Role of radiological technique in evaluation of Normal Pressure Hydrocephalous (NPH)

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Learning objectives

1. To study the various findings in cases of NPH in CT, MRI and Other modalities.
2. To study the Contribution of phase-contrast MRI to the management of patients with normal pressure hydrocephalus: Can it predict response to shunting?
3. Functional analysis of third ventriculostomy patency by quantification of CSF stroke volume by using cine phase-contrast MR imaging.
4. To study use of cerebrospinal fluid flow rates measured by phase-contrast MR to predict outcome of ventriculoperitoneal shunting for idiopathic normal-pressure hydrocephalus.
5. MRI findings in Cine-MR imaging of aqueductal CSF flow in normal pressure hydrocephalus syndrome before and after CSF shunt.
Background

NORMAL-PRESSURE HYDROCEPHALUS

The clinical syndrome of normal-pressure hydrocephalus (NPH) is characterized by three main findings: cognitive decline, gait disturbance, and incontinence.

When these clinical symptoms are observed in a patient with enlarged ventricles, a diagnosis of NPH can be considered.

However, management of such patients is difficult because the diagnosis is often uncertain, and the treatment with shunt surgery carries significant risk.

The reason the diagnosis is difficult is that the clinical symptoms are not unique to NPH, but rather are common in the elderly and overlap with many other conditions. Estimates of the prevalence of NPH are unreliable because of small numbers.

Two competing theories exist to explain the etiology of this syndrome: (a) impaired extra ventricular CSF resorption due to prior subarachnoid haemorrhage or meningitis and (b) decreased white matter tensile strength due to deep white matter infarction/ischemic change.

A positive association of NPH with arterial hypertension supports the latter mechanism. Three primary MRI findings have been described in NPH: (a) enlargement of the ventricular system out of proportion to the subarachnoid space, (b) a prominent periventricular halo, (c) and a prominent CSF flow void in the cerebral aqueduct. The prominent periventricular halo has been ascribed to centrifugal flow of CSF from the ventricular system radially into the periventricular white matter. The prominent flow void in the cerebral aqueduct has been attributed to excessively rapid pulsatile CSF flow. The putative result of loss of brain elasticity in this condition produces excessively forceful transmission of the arterial pressure pulse during cardiac systole to the incompressible CSF in the ventricular system. This forceful pressure wave is transmitted from the CSF in the lateral ventricles through the third ventricle to the CSF in the aqueduct, resulting in pulsatile flow in the aqueduct that is more prominent than normal. This in turn results in a loss of coherent signal in aqueductal CSF, which is more prominent than normal. MRI markers of this hyperdynamic aqueductal CSF flow have been prominent signal loss, prominent antero-posterior extent of the aqueductal CSF signal void, and excessive aqueductal flow velocity using formal velocity measurements with cine phase contrast methods. A key element in managing this condition is appropriate selection of patients for surgery. Whereas shunt surgery can result in amelioration of symptoms, the surgery carries obvious risks (240). Tests used clinically to predict response to shunting include removal of 30 to 50 mL of CSF by repeated lumbar punctures; if symptoms
improve, particularly gait, this is taken as a sign that shunt surgery will be successful. The lumbar puncture test can be extended by inserting an indwelling catheter in the lumbar CSF space to assess the effect of continuous CSF drainage. Other tests include infusion of uid into the CSF space to assess resistance to uid resorption. Imaging tests have also been used to assess the potential success of shunt surgery. These include cisternography and cerebral blood ow measures. A more prominent defect in frontal than posterior parietal and temporal hypo perfusion has been proposed to predict a favourable outcome of shunt surgery, on the assumption that more prominent posterior hypo perfusion is suggestive of AD, which would not respond to shunting. MRI findings have been proposed to predict response to shunting. However, the utility of MRI in predicting response to shunting is not universally embraced. At some sites, measurements of aqueductal CSF velocity that exceed normal limits are used to indicate which patients suspected of having NPH will respond favorably to shunting. Another measure derived from CSF velocity mapping that has been used to predict response to shunting is the CSF stroke volume, which is a measure of the volume of CSF ow through the aqueduct over the cardiac cycle.
Fig. 1: TYPICAL MRI FINDINGS OF NPH

CSF flow void in the cerebral aqueduct (arrow). Flow void lacks signal and appears black, while non-turbulent CSF hyperintense on T2-weighted images.

The enlarged ventricular system, especially the atria of the lateral ventricles (V), which is out of proportion with sulcal atrophy.

Fig. 2: TYPICAL MRI FINDINGS OF NPH

left anterior, or frontal, horn of the paired lateral ventricles

enlarged ventricles with normal volume of brain parenchyma

NORML MRTI

NORMAL PRESSURE HYDROCEPHALUS

The hypointensity in the third ventricle and wide

The volume of parenchyma is maintained.
Imaging findings OR Procedure details

MC MRI finding -- ventriculomegaly out of proportion with sulcal atrophy. More specifically, the temporal horns of the lateral ventricles may show dilatation out of proportion with hippocampal atrophy. CSF flow void in the cerebral aqueduct (arrow). Flow void lacks signal and appears black, while non-turbulent CSF hyperintense on T2-weighted images.

- Kizu and colleagues using PROTON CHEMICAL SHIFT IMAGING have suggested that intraventricular lactate measurements may be useful in discriminating patients with NPH from those with other forms of dementia."patients with clinically diagnosed NPH exhibited ventricular lactate peaks by way of proton chemical shift imaging. "

MRI Spectroscopy -- This metabolite reflects ischemic changes in the periventricular regions despite normal CSF pressures in patients with NPH.

Other findings in T-1 AND T-2 WI

- Cerebral aqueduct may demonstrate a pulsatile flow void.
- A jet of turbulent CSF flow may be observed distal to the aqueduct in the fourth ventricle.
- Transependymal CSF flow in the form of a periventricular high signal on T2-weighted images, primarily anterior to the frontal horns or posterior to the occipital horns of the lateral ventricles.
- only the CSF flow void sign may be predictive of shunt responsiveness and that periventricular signal hyperintensity and corpus callosal morphology are not predictive of positive treatment results.
- 3-DIMENSIONAL MRI VOLUME-ACQUISITION TECHNIQUES (Tsunoda and colleagues) - To objectively assess ventriculosulcal disproportion. They measured ventricular volume (VV) and intracranial CSF space volume (ICV) and then calculated the VV/ICV ratio. a VV/ICV ratio greater than 30%, while no patients in the other groups had ratios higher than 30%.
- CSF VELOCITY MAPPING - Aqueductal CSF velocity & CSF stroke volume

# aqueductal CSF velocity that exceed normal limits are used to indicate which patients suspected of having NPH will respond favorably to shunting

# More value of CSF velocity

(#)CSF stroke volumes greater than 42 microL responded favorably to CSF shunting.

- Nuclear Imaging
Isotope cisternography and CT cisternography have been used in NPH to assess for disturbances in CSF dynamics, such as reversal of flow. Radionuclide cisternography can also be used to confirm the diagnosis of NPH and predicting outcome.

**METHOD** -- After lumbar subarachnoid injection of a radio-isotope, cisternograms are obtained at 3, 6, and 24 hours after injection (also at 48 hours if intraventricular activity is still seen on the 24 hours image).

**RESULTS**

Conventional criteria for a normal study ---radioactivity symmetrically distributed over the convexity 24 hours after injection, with no intraventricular activity at any point. However, up to 41% of normal individuals will demonstrate transient (up to 24 hours, but not longer) activity in the ventricles.

For NPH --- (Persistence of ventricular activity on a late scan (48-72 hours) is best predictor of improvement with shunting- approximately 75% chance of improvement.

Cranial CT and high resolution measurements of regional cerebral blood flow (rCBF) with brain dedicated single photon emission computer tomography (SPECT) and [99mTc]-d,l-hexamethylpropyleneamine oxime ([99mTc]-d,l-HMPAO)

- NPH --- characterised by an enlarged subcortical low-flow region, significantly reduced rCBF and enhanced side-to-side asymmetry of rCBF in the central white matter, and enhanced side-to-side asymmetry in the inferior and mid-temporal cortex. Global CBF was normal. Shunt operation reduced the mean area of the ventricles on CT and of the subcortical low-flow region on SPECT. Global CBF was unchanged.
- SPECT with [99mTc]-d,l-HMPAO is a useful supplement in the diagnosis of NPH versus normal ageing, and that SPECT may help to identify patients not likely to benefit clinically from surgery.
- Using single-photon emission computed tomography (SPECT) and statistical brain mapping, Sasaki found regional cerebral blood flow reduction with frontal dominance and severe hypoperfusion around the corpus callosum. This was consistent with some of the regions of brain dysfunction that clinical assessment has indicated are involved.
### Predictors of Good Surgical Candidate for VPS

<table>
<thead>
<tr>
<th>Evaluation Parameters</th>
<th>Positive Predictor</th>
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<tbody>
<tr>
<td>Clinical exam</td>
<td>presence of classic triad; especially gait disturbance as the primary symptom</td>
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<tr>
<td>Lumbar puncture</td>
<td>opening pressure &gt; 100 mm water</td>
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<tr>
<td>Cisternogram</td>
<td>typical NPH pattern; especially persistent ventricular activity at 48 hours</td>
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<tr>
<td>Continuous CSF monitoring</td>
<td>CSF recording pressure &gt; 180 mm water; frequent beta waves</td>
</tr>
<tr>
<td>Cranial CT scan</td>
<td>enlarged ventricles; periventricular hypodensities; flattened cortical sulci; small or absent perihippocampal fissures</td>
</tr>
<tr>
<td>MRI</td>
<td>all of the above; esp small or absent perihippocampal fissures</td>
</tr>
<tr>
<td>Tran cranial Doppler studies with carbon dioxide reactivity</td>
<td>reactivity above 25% with pathologic readings on pressure recordings</td>
</tr>
</tbody>
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**Fig. 3:** FINDIND OF DIFFERENT CONVENTIONAL AND NON-CONVENTIONAL RADIOLOGICAL METHODS

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Fig. 4: NPH SPECTROSCOPY FINDINGS

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The spectra obtained from periventricular regions (upper row) with the intraventricular spectra (lower row) are shown. Apparent inverted doublet peaks at 1.3 ppm are observed in the intraventricular spectrum of one case (left side) and can be recognized as lactate peaks. In the other case (right side), good qualities of lactate peaks are seen compared with the peaks from the periventricular region in the upper row.

**Fig. 5: NPH SPECTROSCOPY FINDINGS**

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Intraventricular lactate in NPH may be a key factor in differentiating NPH from other dementias. This metabolite reflects ischemic changes in periventricular regions despite normal CSF pressures in patients with NPH.

Fig. 6: Radionuclide cisternogram
Fig. 7: Radionuclide cisternogram

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Conclusion

- CSF velocity MR imaging is useful in the selection of patients with NPH to undergo shunt formation.

Source - Long Beach Memorial Medical Center, Memorial MRI Center, CA 90806, USA

- Quantitative analysis with phase-contrast MR imaging indicates that ETV is an efficient technique for restoring CSF pulsation, with efficacy being maintained during the follow-up controls.

Quantification of stroke volume at ventriculostomy is a good indicator of the functional status of ETV, and a high stroke volume in the ventriculostomy appears to be a positive predictor of favourable clinical outcome.

Source - Department of Radiology Hospital Clínic i Provincial de Barcelona, Barcelona, Spain.

- MR examination allows the determination of the absence or presence of CSF-flow and its direction and velocity in the cerebral aqueduct of Sylvius and in the drain of the ventriculoperitoneal shunt. This examination enables the differentiation between the shunt-dependent and shunt-independent type of hydrocephalus, which is of great significance in clinical management of patients after a shunt implantation.

Source - Katedra Radiologii, Uniwersytet Jagielloński, Collegium Medicum, Kraków

---- SPECT with [99mTc]-d,l-HMPAO is a useful supplement in the diagnosis of NPH versus normal ageing, and that SPECT may help to identify patients not likely to benefit clinically from surgery.

- Cine-MR with inflow technique yields a reproducible evaluation of flow-related aqueductal CSF signal changes which might help in identifying shunt
responsive NPH patients. These are likely to be those with hyperdynamic aqueductal CSF or aqueductal obstruction.


MR examination allows the determination of the absence or presence of CSF-flow direction and velocity in the cerebral aqueduct of Sylvius and in the drain of the V-P shunt. This examination enables the differentiation between the shunt-dependent and shunt-independent type of hydrocephalus, which is of great significance in clinical management of patients after a shunt implantation. The shunt responders appear to be the patients with hyperdynamic ventricular CSF flow and normal cervical CSF flow.
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