) was examined at pre- and post-ELD to determine whether this measure is appropriate for use in patients with NPH, which has been rarely used in neurosurgical populations[13] in spite of its rapidly increasing popularity in neuropsychology assessments.[14–16] To our knowledge, this is the first article to examine RBANS as a possible indicator of cognitive improvement after VPS for NPH patients. RBANS is an attractive measure in this population for several reasons. It is brief (approximately 30 minutes to administer), has alternate forms, has a low floor making it appropriate for patients with dementia, has good older adult normative data, and it assesses several cognitive domains. As a preliminary step to examining the adequacy of RBANS for cognitive evaluation for possible NPH patients, the relation between preoperative RBANS score (differences between pre- and post-ELD) and the judgment of neuropsychologists in ELD cognition screening, based on multiple neuropsychological evaluations other than RBANS, were analyzed with other possible relating factors on their judgment.

This study primarily examined the ability of ELD screening to predict the improvement after VPS, with respect to each symptom. Inconsistent results of ELD screening with VPS outcome, especially in cognition, were further evaluated from their postoperative clinical follow-up records. Then, the adequacy of RBANS as a neuropsychological examination was addressed by comparing its scores with the neuropsychologist clinical judgment in the preoperative ELD screening. In addition, the relation between preoperative RBANS score and the outcome after VPS were evaluated with possible preoperative predictive factors, in order to identify any preoperative tendency for patients with cognitive improvement after VPS.

Methods

I. Patient population

The patients for the current study were drawn from the clinical neurosurgical practice of the senior author (AMA). These patients, since January 2009, consented to have their clinical data used for research, and this retrospective study was approved by the University of Washington (UW) Institutional Review Board (No. 40068, title: CSF analysis in patients with aging and neurodegenerative disorders including NPH on May 31, 2011). Possible idiopathic NPH patients were enrolled in this program between January 2009 and December 2010. This study is purely observational as no invasive procedures for the clinical study were performed. The standard clinical protocol at UW involves the placement of a temporary ELD to diagnose NPH and identify patients who are likely to respond favorably to VPS. A lumbar drain trial was considered successful based on any objective improvement in (1) the physical therapist's assessment and/or (2) neuropsychological assessment. It was recommended that patients with a successful lumbar drain trial undergo VPS. Candidates for the current study were identified in neurosurgery clinic at Harborview Medical Center in Seattle, and were older than 40 years of age, had both gait problems and cognitive complaints, and had evidence of ventriculomegaly on magnetic resonance (MR) imaging (Evans ratio ≥ 0.3). Patients who were unable to ambulate, and thus not able

to be evaluated for improvement in gait instability, were excluded. Idiopathic NPH was diagnosed by confirming that the patients had no prior history of any inciting events, including intracerebral hemorrhage, intracerebral infection such as meningitis, severe head trauma, major stroke, or brain surgeries for intracerebral structural lesions such as tumors. Candidates for VPS due to NPH symptoms were initially determined in clinic to have a clinical presentation suggestive of possible NPH although incontinence was not necessary for inclusion. By the end of 2011, 36 patients had been diagnosed with possible idiopathic NPH, had undergone an outpatient comprehensive neuropsychological assessment (including RBANS), completed a gait evaluation with a physical therapist, undergone ELD placement, and completed repeat gait and cognitive testing 72 hours after ELD placement. The patients who underwent VPS were followed up for at least 6 months in the clinic by the senior author (AMA).

II. Management protocol

Candidates of VPS for their possible NPH were admitted to Harborview Medical Center for ELD screening. Sterilized ELD were set up in the operating room. The CSF pressure was obtained and recorded as an "opening CSF pressure" at the time of ELD placement. The patient was then monitored on the neurosurgery floor where we drained CSF to fall within 100–250 ml per day. After 72 hours of ELD, gait/balance evaluations and neuropsychological examinations were performed as described below. The patients who proceeded to VPS were readmitted later, typically within 1 month. VPS was performed using a Medtronic Strata valve, and the pressure was initially set at the 2.5 level (13.5–15.5 cmH_2O in the supine position). The patients were scheduled to visit the outpatient clinic at 1 month, 3 months, and 6 months after VPS, and adjustment of valve pressure was made if considered necessary.

III. Evaluation summary

The gait/balance evaluations were conducted by a physical therapist and included duration of standing on one foot (30 seconds maximum), the functional reach test, and timed up and go test. Gait assessment occurred prior to ELD placement on the same day. The physical therapist judged whether gait/balance was generally impaired. The baseline cognitive examination consisted of a comprehensive outpatient neuropsychological evaluation administered by a trained psychometrist and supervised by one of two board certified clinical neuropsychologists (NC and VP). The baseline clinical neuropsychological evaluation included the RBANS, as well as several other measures of memory, executive functioning, processing speed, attention, intelligence, and language (i.e., several subtests of the third edition of the Wechsler Adult Intelligence Scale and the third edition of the Wechsler Memory Scale as traditional examinations of cognitive and memory function, full-scale intelligence quotient obtained from two-subtest form of the Wechsler Abbreviated Scale of Intelligence as an estimate of general intellectual ability, Token Test and Boston Naming Test as the evaluation of aphasia, the Wechsler Test of Adult Reading as the evaluation of reading recognition, Delis-Kaplan Executive Function System, and Frontal Systems Behavior Scale). All these examinations were completed for most patients except for few patients who refused to continue these prolonged examinations due to fatigue or poor attention, and with the results of these examinations, the neuropsychologist determined whether cognitive impairment exists in each patient. In addition, the neuropsychologist evaluated the depression and anxiety status of patients with the Beck Depression Inventory-II and Beck Anxiety Inventory. The neuropsychologist interpreted the data and indicated whether there was any concern about other causes of cognitive impairment, such as severe depression or Alzheimer's type dementia. Urinary function, including urgency, increased frequency, and incontinence was assessed via patient and family self-report.

After ELD for 72 hours and removal of the ELD, repeat gait/balance testing and repeat RBANS testing as well as other neurophysiological evaluations, considered to be appropriate for individual conditions, were completed prior to discharge and compared with the baseline data obtained prior to ELD placement. The physical therapist judged whether the patient's gait improved based on the change in gait testing. The decision of cognition improvement after ELD was based on the neuropsychologist's regular evaluation and the objective neuropsychological examinations other than RBANS, since the purpose of this study was to evaluate the appropriateness of RBANS as a diagnostic tool of cognition. According to the ELD screening results, the patients were grouped into the positive and the negative group, and the neurosurgeon (AMA) recommended VPS to patients grouped into the positive group in gait and/or cognition.

The response of triad symptoms after VPS was assessed at the follow-up visit to the clinic with the senior author (AMA). Most patients were referred for post-operative physical therapist assessment and, for the patients whose improvement in cognition was marginal, the post-operative neuropsychological evaluations were used as supportive measures for

the outcome judgment, although no neuropsychological test was performed constantly in all patients as postoperative evaluations. The outcome decision of whether the patient improved or not, was finally made by AMA in a clinically typical manner (e.g., quicker gait, more verbal, and improved urinary incontinence), with the physical therapist assessment, the results of postoperative neuropsychological test if performed, and patient and/or family self-report at 6-month follow-up.

IV. RBANS

RBANS was originally developed for cognitive screening of dementia in the elderly by Randolph et al.[17] and assesses five cognitive domains, including immediate and delayed memory, visuospatial skills, attention, and language functioning. It also yields a total score of overall cognitive functioning. Raw scores are converted to age referenced standard scores with a mean of 100 and standard deviation of 15 (range 40–160). The RBANS takes approximately 30 minutes to administer and is a level C test (requires an advanced degree in psychology or equivalent for ethical interpretation). This measure was given as part of the baseline outpatient neuropsychological evaluation and 72 hours after the ELD procedure for all patients. However, during the study period, RBANS was not performed uniformly as the postoperative routine examination, since its adequacy for NPH patients has not yet been evaluated.

V. Statistical analysis

The VPS outcome was determined in gait, cognition, and urinary incontinence respectively, and was grouped into two categories; "improved" or "unimproved" groups according to each symptom. After evaluating the overall results of ELD screening and its predictability on VPS outcome, the factors affecting ELD cognition screening were statistically analyzed with RBANS scores, in order to analyze the adequacy of RBANS for NPH cognitive screening. The continuous variables possibly related to the ELD cognition screening results were compared between the positive and the negative groups using Mann-Whitney U test, age, Evans ratio, opening CSF pressure, and total drained CSF volume as well as RBANS index scores (i.e., the five cognitive domains and the total score). Examined RBANS scores were the baseline scores (scores obtained prior to ELD), and the differences between baseline and post-ELD performance (plus when getting better and minus when getting worse). If there were significantly different scores between groups found in the Mann-Whitney U test, the variable was analyzed with multiple logistic regression analysis along with the categorical variables (sex and urinary incontinence); however, in order to avoid multicollinearity, significant RBANS scores based on the Mann-Whitney U test were analyzed individually in the logistic regression model.

In order to evaluate the preoperative RBANS score with VPS outcome in cognition, the continuous variables (age, Evans ratio, and opening CSF pressure) were also included in the analysis between the "improved" and "unimproved" groups after VPS, in the same manner as described above; first screened by the univariate method (Mann-Whitney U test), then analyzed multivariately (logistic regression model) together with the categorical variables (sex, urinary incontinence, and the ELD results).

The variables with a probability level of $P < 0.05$ in the multivariate logistic regression analysis were considered significant variables relating to ELD results or VPS outcome.

Results

I. Demographic characteristics

Among 36 patients with gait and cognitive problems, 6 patients did not complain of any urinary problems, and their intact urinary continence was confirmed during their hospital stay for the ELD screening, while the other 30 patients presented with all triad symptoms. There were 18 male, and 18 female patients, aged between 52.1 years and 89.2 years (mean 71.3 years), with an Evans ratio of 0.30–0.50 (mean 0.40). The opening pressure of ELD was 5.0–22.0 cmH_2O (mean 15.3 cmH_2O) and the total amount of drained CSF for 3 days was 251–773 ml (mean 502 ml).

II. Results of ELD screening

The results of the ELD screening are summarized in Fig. 1. Out of 36 patients, 28 had some improvement in gait/balance, and were rated as the positive group. All but 1 patient proceeded to VPS per protocol. This patient declined VPS due to a lack of cognitive improvement after ELD. Out of 36 patients, 17 were judged to have a positive cognitive response to the ELD screening. One patient who did not show any improvement in gait was judged to have a positive cognitive response, and this patient proceeded to VPS. Therefore, a total of 28 patients underwent VPS (all 17 with cognitive improvement, and 27/28 with gait improvement underwent VPS).

It was difficult for most patients to confirm improvement in urinary incontinence during the 3-day ELD trial; however, 3 patients among 30 patients who complained of urinary incontinence reported some subjective improvement.

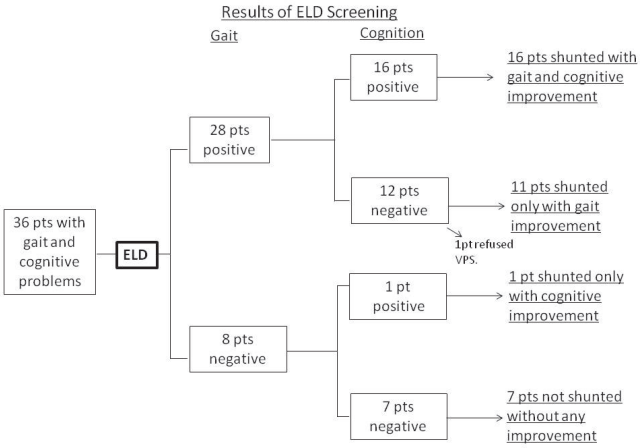

Fig. 1 Flowchart showing results of the ELD screening in gait and cognition and assignments of shunting. ELD: external lumbar drainage, pts: patients, VPS: ventriculo-peritoneal shunting.

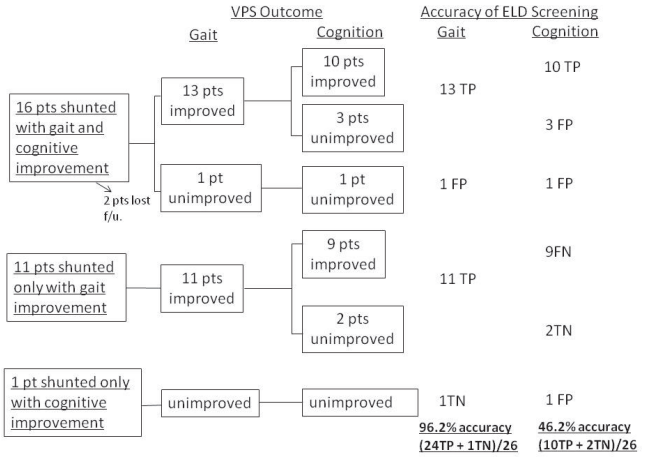

Fig. 2 Flowchart showing VPS outcome in gait and cognition and the accuracy of the ELD screening in each symptom. ELD: external lumbar drainage, FN: false negative, FP: false positive, pts: patients, TN: true negative, TP: true positive, VPS: ventriculo-peritoneal shunting.

III. Predictability of ELD screening on VPS outcome

The outcomes of VPS are summarized in Fig. 2. Among 28 patients who underwent VPS, 2 patients were lost to follow-up due to moving out of town. Both patients were positive for improvement in gait and cognition with the ELD screening. Outcome data is available on the other 26 patients. As for gait, 24 among 26 patients felt improvement after VPS, being consistent with the physician's clinical observation. Two other patients, 1 of whom was negative for gait improvement after ELD, did not feel any clear improvement, which was confirmed with the postoperative physical therapist assessment, then diagnosed as "unimproved in gait." So the VPS was considered to be effective for improving gait in 92.3% (24/26 patients) of this patient cohort. The positive predictive value of ELD gait screening is calculated as 96.0% (24/25 patients) and the accuracy is 96.2% (25/26 patients, including 1 true negative patient). The sensitivity and the specificity of ELD gait screening were not calculated due to the small numbers of false negative or true negative patients, since we did not perform VP shunt except for one with negative ELD gait screening. As for cognition, 13 patients felt their cognitive improvement after VPS, and 5 patients felt no cognitive improvement, which was concordant with the physician's clinical judgment. The patients were grouped into "improved" and "unimproved in cognition," respectively. The other 8 patients were unsure of their cognitive improvement. The physician felt improvement in 3 patients among them although in the other 5 patients cognitive improvement was considered to be marginal. For these 8 patients, further neuropsychological evaluations by the same clinical neuropsychologists, who examined preoperatively, were made to compare the postoperative cognition with the preoperative cognitive baseline. In the postoperative evaluations, appropriate examinations for each patient were chosen among those examined preoperatively, considering the cognitive traits of each patient. With these evaluations, 6 patients, including 3 patients the physician felt improved, were judged as "improved in cognition" and the other 2 patients were judged as "unimproved in cognition." Thus cognition was judged to be improved after VPS in 73.1% of this patient cohort (19/26 patients). The positive predictive value of the ELD cognition screening is calculated as 66.7% (10/15 patients) and the accuracy is 46.2%, including 9 false negative and 2 true negative patients. The sensitivity of ELD cognitive screening is calculated as 52.6% and the specificity is 28.6%. However, these statistical parameters should be carefully interpreted since only the patients with positive ELD screening consisted of the cohort, and even two missing patients may have an impact on these calculations due to the small amount of studied patient group. As for urinary incontinence, 13 of 21 patients complaining of incontinence preoperatively had improvement after VPS (61.9%). Among 3 patients who had subjective improvement in urinary incontinence after ELD, 2 improved after VPS but 1 did not.

IV. Patients with inconsistent results of ELD screening

Since we did not perform VPS on 7 patients who had no gait or cognitive improvement after ELD, there may have been false negatives in this

patient cohort. Among 26 shunted patients, there was only 1 patient who had gait improvement after ELD, but did not have gait improvement after VPS (false positive). This patient also did not improve in cognition. Comparatively, there were more patients with inconsistent cognitive results between the ELD and VPS: 5 false positive and 9 false negative. Among the 5 false positive patients, 3 patients had some improvement in cognition noted in the post-operative period of VPS; however this improvement was only a "temporary relief" within a month, then they returned to their baseline cognition level at the 3-month follow-up.

V. RBANS in ELD cognition screening

Table 1 shows the characteristics of each group divided by the ELD cognition screening results. There were no significant differences between the positive group (17 patients) and the negative group (19 patients) in age, Evans ratio, or opening CSF pressure, but there was a significant difference in total drained CSF volume (the positive group: 457.4 ± 79.8 versus the negative: 542.7 ± 93.4 ml, $P = 0.01$). Table 2 indicates the results of the RBANS scores. Among 36 patients, 4 patients had some defects of scores in several domains due to the patients fatigue or reporting errors. As for the differences of RBANS scores, significant improvement was observed in the positive group, using the Mann-Whitney U test, in immediate memory (6.9 ± 9.5 vs. 0.05 ± 10.8, $P = 0.04$), delayed memory (11.1 ± 11.8 vs. –4.2 ± 9.1, $P = 0.001$), and total score (9.0 ± 13.0 vs. 0.12 ± 6.0, $P = 0.001$), although no significant improvement was observed in visuospatial skills, attention, or language functioning. These factors (i.e., total drained CSF volume, improvement of the RBANS score in immediate memory, delayed memory, and total score) were analyzed using logistic regression analysis. Only the delayed memory RBANS difference score was significantly larger in the positive group ($P = 0.04$). This indicates that the judgment of neuropsychologists in ELD cognition screening is most consistent with the improvement of RBANS score in delayed memory, rather than other aspects of cognition.

VI. Relation of preoperative RBANS to VPS outcome in cognition

In terms of cognitive outcome, the shunted patients were divided into two groups (i.e., 19 in the improved group and 7 in the unimproved group) based on the neurosurgeon's judgment during the follow-up visit to the clinic and the results are shown in Table 3. There were no significant differences between groups in age, Evans ratio, and opening CSF pressure. As for RBANS scores (Table 4), all baseline scores except language functioning were significantly lower in the improved group, using univariate analysis (64.9 ± 22.0 vs. 89.3 ± 16.0 in immediate memory, $P = 0.018$, 62.6 ± 21.1 vs. 89.0 ± 13.9 in delayed

Table 1 Demographic characteristics of each group divided by external lumbar drainage cognition screening results

	Age (years)	Sex (M/F)	Evans ratio	CSF pressure (cmH_2O)	*Drained CSF volume (ml)	Patients with incontinence
Positive (17 patients)	72.3 ± 10.1	9/8	0.40 ± 0.05	15.0 ± 4.3	457.4 ± 79.8	2
Negative (19 patients)	70.4 ± 8.5	9/10	0.40 ± 0.05	15.6 ± 4.7	542.7 ± 93.4	4

*indicates significant differences between the positive and negative groups by Mann-Whitney U test, CSF: cerebrospinal fluid.

Table 2 Pre- and post external lumbar drainage (ELD) Repeatable Battery for the Assessment of Neuropsychological Status scores of each group divided by ELD cognition screening results

	Immediate memory	Delayed memory	Visuospatial skills	Attention	Language functioning	Total score
Positive (17 patients)						
Baseline score	75.7 ± 19.1	69.2 ± 19.0	82.8 ± 21.1	80.2 ± 15.7	88.0 ± 16.3	74.9 ± 14.9
Differences	6.9 ± 9.5	11.1 ± 11.8	5.2 ± 14.8	5.2 ± 13.9	–1.5 ± 6.4	9.0 ± 13.0
Negative (19 patients)						
Baseline score	66.8 ± 22.5	68.1 ± 23.5	76.1 ± 25.0	72.9 ± 22.2	77.1 ± 17.7	66.5 ± 20.7
Differences	0.05 ± 10.8*	–4.2 ± 9.1*#	–1.6 ± 10.8	–0.06 ± 9.5	0.67 ± 6.6	0.12 ± 6.0*

Differences are obtained from post external lumbar drainage (ELD) score minus pre-ELD score. *indicates significant differences between the positive and negative groups by Mann-Whitney U test, and # by multiple logistic regression analysis ($P < 0.05$).

Table 3 Demographic characteristics of each group divided by ventriculo-peritoneal shunting outcome in cognition

	Age (years)	Sex (M/F)	Evans ratio	CSF pressure (cmH_2O)	Patients with incontinence	Patients with positive ELD
Cognition						
Improved (19 patients)	71.2 ± 9.0	7/12	0.41 ± 0.06	14.4 ± 4.5	2	10
Unimproved (7 patients)	68.9 ± 8.8	5/2	0.39 ± 0.05	14.7 ± 3.9	2	5

CSF: cerebrospinal fluid, ELD: external lumbar drainage, F: female, M: male.

Table 4 Pre- and post external lumbar drainage (ELD) Repeatable Battery for the Assessment of Neuropsychological Status scores of each group divided by ventriculo-peritoneal shunting outcome

	Immediate memory	Delayed memory	Visuospatial skills	Attention	Language functioning	Total score
Improved (19 patients)						
Baseline score	64.9 ± 22.0	62.6 ± 21.1	73.0 ± 23.9	70.3 ± 17.7	80.1 ± 17.4	64.1 ± 18.9
Differences	4.3 ± 8.8	4.9 ± 12.5	1.9 ± 12.0	5.6 ± 14.9	0.0 ± 7.5	7.6 ± 12.9
Unimproved (7 patients)						
Baseline score	89.3 ± 16.0*#	89.0 ± 13.9*#	102.3 ± 14.4*	94.0 ± 20.1*	90.3 ± 13.3	90.0 ± 8.6*
Differences	6.9 ± 8.1	10.9 ± 9.2	0.43 ± 18.0	0.29 ± 8.6	–0.29 ± 4.3	4.6 ± 4.8

Differences are obtained from post external lumbar drainage (ELD) score minus pre-ELD score. *indicates significant differences between the improved and unimproved groups by Mann-Whitney U test, and # by multiple logistic regression analysis ($P < 0.05$).

memory, $P = 0.004$, 73.0 ± 23.9 vs. 102.3 ± 14.4 in visuospatial skills, $P = 0.008$, 70.3 ± 17.7 vs. 94.0 ± 20.1 in attention, $P = 0.021$, 64.1 ± 18.9 vs. 90.0 ± 8.6 in total score, $P = 0.002$). No improvement in RBANS scores after ELD differed between the two groups. The baseline RBANS scores that were significantly low using univariate analysis were then analyzed along with categorical variables (i.e., sex, urinary incontinence, and ELD screening results in cognition) using multivariate analysis. The baseline RBANS scores in immediate memory ($P = 0.047$) and delayed memory ($P = 0.027$) were associated with VPS outcome. This means, VPS is likely to be effective if the baseline RBANS immediate memory and delayed memory score are low. With these results, we re-examined the scores of immediate memory and delayed memory. Fig. 3 indicates the scores of both cognitive domains for 26 shunted patients. If both scores were ≤ 80 (13 patients), all patients were judged to have improved cognition after VPS. All these improved patients had a positive gait response to the ELD screening, and 5 among 7 unshunted patients were negative for both ELD gait and cognitive screening, and therefore did not undergo VPS, also had low scores (≤ 80) on both cognitive domains. Therefore, low baseline RBANS immediate and delayed memory predicts a uniformly good cognitive outcome after VPS in patients who are positive for ELD gait screening.

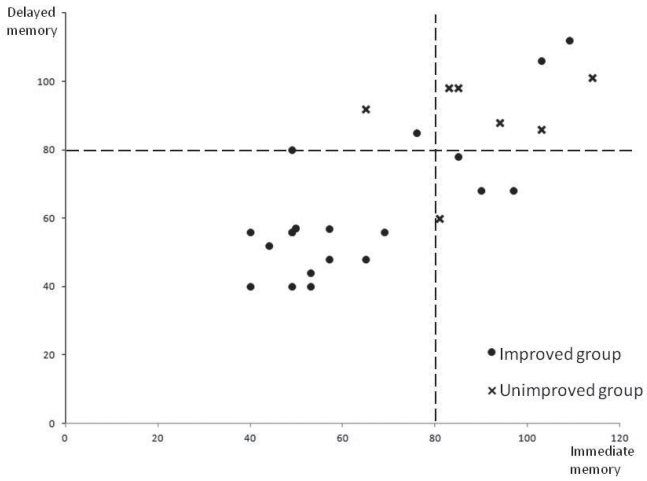

Fig. 3 Scatter chart showing 26 shunted patients' cognitive domains of Repeatable Battery for the Assessment of Neuropsychological Status at the baseline, the score of immediate memory on the X-axis and that of delayed memory on the Y-axis. All the patients with both scores ≤ 80 (13 patients) at the baseline improved cognitively after ventriculo-peritoneal shunting.

VII. Overall complications in the ELD cohort that went on to VPS

With ELD procedures, 2 patients complained of severe headache, and 1 required a blood patch. One patient complained of bilateral leg pain, which resolved

spontaneously. After VPS, two minor abdominal wound infections occurred, which resolved with 1 week of oral antibiotics. One revision, converting to ventriculo-atrial shunting, was performed 9 months later due to abdominal pain, presumably resulting from noninfectious irritation by the abdominal distal catheter, and the symptom resolved with this revision. No VPS have been removed to date.

Discussion

According to an extensive review of the literature up to March 2000 by Hebb et al.,[7] two groups reported a high accuracy for the ELD screening test in determining candidacy for VPS. Several articles examining the utility of ELD have followed since March 2000 with variable results. Therefore, we performed a literature search of English language publications in the MEDLINE database for the years between April 2000 and December 2011 by using the terms, "normal," "pressure," "hydrocephalus," "lumbar," and "drain." Then we eliminated case reports, animal experiments, reviews, or meta-analysis papers without original data. The inclusion criteria for our literature review were (1) the ELD screening is performed before VPS for NPH, (2) the judgment of the ELD screening is described, (3) the VPS outcome is described, and (4) the relation between the ELD screening results and VPS outcome is mentioned with the patient number. There were eight articles that met our inclusion criteria.[3–5,8,10,12,18,19] The positive predictive value was calculated from their data and we also noted whether cognitive improvement was analyzed separately. Table 5 shows the results of the literature review, which reveals the high positive predictive value of the ELD screening for gait, between 78.0% and 91.2%. However, only three studies focused on cognitive change. Panagiotopoulos et al.[10] reported 100% (9 out of 9 patients) cognitive improvement if the ELD screening in cognition was positive, using the Mini-Mental State Examination and Duinkerke et al.[8] reported 80% (8 out of 10 patients) using multiple neuropsychological measures. On the contrary, Marmarou et al.[12] conducted a detailed analysis with their large sample, up to 151 patients with multiple neuropsychological measures, and concluded that neuropsychological change associated with ELD was unable to predict VPS outcome. As a predictive tool of cognitive VPS outcome, there seems to be no consensus regarding the usefulness of the ELD cognitive change. The establishment of an accurate prediction method for cognitive improvement after VPS is an important requirement.

Our results support the findings presented by the former reports, that is, the high accuracy of the ELD gait screening as a predictor of post-shunt gait outcome. It is generally accepted that gait will improve after VPS if the ELD gait result is positive.[20] However, a negative ELD gait screening does not necessarily mean the patient will be unresponsive to VPS,[6] and a considerable number of patients who responded to VPS even with negative ELD gait screening results were reported, resulting in the relatively low negative predictive value: 36.4%[5] to 78%.[12] Nevertheless, due to the uncertainty of VPS efficacy, we did not perform VPS on any patients with negative ELD gait screening results except for a single patient who had a positive ELD cognitive screening result. A screening method with higher negative predictive value is a future concept to be explored.[6]

Table 5 Literatures employing external lumbar drainage as screening for ventriculo-peritoneal shunting candidacy

Author (Year)	Shunted Pts No.	ELD positive Pts No.	PPV with any improvement	Separate analysis on cognition	PPV with cognitive improvement
Walchenbach et al. (2002)[5]	38	16	87.5% (14/16)	No	N/A
Duinkerke et al. (2004)[8]	10	10	80% (8/10)	Yes	80% (8/10)
Marmarou et al. (2005)[12]	102	84	90.5% (76/84)	Yes	Unable to predict
Panagiotopoulos et al. (2005)[10]	22	19	84.2% (16/19)	Yes	100% (9/9)
Goodwin et al. (2007)[18]	15	15	86.7% (13/15)	No	N/A
Kilic et al. (2007)[4]	57	57	91.2% (52/57)	No	N/A
Woodworth et al. (2009)[19]	51	41	78.0% (32/41)	No	N/A
Eide et al. (2010)[3]	21	18	83.3% (15/18)	No	N/A
Our results	26	24	96.0% (24/25)	Yes	66.7% (10/15)

ELD: external lumbar drainage, PPV: positive predictive value, pts: patients.

As for the usefulness of the ELD screening for cognitive improvement after VPS, our results were disappointing, with a positive predictive value of 66.7% and an accuracy of 46.2%. Further, one report raises doubts regarding the ability of ELD prediction, since no cognitive response to ELD was observed although significant responses were obtained in gait assessment.[11] Our low accuracy resulted from two error types: those were false negative (9 patients among 26 shunted patients) and false positive (5 patients). As a possible reason for false negatives, "delayed success" is somewhat understandable, since the screening by temporary CSF drainage for several days may not be long enough for cognitive resolution. Certainly, in clinical experience, it is not rare for neurosurgeons to see shunted patients improving more than 1 month later. In contrast, false positive is problematic, since the expectation of the patients for the operation should be high with a positive ELD cognitive result. We do not know why such a false positive could happen, but it is interesting that among the 5 patients with false positive results, a "temporary relief" in cognition (i.e., a transient improvement that was seen within a month of VPS, but disappeared at 3 months follow-up) was seen in 3 patients. Temporary relief may result from a placebo effect, which was once reported in the gait evaluation as a single case report.[21] This effect may relate to the daily fluctuations in symptoms NPH patients have, and positive expectations could transiently improve cognition.[18] Another speculation is there are some significant changes in neuronal activity during ELD, which lead to a transient cognitive alteration. Lactate, vascular endothelial growth factor, glial fibrillar acidic protein, and tau were reported to increase and heavy chain of neurofilament to decrease after 72-hour ELD.[22] These neurochemical changes during ELD may lead to some transient cognitive improvement unrelated to NPH resolution. Although the mechanism of "temporary relief" is unknown, we should recognize this phenomenon when utilizing the ELD screening for cognition. Further, the "temporary relief in cognition" may be related to these patients having other causes for their cognitive decline such as Alzheimer's disease, multi-infarct dementia, and others.

As there is currently no agreement upon any neuropsychological test battery that should be used before and after ELD or VPS, many different measures have been given across studies. Even in the tests that have been used, there is no clear direction regarding how much change is required to be considered significant.[23] Moreover, patients and/or family members' perceptions of cognitive change are occasionally unrelated to the objective neuropsychological results. Although the satisfaction of the patient is important, it is still true that patients may report improvement when none has occurred or may fail to notice meaningful improvement. Detailed neuropsychological evaluations with multiple tests by professional clinicians are desirable for the judgment; however, practically, that is not always possible. In this study, such evaluations were performed at pre- and post-ELD, then the judgment by board certified clinical neuropsychologists. However, even with such detailed evaluations, the subjective biases of neuropsychologist may contaminate the judgment since most neuropsychological evaluations do not have clear standard scores for detecting cognitive alterations. The establishment of a neuropsychological battery, possible to be performed without specialists and free from subjective biases, is required, and we believe the RBANS may be the way forward. In the statistical comparison of RBANS scores, significant differences between groups divided by the judgment of professional clinicians were observed in immediate memory, delayed memory, and total score, but not in visuospatial skills, attention, or language functioning. This result indicates memory domains of RBANS seem important in judging the cognitive improvement of patients with NPH. In the current study, we could not compel all the patients to undergo a postoperative RBANS evaluation due to the uncertainty of its adequacy for NPH evaluation. Now we believe it justifiable to examine the patients with postoperative RBANS as the cognitive outcome evaluation. The RBANS test was originally developed to distinguish cortical dementia from subcortical dementia.[17] NPH is expected to produce a subcortical pattern on RBANS,[15] although this has not been studied specifically for NPH. In future study, the adequacy of RBANS as the standard outcome test should be explored further, by comparing the conventional outcome decision with the concurrently examined postoperative RBANS score.

Although we failed to find that ELD cognition screening is a predictive tool of cognitive improvement after VPS, we did find that baseline RBANS memory scores may be a possible indicator of post-VPS cognitive outcome. Our results show lower baseline RBANS, immediate and delayed memory scores are associated with a good cognitive shunt response. The idea that baseline cognitive analysis can be predictive of VPS outcome has already been presented;[24] however, those findings showed that patients with lower baseline scores were less likely to improve. One possible reason for our result is that in impaired people with low scores, even minor improvements in cognition may be noticed by caregivers, whereas higher functioning

people may continue to notice cognitive problems and complaits. Without actual postoperative test scores, we cannot know whether this is a subjective reporting issue or if their cognition becomes significantly better, and further study with postoperative RBANS is indicated in order to establish a strategy for the prediction of cognitive outcome. Importantly, this finding was obtained only from the patients who had a positive ELD screening in gait. With high accuracy of ELD gait screening, our operated patient cohort is considered to consist of mostly true NPH patients. Several prior studies have compared pre- and post-shunt neuropsychological performance without separating patients according to the VPS outcome judgment.[25,26] This method is free from subjective contamination resulting from the grouping; however, by considering the shunted patients as a single group, the successful and unsuccessful patients will be analyzed in the same group, thus non-NPH patients who underwent unnecessary shunting will mask the surgical effects in cognition. Our current study suggests how to avoid such a dilemma; that is, grouping the patients by VPS outcome in gait. The improvement in gait can be grasped more objectively than that in cognition, and the cognitive evaluation only with the improved patients in gait may reveal more consistent information. In this sense, ELD screening is necessary to identify true NPH patients by gait improvement.

Conclusion

It continues to be difficult to select patients with NPH who will benefit from VPS. ELD screening is highly predictive for gait improvement, although patients may respond to VPS with negative ELD results. This screening method, however, has not been found to be predictive of cognitive improvement after VPS, possibly due to "delayed success" and "temporary relief." The preoperative value of RBANS, which requires approximately 30 minutes for administration, has the potential to predict VPS outcome in cognition. ELD screening is necessary for predicting gait improvement and identifying true NPH patients. Further analysis focused on predicting cognitive outcome with responding patients on ELD gait screening promises new insights.

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Conflicts of Interest Disclosure

The authors have no personal, financial, or institutional interests in any of the drugs, materials, or devices cited in this article. All authors who are members of The Japan Neurological Society (DN and TF) have registered online their self-reported COI disclosure statements.

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