DIAGNOSIS, TREATMENT, AND ANALYSIS OF LONG-TERM OUTCOMES IN IDIOPATHIC NORMAL-PRESSURE HYDROCEPHALUS

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OBJECTIVE: The response to shunt surgery for idiopathic normal-pressure hydrocephalus (INPH) is variable because INPH is difficult to distinguish from other conditions causing the same symptoms. To date, no clinical picture or diagnostic test can distinguish INPH or predict response to cerebrospinal fluid (CSF) shunt surgery. We reviewed our 10-year experience with INPH to characterize long-term outcome and to identify independent predictors of outcome after shunt surgery.

METHODS: Patients were classified as having INPH only if they had: 1) ventriculomegaly, 2) two or more INPH clinical features, 3) no risk factor for secondary normal-pressure hydrocephalus, 4) A- or B-waves on CSF pressure monitoring, and 5) clinical improvement during a 3-day CSF drainage trial via a spinal catheter. Independent predictors of outcome were assessed via a multivariate proportional hazards regression analysis.

RESULTS: One hundred thirty-two patients underwent 179 shunt surgeries. Forty-four (33%), 79 (60%), and 99 (75%) patients demonstrated objective improvement 3, 6, and 24 months after shunt surgery, respectively. Gait improved first in 88 (93%) patients. Dementia and urinary incontinence were twofold less likely to improve. Radiological evidence of corpus callosum distension, gait impairment as the primary symptom, and shorter duration of INPH symptoms predicted improvement. Duration of symptoms and gait as the primary symptom were independent predictors by multivariate analysis.

CONCLUSION: INPH can be diagnosed accurately with CSF pressure monitoring and CSF drainage via a spinal catheter. CSF shunting is safe and effective for INPH with a long-term shunt response rate of 75%. Independent predictors of improvement are the presence of gait impairment as the dominant symptom and shorter duration of symptoms.

KEY WORDS: Cerebrospinal fluid shunt, Idiopathic normal-pressure hydrocephalus, Outcome, Predictors

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The term *normal-pressure hydrocephalus* (NPH) was coined by Solomon Hakim (1) in 1965 to describe the syndrome of progressive cognitive deterioration with psychomotor retardation, gait apraxia and imbalance, and urinary incontinence associated with hydrocephalus and normal cerebrospinal fluid (CSF) pressure on lumbar puncture. NPH can be secondary to disease processes that cause inflammation of the arachnoid, such as subarachnoid hemorrhage, traumatic brain injury, or meningitis, but as many as half of patients with NPH have no identifiable risk factor, in which case it is called idiopathic NPH (INPH). Despite nearly 4 decades of investigation, the pathological cause of INPH remains unclear. Most evidence suggests that ventricular dilation is caused by impaired CSF resorption at the arachnoid granulations or impaired CSF conductance through the subarachnoid space. The associated symptoms have been ascribed to ischemia, stretching of the periventricular white matter, increased transmantle pressure, asymptomatic fibrosing meningitis, or insufficiency of the cortical extracellular space for CSF transit to the sub-

arachnoid space (12, 17, 32, 38, 42). Others suggest that ventricular dilation may be unrelated to CSF malabsorption, and instead is secondary to periventricular microvascular disease that results in encephalomalacia and dilation of the cerebral ventricles (8), an hypothesis supported by the observed association between INPH and hypertension, ischemic heart disease, diabetes, and reduced high-density lipoprotein cholesterol (10, 14).

Treating INPH with CSF shunting is controversial because of the difficulty in distinguishing patients with INPH before shunting from those with many other neurological conditions that can produce symptoms of NPH (e.g., vascular dementia, Parkinson's disease, Lewy body dementia, cervical spondylotic myelopathy, peripheral neuropathy) but do not respond to CSF shunting (8, 14, 16, 19, 39). Because INPH is a disease of the elderly population, correct identification of INPH, often in the setting of coexisting disease, is critical to successful treatment; however, the criteria for selecting patients for shunt surgery remain unclear. To date, no clinical picture or diagnostic test available in community practice can distinguish INPH adequately from other dementias that present in the elderly.

The gold standard for comparison of any diagnostic test for INPH remains an improvement of symptoms after shunt surgery. Choosing to shunt patients based on preoperative clinical suspicion and neuroimaging alone is associated with widely varying and generally unsatisfactory outcomes. Furthermore, reported outcomes suggest that patients with INPH are much less likely to respond to CSF shunting (37%) compared with patients with secondary NPH (80%), resulting in much pessimism regarding the treatment of INPH (3, 7, 28, 33, 37). We report our 10-year institutional experience in the diagnosis and treatment of INPH, with the aim of characterizing long-term outcomes and identifying independent clinical, physiological, and radiological predictors of outcome after CSF shunting for INPH.

METHODS

Preoperative Assessment

From 1993 through 2003, all patients who were referred for evaluation of INPH were examined clinically by both senior authors (MAW and DR). A computed tomographic (CT) or magnetic resonance imaging (MRI) scan was obtained for all patients to assess ventriculomegaly or additional intracranial pathological features. Patients with ventriculomegaly and at least two clinical features of NPH were admitted to the hospital for 2 days of continuous CSF pressure (Pcsf) monitoring followed by a 3-day trial of controlled CSF drainage.

The spinal catheter (Codman/Johnson & Johnson, Raynham, MA or Medtronic PS Medical, Goleta, CA) was inserted percutaneously into the lumbar subarachnoid space using a 14-gauge Touhy needle under local anesthesia at the bedside. Physiological parameters, including Pcsf, were recorded continuously for 2 days. Pcsf was analyzed only during epochs that were free from artifact when the record indicated that the transducer was leveled properly and the patient was quiet, usually during sleep or quiet rest. Abnormal Pcsf waveforms were identified according to criteria adapted from the original description of Lundberg (29).

A 3-day trial of controlled continuous CSF drainage then was performed. The CSF drainage rate was controlled to approximately 10 ml/h (240 ml/d). Patients were examined clinically for their response at least once daily. Response to drainage was defined as objective improvement in gait, cognition, or bladder control.

Diagnostic Criteria and Treatment Algorithm

Patients were classified as having INPH and underwent CSF shunting only if they had: 1) ventriculomegaly confirmed on CT or MRI scan, 2) presence of two or more clinical features of NPH, 3) no risk factor for secondary NPH (history of subarachnoid hemorrhage, meningitis, encephalitis, concussion, traumatic brain injury, cerebral infarction, venous thrombosis, Paget's disease of cranium, or achondroplasia), 4) either A- or B-waves present during artifact-free time on continuous Pcsf monitoring (*Fig. 1*), and 5) clinical improvement in symptoms during a 3-day trial of controlled CSF drainage. If fixed pressure valves were used (most shunts before 2000), most commonly a medium-pressure valve was implanted initially. If minimal or no symptomatic improvement was observed by 6 months and there was no evidence of shunt malfunction, a lower-pressure valve was implanted surgically. If adjustable valves were used (all shunts after 2000), they were initially set to medium pressure settings to avoid overdrainage and the valve setting was changed as indicated until maximum symptomatic improvement was noted without low-pressure side effects. Shunt malfunction was suspected when patients wors-

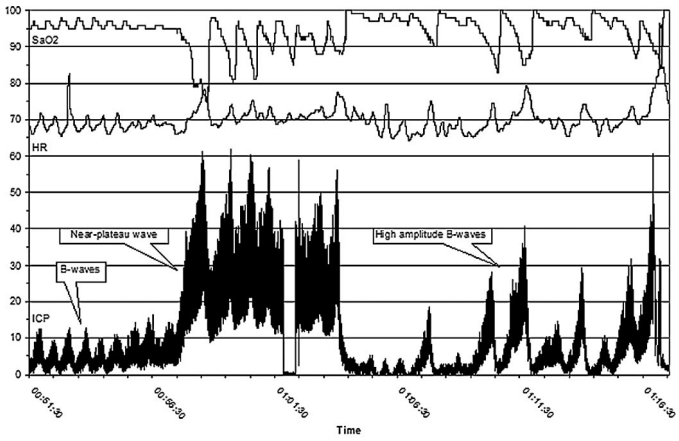

FIGURE 1. *Characteristic CSF pressure monitoring profile of a shunt-responsive patient with INPH showing the B-waves waves and a near-plateau wave during an artifact-free period. The gap in the middle of the plateau wave is artifact from calibrating the transducer. Corresponding changes in heart rate (*HR*) and oxygen saturation (*Sao_2*) also are shown.*

ened after initial improvement or failed to improve after surgery. Shunt malfunction was assessed by shunt radiographs, radionuclide shunt scintigraphy, or Pcsf monitoring via the shunt.

Outcome Assessment

Follow-up consisted of clinical evaluation at 1, 3, and 6 months after surgery and yearly thereafter, and radiological evaluation as indicated. Follow-up examination was performed by both senior authors (MAW and DR) on all patients. All patients underwent the Folstein Mini-Mental State Examination at each follow-up visit (18). Patients and their families also were questioned regarding observed cognitive change at home after shunt surgery, with particular attention to functional impairment resulting from dementia. Improvement in cognitive function was defined as at least a three-point improvement in the Mini-Mental State Examination score and improvement in the patient's cognitive function from either the patient's or family's perspective. Improvement in urinary incontinence was defined as a decrease in incidence of urinary frequency, urgency, or incontinence that was thought by the patient or family to have improved (often characterized by less dependence on an incontinence undergarment or pad). Improvement in gait was documented by change in detailed clinical evaluation (e.g., stride length, pace, base, stability on turning, presence of shuffling or side-stepping) and also was assessed on the basis of the patient's and family's perspective, including documentation of dependence on assistive devices (e.g., cane, walker, wheelchair). Symptoms were classified as improved if they resulted in an improvement in the patient's quality of life. To evaluate predictors of outcome, treatment response to CSF drainage was defined as improvement in at least one symptom of INPH (gait impairment, urinary incontinence, dementia). Univariate predictors of treatment response were assessed via log-rank analysis for stratified covariates and proportional hazards analysis for continuous covariates. To assess independent predictors of outcome, a multivariate proportional hazards regression model was created, including all variables significant ($P < 0.05$) in univariate analysis.

RESULTS

Patient Population and Clinical Presentation

A total of 234 patients were referred for evaluation of suspected NPH. Of these 234 patients, 102 (43%) were not referred for shunt surgery because of a lack of clinical improvement during the CSF drainage trial or because of an absence of A- or B-waves on continuous Pcsf monitoring or both. One hundred thirty-two patients underwent 179 shunt surgeries during the study period. There were 68 (51%) women and 64 (49%) men. Mean age at time of presentation was 73 ± 9 years.

Gait impairment was a feature for 130 (98%) patients, occurring for an average of 36 ± 30 months before presentation. Urinary incontinence or urgency was present for 104 (79%) patients, occurring for an average of 30 ± 28 months. Cognitive decline was present for 103 (78%) patients, occurring for an average of 30 ± 25 months. Twenty patients (15%) had headaches or head fullness. The complete INPH triad of dementia, urinary incontinence, and gait impairment was present for 82 (62%) patients. The primary (and most debilitating) symptom was gait impairment for 108 (82%) patients, cognitive impairment for 16 (12%) patients, and urinary incontinence or urgency for 8 (6%) patients.

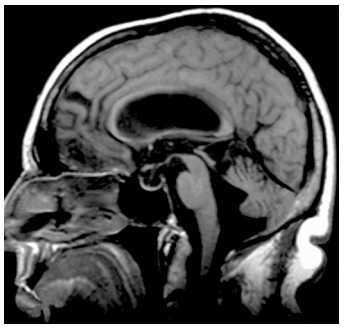

FIGURE 2. *MRI scan demonstrating corpus callosum distention in a patient with shunt-responsive INPH.*

Comorbidities included hypertension in 50 (38%) patients, diabetes in 30 (23%) patients, depression in 19 (14%) patients, smoking in 16 (12%) patients, prior myocardial infarction in 14 (11%) patients, and hypothyroidism in 11 (8%) patients. On preoperative CT or MRI scans, periventricular white matter changes consistent with microvascular disease were observed in 58 (44%) patients, corpus callosum distension (*Fig. 2*) was observed in 30 (28%) patients, and diffuse cerebral atrophy was observed in 30 (28%) patients.

Ventriculoperitoneal shunts were used in 170 (95%) patients, ventriculoatrial shunts were used in 5 (3%) patients, and lumboperitoneal shunts were used in 4 (2%) patients. Programmable valves were used in 154 (86%) patients, and fixed pressure valves were used in 25 (14%) patients.

Outcome

Ninety-nine (75%) of 132 patients had improvement in at least one INPH symptom at a mean follow-up of 18 ± 13 months. Sixty-two (46%) of 132 patients had improvement in all presenting INPH symptoms at a mean follow-up of 18 ± 13 months. By 3 months after shunt surgery, 33% of patients experienced symptomatic improvement, and by 6 months, 60% were improved. Between 6 and 24 months, only a 15% further increase in response rate was observed (*Fig. 3*). Of the 99 patients who responded to CSF shunting, 9 (9%) patients had late deterioration 10 ± 6 months after their initial improvement, despite no evidence of shunt malfunction.

Gait improvement was the earliest and most likely clinical response in 88 (93%) patients responding to CSF shunting. Dementia and urinary incontinence were twofold less likely to improve after CSF shunting compared with gait abnormalities (relative risk [RR], 0.49; 95% confidence interval [CI], 0.4–0.9; *Fig. 3*). After shunt surgery, 20 (15%) patients reported low-pressure headaches, all of whom improved after change in the valve setting. Three (2%) patients experienced subdural hematomas. One (1%) patient died as a result of a pulmonary embolism, which was a complication after a frontal lobe hematoma that developed along the catheter track after shunt surgery.

During the study period, 59 (33%) shunts were revised. The reason for revision was distal obstruction in 28 (47%), proximal obstruction (ventricular catheter or valve mechanism) in 12 (20%), persistent lack of clinical response in 9 (15%), infection in 7 (12%), and overdrainage in 3 (5%). Overall rate of shunt infection was 6.7%.

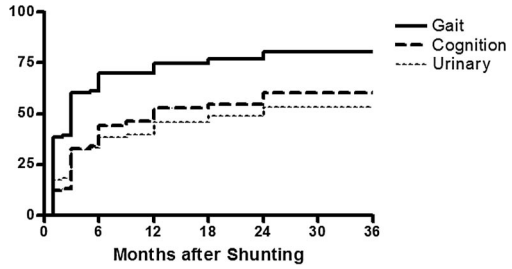

FIGURE 3. *Graph demonstrating percentage of patients experiencing symptomatic improvement as a function of time after shunt surgery. The rate of symptomatic improvement was greatest the first 9 months after CSF shunt implantation; however, the percentage of patients experiencing improvement continued to increase for up to 2 years. Gait abnormalities were more likely to improve with CSF shunting versus urinary or cognitive deficits.*

Predictors of Symptomatic Improvement after CSF Shunting

In univariate analysis, the preoperative appearance of corpus callosum distension on MRI was associated with nearly a twofold increase in the likelihood of symptomatic improvement after CSF shunt surgery (*Table 1, Fig. 4A*). Patients who described gait impairment as their primary and most debilitating symptom were nearly twofold more likely to respond to CSF shunting than patients whose primary symptom was dementia or incontinence (*Fig. 4B*). Longer duration of INPH symptoms before CSF shunting was associated with lower likelihood of improvement after CSF shunting (*Tab. 1, Fig. 4C*). Each additional year of INPH symptom duration was associated with a 13% lower likelihood of treatment response. Age, sex, vascular comorbidities, the presence or absence of any single INPH symptom or the complete clinical symptom triad (gait, urinary, and cognitive symptoms), diffuse cerebral atrophy, and periventricular white matter change were not associated with outcome after CSF shunting for INPH.

In multivariate analysis, duration of symptoms (RR,0.89; 95% CI, 0.82-0.98) and gait impairment as the primary symptom (RR,1.87; 95% CI, 1.02-3.43) were independent predictors of outcome after CSF shunting for NPH (*Table 1*).

TABLE 1. Univariate and multivariate predictors of response to cerebrospinal fluid shunting in patients with idiopathic normal-pressure hydrocephalus[a]

Variable	Univariate RR (95% CI)	Multivariate RR (95% CI)
Demographics/comorbidity	—	—
Age (yr)	0.98 (0.97–1.01)	—
Female	0.80 (0.53–1.20)	—
Hypothyroid	1.76 (0.81–3.81)	—
Depression	0.93 (0.52–1.67)	—
Smoker	0.85 (0.46–1.56)	—
Hypertension	1.15 (0.75–1.74)	—
Coronary artery disease	0.87 (0.63–2.49)	—
Diabetes	1.25 (0.63–1.68)	—
Clinical presentation	—	—
Cognitive decline	1.24 (0.77–1.99)	—
Gait impairment	1.71 (0.42–6.91)	—
Urinary incontinence	0.83 (0.49–1.36)	—
Headache	0.71 (0.45–1.38)	—
Complete INPH triad	1.03 (0.68–1.55)	—
Gait impairment as primary symptom	1.91 (1.04–3.49)	1.87 (1.02–3.43)
Increasing duration of symptoms (yr)	0.87 (0.79–0.96)	0.89 (0.82–0.98)
CT/MRI findings	—	—
Cerebral atrophy	1.13 (0.69–1.83)	—
Corpus callosum distension	1.64 (1.05–2.58)	1.38 (0.85–2.20)
Periventricular white matter change	1.11 (0.74–1.66)	—

[a] RR, relative risk; CI, confidence interval; INPH, idiopathic normal-pressure hydrocephalus; CT, computed tomographic; MRI, magnetic resonance imaging. Patients with corpus callosum distension on MRI or gait abnormality as their primary symptom were nearly twofold more likely to improve after CSF shunting. Increasing duration of symptoms before CSF shunting was associated with poorer outcome.

DISCUSSION

In this retrospective study, we reviewed our 10-year experience at The Johns Hopkins Hospital using a diagnostic protocol of Pcsf monitoring and controlled CSF drainage to recommend CSF shunting for the treatment of 132 patients with INPH. Our series is the first to report a long-term response rate for INPH as high as 75% with a significant patient follow-up period (mean, 18 mo). These results should dispel the belief that INPH is either poorly responsive to shunting or is an untreatable disease and suggest that patients diagnosed with INPH, like those diagnosed with secondary NPH, should be offered CSF shunting.

Over the past 40 years, there have been numerous reports on the use of CSF shunting for INPH (2, 3, 6, 13, 20, 27, 28, 31, 33, 35, 40). These have used a wide range of selection criteria and lengths of follow-up and have varied considerably in

the numbers of patients studied. Consequently, the outcomes also have differed markedly. Our series of 132 patients, diagnosed using a rigorous set of five selection criteria that included clinical, radiographic, and physiological measures (Pcsf and CSF drainage response), contrasts with early studies such as those of Black et al. (2), Vanneste et al. (40, 41), and Greenberg et al. (20), in which only ventricular enlargement and either dementia or gait disturbance were used. The series reported by Malm et al. (30, 31) and Larsson et al. (28) expanded on these basic inclusion criteria by including functional parameters such as improvement with simple CSF tap testing. Our study, however, comprises the only large series of patients where the identification of A- or B-waves on Pcsf monitoring and response to controlled CSF drainage was used to select patients who would be offered CSF shunting.

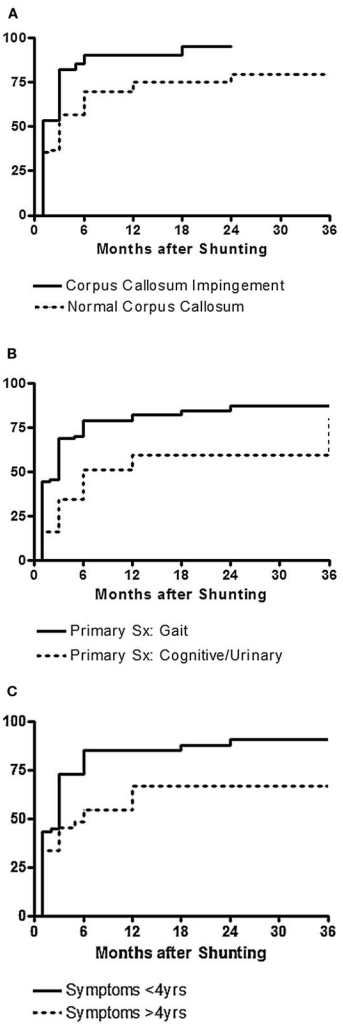

FIGURE 4. *Graphs demonstrating the percentage of patients experiencing symptomatic improvement as a function of time after shunt surgery.* A, *patients with corpus callosum distension shown on preoperative MRI scan were more likely to experience improvement after CSF shunting* ($P < 0.05$). B, *patients with urinary incontinence or cognitive decline as their primary symptom were less likely to experience improvement after CSF shunting* ($P < 0.01$). C, *patients experiencing symptoms more than 4 years before CSF shunting were less likely to experience improvement after surgery* ($P < 0.05$).

Just as the extent and type of selection criteria used to screen patients has varied in the literature, so have the short-term and long-term response rates and length of patient follow-up. The largest series to date by Vanneste et al. (40) enrolled 127 INPH patients and reported only a 31% rate of improvement. The Dutch NPH Study (3–5) enrolled 95 patients who were followed for 1 year and observed a 64% rate of improvement, but only a 37% rate of "significant improvement." Numerous other small series with 25 to 45 participants (2, 6, 7, 20, 28, 30, 31, 33, 35, 43) have shown highly variable response rates ranging from 14 to 89% (with most being less than 50%) with follow-up typically of 1 year or less. A recent meta-analysis by Hebb et al. (23) of all series reported in the literature found a combined long-term response rate to CSF shunting of 29%.

We attribute the 75% long-term response rate in the present study to our selection criteria, which include clinical, radiological, and CSF pressure measures. Indeed, the goal of diagnosis is to correctly refer patients with INPH for shunt surgery and to correctly identify patients who do not have INPH and recommend against shunt surgery, thus minimizing the burdens of undiagnosed INPH or the complications of unnecessary shunt surgery. Recent work has shown that both a high percentage of time threshold for A- and B-waves on Pcsf monitoring and response to controlled lumbar CSF drainage conveys a high predictive value of CSF shunting success (44). These findings have been confirmed in two other small series of patients by Chen et al. (11) and Haan and Thomeer (21).

CSF shunting for the treatment of INPH has long been associated with complications. The meta-analysis by Hebb et al. (23) showed a mean complication rate of 38% (range, 5–100%), mostly shunt revisions (22%; range, 0–47%), and 6% death or permanent neurological deficit. The Dutch NPH study reported subdural effusions in 53% of shunted patients, two thirds of which spontaneously decreased or resolved (4). In our series, only a single intraoperative complication was observed, only 3 (2%) patients experienced delayed subdural hematoma, and the perioperative mortality was only 1%. We think this low rate of subdural hematoma is the result of regular clinical evaluation after shunt surgery to identify early signs of overshunting with frequent valve setting changes as needed. Symptomatic overdrainage occurred in 20 (15%) patients and was reversed by raising the shunt setting in all patients. Our shunt revision rate of 33% is comparable with that of previous reports (23).

Considering that the operational definition of INPH over the years has been postoperative response to CSF shunting, much attention has been focused on elucidating clinical or imaging factors that will predict which patients will respond to a shunt. The presence of the complete INPH symptom triad previously was shown to have a low positive-predictive value for shunting response (40). Similarly, in our series, there was no association between the INPH triad and response to CSF shunting. Two small series showed, as did our series, that when gait disturbance is the primary presenting symptom, high response rates can be achieved (27, 43). Furthermore, our results demonstrate that it is not dementia that bothers patients or their families, but rather gait impairment. Insofar as INPH epidemiology has been described primarily in the context of a subset of dementia, we believe that it would be clinically and scientifically more prudent and fruitful to consider INPH in the context of the epidemiology of gait impairment and falling among the elderly (15, 22, 24, 34).

Our analysis also has confirmed previous reports that a longer duration of INPH symptoms is associated with decreasing likelihood of response to shunting. Petersen et al. (33) showed that those who responded to shunting had a lower mean duration of symptoms than those who did not (25 versus 38 mo). Caruso et al. (9) found that all patients with symptoms lasting less than 6 months responded to shunting, whereas no patients with symp-

toms for longer than 3 years responded. In our series, each additional year of symptom occurrence was associated with a 13% lower likelihood of responding to CSF shunting. These results corroborate the consensus that early INPH is more amenable to CSF diversion treatment, but at the same time do not exclude the possibility that patients with prolonged NPH symptoms can still benefit from shunt surgery.

Much attention also has been focused on identifying radiological abnormalities that would predict response to CSF shunting. The frequently used Evans ratio, or the ratio of the maximum width of the frontal horns to the maximum width of the inner table of cranial vault, does not correlate with shunting response (6, 37). The presence of cortical atrophy or periventricular white matter changes on CT scan have been associated with shunt response rates near 50% (13), but are present to some degree in all senescent brains and do not correlated with surgical responses (26, 36). This is supported by our series as well. We did observe that patients with preoperative corpus callosum distension were nearly twofold more likely to respond to CSF shunting, consistent with hypotheses that ventriculomegaly in INPH is the result of altered CSF conductance, pressure, and resorption, rather than atrophy-associated ex vacuo ventricular enlargement. Indeed, corpus callosum distension can be considered an anatomic marker of dilation from increased Pcsf within the ventricular system (25, 45).

Although our series demonstrates that INPH is a treatable disease when appropriately identified, this study has weaknesses inherent to all nonrandomized studies. We report the outcomes of a single treatment arm, using historical comparisons only. Therefore, although we can only speculate that our diagnostic protocol has a high positive predictive value, which underlies our high success rate, we cannot assess the negative predictive value of the absence of either B-waves or of clinical improvement with CSF drainage.

CONCLUSION

In this study, our 10-year experience demonstrates that INPH can be diagnosed accurately with a protocol of Pcsf monitoring and controlled CSF drainage performed via a spinal catheter. In this setting, shunting is likely to be successful with a 75% long-term response rate, significantly higher than previously reported INPH outcomes. The presence of gait impairment as the dominant symptom and shorter duration of symptoms are independent predictors of symptomatic improvement after shunt surgery. These data suggest that CSF shunting is a safe and effective intervention that should be offered to appropriately screened patients with INPH.

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COMMENTS

The authors have made an outstanding contribution to the growing literature regarding patients with idiopathic normal pressure hydrocephalus (INPH). If everyone used the authors' strict criteria for shunting, there would be a higher overall success rate from the procedure. My only concern is that there are very likely a number of patients in the group that was denied surgery that would have benefited from the procedure. Do we know for sure that a patient with classic symptoms of INPH will not benefit from shunting if they fail to demonstrate A or B waves with lumbar cerebrospinal fluid (CSF) pressure monitoring? Lundberg's original work involved measuring ventricular pressures, and it is not clear that lumbar monitoring for A or B waves is quite the same thing.

The authors do make it very clear that a select group of patients with adult onset hydrocephalus will benefit greatly from CSF shunting. It is of considerable interest that the percentage of patients showing improvement actually increases significantly with the passage of time. There are precious few procedures we do that show a higher response rate at 24 months than at 6 months.

William F. Chandler
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This study examines the outcome of 132 patients shunted for INPH. A significant objective improvement was noted in 33% of the patients at 3 months, 60% at 6 months, and 75% at 24 months. A positive correlation for a good outcome was noted the shorter the duration of symptoms, and gait impairment was the most debilitating symptom of the triad, with dementia and urinary incontinence being less relevant. Distention of the corpus callosum, seen in only 30 patients, was the only image finding that correlated with a good outcome. The shunt revision rate was 33%. There were three patients who developed subdural hematomas. However, the authors do not state whether or not they required surgical intervention. There was one operative complication of a frontal lobe hematoma that led to death from a pulmonary embolus. The shunt procedure infection rate was 6.7%.

What sets this study apart is a large number of patients, the low complication rate, and the relatively "long-term" good outcome in 75 of those treated with shunting. The use of programmable valves toward the latter part of the study was thought to be beneficial, but the authors did not attempt to quantify this factor.

The authors feel that their high success rate was due in large part to their making the diagnosis of INPH only if the patients has ventriculomegaly, two or more of the INPH clinical triad, no risk factors for secondary INPH, A or B-waves on CSF monitoring and clinical improvement during a 3-day CSF drainage trial via a lumbar drain.

An increased good outcome coupled with a reduced complication rate should encourage the evaluation of more potential candidates for treatment of INPH. The pathophysiology of INPH remains elusive and is still often defined by the successful response to shunting. The fact that CSF diversion proves beneficial in those patients with INPH indicates that what is defined as normal-pressure is not necessarily normal in this clinical setting.

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The authors provide useful predictors of outcome following CSF shunting in a large series of 132 patients with INPH. The best outcomes were found in patients who had gait impairment as their major symptom and who had symptoms of short duration. Selection criteria for surgery included clinical and radiological criteria, but most importantly the use of CSF pressure and wave-form monitoring via lumbar catheter, with the identification of Lundberg A or B waves, and a favorable clinical response to the test drainage of CSF at 10-ml-per hour for 3 days. With these criteria, the authors have obtained clinical improvement in three-quarters of their patients, demonstrating the value of such rigorous preoperative testing.

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