Utility of radiologic imaging in the diagnosis and follow up of normal pressure hydrocephalus

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Aims and objectives

• To evaluate the utility of imaging features in the diagnosis of normal pressure hydrocephalus (NPH) and in predicting the outcome after ventriculoperitoneal shunt (VPS).

• To illustrate the radiological changes after surgery.

• To investigate whether there is a relationship between clinical outcome and onset time of symptoms.
Introduction:

Normal pressure hydrocephalus (NPH) is a treatable symptomatic complex, characterized by gait disorders, progressive dementia and urinary incontinence (Hakim-Adams triad). Even though the intracranial pressure in NPH has been considered to be normal, various studies have shown alterations which encompass a wide spectrum, from average normal pressures without fluctuations to high pressures with fluctuations.

Etiology:

With regard to the etiological mechanisms in NPH, there are idiopathic forms and forms secondary to other neurological processes (two-thirds of the cases), such as subarachnoid hemorrhage (the most frequent within this group), brain injuries, meningitis or intracranial surgery.

The idiopathic forms of NPH generally appear in the 6th-7th decades of life, while the secondary ones appear at any age.

Physiopathology:

In normal conditions, during systole, the cerebral volume expands and a pressure wave is produced which compresses both the cortical veins and the lateral ventricles, which secondarily leads to a descending flow of the cerebrospinal fluid (CSF) through the Sylvian aqueduct. On the contrary, during diastole, the decrease in the cerebral blood volume produces an ascending flow of CSF through the Sylvian aqueduct and enlarged ventricles.

In NPH, due to a decrease in the distensibility of the cerebral parenchyma, the CSF tends to accumulate in the ventricular system, resulting in a much greater CSF in the aqueduct.

Imaging findings:
The preferred imaging modalities for the study of this entity are computed tomography (CT) and magnetic resonance imaging (MRI), whose main radiological findings are:

1. Disproportionately expanded ventricles (figure 1).
2. Rounded appearance of the frontal horns of the lateral ventricles (figure 1).
3. Ballooning of the 3rd ventricle (figure 1).
4. Increase of Evan’s index (figure 2).
5. Expanded Sylvian fissures (figure 3).
6. Thinning of the corpus callosum, due to the pressure exerted on it by the dilated ventricles (figure 3).
7. Tight high-convexity subarachnoid spaces (figure 4).
8. Focal dilatation of the cerebral sulci (figure 4).
9. Periventricular hyperintensities related to chronic ischemia (figure 5).
10. Absence of signal in proton density weighted MRI due to an increase of the dynamics of CSF and the increased rate through narrow structures such as the Sylvian aqueduct (figure 6).

**Phase-Contrast Cine MR Imaging:**

Phase-Contrast Cine MR Imaging Technique with cardiac gating allow the study of the dynamic CSF flow measurements at the level of the acqueduct with an analysis that is both qualitative and quantitative, through the calculation of the velocity and the volume of systolic, diastolic and average flow, as well as the flow volume per cycle, called stroke volume (SV). The SV or volume of the CSF per beat is the flow volume during the diastole and during the systole measured in microlitres per beat. It is the average flow volume per cycle regardless of the direction (figure 7).

In the year 1996, Bradley W. et al published an article affirming that the patients with a SV greater than 42 microlitres/beat were patients who were supposedly good responders to the implantation of VPS, while those presenting a stroke volume of less than 42 were considered to be bad responders. Subsequently it was verified that the values of SV are modified throughout the evolution of the disease. Therefore, in the first months, there is a progressive increase in the values of this parameter, subsequently they reach a maximum value and finally there is a progressive decrease; thus, the question is posed of whether the time of evolution also affects the response to surgical treatment, as well as the values of the SV.

**Patients:**
Between January 2007 and February 2013, we examined 50 patients with suspected NPH. 21 patients were not candidates for VPS on the basis of comorbidity or age, 3 were on waiting list for surgery and the remaining 26 were treated with VPS.

For the clinical and radiological evaluation in shunted patients, lumbar puncture, Katzman test, Evan’s index, size of the Sylvian fissures, presence or absence of focal dilatation of the cerebral sulci, white-matter changes and SV were recorded. Onset time on symptoms until VPS and radiological changes after surgery were also recorded.
**Fig. 1:** Enlarged ventricles, rounded appearance of frontal horns and rounded appearance of frontal horns.

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Fig. 2: Evans’ Index.

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Fig. 3: Expanded Sylvian fissures and thinning of the corpus callosum.

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**Fig. 4:** Tight high-convexity and focal dilatation of the cerebral sulci.

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**Fig. 5:** White matter-hyperintensities.

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Fig. 6: Hypointensity at the level of the aqueduct on proton density-weighted MRI.

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Fig. 7: Stroke-Volume (SV).

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Results

The value of cine-PC in the study of NPH does not predict the response to the implantation of VPS, to the contrary of what was thought at first. There is no value of the SV above which patients will be good responders to surgery, as its value varies throughout the evolution of the disease and only reflects a state of hyperdinamia of the CSF.

In our study, of the 26 patients operated on, 11 improved clinically, in all (5) or some symptom (6) (table 1). Of these 11 patients, 9 had been operated on in the first 12 months after the clinical diagnosis (table 2). With regard to the preoperative imaging study, 11 patients presented periventricular hyperintensities of absent or mild degree, of which 5 presented clinical improvement after surgery. Of the 15 patients with preoperative hyperintensities of moderate or generalized degree (table 3), 9 did not present clinical improvement after the shunt procedure (table 4). These differences were not statistically significant, due to the small number of patients included in the study.

The imaging control studies after surgery showed reversal of the dilation of the Sylvian fissures in 2 patients, decrease of arachnoid spaces in 5 and recovery of the cerebral sulci in 7 (table 5 and figure 8). Among all patients with radiological improvement after VPS, 4 also experienced clinical improvement. We do not have long-term imaging controls, basically because many of the patients included in our study have been operated on recently or they have only been controlled by clinical evolution.
Table 1: Clinical improvement.

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Table 2: Clinical improvement.

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Table 3: Clinical improvement in absent-mild eriventricular hyperintensities group of patients.

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Table 4: Clinical improvement in moderate-generalized periventricular hyperintensities group of patients.

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Table 5: Radiological improvement.

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**Fig. 8**: Radiological improvement.

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Conclusion

The presence of white-matter hyperintensities associated with ischemic degeneration in patients with NPH, and long time elapsed from onset of symptoms to VPS, were predictors of a poor outcome after shunt surgery. The fact that many patients were not candidate for surgery on the basis of comorbidity or age means an important limitation of the study sample.
References


