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Optimal Counseling And The Utility Of Imaging Parameters In Patients With Idiopathic Normal Pressure Hydrocephalus

Harry Eswar Subramanian

OPTIMAL COUNSELING AND THE UTILITY OF IMAGING PARAMETERS IN PATIENTS WITH IDIOPATHIC NORMAL PRESSURE HYDROCEPHALUS

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HARRY ESWAR SUBRAMANIAN
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ABSTRACT

OPTIMAL COUNSELING AND THE UTILITY OF IMAGING PARAMETERS IN PATIENTS WITH IDIOPATHIC NORMAL PRESSURE HYDROCEPHALUS

Harry E. Subramanian, Charles C. Matouk, and Amit Mahajan. Departments of Neurosurgery and of Radiology & Biomedical Imaging, Yale School of Medicine, New Haven, Connecticut.

It is very difficult to counsel patients who are suspected to have idiopathic normal pressure hydrocephalus (iNPH) due to the variability in diagnostic criteria and clinical presentations, as well as the difficulty in evaluating prognosis. This two part study was conducted in order to identify ways to improve the counseling of patients with iNPH. A qualitative analysis of patient experience with iNPH and shunting was initially performed. This was followed by an imaging analysis to identify predictors of outcome after shunt surgery.

A cohort of patients with iNPH who were shunted at a single institution were identified retrospectively and interviewed to explore patient experience. Interview transcripts were analyzed using the principles of grounded theory, which yielded seven overarching themes. From these themes, it was concluded that patients: suffer from a long preoperative course, desire improvement in functional independence, are not affected by the inability to provide a prognosis associated with shunt surgery, are confounded by comorbid conditions, and

receive heavy influence from family members and caregivers. These conclusions can be incorporated by physicians to improve patient counseling.

Features on the brain imaging of the same cohort of patients were reviewed retrospectively and compared with patient-reported subjective binary outcomes obtained from the patient interviews. A few imaging features were found to be possible predictors of outcome after shunting. The presence of focally dilated sulci may be a predictor of gait improvement, and a larger Evans' index, larger third ventricular diameter, and larger callosal height, may all be predictors of cognitive improvement. However, there is significant discordance in the literature regarding the predictive value of imaging features. The utility of imaging parameters in patient counseling remains limited until more consistent results can be produced.

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Thesis Advisors:

Amit Mahajan, M.D.
Assistant Professor of Radiology & Biomedical Imaging
Yale School of Medicine

Charles C. Matouk, M.D.
Associate Professor of Neurosurgery and of Radiology & Biomedical Imaging
Yale School of Medicine

Thesis Reviewers:

Kristopher T. Kahle, M.D. Ph.D.
Assistant Professor of Neurosurgery and of Cellular and Molecular Physiology
Yale School of Medicine

Charles C. Matouk, M.D.
Associate Professor of Neurosurgery and of Radiology & Biomedical Imaging
Yale School of Medicine

Department of Radiology & Biomedical Imaging Thesis Committee Chair:

Cicero T. Silva, M.D.
Associate Professor of Radiology & Biomedical Imaging
Yale School of Medicine

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INTRODUCTION AND BACKGROUND

Introduction

Normal pressure hydrocephalus (NPH) is a syndrome that presents with dilated lateral ventricles and clinical symptoms involving gait, cognition, and urination, as well as a lack of elevated cerebrospinal fluid (CSF) pressure or visible CSF obstruction. The etiology of this condition is poorly understood, but thought to represent a problem of CSF dynamics. In cases where some condition such as meningitis or subarachnoid hemorrhage precedes the onset of NPH, the syndrome is referred to as secondary NPH. When there is no preceding condition, it is considered idiopathic normal pressure hydrocephalus (iNPH). The prevalence of iNPH in patients greater than 65 years old has been calculated to be 1.3%, with an annual incidence of 120 cases per 100,000 people (1). However, these calculations are limited because there is no standard consensus of how to diagnose iNPH.

Typical diagnostic criteria utilized by physicians include older age (greater than 60 years), dilated lateral ventricles on imaging, and the classical symptom triad of gait disturbance, cognitive impairment, and urinary incontinence (2). The gait in patients with iNPH can be described as having low speed, short stride length, wide base, and increased double support time (3). The cognitive deficits seen in patients with iNPH include diminished working memory, diminished psychomotor speed, and decreased attention (4). The urinary symptoms seen in patients with iNPH usually include overactive bladder, which can present in patients as urge incontinence or increased nocturnal urinary frequency (5).

Diagnosis of iNPH

The formal diagnostic criteria currently in use come from two major guidelines. The international guidelines published in 2005 characterize the diagnosis of iNPH into three categories: probable, possible, or unlikely (6). The more recent Japanese guidelines published in 2012 use symptomatic and imaging criteria to also characterize the diagnosis of iNPH into three categories: possible, probable, or definite (2). Possible iNPH can be diagnosed when a patient meets all of five major features: age greater than 60 years, at least two symptoms of the classical symptom triad, ventricular dilation with an Evans' index greater than 0.3, no other disease that can explain the patient's symptoms, and no preceding condition that may cause ventricular dilation. Many additional features which would support a diagnosis of possible iNPH include: a slow progression of symptoms, gait disturbance being the most prevalent feature with a shuffling and unstable gait, and enlarged Sylvian fissures and basal cistern. A diagnosis of possible iNPH can be upgraded to probable iNPH if there is a measured CSF pressure less than 200 mm H_2O with normal CSF content, and the patient also has at least one of the following features: disproportionately enlarged subarachnoid space with narrow sulci over the high convexity on imaging observed concurrently with gait disturbance, improvement of symptoms after a CSF tap test, or improvement of symptoms after a CSF drainage test. A diagnosis of definitive iNPH can be given only with observation of clinical improvement following CSF shunt placement.

Despite the presence of these guidelines, it remains difficult to diagnose iNPH when patients do not obviously meet all of the stated criteria. The clinical presentation of iNPH can overlap with a number of conditions, which can make it very difficult for the physician to arrive at a diagnosis (7). The symptoms of iNPH are often attributed to other neurological disorders such as Parkinson's disease (8) or Alzheimer's disease (9), or vice-versa.

Unfortunately, the only means to provide a definitive diagnosis of iNPH is to observe clinical improvement following CSF shunt placement. The CSF removal test (sometimes referred to as the CSF tap test) is a commonly used method to predict patient improvement from shunting. This test involves draining a small volume, approximately 50 mL, of CSF through a lumbar puncture and observing the patient for subsequent clinical improvement. When used to predict improvement from shunting, the CSF removal test has demonstrated an average sensitivity of 58% (26-87%) and specificity of 75% (33-100%) (10). Therefore, even with a positive tap test, it remains difficult to predict which patients will improve with shunt placement.

Treatment of iNPH

The preferred treatment for iNPH is surgical placement of a ventriculoperitoneal shunt that is used to divert CSF flow. The Japanese guidelines suggest shunting as a treatment for probable iNPH but not possible iNPH (2). However, the authors also indicate that this guideline should be used in combination with the clinical judgment of the treating physicians. As a result, there is significant variability regarding which patients are candidates for shunt placement, and the decision-making process includes a discussion

with the patient about the possibility of improvement in quality of life. While shunting can provide significant benefits, it is not without complications. These include serious adverse events such as shunt obstruction, bowel perforation, and subdural hematoma, as well as less serious adverse events such as headache and subdural effusion (11).

Outcomes after CSF Shunting

The Japanese guidelines compile a summary of outcomes after shunting that have been reported in the literature. In the three to six months after shunt placement, there is a reported improvement in 64-96% of patients. At one year after shunt placement, improvement is seen in 41-95% of patients. In the three to five years after shunt placement, improvement is seen in 28–91% of patients (2).

There is currently no universally adopted method to measure the outcomes after shunting in patients with iNPH. Numerous tests are available to evaluate the three main symptoms of gait disturbance, cognitive impairment, and urinary dysfunction. The Timed Up and Go test can measure gait function (12), the Mini-Mental State Examination can measure overall cognitive function (13), the Frontal Assessment Battery can evaluate frontal lobe function (14), and the International Consultation on Incontinence Questionnaire is a self-administered questionnaire that can be used to assess urinary dysfunction (15). In addition, an iNPH Grading Scale has been developed, which is used to separately assess cognitive impairment, gait disturbance and urinary symptoms. Each of the symptoms is assessed by physician observation as well as patient interview, and given a score on an ordinal scale between 0 and 4 (16). Another option to measure outcomes is the modified Rankin scale,

which is a well-established but non-specific test primarily used to grade the overall clinical status of patients recovering from stroke. This test scores patients on an ordinal scale from 0 to 5 (17). The Japanese guidelines recommend use of the modified Rankin scale as the primary method to assess functional impairment, and use of the iNPH Grading Scale to assess each individual symptom (2).

While these outcomes provide an objective assessment of the symptomatic response to shunting, they do not provide a complete measure of the patient's quality of life. Because shunt placement is an elective procedure that is used to improve overall living condition, it is important to identify if shunting has provided any noticeable benefit to the patient. To accomplish this, subjective patient-reported outcomes can be used to find which patients perceive an improvement in quality of life after surgery. The Impact on Participation and Autonomy questionnaire can be used to measure patient-reported outcomes related to eight general domains of daily life (18). Furthermore, the experiences of the long-term caregiver for the patient can be measured by the caregiver burden scale, which is a subjective questionnaire that explores 5 categories of caregiver burden (19). A recent study of 37 iNPH patients found that self-reported quality of life six months after shunt surgery was increased in 86% of patients while only 65% of patients demonstrated symptomatic improvement measured using objective scales. Half of the patients who showed no objective symptomatic improvement reported an improvement in quality of life (20). This suggests that there are important outcomes that are not captured by the objective symptom scales currently in use.

Objectives

With the large number of diagnostic criteria for iNPH, the numerous possible clinical presentations of patients, and the tremendous range of reported outcomes, it is very difficult to counsel patients who are suspected to have iNPH regarding their prognosis and shunt surgery. This study was undertaken in order to identify how physicians can improve counseling of patients with iNPH. To answer this question, two major endeavors were attempted. In the first study, a qualitative analysis was conducted with patients who had undergone shunt surgery for iNPH. This was done in order to gain information about patient perspectives and experiences regarding their illness and the shunt surgery. Long term patient-reported subjective outcomes after shunting were obtained as well. In the second study, patient preoperative imaging features were evaluated and measured retrospectively. This was done in order to identify any potential associations between imaging features and patient outcome after shunting, with the hope that this information could be used to help counsel future patients.

STATEMENT OF PURPOSE

Specific Aims

- To improve the counseling of patients with iNPH.

- To study the subjective experience of patients undergoing the diagnostic workup and surgical treatment for iNPH.

- To identify the challenges and unmet needs of patients with iNPH in order to improve patient outcomes and satisfaction.

- To investigate the associations between imaging parameters and outcome after shunt surgery in patients with iNPH.

QUALITATIVE STUDY OF iNPH

INTRODUCTION

It is very challenging to counsel patients who are suspected to have iNPH regarding their prognosis and the possibility of shunt surgery. This is due to diagnostic difficulty arising from the tremendous variability in the diagnostic criteria for iNPH and in the clinical presentations of patients. It is difficult to predict both who will derive clinical benefit from shunt surgery, and the extent of improvement that may be seen with shunting. The outcomes after shunt surgery reported in the literature are variable. One set of guidelines reports gait is improved in 58-90% of patients, cognition is improved in 29-80% of patients, and urinary symptoms are improved in 20-82.5% of patients (2). Another set of guidelines has reported overall subjective improvement in 96% of patients, however studies designed to produce high level evidence supporting shunting have not yet been produced (21).

Understanding how patients experience such a complicated illness could allow physicians to better care for their patients. Qualitative research is useful to gain insight into patient perceptions and experiences. It can be used to explore social and emotional phenomena and to provide contextual information, which can be used to develop conceptual frameworks or theories (22, 23). Subjective questioning can be used to identify the impact of symptoms on patient quality of life, patient thoughts and concerns regarding shunt placement, patient motivations, and what benefits patients perceive from shunt surgery.

This information could be used to help physicians counsel patients who may be candidates for shunt placement, and also to identify patients who may benefit from shunt placement without showing signs of objective improvement. A study of the subjective experience of patients undergoing diagnostic workup and surgical treatment for iNPH has not been previously reported. This study was done to explore patients' experience with iNPH and shunt surgery, in order to investigate how patients make decisions and how they benefit from shunting, and to identify how patient experience could be improved.

METHODS

A qualitative study was conducted to examine patient experience with iNPH and shunt surgery. A consecutive series of patients who were diagnosed with iNPH and underwent ventriculoperitoneal shunt surgery between January 2012 and March 2016 at a single institution were retrospectively reviewed from a prospectively maintained database. A total of 64 living patients were identified to participate in the study. All patients were treated by one neurosurgeon and had lived for at least one year with their shunt at the time of their interview. These patients were enrolled to participate by telephone and provided information about the study. Patients who agreed to participate in the study were subsequently interviewed by telephone. All interviews were conducted by one investigator. Family members and other caregivers of patients were encouraged to participate when possible.

A semi-structured interview was conducted using a written template of interview questions where the interviewer had freedom to deviate from the template as needed. The interview template was modified as new themes developed throughout the study. The final interview template is shown in the **Appendix**. Interviews were recorded and transcribed verbatim. The transcripts were analyzed using open and axial coding, based on the principles of grounded theory (24). The analysis involved organizing the data into different overarching themes. Data analysis was conducted simultaneously as the interviews were conducted. Saturation of themes was reached after interviewing 31 patients.

Patient demographic data and information regarding patient preoperative course were collected through retrospective review of the medical record. Patient self-reported subjective outcomes were assessed in the interview by asking patients specifically if they had any improvement with each of gait, cognitive, and urinary symptoms. Informed consent was obtained from all participants in this study. This study was approved by the Yale University Institutional Review Board.

RESULTS

Patient Information

A total of 64 consecutive patients were eligible to participate, of which 40 volunteered to partake in the study and were interviewed. Saturation of themes was reached after the first 31 interviews, and these 31 patients comprise the study population. Patient characteristics including medication use and select comorbid conditions are summarized in **Table 1**. Patient symptoms related to iNPH as well as postoperative outcomes are summarized in **Table 2**. The median age was 77 years (range 64 - 90). The median duration between shunt surgery and interview was 30 months (range 16 - 56). Cardiovascular disease was present in 84% of patients, diabetes mellitus in 32%, and a history of stroke in 23%. At the time of diagnosis of iNPH, gait disturbance was the most common symptom and present in 100% of patients, followed by urinary incontinence in 81%, and cognitive impairment in 71%. After shunt surgery, 74% of patients reported improvement in gait, 44% reported improvement in urinary incontinence, and 45% reported cognitive improvement.

Table 1. Patient characteristics (n=31)

Characteristic	Number of Patients (%)
Age	
Median	77 years
Range	64 - 90 years
Sex	
Male	14 (45%)
Female	17 (55%)
Race	
Caucasian	29 (94%)
African-American	1 (3%)
Asian	1 (3%)
Medications	
Anti-hypertensive	23 (74%)
Lipid lowering	19 (61%)
Anti-platelet or anti-coagulation	17 (55%)
Anti-diabetic	10 (32%)
Anti-psychotic	4 (13%)
Anti-depressant	15 (48%)
Benzodiazepine	8 (26%)
Anti-Parkinson's disease [A]	4 (13%)
Cognition enhancing [B]	6 (19%)
Comorbid cardiovascular disease	
Any	26 (84%)
Hypertension	21 (68%)
Hyperlipidemia	15 (48%)
Coronary artery disease	8 (26%)
Comorbid neurological disease	
Stroke	7 (23%)
Alzheimer's disease	0 (0%)
Parkinson's disease	3 (10%)
Other comorbid condition	
Diabetes mellitus	10 (32%)

[A] includes carbidopa-levodopa and rasagiline

[B] includes rivastigmine, donepezil, and memantine

Table 2. Patient preoperative symptoms and postoperative outcomes (n=31).

Characteristic	Number of Patients (%)
Preoperative symptoms	
Gait disturbance	31 (100%)
Cognitive impairment	22 (71%)
Urinary incontinence	25 (81%)
Duration of preoperative symptoms	
≤ 1 year	21 (68%)
> 1 year	10 (32%)
Time between surgery and interview	
Median	30 months
Range	16 - 56 months
Patient reported outcome at interview	
Gait improvement	23 (74%)
Cognitive improvement	10 (45%[A])
Urinary improvement	11 (44%[B])
Other interview information	
Satisfied with shunt surgery	25 (81%)
Would recommend surgery to another patient	28 (90%)
Caregiver participated in interview	12 (39%)

[A] represents 10 out of 22 patients

[B] represents 11 out of 25 patients

Thematic Analysis

Analysis of the patient interviews produced seven overarching themes. Examples of responses from patient interviews are shown in quotations.

1. Long preoperative course and diagnostic uncertainty are a major source of morbidity.

Patients often had a long preoperative course that involved consultation with multiple physicians. Ten (32%) patients reported having symptoms for greater than one year before having shunt surgery. In these cases, there was diagnostic uncertainty, and patients may

have been incorrectly diagnosed with Parkinson's disease or with another cause of dementia. Eventually a neurologist or primary care physician would suggest the diagnosis of iNPH and refer the patient to a neurosurgeon for further evaluation.

"They didn't really know what was wrong with me. This went on for a long time and nobody had any clue. I went to three different hospitals. I finally went back to my primary doctor and he suggested I go to another neurologist outside the hospital."

"We took her to different doctors and people and medical staff, trying to find out what was wrong. Everybody kept telling me it was just her behavior. No one gave me sound advice."

As a result, patients often presented to the neurosurgeon frustrated and desperate for answers. Patients suggested that the excessive medical visits and testing they endured were more difficult than the shunt surgery itself.

"They were doing a lot of tests and he just kept getting worse. He went from this doctor to that doctor."

Some patients expressed disappointment with the delay in time from the onset of their symptoms to their shunt surgery. They believed quicker intervention would have resulted in a better postoperative outcome.

"I wish it had been caught sooner. I feel like if it had been caught sooner, maybe I would have benefitted more."

2. The decision to have shunt surgery is very easy to make.

Patients did not report any difficulty in deciding whether or not to have shunt surgery. Most were willing to have the surgery as soon as it was presented as an option by the neurosurgeon. Patients reported that they were unwilling to continue with their symptoms or decline in function, and some viewed proceeding with no intervention as unacceptable. As a result, even in cases where the surgeon could not state that a good outcome was likely to occur, patients did not have difficulty in deciding to procced with shunt surgery.

"I had no choice. I couldn't function. It was as bad as I described to you. So, I really had no choice. I just wanted to see if my condition could be corrected."

Patients relied on the neurosurgeon to tell them what to do. They stated that a recommendation to proceed with shunt surgery made by the neurosurgeon had a large influence.

"I just took his [the neurosurgeon's] word that I needed it done."

3. The main reason to have shunt surgery is to gain improved mobility and independence.

All patients expressed their primary desire was to be independent in daily functioning and to be able to move around without assistance from another person. A common aspiration was to walk without a fear of falling down. Improvement in gait symptoms was always more important than improvement in cognitive or urinary symptoms. Patients used their functional status at a time they perceived to be before the onset of iNPH as a reference and goal for their desired improvement after surgery. Patients also desired not to be a burden on their family or caregivers.

"I missed being independent. I don't like to have to depend on people to do anything for me."

"I wanted to be able to live my life without my daughter shuffling me all over the place."

4. Variable levels of anxiety surrounding shunt surgery are reported.

There was a wide range of anxiety reported by patients. Some had significant anxiety, some had minimal anxiety, and others did not report any anxiety. Patients with anxiety attributed it to multiple causes, including anxiety that comes with any operation, the serious connotation of "brain surgery", or simply being in the hospital.

"I was anxious because it was brain surgery and I had never experienced brain surgery or known anyone who had had brain surgery."

Patients stated their anxiety was alleviated when there was good communication with the neurosurgeon. Patients who did not report anxiety often cited their experience with previous surgeries.

"He had open heart surgery before. He joked all the way to the OR [operating room]."

Others described benefitting from their interactions with other iNPH patients who had already been shunted.

"I spoke to the daughter of someone who had a shunt put in and she reassured me that it really wasn't a big deal to have the shunt put in."

Patients did not report anxiety due to any uncertainty regarding the potential outcomes after surgery.

5. Difficulty describing any improvement after surgery arises due to symptoms from other comorbid conditions.

Patients had difficulty isolating the effect of iNPH and shunt surgery from their entire clinical picture. Patients reported fractures, osteoarthritis, and other musculoskeletal injuries that interfered with gait and mobility. Cerebrovascular accident or progression of dementia interfered with cognition. And recurrent urinary tract infections and prostate disease interfered with urination.

"I'm fine with my walking except for the fact that I have two bad knees. I have used a cane occasionally because of my knees bothering me."

"Immediately after the surgery she was clearer but it wasn't great. But then after that, the Alzheimer's started to show more so it's hard to tell if the shunt surgery made a big difference."

"I had prostate cancer. With that I have uncontrollable urine."

Patients who reported improvement in their symptoms and functioning often attributed any persistent postoperative symptoms to other comorbid conditions rather than to their iNPH.

"He uses a walker and that is only because of the arthritis."

In some cases, comorbid conditions caused much more distress than anything associated with iNPH or shunting.

6. Patients stand by their decision to have shunt surgery regardless of the outcome.

The satisfaction patients reported after having surgery was very variable and did not seem related to the degree of improvement. Some patients were satisfied with partial recovery of

function while others were happy with minimal improvement, and others expected a full recovery to preoperative function.

"Any improvement we thought was acceptable no matter what."

"With my walker, I can go wherever I want, but it's a pain in the neck. Other than that, I've come to live with it and it doesn't bother me."

Regardless of what outcome patients had after shunt surgery, they all expressed satisfaction with their neurosurgeon. Patients attributed their clinical improvement to the effectiveness and skill of their surgeon, but did not blame the surgeon for poor outcomes. Instead patients who were not satisfied attributed their lack of improvement to the natural state of their illness.

"I am not at all unhappy about the way things went. I am very grateful for the surgeon trying everything he could for me."

"I'm not saying the surgeon did anything wrong. The point is whatever procedure he did was not effective in any way."

Patients stated desirable qualities in their neurosurgeon included a calm demeanor, confidence, good communication, availability, intelligence, and an accommodating manner.

"He [the neurosurgeon] did everything well. He talks to you, he listens to you, he follows up with you, and he helps you out when you come back after the surgery."

Patients remained confident that having shunt surgery was the correct decision to make, regardless of their outcome afterwards. Many expressed their hope for improvement and the desire to take a chance even without a guarantee of improvement after surgery.

"I would always have regretted it if we didn't have the surgery, but I had hoped that the outcome would be better."

"I would have done the surgery no matter what because I wanted to be able to walk."

Patients were willing to speak to other patients with iNPH who may be considering shunt surgery. Most patients would recommend shunt surgery to someone else. Some patients reported having already counseled other patients with iNPH.

"We have a neighbor who had the same exact condition [iNPH]. I told her everything that happened with me, and I gave her a lot of support."

"I would recommend the surgery. In fact, I have already done that. There was a patient that was on the fence whether he was going to have it done. He wanted to talk to me, so I talked to the guy and he ended up having the procedure."

7. Outside information is utilized from the internet, books, or friends and family members, prior to shunt surgery.

Patients attempted to gather outside information in order to learn more about the diagnosis of iNPH as well as details about the shunt surgery. Most often patients searched for information on the internet, however there was no specific website or online resource that was reported as helpful. Patients also looked up information that had already been provided to them by their doctors, using that information as a second opinion, which helped patients feel less anxious about the surgery.

"The support group is called the hydrocephalus association. It gave me some more information before the surgery about what is hydrocephalus, what causes it, how it's treated, and the symptoms of the condition."

"We were all over the internet and Google. We googled everything, even the information the surgeon gave us before the surgery."

Family members, caregivers, and friends played a large role in counseling patients about their diagnosis and shunt surgery. Patients specifically sought out the opinions of personal contacts who had experience working in healthcare.

“I ended up with this neurosurgeon because my friend’s daughter is an assistant professor in your department.”

“I went and had an interview with the neurosurgeon. My daughter was with me and we agreed that I should have it done.”

DISCUSSION

A qualitative study of patients with iNPH undergoing shunt surgery has not been previously reported in the literature. This study exploring iNPH patients' experiences with their illness and with shunt surgery produced several overarching themes. iNPH is difficult to diagnose due to the variability in diagnostic criteria and in patient presentation. By the time patients present to the neurosurgeon for evaluation, many have undergone an extensive preoperative course consisting of multiple healthcare visits, diagnostic testing, and possibly incorrect diagnoses. Uncertainty is a major cause of patient morbidity. Patients are often frustrated, seeking answers, and desperate for any improvement. It is important to recognize this when counseling patients regarding shunt surgery. Communication between physicians is essential to ensure uniformity in the treatment plan and to ensure the correct diagnoses are given, especially regarding neurologic diagnoses.

Patients described no difficulty in making the decision to proceed with shunt surgery. The desperation felt by patients when they present to the neurosurgeon likely plays a role here. In addition, patients may be heavily influenced by the surgeon's recommendation, and would have the shunt surgery if the neurosurgeon suggested it should be done. In these instances, care must be taken to ensure patients are provided with all of the information possible, including the comparison of risks to benefits and the difficulty of predicting postoperative outcome.

The primary reason for patients to have shunt surgery was to improve mobility and independent functioning. All patients in this study experienced gait disturbance prior to surgery. The preoperative prevalence of gait disturbance (100%), cognitive impairment (71%) and urinary incontinence (81%) in this study is consistent with the prevalence reported in the literature (2). The rates of gait improvement (74%), cognitive improvement (45%), and urinary improvement (44%) in this study are consistent as well, however there is a wide range of reported improvement in the literature.

Anxiety surrounding the shunt surgery arose from the fact that it was an invasive procedure and from the serious connotation given to "brain surgery". Therefore, it seems appropriate that patients who had undergone previous surgeries reported less anxiety. Interestingly, patients were not worried about the chance they would not improve after surgery.

It is important to acknowledge the difficulty that exists in measuring outcomes after shunt surgery. The patient population in this study had numerous comorbid conditions including cardiovascular and neurological diseases. This is not surprising given iNPH is a disease of the elderly. Because of comorbidities confounding the clinical picture, it is often impossible to isolate the effects of iNPH and shunt placement from everything that is happening with the patient. Recommendations regarding the recognition and management of prominent comorbidities in iNPH patients have been published by the International Society for Hydrocephalus and Cerebrospinal Fluid Disorders (9). However, due to a lack of clinical trials, these recommendations are based on expert consensus opinion.

There is currently no standard method to measure patient outcomes after shunt surgery. Some prominent methods reported in the literature include the iNPH Grading Scale (16) and the modified Rankin scale (17). In addition the Timed Up and Go test can evaluate gait (12), the Mini-Mental State Examination can evaluate cognitive function (13), and the International Consultation on Incontinence Questionnaire can assess urinary symptoms (15). Subjective physician and patient reported outcomes have also been used to assess patient functioning and quality of life after shunting (20). In this study, subjective patient-reported outcomes were assessed for gait, cognition, and urination.

Reporting outcomes can be affected by comorbidities regardless of which method is used to assess patients. For example, in a patient with worsening gait after shunt placement, this decline could be attributed to worsening osteoarthritis or other musculoskeletal injuries. It may not be possible to determine the benefit from shunting, as any gains from the shunt are overshadowed by the worsening musculoskeletal comorbidities. It is also not possible to state if that patient's gait would have declined more rapidly without shunt placement. Patients are likely to report a successful shunting and attribute persistent symptoms to their comorbid conditions. This may be because of a strong desire to feel as if the surgery was worth doing. Caution is needed when evaluating clinical outcomes.

Overall, 81% of patients in this study said they were satisfied with the results from their shunt surgery. However, the degree of improvement affecting patient satisfaction was variable. Therefore, it is important to discuss in specific detail the patient's goals prior to shunt surgery in order to lessen instances of disappointment postoperatively. Patient

outcome also did not correlate with satisfaction with the neurosurgeon, as patients credited the surgeon with their improvement but did not blame the surgeon for poor outcomes. This could be due to the strength of the doctor-patient relationship and the confidence patients had in their surgeon. Patients also stood by their decision to have shunt surgery even when they were not satisfied with the outcome. This is likely connected to their decision-making process, their desperation, and their willingness to take a chance with surgery to hope for improvement.

With the abundance of information available online and through other sources, it is not surprising that patients would read on their own about their diagnosis and treatment. This was primarily a tool to reduce patient anxiety, as much of the information found by patients was already provided to them by their doctors. However, given the variation in quality among all possible sources of available information, it is important for physicians to discuss with patients any outside research. It is likely that seeing the same information presented twice provided patients with reassurance and helped put them at ease. Similarly, patients prior to shunt surgery benefitted from speaking to other patients with iNPH who had already undergone shunt placement. Speaking to someone with firsthand experience with shunting provided reassurance and reduced anxiety. Patients also indicated a willingness to speak to other patients who are diagnosed with iNPH and are candidates for shunt surgery. It is possible that facilitation of this patient-patient interaction by the neurosurgeon may improve patient experience.

Outside research was not reported to have much effect on the decision to have shunt surgery. This is in contrast to counseling from family members and friends, which had a large impact on patient decision-making. Patients often decided to have surgery after agreement by their family members, and personal contacts influenced where patients received their medical care. The importance of patient family members and caregivers on patient motivations, decision-making, and clinical course cannot be overstated. Patients routinely expressed their motivation to have shunt surgery due to their fear of imposing a burden on their caregivers. Because of the large impact they have, family members and caregivers should be included in the appointments and discussions when counseling patients regarding iNPH and shunt surgery.

Limitations

This study represents the experiences of a population of patients with iNPH treated at a single institution by a single surgeon. Due to the variability in diagnosis and treatment guidelines for iNPH, caution should be used when translating these results to different patient populations at different institutions. In addition, patients were recruited retrospectively and voluntarily, and there is the possibility of associated selection bias. Patients with iNPH who were not shunted were not included in this study and those patients may have different experiences, which should be taken into account when applying these results to patient counseling. There is also the potential to receive biased answers when patients believe they are speaking to their surgeon or someone else who is providing them with clinical care. Care was taken to encourage patients to respond freely, and the interviews were conducted by someone who did not provide any of the clinical care for the

patients. Interviews in this study were conducted by telephone. The preferred method for qualitative interviewing is to conduct interviews in person, in order to utilize body language and cues to obtain information and promote conversation. However, this was not possible in this patient population, as many patients had difficulty with mobility and required significant caregiver assistance to travel, and conducting interviews in person would have placed an undue burden on the patients.

CONCLUSIONS

Shunt surgery is the standard treatment for iNPH, and a definitive diagnosis can only be provided postoperatively. It is difficult to predict which patients will improve after shunting or how they will improve. Due to variable clinical presentations and difficulty predicting outcomes, it is challenging to counsel patients with iNPH. Patients often present to the neurosurgeon frustrated after a long preoperative course, and their desperation plays a major role in their decision-making process. Patients are desperate to gain improved mobility and functional independence, and are willing to take a chance with shunting despite the inability to guarantee a successful outcome. It is important to acknowledge the uncertainty regarding diagnosis and response to shunting when counseling patients. There are a wide variety of methods to measure outcomes after shunt surgery. However, patients' comorbid conditions can interfere with the ability to assess the effectiveness of the shunt. It may be difficult to separate iNPH from the patient's entire clinical picture. Patient family members and caregivers play a large role in patient decision-making and clinical course. Patients rely on these personal contacts for support and are often motivated by the desire to not impose a burden on them. Family members and caregivers should be included when counseling patients about iNPH and shunt surgery.

IMAGING ANALYSIS OF iNPH

INTRODUCTION

Imaging with magnetic resonance imaging (MRI) or computed tomography (CT) scanning is an essential diagnostic as well as prognostic component in the evaluation of patients with iNPH. The most commonly measured radiologic feature is the Evans' index, which is a marker of ventricular dilation, and calculated as the ratio of the maximum width of the frontal horns of the lateral ventricles to the maximum width of the inner table of the cranium (25). Both the international and Japanese guidelines require an Evans' index greater than 0.3 to diagnose iNPH (2, 6). In addition, the international guidelines recommend evaluation for an enlargement of the temporal horns of the lateral ventricles, a callosal angle greater than 40 degrees, the presence of periventricular lesions, and an aqueductal or fourth ventricular flow void, to support the diagnosis of iNPH (6).

The angle of the corpus callosum is an important feature on imaging. Patients with iNPH have been noted to have smaller callosal angles compared to healthy patients. In one study that evaluated patients with an enlarged Evans' index, using a threshold angle of 90 degrees, patients with iNPH could be identified with a sensitivity of 97% and specificity of 94% (26). In addition, patients with iNPH who respond to shunting have been found in another study to have a smaller callosal angle than those who do not respond. Using a

threshold angle of 63 degrees allowed for prediction of shunt responders with a sensitivity of 67% and a specificity of 65% (27).

A recently published retrospective study of 390 patients identified that a disproportion between supra-Sylvian and Sylvian subarachnoid spaces and a smaller mean width of the temporal horns on imaging were associated with the diagnosis of probable iNPH. However, no radiological markers were predictive of shunt response (28). Another recently published retrospective study of 108 patients identified that a smaller callosal angle, wider temporal horns, and the presence of disproportionately enlarged subarachnoid space were associated with a better outcome after shunting. However, the authors were not able to establish threshold values for these features and therefore could not make any recommendations regarding which patients would be better candidates for shunt placement (29).

A subset of patients with iNPH have narrowed subarachnoid spaces over the cerebral convexity and medial surface of the cerebral hemispheres, in conjunction with enlarged subarachnoid spaces over the Sylvian fissures. This subset of iNPH has been given the term disproportionately enlarged subarachnoid space hydrocephalus (DESH) (11) and the Japanese guidelines recommend classification of iNPH as DESH or non-DESH (2). Few studies have examined the prognostic value of DESH, and the utility of DESH remains controversial.

Although there are numerous imaging features associated with the diagnosis of iNPH, there remains significant uncertainty regarding which features can be useful prognostic factors.

The variability in the measurement of patient outcomes also complicates any comparisons made between different studies that evaluate imaging features in patients with iNPH. Identification of imaging parameters that could be used to predict a response to CSF shunt placement would provide great value to the treating physician. This study was done to evaluate the preoperative imaging of patients with iNPH and to identify any associations between patient imaging and long term patient-reported outcome after shunt placement, with the hope of using this information to improve patient counseling regarding iNPH and shunt surgery.

METHODS

This study was performed with the same patient population used in the qualitative study presented in the previous section. A detailed description of the patient sample and interview data acquisition is described in the methods of that section. In summary, a total of 40 patients who were diagnosed with iNPH and underwent ventriculoperitoneal shunt surgery were interviewed by telephone using the interview template shown in the **Appendix**. Patient demographic data and information regarding patient preoperative course were collected through retrospective review of the medical record. Patient self-reported subjective outcomes were assessed in the interview by asking patients specifically if they had any improvement with each of gait, cognitive, and urinary symptoms. Outcomes were reported as improvement or no improvement. A total of 37 patients were deemed eligible to be included in the final study population. Informed consent was obtained from all participants in this study, and this study was approved by the Yale University Institutional Review Board.

Patient imaging parameters were retrospectively evaluated by a board certified neuroradiologist using the most recent brain CT or MRI scan prior to shunt surgery. The Evans' index was measured as the ratio of the maximum width of the frontal horns of the lateral ventricles and the maximum internal diameter of the skull in the same axial image. The temporal horn width was reported as the average of the left and right maximum diameters of the temporal horns on axial images. The diameter of the third ventricle was measured as the transverse diameter, taken at the center of the ventricle in the

anteroposterior direction, on the axial image which demonstrated the widest diameter (29). The callosal angle was measured as the angle between the left and right corpus callosum on the coronal image through the posterior commissure and perpendicular to the anteroposterior commissure plane (26). The callosal height was measured on the midline sagittal image as the maximum orthogonal distance between the roof of the lateral ventricle and the anteroposterior commissure plane. The thickness of the corpus callosum was measured in the same line used to measure the callosal height.

The dilation of the Sylvian fissures was classified into three groups: narrow or normal, mildly dilated, and severely dilated. This was done using the method described by Hashimoto et al. (11). Compression of the medial high convexity was graded by means of a method modified from Narita et al. and using the following ordinal scale: 0 = dilated or normal, 1 = mild compression, and 2 = severe compression. This was evaluated on the four uppermost contiguous transverse sections and on the three contiguous coronal sections on and anterior to the posterior commissure (30). DESH was graded as present if compression of the medial high convexity and dilation of the Sylvian fissures were both present. If compression of the medial high convexity was graded as dilated or normal, or the dilation of the Sylvian fissures was graded as narrow or normal, then DESH was graded as absent. Compression of the peripheral high sulci was graded on the same images and with the same ordinal scale used to grade compression of the medial high convexity. Focally dilated sulci, as originally described by Holodny et al., were reported as present or absent (31).

Deep white matter hyperintensities (DWMH) were graded on T2 fluid attenuation inversion recovery (FLAIR) images using the method developed by Fazekas et al., and reported with the following ordinal scale: 0 = no lesions, 1 = punctate foci, 2 = beginning confluence of foci, and 3 = large confluent areas (32). Periventricular hyperintensities (PVH) were graded on T2 FLAIR images using the method developed by Virhammar et al. (29) which is modified from the method originally developed by Fazekas et al. (32) . PVH were reported with the following ordinal scale: 0 = absent or normal "pencil-thin" lining along the ventricular wall, 1 = increased, and 2 = irregular large symmetric hyperintensities extending into the deep white matter, with extension from the ventricles to the cortex in at least two locations.

The measured imaging features were analyzed as independent variables to identify any possible associations with improvement in each of gait, cognitive, and urinary function. The chi-square test and Student's *t*-test were used to identify associations between imaging features and postoperative outcome. Associations with a *P* value < .30 were analyzed using univariate logistic regression to identify any predictive relationship. All statistical analyses were performed using SAS software version 9.4 (Copyright © 2013 SAS Institute Inc.).

RESULTS

A total of 64 consecutive patients were eligible to participate, of which 40 volunteered to partake in the study and were interviewed. Three patients were deemed ineligible for inclusion after the interview due to removal of the shunt in the time between the initial surgery and the interview. A total of 37 patients are included in the final analysis.

Patient characteristics including medication use and select comorbid conditions are summarized in **Table 3**. The median age was 76 years (range 64 - 90). Cardiovascular disease was present in 84% of patients, diabetes mellitus in 30%, and a history of stroke in 22%. Thirty-four (92%) patients had an MRI scan of the brain prior to shunt surgery, while three (8%) had a CT scan.

Patient symptoms related to iNPH as well as postoperative outcomes are summarized in **Table 4**. The median duration between shunt surgery and interview was 30 months (range 12 - 56). At the time of diagnosis of iNPH, gait disturbance was the most common symptom and present in 100% of patients, followed by urinary incontinence in 84%, and cognitive impairment in 76%. After shunt surgery, 84% of patients reported improvement in gait, 48% reported improvement in urinary incontinence, and 43% reported cognitive improvement.

Table 3. Patient characteristics (n=37)

Characteristic	Number of Patients (%)
Age	
Median	76 years
Range	64 - 90 years
Sex	
Male	17 (46%)
Female	20 (54%)
Race	
Caucasian	35 (95%)
African-American	1 (3%)
Asian	1 (3%)
Medications	
Anti-hypertensive	28 (76%)
Lipid lowering	22 (59%)
Anti-platelet or anti-coagulation	18 (49%)
Anti-diabetic	11 (30%)
Anti-psychotic	7 (19%)
Anti-depressant	18 (49%)
Benzodiazepine	11 (30%)
Anti-Parkinson's disease [A]	4 (11%)
Cognition enhancing [B]	6 (16%)
Comorbid cardiovascular disease	
Any	31 (84%)
Hypertension	24 (65%)
Hyperlipidemia	19 (51%)
Coronary artery disease	8 (22%)
Comorbid neurological disease	
Stroke	8 (22%)
Alzheimer's disease	0 (0%)
Parkinson's disease	4 (11%)
Other comorbid condition	
Diabetes mellitus	11 (30%)
Imaging modality	
MRI	34 (92%)
CT	3 (8%)

[A] includes carbidopa-levodopa and rasagiline

[B] includes rivastigmine, donepezil, and memantine

Table 4. Patient preoperative symptoms and postoperative outcomes (n=37)

Characteristic	Number of Patients (%)
Preoperative symptoms	
Gait disturbance	37 (100%)
Cognitive impairment	28 (76%)
Urinary incontinence	31 (84%)
Duration of preoperative symptoms	
≤ 1 year	26 (70%)
> 1 year	11 (30%)
Time between surgery and interview	
Median	30 months
Range	12 - 56 months
Patient reported outcome at interview	
Gait improvement	31 (84%)
Cognitive improvement	12 (43%[A])
Urinary improvement	15 (48%[B])
Other interview information	
Satisfaction with shunt surgery	31 (84%)
Would recommend surgery to another patient	34 (92%)
Caregiver participated in interview	13 (35%)

[A] represents 12 out of 28 patients

[B] represents 15 out of 31 patients

Comparisons of preoperative imaging features and patient-reported outcomes for gait are shown in **Table 5**. The presence of focally dilated sulci was the only imaging feature associated with gait outcome. Gait improvement after shunting was present more often in patients without focally dilated sulci (95% vs. 71%, $P = .04$). Logistic regression analysis showed that the presence of focally dilated sulci was a predictor of gait improvement (OR 0.13 [95% CI, 0.01-1.22]; $P = .07$).

Comparisons of preoperative imaging features and patient-reported outcomes for cognition are shown in **Table 6**. Cognitive outcome was associated with Evans' index, diameter of

the third ventricle, height of the corpus callosum, and dilation of the Sylvian fissures. Patients with cognitive improvement after shunting had a larger preoperative Evans' index (mean 0.41 vs. 0.36, $P < .01$), larger third ventricular diameter (mean 11.3 mm vs. 9.5 mm, $P = .05$), and larger callosal height (mean 40 mm vs. 36 mm, $P = .06$). Logistic regression analysis showed that Evans' index was a predictor of cognitive improvement (OR 1.40 [95% CI, 1.08-1.81] using a scale of 0.01; $P = .01$), the diameter of the third ventricle was a predictor of cognitive improvement (OR 1.57 [95% CI 0.99-2.49]; $P = .06$), and the height of the corpus callosum was a predictor of cognitive improvement (OR 1.17 [95% CI 0.99-1.40]; $P = .07$). Cognitive improvement was also present more often in patients with severe dilation of the Sylvian fissures (83% severe vs. 29% mild vs. 40% normal, $P = .07$). However, logistic regression analysis showed that severe dilation of the Sylvian fissures was not a significant predictor of cognitive improvement (OR 7.50 [95% CI 0.46-122.68]; $P = .16$). The callosal angle and the presence of focally dilated sulci were not associated with cognitive improvement, but met the threshold of $P < .30$ to be evaluated with logistic regression. Analysis showed that both callosal angle (OR 0.97 [95% CI 0.93-1.02]; $P = .25$) and focally dilated sulci (OR 0.39 [95% CI 0.08-1.84]; $P = .23$) were not predictors of cognitive improvement.

Comparisons of preoperative imaging features and patient-reported outcomes for urinary symptoms are shown in **Table 7**. No imaging feature was associated with urinary outcome. When examined with logistic regression analysis, the presence of grade 2 PVH was not found to be a predictor of urinary improvement (OR 3.50 [95% CI 0.15-84.69]; $P = .44$).

Table 5. Comparison of patient imaging features and gait outcome (n=37)

Imaging Feature	Gait Improvement (n=31)	No Gait Improvement (n=6)	*P* Value
Evans' index	0.39	0.36	.48
Temporal horn width (mm)	7.4	7.5	.86
Diameter of the third ventricle (mm)	10.7	12.5	.54
Height of corpus callosum (mm)	39 (n=30)	40	.83
Thickness of corpus callosum (mm)	4.4 (n=30)	4.5	.84
Angle of corpus callosum (degrees)	69 (n=30)	70	.89
Dilation of the Sylvian fissures			
Narrow or normal	8 (89%)	1 (11%)	.85
Mild dilation	17 (81%)	4 (19%)	
Severe dilation	6 (86%)	1 (14%)	
Compression of the medial high convexity			
Grade 0	3 (100%)	0 (0%)	.32
Grade 1	1 (50%)	1 (50%)	
Grade 2	27 (84%)	5 (16%)	
Compression of the peripheral high sulci			
Grade 0	5 (71%)	2 (29%)	.62
Grade 1	13 (87%)	2 (13%)	
Grade 2	13 (87%)	2 (13%)	
Disproportionately enlarged subarachnoid space			
Present	22 (81%)	5 (19%)	.53
Absent	9 (90%)	1 (10%)	
Focal dilation of sulci			
Present	12 (71%)	5 (29%)	.04**
Absent	19 (95%)	1 (5%)	
Deep white matter hyperintensity			
Grade 0	6 (100%)	0 (0%)	.36
Grade 1	11 (79%)	3 (21%)	
Grade 2	13 (87%)	2 (13%)	
Grade 3	1 (50%)	1 (50%)	
Periventricular hyperintensity			
Grade 0	2 (67%)	1 (33%)	.61
Grade 1	21 (88%)	3 (13%)	
Grade 2	8 (80%)	2 (20%)	

*$P < .10$, **$P < .05$, ***$P < .01$

Table 6. Comparison of patient imaging features and cognitive outcome (n=28)

Imaging Feature	Cognitive Improvement (n=12)	No Cognitive Improvement (n=16)	*P* Value
Evans' index	0.41	0.36	.002***
Temporal horn width (mm)	7.4	7.1	.65
Diameter of the third ventricle (mm)	11.3	9.5	.05*
Height of corpus callosum (mm)	40	36 (n=15)	.06*
Thickness of corpus callosum (mm)	4.4	4.5 (n=15)	.79
Angle of corpus callosum (degrees)	63	71 (n=15)	.26
Dilation of the Sylvian fissures			
Narrow or normal	2 (40%)	3 (60%)	.07*
Mild dilation	5 (29%)	12 (71%)	
Severe dilation	5 (83%)	1 (17%)	
Compression of the medial high convexity			
Grade 0	1 (33%)	2 (67%)	.62
Grade 1	0 (0%)	1 (100%)	
Grade 2	11 (46%)	13 (54%)	
Compression of the peripheral high sulci			
Grade 0	1 (25%)	3 (75%)	.54
Grade 1	5 (38%)	8 (62%)	
Grade 2	6 (55%)	5 (45%)	
Disproportionately enlarged subarachnoid space			
Present	10 (45%)	12 (55%)	.59
Absent	2 (33%)	4 (67%)	
Focal dilation of sulci			
Present	4 (31%)	9 (69%)	.23
Absent	8 (53%)	7 (47%)	
Deep white matter hyperintensity			
Grade 0	1 (20%)	4 (80%)	.39
Grade 1	6 (60%)	4 (40%)	
Grade 2	5 (42%)	7 (58%)	
Grade 3	0 (0%)	1 (100%)	
Periventricular hyperintensity			
Grade 0	1 (33%)	2 (67%)	.67
Grade 1	7 (39%)	11 (61%)	
Grade 2	3 (43%)	4 (57%)	

*$P < .10$, **$P < .05$, ***$P < .01$

Table 7. Comparison of patient imaging features and urinary outcome (n=31)

Imaging Feature	Urinary Improvement (n=15)	No Urinary Improvement (n=16)	*P* Value
Evans' index	0.39	0.39	.63
Temporal horn width (mm)	7.6	7.5	.89
Diameter of the third ventricle (mm)	11	11.3	.86
Height of corpus callosum (mm)	41 (n=14)	40	.75
Thickness of corpus callosum (mm)	4.4 (n=14)	4.4	.97
Angle of corpus callosum (degrees)	72 (n=14)	66	.46
Dilation of the Sylvian fissures			
Narrow or normal	3 (33%)	6 (67%)	.44
Mild dilation	8 (50%)	8 (50%)	
Severe dilation	4 (67%)	2 (33%)	
Compression of the medial high convexity			
Grade 0	2 (67%)	1 (33%)	.80
Grade 1	1 (50%)	1 (50%)	
Grade 2	12 (46%)	14 (54%)	
Compression of the peripheral high sulci			
Grade 0	2 (33%)	4 (67%)	.70
Grade 1	6 (50%)	6 (50%)	
Grade 2	7 (46%)	6 (54%)	
Disproportionately enlarged subarachnoid space			
Present	11 (52%)	10 (48%)	.52
Absent	4 (40%)	6 (60%)	
Focal dilation of sulci			
Present	6 (46%)	7 (54%)	.83
Absent	9 (50%)	9 (50%)	
Deep white matter hyperintensity			
Grade 0	1 (20%)	4 (80%)	.33
Grade 1	5 (42%)	7 (58%)	
Grade 2	8 (67%)	4 (33%)	
Grade 3	1 (50%)	1 (50%)	
Periventricular hyperintensity			
Grade 0	1 (50%)	1 (50%)	.10
Grade 1	7 (35%)	13 (65%)	
Grade 2	7 (78%)	2 (22%)	

*$P < .10$, **$P < .05$, ***$P < .01$

DISCUSSION

This study was undertaken to identify any association between preoperative imaging features and long term patient-reported subjective outcomes following shunt surgery in patients with iNPH. The preoperative prevalence of gait disturbance (100%), cognitive impairment (76%) and urinary incontinence (84%) in this study is consistent with the prevalence reported in the literature (2). The rates of gait improvement (84%), cognitive improvement (43%), and urinary improvement (48%) in this study are consistent as well, however there is a wide range of reported improvement in the literature.

A few imaging features were associated with outcome after shunting, and these associations demonstrated a trend towards statistical significance. Patients with focally dilated sulci were less likely to have gait improvement. Patients with a larger Evans' index, larger third ventricle, and larger callosal height were more likely to have cognitive improvement. No imaging feature was associated with urinary outcome. The mechanism behind this relationship between imaging and outcome after shunting is unclear. The major finding from this study appears to be that patients who present with a more dilated ventricular system have a greater chance to experience long term cognitive improvement.

The results of this study add to the sparse literature that is present regarding the relationship between patient imaging and postoperative outcome in iNPH. The retrospective study by Virhammar et al. identified the angle of the corpus callosum, width of the temporal horns of the lateral ventricles, and DESH to all be associated with improvement after shunt

surgery (29). The outcomes were measured using physician-reported objective outcome scales at one year after shunt surgery. A smaller callosal angle, wider temporal horns, and the presence of DESH, were predictors of improvement after shunting. Still, none of these features could be used to exclude patients from surgery as 57% of patients with a callosal angle > 90 degrees had improvement postoperatively, 64% of patients without DESH had improvement, and 47% of patients with temporal horns smaller than 5 mm had improvement. The retrospective study by Kojoukhova et al. examined numerous imaging features including DESH, Sylvian fissures, focal dilation of sulci, temporal horn width, Evans' index, and callosal angle (28). However, no feature on imaging was associated with outcome after shunt surgery. The outcome was measured using a subjective binary measurement of improvement or no improvement observed and reported by a physician at two to three months postoperatively. The present study differs from these previously reported studies in that the outcomes in this study were measured at a later time, mostly multiple years after shunt surgery. In addition, the outcomes were measured as patient-reported subjective outcomes, and they were measured for each of the three major symptoms separately.

Interestingly, in this study the presence of DESH was not associated with patient outcome. This is in contrast to previously reported studies in the literature. DESH was first described as a subset of iNPH based on the results from the Study of Idiopathic Normal Pressure Hydrocephalus on Neurological Improvement (SINPHONI) trial (11). Since that time, the significance of DESH has been increasingly studied, with a few studies investigating the association between DESH and postoperative outcome. One single institution analysis of

iNPH patients examined the association between DESH and response to shunting at one year after surgery (33). Outcomes were reported as improvement or no improvement based on a combination of objective physician-reported measurements and subjective patient-reported perceptions. The presence of DESH was found to have a positive predictive value of 77% and the absence of DESH was found to have a negative predictive value of 25% when used to predict a response to shunting. The low negative predictive value seen in this study would indicate that the absence DESH cannot be used to exclude patients from shunt surgery. Another group of researchers developed a method to create a DESH score for each patient using five imaging features: ventriculomegaly, dilated Sylvian fissures, tight high convexity, acute callosal angle, and focal sulcal dilation (34). Outcomes were measured using various scales including the modified Rankin scale, iNPH grading scale, Mini-Mental State Examination, and Timed Up and Go test. For each outcome measure, patients who demonstrated improvement at one year after shunt placement were found to have higher DESH scores compared to patients with no improvement. Despite the results of these studies, the use of DESH to predict outcome after shunt surgery remains limited.

The results of the present study taken in combination with the major studies reported in the literature would suggest that any relationship between imaging features and outcome after shunting in iNPH patients remains controversial, with different and conflicting results reported by the different studies. As a result, it is difficult to translate any associations between imaging and outcome into information that can be used to better counsel patients. Therefore, the role of imaging in patient counseling remains limited until more robust data and more consistent results can be produced.

Limitations

This study represents a population of patients with iNPH treated at a single institution. The variability in diagnostic criteria and criteria for shunt placement among different physicians will limit any comparisons of these results to those across different institutions. In addition, there is great variability in the measurement of patient outcomes in the literature. Outcome after shunt surgery in this study was measured as a patient-reported subjective binary outcome, and comparison of these results to other studies can be limited by differences in outcome measurements. Patients were recruited retrospectively and voluntarily to track their outcome after shunt surgery, which carries a possibility of associated selection bias. Future prospective studies are needed to better examine the relationship between imaging features and postoperative outcome in iNPH. Finally, all imaging parameters in this study were measured by a single neuroradiologist. The methods used to measure imaging features were kept as specific, objective, and reproducible as possible, however there always remains the possibility of interobserver variation when analyzing imaging.

CONCLUSIONS

In patients with iNPH, the presence of focally dilated sulci on preoperative imaging may be a predictor of gait improvement after shunting. A larger Evans' index, larger third ventricular diameter, and larger callosal height, may all be predictors of cognitive improvement. No imaging feature was found to be predictive of urinary improvement. The angle of the corpus callosum and the width of the temporal horns of the lateral ventricles were both not associated with postoperative outcome. The presence of DESH was also not associated with outcome after shunt surgery. The results of this study add to the discordant results produced by the other major studies in the literature that examine the controversial relationship between imaging and outcome after shunting in iNPH. It remains difficult to utilize any associations between imaging features and outcome in the counseling of patients with iNPH. The role of imaging in patient counseling remains limited until more robust data and more consistent results can be produced.

CONCLUSIONS

It is very difficult to counsel patients who are suspected to have iNPH. There are numerous diagnostic criteria for iNPH, many possible clinical presentations, and great variability among physicians who treat iNPH patients. It is also difficult to predict which patients will improve and the extent of improvement that will be seen after shunting. In addition, there are a wide variety of methods used to measure outcomes after shunt surgery. This two part study was conducted in order to identify ways by which physicians could better counsel patients with iNPH.

The first study involved a qualitative analysis of patients with iNPH who had undergone shunt surgery and lived with their shunt for at least one year. Numerous themes emerged from the thoughts and experiences shared by the patients. Patients often have a long and difficult clinical course prior to receiving a diagnosis of iNPH. Patients are also desperate to gain functional independence and mobility. Their frustration and desperation have a great influence on their decision-making process. There is a willingness among patients to take a chance with shunt surgery despite the inability of the surgeon to predict the outcome. Patients also have numerous comorbid conditions that make it difficult to assess the progression of their iNPH or any response to CSF shunting. Finally, the family and caregivers of patients need to be included in patient counseling due to the immense influence they wield over patients' clinical course and motivations. These themes can be incorporated into physician practice to improve patient counseling.

The second study involved a comparison of preoperative brain imaging features and long term patient-reported subjective outcome after shunt surgery in patients with iNPH. A few imaging features were identified as possible predictors of postoperative improvement. The presence of focally dilated sulci may be a predictor of gait improvement. A larger Evans' index, larger third ventricular diameter, and larger callosal height, may all be predictors of cognitive improvement. No imaging feature was predictive of urinary improvement. These results are discordant with other major published studies that examine the association between imaging and outcome, and which themselves produce conflicting results. The utility of imaging parameters to predict outcome after shunting remains too controversial to be included in patient counseling until more consistent results can be produced.

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APPENDIX

Final version of the semi-structured patient interview template.

Preoperative Experiences

Please describe how you were doing prior to neurosurgery and the events that lead you to see a neurosurgeon.

How did you make the decision whether or not to have shunt neurosurgery? What factors did you consider?

What did you hope to gain from the surgery?

Was there any anxiety surrounding the surgery and what factors were responsible?

Postoperative Outcomes

What was the most significant benefit that you experienced after shunt surgery?

Has your ability to walk improved after shunt surgery? Describe how you feel it has improved.

Has your ability to clearly think improved after shunt surgery? Describe how you feel it has improved.

Have your urinary symptoms improved after shunt surgery? Describe how you feel they have improved.

Patient Reflections

Are you satisfied with your decision to have shunt surgery? Are you satisfied with the outcome after surgery? Please explain.

What were some things the neurosurgeon did well or did not do well in your interactions?

Is there anything during the course of your illness and treatment that you would have done differently?

What have been the most difficult things for you throughout the course of your illness?

How would you counsel another patient with normal pressure hydrocephalus? Would you recommend shunt surgery? What things would you discuss with them?

Other than what the doctors told you, did you use any outside resources or information?