

# The value of temporary external lumbar CSF drainage in predicting the outcome of shunting on normal pressure hydrocephalus

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**Objective:** It has been reported that temporary external lumbar CSF drainage (ELD) is a very accurate test for predicting the outcome after ventricular shunting in patients with normal pressure hydrocephalus (NPH). However, only a limited number of patients have been studied for assessing the predictive accuracy of ELD. Therefore, the value of ELD in predicting the outcome after a ventriculoperitoneal shunt in patients with presumed NPH was assessed.

**Methods:** All patients with presumed NPH were invited to participate in this study. Clinical assessment, MRI, and neuropsychological evaluation were followed by a lumbar CSF tap test consisting of removing 40 ml CSF. When this test resulted in marked clinical improvement of gait impairment, mental disturbances, or both, the patient was shunted without further tests. In patients with either questionable or no improvement after the CSF tap test, ELD was carried out. The value of ELD for predicting the outcome after shunting was calculated by correlating the results of ELD with that of ventriculoperitoneal shunting.

**Results:** Between January 1994 and December 2000, 49 presumed NPH patients from three institutes were included. Forty three had idiopathic, and the remaining six had secondary NPH. Forty eight patients were shunted; 39 had an ELD of whom 38 completed the test. After 2 months 35 of the 48 (73%) shunted patients had improved. The predictive value of a positive ELD was 87% (95% confidence interval (95% CI) 62–98) and that of a negative ELD 36% (95% CI 17–59). In two patients serious test related complications (meningitis) occurred without residual deficit.

**Conclusion:** The study suggests that although the predictive value of a positive ELD is high, that of a negative ELD is deceptively low because of the high rate of false negative results. The costs and invasiveness of the test and the possibility of serious test related complications further limits its usefulness in managing patients with presumed NPH.

Sporadic reports have described temporary external CSF drainage (ELD) as a highly accurate test in predicting the outcome after ventricular shunting in patients with symptomatic chronic adult hydrocephalus, commonly called normal pressure hydrocephalus (NPH).<sup>1–3</sup> However, this predictive value of ELD has only been assessed in a small series of patients, thus not allowing firm conclusions concerning its validity. Therefore we conducted a prospective multicentre study on the accuracy of ELD in predicting the outcome of shunting in patients with presumed NPH.

## METHODS

All patients with presumed NPH referred to one of our departments (Amsterdam, den Haag, Leiden) were invited to participate in this prospective study on the predictive value of ELD. Inclusion criteria for this study were the following: (1) clinical signs consisting of gait disturbances (either wide based gait imbalance or small stepped shuffling gait) either in combination with mental impairment and urinary incontinence or not; (2) evidence of chronic hydrodynamic hydrocephalus on CT or MRI. Exclusion criteria were: (1) no or only minimal gait disturbances combined with severe dementia; (2) severe cerebral atrophy on CT or MRI; (3) increased CSF pressure at lumbar puncture; (4) absence of informed consent.

Gait impairment was rated on a five point scale: (0) normal, (1) slight gait imbalance, (2) marked gait imbalance but not requiring aid, (3) walking not possible without a cane or the help of one person, (4) gait severely impaired, only possible with the aid of one person on each side, (5) total incapacity for standing or walking, even with help. A video of the gait

pattern was made. Mental disturbances were evaluated with the mini mental state examination (MMSE),<sup>4</sup> and with a series of neuropsychological tests assessing cortical functions including language, visuoperceptive skills and praxis, memory functions (including delayed recall and delayed recognition), and tests assessing subcortical functions including mental speed, concept shifting, and abstract reasoning. Quantitative psychometric tests included the 10 word memory test (recall and recognition),<sup>5</sup> the Wechsler memory tests,<sup>6</sup> the trail making task, parts A and B assessing psychomotor speed,<sup>7</sup> the symbol digit memory test,<sup>8</sup> and the Stroop tests I-III for evaluating attention.<sup>9</sup> Bladder function was registered as (0) normal, (1) increased bladder urgency, and (2) urinary incontinence. Brain MRI was performed in all patients and included T1 and T2 weighted images, proton density sequences, and during the past 3 years of this study coronal slices with a fluid attenuated inversion recovery sequence (FLAIR). Measurement of the ventricles included the frontal horn index (the ratio between the maximal width of the frontal horns and the width of the whole brain at the same level<sup>10</sup>); roundness of the frontal horns (0, not; 1, slight; 2, marked); and width of the temporal horns (0, not visible; 1, slightly enlarged; 2, markedly

**Abbreviations:** ELD, external lumbar CSF drainage; NPH, normal pressure hydrocephalus; MMSE, mini mental state examination; FLAIR, fluid attenuated inversion recovery sequence; HI, white matter hyperintensities; SR-NPH, shunt responsive NPH; clin/MRI score, global clinical plus MRI score; CSFTT, CSF tap test; VPS, ventriculoperitoneal shunting

enlarged). Cerebral atrophy was assessed by grading the cortical sulci as not detectable (0), present (1), enlarged (2), or markedly enlarged (3). The fourth ventricle rated as either normal or enlarged. Periventricular frontal and occipital hyperintensities on T2 images were noted as absent or present. The presence of white matter hyperintensities (HI) was rated as follows: no HI (0); discrete or sporadic HI (1); moderate HI (2); pronounced and diffusely distributed HI (3). The flow void sign through the aqueduct on proton density images<sup>11</sup> was ranked as absent (0), slight (1), or pronounced (2).

### Classification of combined clinical and MRI criteria for predicting the outcome after shunting

We estimated the pretest probability of shunt responsive NPH (SR-NPH) based on clinical and MRI criteria. Clinical and MRI data were lumped together into a global clinical plus MRI score (clin/MRI score). This score was very similar to the global clinical plus CT score used in other studies on the additional predictive value of ancillary tests in NPH.<sup>12–13</sup> In the present study CT criteria were replaced by MRI criteria, based on the literature on the diagnostic characteristics of MRI in NPH.<sup>14–17</sup>

The global clin/MRI score divided the patients into three categories of pretest probability: SR-NPH (1) probable, (2) possible, or (3) improbable. Criteria for these categories were:

#### Probable SR-NPH

The combination of all the following clinical and MRI characteristics: (1) *Clinical*: predominance of gait disturbances; mental impairment ranging from not clinically evident to moderate impairment; absence of another disease which might explain the clinical symptoms. (2) *MRI data*: rounded frontal horns grade 2, at least moderate ventricular enlargement (frontal horn index 0.40 or higher), absence of moderate (grade 2) or pronounced (grade 3) white matter HI, and absence of markedly enlarged sulci (grade 3).

Urinary urgency or incontinence, known aetiology, or rapid clinical progression increased the probability of NPH, but were not necessary to rank a patient into this category.

#### Possible SR-NPH

This category included all patients who could not be ranked as probable (see above) or improbable (see below) SR-NPH, such as patients with marked ventricular enlargement (frontal horn index 0.45 or higher) and only moderate white matter involvement on MRI (grade 2) not explaining a huge ventriculomegaly.

#### Improbable SR-NPH

Only one of the following clinical or MRI characteristics was sufficient to consider SR-NPH as improbable: (1) *Clinical*: absence of gait disturbances; marked predominance of dementia; dementia characterised by predominance of cortical dysfunction such as aphasia or agnosia; presence of another disease explaining the clinical signs. (2) *MRI*: only slightly dilated ventricles (frontal horn index <0.38); pronounced and diffusely distributed white matter HI (grade 3); markedly enlarged cortical sulci (grade 3).

#### The CSF tap test

A CSF tap test (CSFTT)<sup>18–19</sup> was planned in all patients who had consented to participate in our study. Removal of 40 ml CSF by lumbar puncture was followed by assessment of the effect of CSFTT on gait and mental impairment 6–8 hours after CSF removal. Improvement of gait was categorised as follows: (1) obvious improvement when the gait score improved at least one point on the five point gait score; (2) questionable when gait improvement seemed present but not sufficient to improve one point on the five point gait score, and when there was no agreement on improvement on video assessment by

four independent assessors not involved in performing the test; (3) no improvement: no amelioration on the gait score and consensus by the video assessors that gait had not improved.

Improvement of mental dysfunction was arbitrarily defined as improvement of 30% or more on at least three psychometric quantitative tests assessing mental speed, concept shifting, and concentration, and no worsening on other tests. Improvement of mental deficit was not required for considering the CSFTT as positive.

Patients with obvious gait improvement after the CSFTT were shunted without additional ELD, because a markedly positive CSFTT was considered as a good predictor for shunt effectiveness.<sup>18–21</sup> All other patients were studied with ELD. Although this was not the primary aim of our study, we also evaluated the predictive value of CSFTT because there is still controversy on the predictive accuracy of the test, especially when it is negative.<sup>22–23</sup>

#### Temporary external lumbar drainage (ELD)

The method previously described by Haan and Thomeer<sup>2</sup> was used: a 16 gauge needle was placed percutaneously in the lumbar intrathecal sac and a galvanised catheter was inserted through this needle. The catheter was attached to a closed external drainage system, collecting the CSF into a bag that could contain 500 ml of CSF. The height of the drip chamber during standing or sitting was maintained at the level of the patient's shoulder—that is, about 20–25 cm lower than the foramen of Monro, and at ear level when the patient was lying down. The ELD system remained in situ for 4 days, except for patients in whom inadvertent disconnection of the system had occurred. In these cases, a new system was placed. In cases of premature termination of the ELD due to a complication or to lack of cooperation of the patient, the test was considered inconclusive. Each day, about 100–150 ml CSF were removed and temperature and pulse rate were measured. Daily laboratory and microbiological controls of CSF samples were done to detect preclinical evidence of intrathecal bacterial contamination. We arbitrarily chose to restrict the drainage period to 4 days because of the fear of test related infectious complications.

Criteria for a “positive” ELD were the same as those described for a “positive” CSFTT. To calculate the predictive value of ELD we correlated the effect of ELD on gait and mental impairment with that of ventriculoperitoneal shunting (VPS). Improvement of gait only was considered sufficient for considering ELD as “positive”.

#### Ventriculoperitoneal shunting and outcome

Ventriculoperitoneal shunting was planned in all patients, irrespective of the results of ELD. Either a Codman-Medos shunt or a shunt with a programmable Medos-Hakim valve was used, depending on the neurosurgeon's personal preference. Clinical neurological examination and quantitative psychometric evaluation were carried out 2, 6, and 12 months after VPS. Thereafter, clinical examinations, psychometric testing, and control CT or MRI were carried out when necessary—that is, when shunt failure was presumed. The definition of SR-NPH was that clinical improvement had to be noticed 2 months after insertion of a VP shunt. Improvement had to be confirmed by the patients themselves, their family, or the nursing team and the patient had to be improved at least one point on the gait score or four independent assessors had to agree that there was gait improvement on the basis of randomly presented videos of the gait pattern. Detailed data on improvement of mental functions and psychometric assessment after ELD and after VPS will be published separately.

**Table 1** Correlation between the global clinical and MRI score and outcome after shunting

Category of GS	SR+	SR-	Total
SR is probable	20	2	22
SR is possible	11	7	18
SR is improbable	4	4	8
Total	35	13	48

SR+, Improvement after shunting; SR-, no improvement after shunting; positive predictive value of "probable" SR: 91% (95% CI 71-99); negative predictive value of "improbable" SR, 50% (95% CI 16-84).

**Table 2** Correlation between the results of CSFTT and outcome after shunting

Response of CSFTT	SR+	SR-	Total
CSFTT+	9	0	9
CSFTT-	2	12	38
Total	35	12	47

CSFTT, CSF tap test; CSFTT+, obvious improvement after CSFTT; CSFTT-, questionable or no improvement after CSFTT; SR+, improvement after shunting; SR-, no improvement after shunting; sensitivity of CSFTT, 26% (95% CI 12-43); specificity of CSFTT, 100% (95% CI 74-100). Predictive value of a positive CSFTT, 100% (95% CI 66-100); predictive value of a negative CSFTT, 32% (95% CI 17-49).

**Drain revision**

Surgical drain revision was carried out in patients with lack of amelioration or clinical deterioration in combination with lack of decrease of the ventricular volume after shunting. In these patients shunt failure was considered due to either cranial or abdominal obstruction, or a too high opening pressure of the pump valve. In patients with symptomatic subdural haematomas or hygromas, the drain was removed or the valve opening pressure in patients with a programmable Medos-Hakim valve was increased.

**RESULTS**

Between January 1994 and December 2000, 51 patients fulfilled the criteria of presumed NPH; 49 agreed to be enrolled in the ELD protocol, and 48 were eventually shunted. The median age was 77 years (range 55-87), 72% were men. Seven patients presented with only gait disturbances without clinical evidence of mental impairment; in all these patients, however, psychometric tests were abnormal showing slowing of mental speed, decreased recall by contrast with unimpaired recognition on memory tests, and disturbed concept shifting. A clinically meaningful improvement after 2 months was seen in 35 of the 48 patients (73%). Seven VP shunt revisions were carried out in six patients, with marked benefit in only one patient.

The accuracy of the global clin/MRI score for predicting improvement after VPS is listed in table 1: the category "probable" SR-NPH was a good predictor for successful shunting (91% true positives, 95% confidence interval (95% CI) 71-99), which contrasted with the low predictive value of the category "improbable" SR-NPH (50% false negatives (95% CI 16-84)).

A CSFTT was carried out in 47 of the 48 shunted patients (table 2); in one patient a CSFTT was not carried out before ELD because this test was negative in another hospital. Nine of these 47 were shunted without ELD because marked improvement had occurred after the CSFTT. They all improved after a

**Table 3** Correlation between the results of ELD and outcome after shunting

Outcome after ELD	SR+	SR-	Total
ELD+	14	2	16
ELD-	14	8	22
Total	28	10	38

ELD, External lumbar drainage; ELD+, improvement after ELD; ELD-, no improvement after ELD; SR+, improved after shunting; SR-, not improved after shunting; sensitivity, 50% (95% CI 31-69); specificity, 80% (95% CI 44-97); positive predictive value of ELD, 87% (95% CI 62-98); negative predictive value of ELD, 36% (95% CI 17-59).

shunt. The predictive value of a negative CSFTT was very low (32%(95% CI 17-51)).

Thirty nine patients were examined with ELD, 38 of them were shunted, and one refused further treatment after an ELD related complication. The predictive value of ELD is shown in table 3: a positive ELD predicted a good shunt response in 87%, but a negative ELD was unreliable as there were 64% false negative predictions. As assessment of the value of ELD for predicting the outcome after a shunt depends on the prevalence of SR-NPH in a particular study group, we recalculated the predictive value of ELD in a hypothetical group with the same sensitivity and specificity as in our group but an arbitrarily chosen lower prevalence of SR-NPH of 30%. When the a priori chance of SR-NPH would have been 30% instead of 73% (as in our series), the predictive value of a positive ELD would have been only 55% (95% CI 23-83), that of a negative ELD 77% (95% CI 56-91), and the predictive accuracy 71% (95% CI 54-85).

Two serious ELD related complications, consisting of bacterial meningitis occurring at the 4th day of ELD were seen; both patients recovered after antibiotic therapy. One of these patients refused further treatment. In five patients, the lumbar drains had to be replaced during the test after disruption or displacement of the drain.

**DISCUSSION**

The results of this study do not confirm the promising results of previous studies<sup>1-3</sup> concerning the high accuracy of ELD in predicting the outcome after ventricular shunting in patients with presumed NPH. A positive ELD accurately predicted postsurgical improvement, but a negative ELD was unreliable as many patients improved after a shunt despite a negative ELD (table 3). This was mirrored by the results of CSFTT, which showed that many patients with a negative CSFTT also improved after a shunt. This disappointingly high rate of false negative results with ELD is the most obvious result because in our study population many patients with a negative ELD might have been withheld from successful shunting had selection for surgery been based on the results of ELD.

Before assessing the predictive accuracy of CSF removal tests, we estimated the pretest probability of SR-NPH based on preselected clinical and MRI criteria, lumped into a global clin/MRI score, because we had found previously that the predictive accuracy of a similar global clin/CT score was quite high.<sup>13</sup> Hence, performing an invasive and costly test such as ELD would only make sense when the test's predictive accuracy would be substantially higher than that based on mere simple clinical and MRI criteria. In the present study we could not reproduce the same good prediction of a global clin/MRI score: the predictive value of the category "probable SR-NPH" was very high (table 1) but the category "improbable SR-NPH" incorrectly predicted lack of improvement after



a shunt in 50% of the patients. This suggests that our criteria for the category “improbable SR-NPH” should be reconsidered.

A drawback of our study is that a selection bias may have been introduced because some patients had already been selected by neurologists who sent presumed patients with NPH for a second opinion or for a shunting procedure. However, notwithstanding this preselection, the bias seemed less severe than at first glance, as only 46% (22/48) were categorised as “probable SR-NPH” on the basis of pre-established clinical and MRI criteria. We therefore considered that the clinical range of NPH was widespread enough to calculate the sensitivity and specificity of ELD, the main limiting factor for making strong conclusions being the large 95% CIs. Despite these large 95% CIs we did not prolong this study because we presumed that even with a larger number of patients, the number of false negative results would have remained too high to rely on this test for further therapeutic management.

It was obvious that 73% of our patients had SR-NPH, a high percentage that may be due to a selection bias. As the predictive value of a test depends on the prevalence of a disease in a particular group, we recalculated the predictive values of ELD with the same sensitivity and specificity, but with a lower a priori chance of SR-NPH of 30%. This percentage may reflect that encountered in some neurological and neurosurgical practices.<sup>24</sup> With this lower a priori chance of SR-NPH, the number of false negative ELD would have decreased to about 20% but that of false positive ELD would have increased to 45%.

This prospective study does not confirm the good results of previous studies on the predictive value of ELD. In patients with a positive ELD shunting may be justified but in patients with a negative ELD many neurologists and neurosurgeons should probably also consider a shunt in view of the high percentage of patients improving after a shunt despite a negative ELD.

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