Normal Pressure Hydrocephalus: An Emerging Dilemma in the Elderly

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ABSTRACT

Normal pressure hydrocephalus (NPH) is a brain disorder that normally occurs in older adults. It deteriorates functional status and quality of life, particularly ambulation, micturation control, and cognitive ability. NPH patients for which there is no identifiable cause are classified as idiopathic NPH, while cases with preceding insults are classified as secondary NPH. Diagnosis is crucial and mainly relies on clinical information and brain imaging. Occasionally, therapeutic diagnosis by spinal tap test is required. Surgery for permanent cerebrospinal fluid (CSF) diversion is the mainstay treatment for this condition. Early surgical treatment usually results in favorable outcome. Most NPH patients are elderly and often have associated major medical conditions, so the benefits of CSF diversion should be weighed against the risks associated with the procedure. Ventriculoperitoneal (VP) shunt is the most commonly used procedure, with lumboperitoneal (LP) shunt being used with increasing frequency in the treatment of NPH.

Keywords: Normal pressure hydrocephalus, elderly, shunt surgery

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INTRODUCTION

Normal pressure hydrocephalus (NPH) is a condition characterized by dilatation of the cerebral ventricles, with no associated abnormal change in intracranial pressure.[1] NPH is classified as a type of communicating hydrocephalus, that is hydrocephalus without obstruction of the cerebrospinal fluid (CSF) pathway in the ventricular system. This syndrome is commonly found in elderly patients older than 60-70 years of age. NPH can occur as a result of various causes (secondary NPH) or from unknown etiology (idiopathic NPH). The classic triad of NPH was first described by Hakim and Adams in 1965. This triad for diagnosing NPH consists of gait disturbance, cognitive decline, and urinary incontinence.[2] Patients with NPH often respond well to shunt placement surgery to facilitate permanent CSF drainage. Most NPH patients can return to normal function or experience a decrease in symptom severity after the operation. Timely and accurate diagnosis of NPH can facilitate appropriate and effective management, resulting in improved outcomes and quality of life for NPH patients.

Cerebrospinal fluid circulation

The normal daily CSF production rate is 500 mL. The majority of CSF (approximately 70%) is produced by the choroid plexus in the cerebral ventricles. The remaining CSF is created by the ependymal wall and brain parenchyma. CSF in the ventricular system flows out to the

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subarachnoid space around the brain, with some of the CSF moving downward to the intrathecal space surrounding the spinal cord. A percentage of the CSF (approximately 100-150 mL/day) is reabsorbed by the arachnoid granulation into the superior sagittal sinus.[3] The anatomy of the CSF pathway and CSF circulation are summarized in Fig 1.

Etiology

Regarding the etiology of hydrocephalus, NPH is classified into idiopathic and secondary NPH. Idiopathic NPH occurs as a consequence of cryptogenic cause, with secondary NPH having obvious or known etiology. Secondary NPH can be caused by events or conditions including subarachnoid hemorrhage, head trauma, infection of the central nervous system, brain tumor, or complications of cranial surgery.[1] Based on the specific diagnostic criteria for NPH, approximately one half of NPH patients have idiopathic NPH and the other 50% of NPH patients have known etiology. Several theories have attempted to explain the existence of ventricular dilatation in idiopathic NPH, including: poor venous compliance found in the superior sagittal sinus,[4] CSF collection in the ventricular system caused by aberrant CSF pulsation and absorption, and elevated CSF pressure and increased frequency of CSF pressure wave.[5]

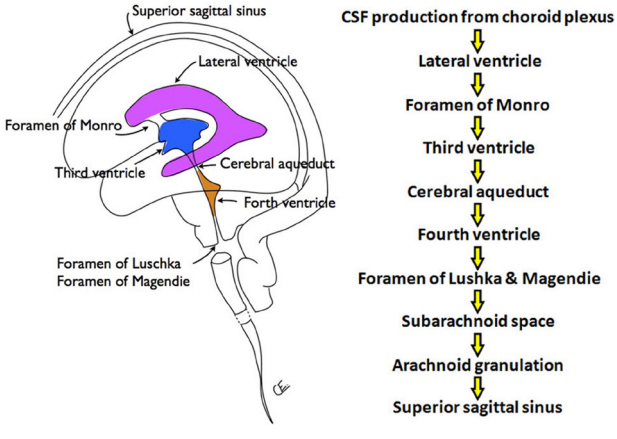


Fig 1. Anatomy of CSF pathway and CSF circulation

Clinical manifestation

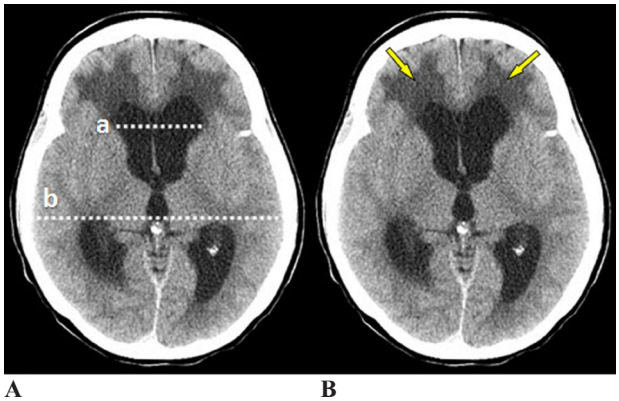
Cardinal symptoms in NPH include gait abnormality, cognitive dysfunction, and urinary incontinence.[1,6] There is significant diversity in the clinical manifestations of NPH. The entire triad need not be found for a diagnosis of NPH. Commonly, gait and balance disturbances occur before or concurrent with urinary incontinence or onset of cognitive dysfunction.[6]

1. **Gait disturbance** is a common manifestation and is most often the first presenting symptom and the symptom that responds best to CSF diversion.[7,8] Hallmarks of gait abnormality consist of gait apraxia, short-stepping gait, slowness of stance, reduced step height, and wide-based gait[1,4]; with difficulty in turning and tandem walking having also been mentioned.[6] Characteristics of gait disorder in NPH are summarized in Table 1[9] and Fig 2. The pathophysiology of gait disorders has been associated with midbrain diameter.[10] Maximal midbrain diameter was found to be smaller in NPH patients than in controls. Maximal anteroposterior and transverse diameters of the midbrain become significantly larger in NPH patients following shunt surgery. Midbrain diameter may play a role in post-shunting gait improvement[11] and have a negative relationship with gait severity in NPH patients.[10]

TABLE 1. Characteristics of gait disorder in NPH (modified from reference 9).

Gait examination	Finding
10-meter walk test	Number of steps > 13 (short-stepping gait) Duration > 10 seconds (slowness of gait)
Step breadth	Distance between toes > 1 foot length (wide-based gait)
Step length	Distance from heel of leading foot to toe of following foot < 1 foot length (short-stepping gait)
360 degree turn test	Use > 4 to 6 steps (short-stepping gait and difficulty turning)
Bipedal gait	Correction of foot position in > 25% of steps

Fig 2. A comparison of foot position between: (A) normal subjects; and, (B) patients with NPH



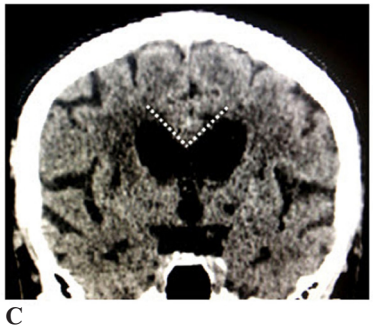


Fig 3. (A) The Evans ratio is the proportion between the maximal ventricular width (a) and the maximal biparietal distance from one side of the inner table of the skull to the other (b). (B) Transependymal CSF resorption demonstrated as periventricular hypodensity (arrows) on cranial CT scan. (C) The callosal angle shows a sharp contour in NPH

2. **Cognitive impairment** in NPH is subcortical type.[6] It is characterized by retardation of thought, psychomotor slowing, impaired short-term memory, impaired attention, impaired concentration, impaired executive function, lack of spontaneity, and behavioral changes.[1,8]

3. **Urinary incontinence** is specifically caused by detrusor muscle overactivity (a loss of micturation reflex),[12] which leads to urinary frequency, urgency, and incontinence.[8] Some NPH patients develop fecal incontinence and nocturnal enuresis.[1] Fecal incontinence usually occurs in the advance staged of the disease.[6]

Diagnosis

Diagnosis of NPH fundamentally depends upon clinical features and neuroimaging studies (computerized tomography (CT) and magnetic resonance imaging (MRI) of the brain). Typical radiographic characteristics found in NPH consist of dilatation of the cerebral ventricles, Evans ratio of 0.3 or greater[8] (Fig 3A), periventricular white matter changes (transependymal CSF resorption)[1] (Fig 3B), tightness of parasagittal brain, and subarachnoid space caused by upward bowing of the lateral ventricles with expanded sylvian fissures (disproportionally enlarged subarachnoid space hydrocephalus or DESH)[8,13] (Fig 4A). The callosal angle in coronal view of CT or MRI is beneficial for differentiating NPH from cerebral atrophy. Collosal angle less than 90 degrees indicates hydrocephalus caused by ventriculomegaly,

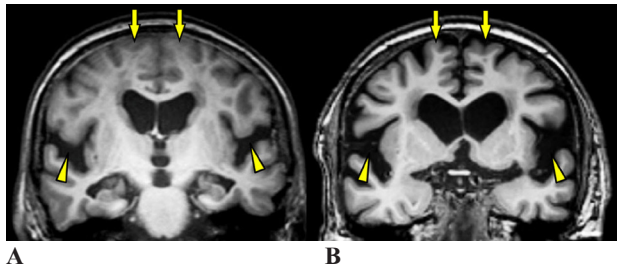


Fig 4. Comparison between DESH and cerebral atrophy. (A) DESH is defined as tight high convexity of the brain and medial surface subarachnoid space (arrows) with expanded sylvian fissures (arrowheads); (B) Radiographic features of cerebral atrophy include atrophic change of the parasagittal brain with prominent medial surface subarachnoid space (arrows) and sylvian fissures (arrowheads).

rather than brain atrophy (Fig 3C).[14] Evidence of hyperdynamic CSF flow (flow void defined by cine MRI) in the posterior third ventricle and within the cerebral aqueduct may increase the probability of shunt responsiveness. CSF flow studies may be helpful in differentiating NPH from cerebral atrophy.[15]

Lumbar puncture for CSF drainage or "spinal tap test" is helpful for increasing accuracy of NPH diagnosis[1,16] and identifying good candidates for surgery.[17] This test is performed by draining a large volume of CSF (30 to 60 mL). Alternatively, lumbar puncture over 2-3 consecutive days or continuous CSF drainage via lumbar spinal catheter (150-200 mL per day) for 2-7 days can also be performed.[1] Positive test results are characterized by gait improvement in 10-meter walk test by a reduction of at least 20% in the number of steps and time duration used for the walk, and at least a 10% improvement in the psychological test. Patients demonstrating temporary improvement in these symptoms are diagnosed as NPH and are considered good candidates for permanent CSF diversion, such as ventriculoperitoneal shunting.[12,17] However, there is no specific or dedicated test for diagnosing NPH. Diagnosis is based primarily on integration of several clinical data. Regarding prediagnostic classification, patients are categorized into 1 of 3 groups according to their chance of being diagnosed as idiopathic NPH, including probable NPH, possible NPH, and unlikely NPH (Table 2).

Treatment

Individuals who are diagnosed as NPH by history, physical examination, and brain imaging and who respond well to spinal tap test should undergo surgery for CSF diversion. Benefits and risks of the operation must be considered. Shunt surgery has been shown to improve symptoms of NPH. Surgical options for CSF diversion in NPH include the following:

1. Ventriculoperitoneal (VP) shunt is the most commonly performed procedure for treatment of NPH. CSF is drained from the lateral ventricle through a shunt valve into the sterile peritoneal cavity where the CSF can be reabsorbed (Fig 5). There are two types of VP shunt: fixed-resistance valve (single-valve setting) VP shunt and variable-resistance valve (programmable valve) VP shunt. Programmable valve VP shunt can be adjusted by using an external magnetic device to optimize patient benefit. Its adjustable property makes it more popular for avoiding CSF underdrainage and overdrainage.[6] Symptoms of NPH may not improve in CSF underdrainage, whereas CSF overdrainage may lead to excessive shrinkage of the brain, followed

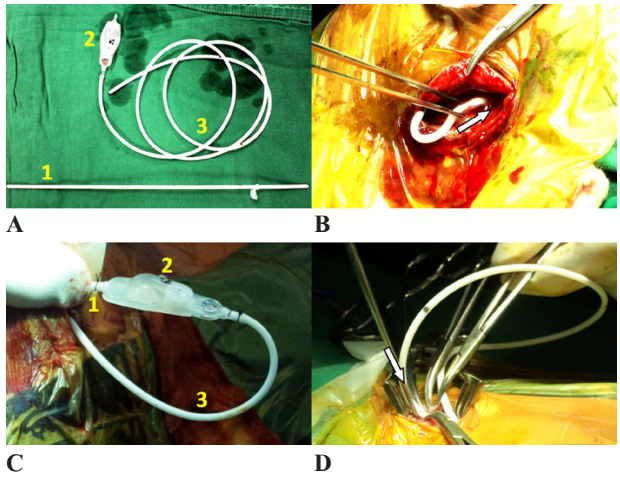


Fig 5. Ventriculoperitoneal shunt device. (A) The shunt device consists of: (1) ventricular catheter, (2) shunt reservoir with internal programmable valve, and (3) peritoneal catheter; (B) Placement of ventricular catheter into the ventricle through the skull in the direction indicated by the arrow; (C) Connection of the device shown in Fig 6A; (D) Insertion of peritoneal catheter into the peritoneal cavity through the anterior abdominal wall in the direction indicated by the arrow.

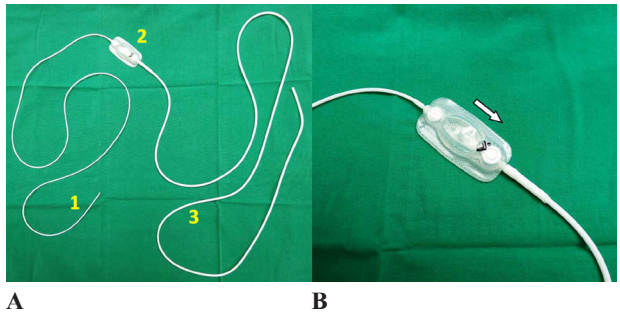


Fig 6. Lumboperitoneal shunt device. (A) LP shunt components include: (1) intrathecal catheter, (2) shunt reservoir, and (3) peritoneal catheter; (B) Shunt reservoir and programmable valve. The arrow points to the direction of the peritoneal catheter.

TABLE 2. Diagnosis of idiopathic NPH (modified from reference 1).

Probable NPH			
History	Insidious onset after 40 years of age		
	Progressive symptoms at least 3-6 months		
	No preexisting cause, including intracerebral hemorrhage, infection of the central nervous system, traumatic brain injury, or other causes of secondary NPH		
	No other neurological, psychiatric, or medical disorders that can explain the presenting symptoms		
Brain imaging	Dilatation of the cerebral ventricle (Evans ratio > 0.3 or comparable measure) that is not associated with brain atrophy or congenital anomaly		
	No obstruction of the CSF pathway		
	At least one of the following abnormalities:		Dilatation of the temporal horn of the lateral ventricle that is not associated with hippocampal atrophy
			Callosal angle of 40 degree or more
			Evidence of altered brain water content, including periventricular white matter change that is not associated with microvascular ischemic changes or demyelinating disease
			CSF flow void in the cerebral aqueduct and fourth ventricle on MRI
Clinical	At least 2 of the following gait abnormalities:		Reduced step height
			Decreased step length
			Decreased walking speed
			Increased trunk sway during walking
			Widened standing base
			Toes turn outward while walking
			Retropulsion (spontaneous or provoked)
			Impaired turn test (en bloc turn)
			Impaired walking balance (two or more corrections out of eight steps in tandem gait testing)
	At least 2 of the following cognitive abnormalities:		Psychomotor slowing
			Reduced fine motor speed
			Reduced fine motor accuracy
			Difficulty maintaining attention
			Impaired short-term memory
			Impaired executive function, such as multistep tasks Behavioral or personality changes
	Urinary incontinence	At least one of the following:	Intermittent or persistent urinary incontinence without primary urological disorders
			Persistent urinary incontinence
			Urinary and fecal incontinence
		Or any two of the following:	Urinary urgency (frequent perception of a pressing need to void)
			Urinary frequency (voiding > 6 episodes within 12 hours despite normal fluid intake)
			Nocturia (the need of urinate more than 2 times in an average night)
Physiological	Opening CSF pressure in the range of 5-18 mmHg (or 70-245 mmH_2O), as determined by a lumbar puncture or a comparable procedure		
Unlikely NPH			
No evidence of ventricular enlargement			
Signs of increased intracranial pressure			
No component of the clinical triad of NPH			
Presenting symptoms can be explained by other causes			
Abbreviation: CSF, cerebrospinal fluid; MRI, magnetic resonance imaging; NPH, normal pressure hydrocephalus.			

by subdural hygroma or chronic subdural hematoma. Major complications associated with this procedure are infection, dysfunction, and occlusion. Intracerebral hemorrhage after VP shunt placement is uncommon. Superficial siderosis of the central nervous system has only rarely been reported. Superficial siderosis may be caused by long-standing contact of the ventricular catheter of VP shunt against the choroid plexus.[18]

2. Lumboperitoneal (LP) shunt is accomplished by implanting a shunt to drain CSF from the lumbar subarachnoid space into the peritoneal cavity (Fig 6). LP shunt is generally performed in patients with communicating hydrocephalus and also for treatment of CSF fistula, idiopathic intracranial hypertension (pseudotumor cerebri), and slit ventricle syndrome.[19,20] Lumboperitoneal shunting is a safe and effective procedure that can be considered as an alternative to VP shunting.[21] At present, LP shunt is increasingly used for primary surgical diversion of CSF in NPH patients. Complications like infection and malfunction are lower than rates associated with VP shunt.[22] A unique complication after LP shunt placement is acquired Chiari malformation, which is a feature of overdrainage. LP shunt with programmable valve can effectively prevent CSF overdrainage.[23] Proximal migration of LP shunt can be encountered in cases of defective device fixation or cases of increased intra-abdominal pressure (IAP). Even though LP shunt does not involve the brain, serious intracranial complications, such as subdural hematoma, can occur following the procedure.[24]

3. Ventriculoatrial (VA) shunt is rarely employed in the treatment of NPH. In this procedure, the tip of a distal shunt catheter is placed into the right atrium through the facial vein or internal jugular vein. Major complications include shunt infection, immune-complex-mediated glomerulonephritis, and pulmonary hypertension.[25] Because VA shunt carries risk of serious complications, it should only be used in cases where the peritoneal cavity will not appropriately accommodate a distal shunt catheter.

4. Endoscopic third ventriculostomy (ETV) is a ventriculoscopic procedure by which an opening is made in the base of the third ventricle. The CSF in the third ventricle is diverted directly to the basal subarachnoid space where it is eventually reabsorbed by the arachnoid granulation into the superior sagittal sinus. ETV is normally used for the treatment of obstructive hydrocephalus. ETV can also be used for treating communicating hydrocephalus, including NPH. Although the major advantage of this procedure is the lack of foreign material (shunt device), treatment outcome in NPH patients is still inferior to that of VP shunt.[26] Complications, including subarachnoid hemorrhage due to injury of the basilar artery and overdrainage with chronic subdural hematoma or subdural hygroma have been reported.[27,28]

Recommendations

Early treatment of NPH leads to high success rates,[6] with delayed treatment yielding suboptimal outcomes.[29] Patients with improved symptoms following a large volume CSF release via lumbar puncture have a greater chance of responding to shunt surgery than patients with negative spinal tap test. A patient manifesting with gait disorders, followed by urinary incontinence and mild dementia and with brain imaging which displays ventricular enlargement and preserved brain parenchyma has a high probability of benefit from surgical diversion of CSF. In NPH patients with dementia, who have improvement in cognitive function after spinal tap test, most achieve clinical improvement in cognitive function after shunt surgery.[30]

CONCLUSION

NPH is an emerging and significant problem in older people. NPH can masquerade as a variety of other medical disorders, including Parkinson's disease, dementia, and urological disorders – all of which lead to incorrect diagnosis. As such, precise diagnosis of this condition and accurate selection of surgical candidates for shunt placement are very important. The mainstay treatment in NPH is operative procedure for diversion of CSF. VP shunt remains the most popular procedure, with LP shunt being used with increasing frequency. After shunt placement surgery, most NPH patients achieve improvement in both symptoms and quality of life.

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