OUTCOME OF SHUNTING IN IDIOPATHIC NORMAL-PRESSURE HYDROCEPHALUS AND THE VALUE OF OUTCOME ASSESSMENT IN SHUNTED PATIENTS

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OBJECTIVE: To develop guidelines for assessing shunt outcome in patients with idiopathic normal-pressure hydrocephalus (INPH). To date, the literature available on this topic has been marked by disparate definitions of clinical improvement, varying postoperative follow-up protocols and periods, and substantial differences in the postoperative management. Because specific criteria for defining clinical improvement are seldom reported, conclusions drawn about shunt outcome may be subjective.

METHODS: A MEDLINE search back to 1966 was undertaken using the query *NPH, normal-pressure hydrocephalus, shunting, shunt treatment, shunt response, outcome,* and *clinical outcome*. The criteria for selection were studies that included INPH from 1966 to the present in which the outcome of INPH was reported in patient groups of 20 or more.

RESULTS: To date, there is no standard for outcome assessment of shunt treatment in INPH. The variable improvement rates reported are not only because of different criteria for selection of patients but also because of different postoperative assessment procedures and follow-up intervals.

CONCLUSION: Studies that have established fixed protocols for follow-up have shown that short- and long-term periods after shunting are determined by many factors. Whereas short-term results were more likely to be influenced by shunt-associated risks, long-term results were independent of factors inherent to the shunt procedure and shunt complications, i.e., death and morbidity related to concomitant cerebrovascular and vascular diseases. Studies have shown that beyond 1 year after surgery, these factors definitely influence the clinical effect of shunting, making the 1-year postshunt period a potential determinant of the shunt outcome. Guidelines for outcome assessment were developed on the basis of the available evidence and consensus of expert opinion.

KEY WORDS: Normal-pressure hydrocephalus, Outcome

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RECOMMENDATIONS

Standard

There is no accepted standard for this topic.

Guideline

There is no validated, universally accepted scale for assessment of treated or untreated idiopathic normal-pressure hydrocephalus (INPH) outcome.

Options

A firm description of shunt outcome can be based on the documentation of either the clinical impairment, improvement after treatment, or both. Grading of either the functional status of the INPH patient or the clinical criteria of gait, incontinence, and dementia should be performed. Examples of reported scales are the Black, Stein and Langfitt, Boon, Mori, and Krauss scales. In addition to gait, improvement in cognition is also correlated with the patient's daily function. Neuropsy-

chological testing may be of value in evaluating subtle cognitive deficits or changes with treatment. The latter have the advantage of having established norms for age and education level; however, the contributions of the various neuropsychological tests in the assessment of clinical outcome of shunt treatment remain to be elucidated. Efforts should be made to investigate how and when clinical outcome from shunt treatment is best assessed with respect to short-term (3–6 mo) and long-term (1 yr or greater) prognosis. The long-term prognosis may be affected by life expectancy and comorbid factors not related to the shunt procedure. In addition, there is a need for standardized reporting of shunt-related complications and their effects on both the clinical outcome and the benefit of shunt treatment in INPH.

OVERVIEW

Although cerebrospinal fluid shunting brings about the complete alleviation of INPH symptoms in some patients, it is more often the case that symptoms are only partially alleviated. In addition, the benefits of shunt treatment may persist for only a short period of time, partially as a result of the overall comorbidity of INPH patients (14, 25). In light of this, the question has been raised as to whether or not cerebrospinal fluid shunting is worthwhile for all patients. Answering this question requires the development of reliable measures to predict the probability and the extent of clinical improvement with a shunt versus more conservative treatments.

To date, the literature available on this topic has been marked by disparate definitions of clinical improvement, varying postoperative follow-up protocols and periods, and substantial differences in postoperative management. Because specific criteria for defining clinical improvement are seldom reported, conclusions drawn about shunt outcome may be subjective. Further obfuscating an objective analysis of shunt outcome is the presence of comorbid factors. This holds particularly true for the long period of shunt treatment, although systematic studies of short-term versus long-term prognoses are few (14, 18, 21).

Studies have documented clinical improvement and outcome of shunt treatment by use of functional grades (3, 23). Other investigators have tried to achieve a more precise evaluation by rating the degree of cognitive impairment and gait and urinary disturbances (3, 4, 9, 24). A few prospective studies have included neuropsychological measures, which have the benefit of incorporating normative data for outcome measurement (4, 10, 13, 17, 21). However, none of these methods have gained a wide acceptance.

PROCESS

A MEDLINE search back to 1966 was undertaken using the query *NPH, normal-pressure hydrocephalus, shunting, shunt treatment, shunt response, outcome* and *clinical outcome* (see Evidentiary Data, *Table 5.1*). The criteria for selection were any studies including INPH from 1966 to the present in which the outcome of INPH was reported in patient groups of 20 or more.

SCIENTIFIC FOUNDATION

No randomized prospective clinical trials were conducted comparing different measures or protocols of shunt outcome assessment. As a result, there is no standard for this topic.

Virtually all studies consider clinical outcome from shunting using terms such as "clinical response," "clinical improvement," or "rate of improvement." These were determined by differences between the preoperative and the last postoperative clinical assessment. The results were generally classified as "improved," "not improved," "stable," or "worse" and further stratified according to the degree of improvement ("excellent," "marked," "moderate," "fair," "transient").

However, there was considerable variability among investigators in how and when they reported improvement in clinical outcome. Moreover, the clinical criteria for determining improvement after shunt treatment were not specified, and thus, outcome was graded subjectively on the basis of clinical judgment (7, 8, 11, 12, 15, 19, 20, 22, 28). This complicates the objective assessment of shunt outcome in INPH.

Across studies, overall improvement rates vary, ranging between bounds of 30 and 96% (8, 12, 17, 23, 25). With respect to the reported rates of improvement and the clinical outcome to shunt treatment, six factors were considered: 1) selection of patients; 2) selection of treatment; 3) postoperative follow-up period (short- and long-term outcome); 4) shunt-related complications: subdural collections and management of nonresponders; 5) use of scales in assessing clinical outcome; and 6) use of psychometric measures in assessing shunt outcome.

Selection of Patients

Improvement rates have been correlated most strongly with the proper selection of INPH patients, with selection either based on clinical and diagnostic findings or further based on adjunctive tests. There is evidence from retrospective studies that the best results were obtained in patients with the typical clinical triad and/or predominating gait disturbance coupled with supportive computed tomographic (CT) criteria (26). The improvement rates were fairly consistent: 61% (2), 77% (3), 65% (26), 67% (11), and 75% (1).

Studies conducted earlier during the 1950s, when CT imaging may not have been available, used more liberal criteria for shunting, e.g., shunting patients with predominating dementia or dementia alone. This resulted in lower improvement rates of 24% (23), 33% (7), 25% (20), and 33% (8, 12).

However, predicting the rate of improvement and/or the outcome of shunt treatment by clinical and radiological criteria alone was not supported by a very early prospective study by Stein and Langfitt (23), in which the results of 33 patients with INPH were analyzed separately. In a larger and more recent retrospective analysis of 74 patients with NPH, in which subjects were prospectively followed up for an average

TABLE 5.1. Evidentiary data: Value of outcome assessment in shunted patients[a]

Series (ref. no.)	INPH/SNPH	Description of study (follow-up and outcome assessment)	Class	Conclusion
Boon et al., 1998 (4)				
Prospective	85/11	1, 3, 6, 9, and 12 mo; outcome after 12 mo was determined by relative differences between the preoperative and the last NPH scale scores (gait scale + dementia scale) and modified Rankin Scale scores. Classes of improvement: none, moderate, marked, and excellent.	II	Patients did better with LPV (74% improvement) than with MPV (53% improvement), the greater differences occurring in Rankin Scale scores ($P = 0.06$).
Savolainen et al., 2002 (21)				
Prospective	51/0 (25 shunted)	Follow-up 3, 12, and 60 mo; 1-yr follow-up was assessed on the basis of neurological and neuropsychological evaluation and ADL confirmed by family. Five-yr outcome was completed by telephone contact or by letter. Improvement was classified as better, without change, and worse. Only 25 patients were shunted on the basis of selection made by ICP monitoring.	II	Improvement rate for those shunted decreased over the period of 5 yr compared with 1 yr, decreasing from 76 to 47% for gait difficulties, from 48 to 38% for memory disturbances, and from 58 to 29% for urinary incontinence at 1 and 5 yr, respectively. The need for care was less in the group shunted than in those who were not shunted (39 versus 52%). Death rates at 5 yr were equal in both groups and were related to cardiovascular and cerebrovascular diseases.
Malm et al., 2000 (14)				
Prospective	42/0	3, 9, 18, 36 mo; outcome was measured by serial videotaping of gait, a comprehensive neuropsychological battery, the MMSE, and the Bartels Index of ADL. Outcome was classified by improvement, no improvement/worse, and dead.	II	Improvement decreased over 3 yr and was 64 and 26% at 3 mo and 3 yr, respectively. NPH patients were 3.3 times more likely to die than healthy individuals. Stroke and ischemic heart diseases affected long-term outcome.
Børgesen, 1984 (5)				
Prospective	40/40	3 and 12 mo; outcome was measured by Stein and Langfitt functional grades and grading of dementia, gait, and urinary incontinence. Outcome was classified by improvement (gait and dementia and/or functional grade), transient improvement (<3 mo), and unimproved/worse.	II	Improvement in functional grades was 64 and 58% at 3 and 12 mo, respectively. Improvement for INPH at 1 yr was only 42% compared with 72% for SNPH ($P = 0.01$).
Børgesen and Gjerris, 1982 (6)				
Prospective	40/40	3 and 12 mo; outcome was measured by Stein and Langfitt functional grades and grading of dementia, gait, and urinary incontinence. Outcome was classified as excellent, good or transient (<3 mo) or unimproved/worse.	III	Only patients with CSF conductance <0.12. 68% improvement for INPH. At 1-yr follow-up, there were few changes compared with the examination at 3-mo follow-up.
Malm et al., 1995 (13)				
Prospective	35/0	3 mo; serial videotaping of gait, a comprehensive neuropsychological battery, and the Bartels Index of ADL measured outcome. Outcome for gait was classified by markedly improved, improved, or not improved.	II	Gait function was improved in 72% of cases. In cognitive function, 67% of cases with an MMSE <25 points improved in MMSE; 37% improved in the spatial function test, and 29% improved in the Fuld Object Memory test. No correlation between improvements in gait versus degree of improvement in psychometric function. No changes in the Barthel ADL index before and after surgery.
Stein and Langfitt, 1974 (23)				
Prospective	33/10	6–30 mo (mean, 18 mo); outcome was assessed by Stein and Langfitt functional grades. Improvement was defined by an increase of one or more grades.	II	Sustained improvement of function to a higher grade occurred in 24% with INPH.

TABLE 5.1. Continued

Series (ref. no.)	INPH/SNPH	Description of study (follow-up and outcome assessment)	Class	Conclusion
Raftopoulos et al., 1994 (17)				
Prospective	23/0	9 d, 2 and 12 mo; outcome at 1 yr was assessed on the basis of the gait (10-m walk), the neuropsychological assessment, and the urinary score. According to the preoperative and postoperative percentage change, five grades were defined: great, moderate improvement, no change, and moderate or severe deterioration. Improvement was considered when at least one aspect of the clinical syndrome showed great or moderate improvement.	II	Outcome at 1 yr showed 95% improvement of gait apraxia at 1 yr; 66.6% improvement in mental function; improvement in bladder function was already present 9 d after surgery (90%).
Raftopoulos et al., 1996 (18)				
Prospective	23/0	9 d, 2 and 12 mo, up to 60 mo; outcome assessment, see above.	II	Improvement at 1 yr was 96%, 5-yr outcome showed a 43% rate of death. One-half of deaths were caused by brain or heart ischemic problems.
Zemack and Romner, 2002 (29)				
Retrospective	147/71	3 mo to 8.8 yr (mean, 26.7 mo) (INPH). Clinical improvement was quantified on the basis of an "Improvement Index" according to the Krauss Scale, and clinical outcome was classified as excellent, good, unchanged, and "worse" on the basis of changes in symptoms and signs.	III	The 5-yr shunt survival rate was 80.2%. Outcomes were excellent or good in 71 (78.9%) of patients with INPH and 30 (69.8%) of 43 patients with SNPH. INPH patients needed readjustments in 53.6% of patients because of "underdrainage" compared with 49% of patients with SNPH. In 46% of these adjustments, improvement of the clinical symptoms has been achieved in INPH: Noninvasive, particularly consecutive, minor or single larger adjustments to the valve opening pressure can further improve outcome in patients with NPH.
Vanneste et al., 1992 (25)				
Retrospective	127/33	12 mo; outcome was assessed on the basis of grading of gait, dementia, and urinary incontinence on ordinal scales. Improvement was classified as none, some, and marked. Transient improvement occurred if NPH recurred at 1 yr (shunt malfunction excluded).	III	Marked improvement in INPH occurred in 31% (marked, 15%). Transient improvement in 44% not segregated out by cause. Outcome in INPH affected by severe shunt complications with residual morbidity. The benefit-to-harm ratio was 1.7.
Vanneste et al., 1993 (26)				
Retrospective	91/21	See above.	III	Highest improvement rate in selected patients based on preoperative clinical and CT data ("probable NPH"). Permanent improvement in INPH, 65%.
Greenberg et al., 1977 (7)				
Retrospective	Series 1: 28/0 Series 2: 45/0	Series 1: 5–30 mo (mean, 9.7 mo); Series 2: 3–29 mo (mean, 16.7 mo); outcome was classified by moderate, excellent, and no improvement (outcome criteria not specified).	III	Inclusion of delayed follow-up of Series 1. A 64% initial improvement at 10 mo decreased to 42% at 3 yr. In Series 2, improvement in 33.3% occurred. For all patients, 45% improved and decreased to 37% in prolonged follow-up. Deterioration was related to premorbidity (degenerative brain diseases).

of 2.1 years, Larsson et al. (10) reported that no single clinical symptom or sign correlated with outcome of the shunt operation in 26 patients harboring INPH.

In the retrospective study by Vanneste et al. (26), of 91 INPH-only patients, proper selection of patients made by "typical" clinical and radiological criteria resulted in an ob-

TABLE 5.1. Continued

Series (ref. no.)	INPH/SNPH	Description of study (follow-up and outcome assessment)	Class	Conclusion
Black, 1980 (2)				
Retrospective	62/0	9–75 mo (mean, 36.5 mo); outcome was assessed on the basis of preoperative and postoperative grading of gait, dementia, and urinary incontinence on ordinal scales and classified as excellent, good, fair, transient, poor, or dead (Black Scale) and by Stein and Langfitt functional grades.	III	47% improvement: 27% excellent, 14.5% good, 14.55 fair, 4.8% transient, 45% poor, and 8.1 dead. By functional grades, only 33% improved. Highest improvement occurred with the clinical triad (61.2%).
Laws and Mokri, 1977 (11)				
Retrospective	56/80	1–108 mo (mean, 21.5 mo); outcome was assessed on the basis of functional grades (not specified) and classified as marked, modest, unchanged, and worse at the latest evaluation compared with the preoperative results.	III	Overall improvement in 50% of patients. Typical INPH had a 74% improvement (follow-up, 19 mo). Atypical INPH 38% (follow-up, 22 mo). Highest improvement occurred with the clinical triad (67%).
McQuarrie et al., 1984 (15)				
Retrospective	47/24	3 mo; outcome was assessed by resolution of gait, cognitive, and urinary symptoms and a change in functional status. Improvement was defined if one or more criteria significantly improved (quantitative assessment not specified).	III	Improvement occurred more frequently in patients with a low-pressure shunt. The case rates for low- and medium-pressure valves were 80 and 50%, respectively. Results for INPH not segregated out.
Petersen et al., 1985 (16)				
Retrospective	45/0	10–157 mo (mean, 51 mo); outcome was assessed by Stein and Langfitt functional grades and classified as improved if a change to a higher grade had occurred.	III	75% improvement found at some time after surgery. Only 42% of cases with continuous improvement. Median duration of improvement 24 mo. Medical and neurological diseases affected long-term outcome.
Krauss et al., 1996 (9)				
Retrospective	41/0	3–59 mo (mean, 16 mo); outcome was assessed by preoperative and postoperative grading of gait, dementia, and urinary incontinence on ordinal scales. Outcome from the last available follow-up was classified as poor, fair/good, and excellent for each symptom. A total improvement index was calculated (Krauss Scale).	III	Initial improvement of gait occurred in 90% of cases, of urinary function in 76%, and of cognition in 88%. Excellent improvement in 15% with respect to all symptoms.
Benzel et al., 1990 (1)				
Retrospective	37/0	2 mo; outcome was assessed using the Black Scale and the Stein and Langfitt functional grades and classified into improvement, no improvement, or worsening of the clinical status.	III	Improvement was found in 75% of patients who presented with the complete triad. Improvement was found in 67% of patients with one or two components of the triad.
Weiner et al., 1995 (27)				
Retrospective	37/0	7–37 mo (mean, 14 mo); outcome was assessed by physical examination of gait, dementia, and urinary incontinence (not specified) and the clinical status classified as improved, unchanged, or worse compared with the preoperative status.	III	Improvement in gait occurred in 86% of patients, 43% improved in urinary incontinence, and 46% in cognition.
Black et al., 1985 (3)				
Retrospective	36/0	3 mo; outcome was assessed on the basis of preoperative and postoperative grading of gait, dementia, and urinary incontinence on ordinal scales and classified as excellent, good, fair, transient, poor, or dead (Black Scale).	III	Improvement occurred in 64% of all patients (32% excellent and good). Highest improvement in patients with primary gait disorder (77%).

TABLE 5.1. Continued

Series (ref. no.)	INPH/SNPH	Description of study (follow-up and outcome assessment)	Class	Conclusion
Salmon, 1972 (20)				
Retrospective	36/49	2 and 6 mo, some 24 mo (not specified); outcome was classified into marked, moderate, and minimal improvement, no change, deterioration, and death (outcome criteria not specified).	III	Patients were classified into four groups based on cause and pneumoencephalographic findings. There was an improvement at 6 mo in 7 of 31 patients attributable to INPH, 10 of 31 showed minimal improvements. At 2 yr, all maintained at the 6-mo level of improvement.
Reinprecht et al., 1995 (19)				
Retrospective	32/58	7–29 mo (13 mo); outcome criteria not stated.	III	11 of 32 INPH patients with good improvement with residual memory and gait.
Hughes et al., 1978 (8)				
Retrospective	27/0 control of 12 untreated patients (not case-controlled)	At least 9 mo; outcome was classified as considerably improved (improvement by family and physician), questionably improved (subjective improvement), stable, or worse in both gait and dementia (qualitative assessment).	III	Overall improvement in 33%, 26% stable, and 41% worse. Of the 12 nontreated patients, 50% worsened and 50% were stable.
Larsson et al., 1991 (10)				
Retrospective	26/48	3 and 12 mo (mean, 2.2 yr); outcome was assessed by calculating six indices of social functioning, neurological signs, gait ability, continence, psychometric performance, and psychiatric condition at the latest available control compared with the preoperative status.	III	Overall 77% improvement in INPH; after 12 mo, deterioration occurred in 22% related to comorbid conditions. Deterioration not segregated out by cause.
Magnaes, 1978 (12)				
Retrospective	26/34	3 and 12 mo; outcome was assessed by qualitative assessment of different criteria (physical examination, opinions of the family, and staff). Classification of outcome not specified.	III	33% improvement in INPH. At 1-yr follow-up, two INPH patients deteriorated despite adequate shunt patency.
Takeuchi et al., 2000 (24)				
Retrospective	25/0	Follow-up period not specified; outcome was assessed on the basis of the standards for NPH grading established by the Research Committee on Intractable Hydrocephalus (Ministry of Health and Welfare of Japan, 1996). The symptoms were expressed as grades, and improvement was considered when the grade improved by 1 or more.	III	48% improvement rate.
Spanu et al., 1986 (22)				
Retrospective	23/31	3, 6, and 12 mo; outcome was classified as marked improvement or no improvement at 6-mo evaluation. Outcome criteria not specified.	III	Improvement of 81% in INPH.
Yamashita et al., 1999 (28)				
Retrospective	20/148	54 ± 13 mo; outcome criteria and classification not specified.	III	Only patients with "effective" shunts were included in the study. Improvement not segregated out by cause.

[a] INPH, idiopathic normal-pressure hydrocephalus; SNPH, secondary NPH; ADL, activities of daily living; ICP, intracranial pressure; MMSE, Mini Mental State Examination; LPV, low-pressure valve; MPV, medium-pressure valve; CSF, cerebrospinal fluid; CT, computed tomography.

served maximum improvement rate of 65%. In summary, shunting based on clinical criteria alone did not result in a high rate of success in shunt treatment. This was improved when clinical criteria were combined with CT imaging (see Part II).

Selection of Treatment

The differences in outcome attributable to different shunt configurations used in treating INPH, e.g., ventriculoperitoneal, ventriculoatrial, or lumboperitoneal, have not been reported. However, the issue of valve type and configuration has garnered more scientific attention (see Part IV).

Table 5.2 shows the clinical outcomes of those studies that have specified the different valve types. Only a few, primarily retrospective, studies have systematically addressed the question of whether valve configuration and selection are a significant factor for shunt outcome in INPH (4, 15, 27).

In a prospective randomized study of both INPH and secondary NPH (SNPH), Boon et al. (4) reported a 74% improvement rate with low-pressure valves and a 53% improvement rate with medium- or high-pressure valves in a series of 96 patients (85 with INPH). Studies by McQuarrie et al. (15) in 72 NPH patients (47 with INPH) reported improvement rates of 80% for low-pressure valves and 50% for medium-pressure valves. Results for INPH were not analyzed separately. Although these studies suggest that low-pressure valves are superior to medium- or high-pressure valves, it is not clear whether this is directly applicable to INPH. It is clear from *Table 5.2* that there is a wide variability among investigators with respect to outcome measures, time of assessment, and type of valve, which emphasizes the need for standardization.

Use of Programmable/Adjustable Valves

More recently, the question has been raised as to whether adjustable valve systems can improve the outcome of shunting in NPH. To date, however, the studies addressing this issue combined all types of infantile and adult hydrocephalus, and the results for INPH were not analyzed separately (19, 28). In one retrospective study using the Hakim programmable valve (24) performed with 25 INPH patients, a 48% improvement rate was reported, with an 8% rate of reprogramming because of "underdrainage." Unfortunately, follow-up periods were not specified, making it difficult to measure the value of adjustable-valve systems on the outcome of INPH.

A recent retrospective study by Zemack and Romner (29), using the Hakim programmable valve in 147 patients with INPH and in 71 patients with SNPH, described the beneficial effect of valve readjustments on the clinical outcome of INPH patients. Outcome was quantified by use of an improvement index (9), and INPH patients were followed up for a mean period of 26.7 months (minimum, 3 mo; maximum, 8.8 yr). The average opening pressure selected at implantation time for both INPH and SNPH patients was 132 mm H_2O (median, 130 mm H_2O), and it has been shown that patients with INPH needed reprogramming in 53.6% of cases because of "underdrainage." In 46% of those adjustments, further improvement was achieved. Thus, having the capability to adjust valve opening pressure translated into improved clinical outcome. In this study, outcomes in INPH were excellent or good in 71 of 90 patients (78.9%), making outcomes in INPH comparable with outcomes of patients with SNPH (69.8%).

In summary, there is insufficient evidence from the existing literature to positively correlate shunt outcome in INPH with any specific valve type or configuration. Although the results of programmable or adjustable valve systems on the outcome of INPH patients seem promising, there is a lack of both prospective and retrospective studies comparing adjustable with nonadjustable valve systems.

Postoperative Follow-up Period (Short- and Long-term Outcome)

Very little can be found in the literature with regard to determining the optimal postoperative follow-up period for shunt outcome assessment and postoperative management of INPH. A key concern is early identification of subdural fluid collections or other shunt-associated complications on routine CT scanning. There is strong evidence from prospective studies demonstrating that the majority of subdural effusions are present within 2 months of surgery (4, 17, 18). The issue of subdural fluid collections will be addressed below.

However, there is a general consensus from the literature that improvement from shunting can be transient, making the time period of postsurgical observation a key parameter in the objective determination of shunt outcome. However, the questions of when, how often, and how long after shunt treatment clinical status should be assessed have not yet been adequately and systematically addressed.

For example, in both retrospective and prospective studies, the range of follow-up periods varied from a few months to longer than 10 years (2, 7, 9, 11, 16, 19, 27, 28). Short- and long-term clinical improvement and prognosis are therefore lumped together, and as a result, clinical outcome data may be biased by patients showing only transient improvement. Although most investigators have chosen to evaluate clinical status at 1 and 3 months after surgery (1, 3, 13, 15), assessment of outcome was reported only for the 12-month time point (4, 5, 10, 12, 17, 22, 25).

Only a small number of studies, all prospective, systematically investigated the patients' long-term prognoses beyond 12 months. Those that did had follow-up reviews between 36 and 60 months (14, 18, 21); at first glance, on the basis of available prospective data, it would seem that the positive clinical effect of shunting is not sustained. For example, Malm et al. (14) showed a decreased overall improvement from 64 to 26% when comparing outcomes at 3 months with those at 3 years in 42 patients with INPH. After 9 months, deterioration of activities of daily living (ADL) function was observed, and only 28% were independent at 3 years after shunt treatment, compared with 74% at the 3-month visit. Savolainen et al. (21) reported a decrease of clinical improvement over a period of 5

TABLE 5.2. Valve types and clinical outcome of shunt treatment using different outcome measures and follow-up periods[a]

Series (ref. no.)	INPH/SNPH	Valve type	% clinical improvement	Follow-up
Boon et al., 1998 (4)				
Prospective	85/11	LPV and MPV	74% (LPV); 53% (MPV)	12 mo
Børgesen, 1984 (5)				
Prospective	40/40	Medium DPV	42% (INPH); 72% (SNPH)	12 mo postoperative
Malm et al., 1995 (13)				
Prospective	35/0	Orbis-Sigma/various DPV	72% (gait function)	3 mo
Raftopoulos et al., 1994 (17)				
Prospective	23/0	Medium DPV (PS Medical)	95% (gait function), 66.6% (cognitive function)	12 mo
Raftopoulos et al., 1996 (18)				
Prospective	23/0	Medium DPV (PS Medical)	43% (gait function)	60 mo
Zemack and Romner, 2002 (29)				
Retrospective	147/71	Hakim programmable DPV	78.9% (INPH), 69.8% (SNPH)	Average: 26.7 mo (INPH); 30.8 mo (SNPH)
Greenberg et al., 1977 (7)				
Retrospective	Series 1: 28/0 Series 2: 45/0	Low, medium DPV	37% (Series 1 and 2)	Average: 16.7 mo (range, 3–29 mo)
McQuarrie et al., 1984 (15)				
Retrospective	47/25	Medium-pressure DPV, low-pressure DPV	80% (low DPV); 50% (medium DPV)	3 mo
Krauss et al., 1996 (9)				
Retrospective	41/0	Medium DPV, programmable DPV	90% (gait); 76% (urinary function); 88% (cognitive function)	Average: 16 mo (range, 3–59 mo)
Weiner et al., 1995 (27)				
Retrospective	37/0	Medium-high DPV/Orbis-Sigma	86% (gait); 43% (urinary function); 46% (cognitive function)	Average: 14 mo (range, 7–37 mo)
Reinprecht et al., 1995 (19)				
Retrospective	32/48	Hakim programmable DPV	30%	Average: 13 mo (range, 7–29 mo)
Børgesen and Gjerris, 1984 (6)				
Retrospective	31/49	Medium DPV	68%	12 mo
Magnaes, 1978 (12)				
Retrospective	26/34	Medium DPV	33%	12 mo
Takeuchi et al., 2000 (24)				
Retrospective	25/0	Programmable DPV/various DPV	48%	Not specified
Yamashita et al., 1999 (28)				
Retrospective	20/148	Hakim programmable valve	Improvement not reported	54 ± 13 mo

[a] INPH, idiopathic normal-pressure hydrocephalus; SNPH, secondary NPH; LPV, low-pressure valve; MPV, medium-to-high-pressure valve; DPV, differential-pressure valve.

years compared with 1 year. This held true for all aspects of the triad: improvement of gait difficulties decreased from 76 to 47%, improvement of memory disturbances decreased from 48 to 38%, and improvement rate of urinary incontinence decreased from 58 to 29%. Raftopoulos et al. (18) reported that 91% of patients with INPH showed permanent clinical improvement over a period of 5 years; however, 13 patients (57%) died at between 9 and 68 months, which is a confounding factor compared with the above studies.

In a retrospective study, Greenberg et al. (7) reported a decrease in improvement from 64% at 10 months to 42% at 3 years. Also, in retrospective studies that incidentally included patients with a follow-up of more than 1 year, there is more evidence that improvement rates are lower, namely, 24 to 42% (11, 16, 23).

Influence of Comorbid Factors in Long-term Shunt Outcome

The clinical deterioration in both the prospective and retrospective studies was clearly related to previous comorbid conditions, such as ischemic brain or heart diseases or other vascular diseases. In the study by Malm et al. (14), the patients' survival curves were compared with those of first-ever stroke patients and elderly control subjects. During the follow-up period of 3 years, a total of 28% of the patients with INPH died, compared with 32% of the patients with a first stroke and 8.5% in the normal population. The progression of comorbid conditions was documented as the "natural history" of treated INPH, and it was concluded that life expectancy is significantly reduced over the 3-year follow-up period (14, 21).

Similar findings appeared in the retrospective study by Larsson et al. (10). Although they did not segregate results for INPH-only patients, a 22% rate of deterioration occurred at 12 months. This was related to the patients' comorbid conditions and not to shunt-associated complications or to shunt malfunction. In these cases, the clinical result seemed to be related less to shunt treatment than to comorbid conditions and life expectancy.

In summary, analysis of available patients alone may skew long-term outcome assessment. An intent-to-treat analysis may be preferable for future studies because the drop-out rate in long-term follow-up is so high.

Shunt-related Complications: Subdural Fluid Collections and Management of Nonresponders

In the retrospective multicenter study by Vanneste et al. (25), 22 of 24 severe complications, primarily subdural hematomas, occurred in patients with INPH. There have been no prospective studies addressing the management of either subdural hematomas or subdural fluid collections. Depending on the shunt system used, subdural collections can be quite common. The prospective Dutch NPH study documented a 71% incidence of subdural effusions (low-density fluid collection on CT imaging) within the first 2 months for those patients receiving a low-pressure differential-pressure valve (4). In that study, the prevalence of subdural effusion had a negligible influence on outcome ($P > 0.05$). Also, small effusions may regress over time (4). What constitutes a large subdural effusion and whether and when large subdural effusions are at risk of converting into subdural hematomas has not been established. Delayed subdural hematomas seem to occur nearly exclusively in conjunction with minor head injury. There are no standards or guidelines delineating the optimal management of these fluid collections.

Few systematic studies have been performed that considered shunt complications with respect to the effect on the clinical outcome of shunt treatment in INPH. Interestingly, those prospective and retrospective studies that have addressed the effect of shunt-associated complications on clinical outcome and morbidity in INPH indicate that there is no long-term detrimental effect. Unfortunately, these studies vary in the frequency and type of assessments performed as well as the severity of complications, making it impossible to identify the specific effects of the shunt-associated complications on clinical outcome after shunt treatment. Clearly, there is a need for standardization (see Recommendations). In the retrospective multicenter study by Vanneste et al. (25), 22 of 24 severe complications, primarily subdural hematomas, occurred in patients with INPH. Furthermore, a prospective randomized study by Boon et al. (4) found that the most frequent complication on shunt outcome in patients with low- and high-to-medium-pressure shunts, subdural effusion, had a negligible influence on outcome ($P > 0.05$).

Interestingly, those prospective and retrospective studies that have addressed the effect of shunt-associated complications on clinical outcome and morbidity in INPH indicate that there is no long-term detrimental effect (8–10, 18). Unfortunately, these studies vary in the frequency and type of assessments performed as well as the severity of complications, making it impossible to identify the specific effects of the shunt-associated complications on clinical outcome after shunt treatment. Clearly, there is a need for standardization (see Recommendations).

Management of the Nonresponder

There have been no prospective studies addressing the management of the INPH patient who does not improve after a shunt or those who improve only transiently. For patients who see no improvement, the question arises as to after what time period improvement should be seen. Again, this question has not been directly addressed in the literature.

The immediate questions that arise in patients who do not improve or who improve for only a brief period after shunting are the possibility of misdiagnosis, insufficient drainage from a working shunt, or whether the shunt is patent. In a retrospective study by Larsson et al. (10), a 31% range of shunt malfunction was found in patients, and invasive testing of shunt patency was recommended to improve the shunt outcome. Another retrospective study also advocated caution toward undiagnosed shunt underdrainage, because it may negatively affect the shunt

outcome (11). Importantly, others report that revision for suspected shunt malfunction has not shown a beneficial effect on shunt outcome (6, 12). These studies were all retrospective, and patient numbers were few, thereby not allowing any specific recommendation from the literature regarding the management of suspected shunt malfunction with respect to improving the outcome of shunt treatment.

Use of Scales in Assessing Clinical Outcome

As mentioned above, there is no practical, standardized system of outcome documentation for research or for routine use that would be similar to, for example, the Glasgow Outcome Scale for head injury management. In those studies that used outcome measures, the evaluation generally included functional grades based on ADL or disability assessment (3, 23) and rating scales based on the three dimensions of gait, incontinence, and dementia (3, 4, 9). The aforementioned rating scales were ordinal scales, with number assignments based on the severity of symptoms.

In an early study, Stein and Langfitt (23) originally introduced the assessment of outcome on the basis of five functional grades that measured ADL and/or disability index that was later used and partially modified by others (1, 2, 16) (*Table 5.3*). On the basis of this scale, Stein and Langfitt (23) reported that only 24% of patients improved to a higher functional grade after shunt when assessed at a mean of 18 months.

In a retrospective study of 62 INPH patients, Black (2) found improvement by Stein and Langfitt functional grades in only 33% of patients. In contrast, a nearly 50% improvement rate resulted when the author used his own classification scheme, which graded outcome on the basis of change in scores, comparing the degree of impairment in dementia, gait, and urinary disturbances before and after surgery (*Table 5.4*). In that study, 27.4% of patients were able to return to normal work with mild or no deficit after a mean follow-up period of 36.5 months (range, 9–75 mo).

Krauss et al. (9) graded the degree of improvement for each of the three cardinal symptoms of the INPH triad. The postoperative outcome was assessed separately: 0, no or only poor improvement; 1, fair or good improvement; and 2, excellent improvement. To better compare the outcome among individuals, the overall symptomatic improvement of each patient was quantified by the calculation of a total improvement index. For this purpose, a fraction was formed with the numerator corresponding to the actual sum of improvement grades of all cardinal symptoms and the denominator corresponding to the possible maximal sum of improvement of the cardinal symptoms that were present before surgery. For example, this method yielded a fraction between 0/4 and 4/4 in patients with only two preoperative cardinal symptoms and a fraction between 0/6 and 6/6 in patients who had presented with the whole triad.

TABLE 5.3. Stein and Langfitt Scale for assessment of shunt outcome

Grade 0	No neurological deficit, able to work
Grade I	Minimal deficit, able to function independently at home
Grade II	Some supervision required at home
Grade III	Custodial care required despite considerable independent function
Grade IV	No practical capacity for independent function

TABLE 5.4. Black Scale for assessment of shunt outcome

Excellent	Resumed pre-illness activity without deficit
Good	Resumed pre-illness activity with deficit, improved in two or more categories
Fair	Improved but did not return to previous work, improved in one category
Transient	Temporary major improvement
Poor	No change or worsening
Dead	Died within 6 wk of surgery or as a result of surgery

In other studies, assessment of functional grades was performed by use of systems used in stroke rehabilitation, such as the Barthels ADL Index (14) or the Rankin Scale (4). In a prospective study of INPH, Malm et al. (13) reported that no significant functional changes occurred using the Barthel ADL index before and after surgery, whereas gait function was improved in 72% of patients measured by videotaping. It must be considered, however, that the follow-up period was only 3 months, thereby obscuring the ability to assess functional improvement, despite considerable changes in NPH symptoms.

Boon et al. (4) both used the Rankin Scale as a handicap or disability score and developed their own "Dutch NPH Scale" for the assessment of clinical outcome to shunt treatment. In the Dutch scale, they incorporated a short neuropsychological test battery (trail-making, 10-words test, finger-tapping, and digit span forward) into a grading system of 1 to 10 points each. This provided a so-called "dementia scale" with an overall range of 4 to 40. They also included 10 features of gait into a walking score (0–20), and the number of steps and the number of seconds for a 10-m walk (2–20) into a "gait scale" score with an overall range of 2 to 40. Finally, clinical outcome was classified as "none," "moderate," "marked," and "excellent" on the basis of the changes in the Rankin Scale, the dementia scale, and the gait scale.

Concerning the postoperative evolution of improvement, gait showed the highest improvement rates among symptoms,

as evidenced by Class II and III studies that systematically investigated postoperative improvement of each of the cardinal symptoms independently (9, 13, 14, 17, 21, 27). However, improvement in gait alone did not correlate well with improvement in ADL scores. Higher correlations with ADL scores were achieved when all three components of the triad were considered (2, 3, 17). Also, in patients who deteriorate in the course of long-term observations, all symptoms have shown a parallel course of decline in daily function (14). In other reports, family member assessments were used to assist in the evaluation of outcome (8, 12, 24, 27).

In summary, scales that assess improvement of the cardinal symptoms as well as improvement in functional outcome are important in the overall evaluation of the INPH patient and in determining the clinical effect of shunt treatment.

Use of Psychometric Measures in Assessing Shunt Outcome

Psychometric measures as a part of a fixed postoperative protocol and for assessment of improvement, as undertaken by the Dutch study group (4), are comparatively few (10, 13, 14, 17, 21). In a prospective study of cognitive recovery after shunt treatment by Raftopoulos et al. (17), a 66.6% improvement in mental function was detected in patients by use of a customized battery of neuropsychological tests.

Furthermore, psychometric measures have enabled some investigators to probe more precisely subtle degrees of clinical improvement, i.e., before and after tap test (13). Larsson et al. (10) reported an improvement rate of 77% in shunt-responsive INPH using quantitative assessment of gait and psychometric function at 1-year follow-up. Psychometrically, the greatest improvements in INPH patients were noted in spatial function and the Fuld Object Memory tests (13). Whereas Larsson et al. (10) reported significant changes in a variety of the psychometric tests used, results for INPH were not reported selectively. In summary, although there is no standardization of tests at present, it seems that psychometric evaluation can contribute to the cognitive dimension of the overall outcome evaluation of the INPH patient.

Summary: Shunt Outcome of INPH

The scales used and the time at which patient outcome is measured are extremely variable throughout the literature. The rates of improvement reported are not synonymous with the clinical outcome of shunt treatment. Across studies, "improvement rates" and "outcome after shunt" are lumped together when the clinical results of shunting are described. Moreover, outcome assessment is complex and incorporates many factors, which do not necessarily relate directly to the alleviation of symptoms by the shunt. For example, the judgment of the patient and his or her family is based primarily on regained functional status and/or improved social abilities. As shown above, these are rarely studied systematically or incorporated into the assessment of shunt outcome (10).

Scales that grade both improvement in symptoms and functional outcome are important in a comprehensive assessment of the response to the shunt and the overall quality of life of the INPH patient. Whereas the assessment of gait and incontinence can be relatively straightforward, assessment of the dementia component is more difficult and may require more sensitive tests than are currently available.

Another factor that confounds the assessment of shunt outcome is the risk-to-benefit ratio on an individual patient basis. It would seem reasonable that with regard to risk, the patient's life expectancy and comorbidity should be taken into consideration. There is a Class II indication that comorbid factors not related to shunt treatment have influenced the patient's clinical outcome and morbidity in long-term studies (1, 18, 21). One year after treatment, such factors increase, making it difficult to determine whether the outcome is directly related to the shunt procedure. Hughes et al. (8) argued that it may be possible that the shunt actually promotes the progression of the comorbid condition and consequently may lead to neurological deterioration.

However, a very recent study comparing 5-year outcomes of 25 shunt-treated patients with those of 26 nontreated INPH patients has indicated a lower need for care in patients who received a shunt than in those who did not (21). Patients were

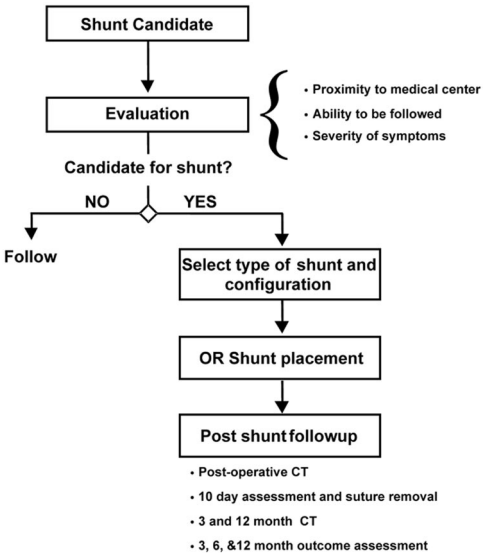

FIGURE 5.1. *Flow chart for surgical management of the INPH patient. After evaluation of shunt candidacy and selection of the type of shunt and shunt configuration, the shunt is placed in the operating room (*OR*). A CT scan should be performed soon after the surgery to confirm proper ventricular catheter placement and to exclude any intracranial hemorrhage. A second CT scan should be obtained after 3 months to rule out expanding subdural effusions that may be at risk of converting into subdural hematomas. Assessment of clinical outcome should be made at 3, 6, and 12 months after shunt treatment, together with a "final" CT scan as part of the routine follow-up of the improved patient. Evaluation of shunt candidacy considers factors related and not related to NPH morbidity. Patients not shunted for a variety of reasons should be followed up.*

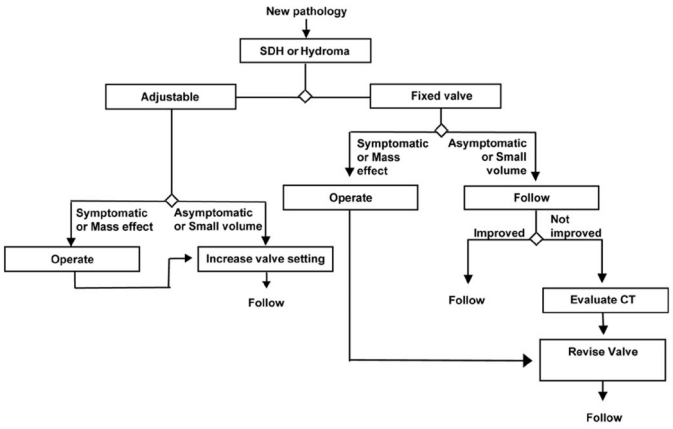

FIGURE 5.2. *Flow chart for management of subdural fluid collections (new pathological findings on CT scan). In case of a subdural hematoma (SDH) or a hygroma with a symptomatic mass effect, surgical evacuation of the hematoma or subduroperitoneal shunting for the hygroma should be performed. In case of adjustable valves, the valve setting should also be increased. In case of fixed valves, the valve should be revised. If the SDH or the hygroma is asymptomatic or of small volume, the valve setting of adjustable valves should be subsequently increased until improved and the patient carefully followed up by repeated CT scans at 1 or 2 weeks after each setting. In case of fixed valves, the SDH or hygroma should be followed by repeated CT scans, and if not improved, the valve should be revised with a higher-pressure valve. Replacement with an adjustable valve or the addition of an antisiphon device should be considered.*

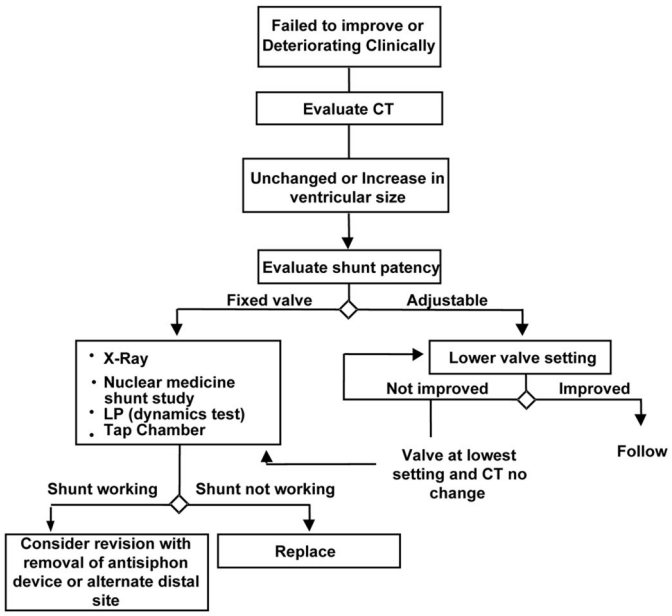

FIGURE 5.3. *Flow chart for management of nonresponders. If patients fail to improve or deteriorate clinically and if the CT scan shows no change or an increase in ventricular size, then shunt patency should be evaluated. In the case of fixed valves, an x-ray of the shunt to confirm proper placement and, if correct placement is established, formal evaluation of shunt patency by invasive testing are recommended. If the shunt is patent, the modalities of the distal site should be changed, and if the shunt is not patent, a surgical revision should be performed. In case of adjustable valves, the setting should be lowered unless the patient has not improved or unless the valve is not at the lowest setting. If the valve is at the lowest setting, the patient has not improved, and the CT scan shows no change, the part for the fixed valves should be followed Table 5.2. Valve types and clinical outcome of shunt treatment using different outcome measures and follow-up periods.* LP, *lumboperitoneal.*

selected for shunt treatment on the basis of strict criteria for intracranial pressure monitoring, and data were derived from the untreated INPH group. Clearly, there is a need for further studies of the effects of comorbidities on long-term outcome of shunt treatment in the INPH patient.

SUMMARY

To date, there is no standard for outcome assessment of shunt treatment in INPH. The variable improvement rates reported are a result not only of different criteria for selection of patients but also of different postoperative assessment procedures and follow-up intervals. Studies that have established fixed protocols for follow-up have shown that short- and long-term periods after shunting are determined by many factors.

Whereas short-term results were more likely to be influenced by shunt-associated risks, long-term results were independent of factors inherent to the shunt procedure and shunt complications, i.e., death and morbidity related to concomitant cerebrovascular and vascular diseases. Studies have shown that beyond 1 year after surgery, these factors definitely influence the clinical effect of shunting, making the 1-year postshunt period a potential determinant of the shunt outcome.

Recommendations

On the basis of the evidence presented, the following basic recommendations can be made, which may provide a common denominator for a standardized evaluation of shunt outcome in INPH.

1. In the short term, the assessment of clinical shunt outcome should be measured at 3, 6, and 12 months after surgery. Longer follow-up periods may be confounded by unrelated comorbidity. The recommended procedure for postoperative follow-up assessment, including an algorithm for the preoperative evaluation of patients with INPH, is shown in *Figure 5.1*. Recommendations for a standardized management of subdural fluid collections are shown in *Figure 5.2*.

2. Patients without clinical improvement after shunting (nonresponders) should be followed up more carefully. A standardized evaluation of shunt function (shunt patency) in every patient who does not improve or who improves only transiently should be made to rule out underdrainage. A flow chart algorithm is proposed to aid in the management of INPH nonresponders shown in *Figure 5.3*.

3. Objective scales should be used to grade the improvement of the "triad" elements, because these are the very components according to which INPH is defined. In addition, a functional scale should be used to assess the impact of shunting on ADL.

4. Long-term outcome assessment should take into consideration comorbid factors, life expectancy, and other social influences.

KEY ISSUES FOR FUTURE INVESTIGATIONS

A common NPH scale for documentation of clinical outcome would allow comparison of treatment results among different centers and allow firm conclusions to be made regarding the outcome from shunting and the value of shunting INPH independent of study environments.

Prospective randomized studies incorporating standardized measures for clinical improvement and outcome instruments with attention to interrater reliability and construct validity will be key in the development or selection of a useful outcome measure.

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