Multimodal Prediction of Shunt Responsiveness in Idiopathic Normal Pressure Hydrocephalus

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Abstract

Idiopathic normal pressure hydrocephalus (iNPH) is a potentially treatable neurologic syndrome, but preoperative prediction of shunt responsiveness remains difficult. This narrative review synthesized evidence across clinical, radiologic, cerebrospinal fluid drainage, physiologic, biomarker, and multimodal predictor domains. Gait-dominant presentation and shorter symptom duration were associated with better outcomes, while imaging markers were weak as independent predictors. Positive CSF drainage and physiologic tests supported likely benefit, but negative findings did not reliably exclude responders. Tau-related biomarkers may indicate neurodegenerative burden associated with non-response. Overall, no single predictor was sufficient. Patient selection should integrate complementary clinical, imaging, physiologic, biomarker, and surgical-risk information.

Introduction

- Idiopathic normal pressure hydrocephalus is characterized by gait disturbance, cognitive impairment, urinary dysfunction, and ventriculomegaly.
- Symptoms may improve following CSF diversion, making iNPH distinct from many progressive disorders affecting older adults.
- Patient selection is difficult because the same symptoms can result from neurodegenerative, vascular, musculoskeletal, and urologic conditions.
- Ventriculomegaly supports the diagnosis, but neither symptoms nor imaging alone establish whether a patient will improve after surgery.
- Therefore, the major clinical challenge is predicting reversibility before shunting.

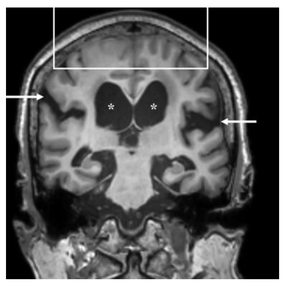

Figure 3. Representative coronal MRI demonstrating classic iNPH features, including ventriculomegaly and disproportionately enlarged subarachnoid-space hydrocephalus (DESH). Adapted from Park et al., 2021.

Methods

- A narrative review of adult iNPH literature was conducted using PubMed, Google Scholar, major guidelines, systematic reviews, meta-analyses, and primary cohort studies.
- The working search period was 2000 to 2026, with older landmark studies included when clinically relevant.
- Search concepts included iNPH, shunt response, patient selection, DESH, callosal angle, tap testing, external lumbar drainage, resistance to CSF outflow, tau biomarkers, and multimodal prediction.
- Sources were prioritized when they directly evaluated diagnosis, preoperative predictors, postoperative improvement, or shunt responsiveness.
- Evidence was organized into clinical, radiologic, CSF drainage, physiologic, biomarker, and multimodal domains. The primary outcome was meaningful postoperative improvement after CSF diversion.

Results

Proposed Multimodal Patient-Selection Framework

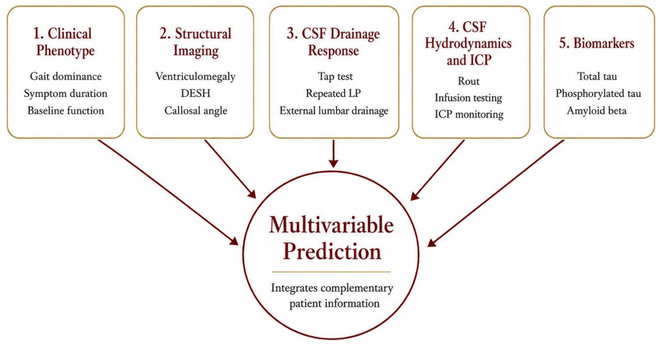

Figure 1. Proposed multimodal patient-selection framework for idiopathic normal pressure hydrocephalus. Clinical phenotype, structural imaging, CSF drainage response, CSF hydrodynamics and intracranial pressure measures, and biomarkers provide complementary information about potential shunt responsiveness. These domains may be integrated through multivariable prediction. This framework is conceptual and requires prospective validation.

Pooled Outcomes of CSF Diversion in iNPH

Outcome	%	Source
Symptomatic improvement	74%	Salih et al., 2024
Complication rate	20.6%	Salih et al., 2024
Revision rate	15.1%	Salih et al., 2024

Figure 2: Pooled outcomes from a 2024 systematic review and meta-analysis of 54 studies involving 4,811 patients show that most patients improve after CSF diversion, although complications and revision remain clinically important.

Source: Salih A, et al. *EClinicalMedicine.* 2024;77:102891.

Discussion

- The evidence distinguishes diagnostic plausibility from prediction of reversibility.
- Clinical phenotype identifies appropriate patients for further evaluation, but symptoms overlap with many disorders of older adulthood.
- MRI is essential for recognizing ventriculomegaly and competing pathology, but imaging should not be used as an isolated surgical gatekeeper.
- CSF drainage and physiologic testing provide the most direct evidence of reversibility, although protocols and negative predictive values remain inconsistent.
- Biomarkers may identify neurodegenerative burden that reduces expected benefit, but they remain complementary rather than decisive.
- Multimodal prediction is the most clinically defensible direction, although current models require better data and external validation.

Conclusion

Shunting can provide meaningful improvement in appropriately selected patients with iNPH. Gait-dominant presentation and shorter symptom duration are clinically relevant, but insufficient alone. MRI supports diagnosis but weakly predicts surgical response when used independently. Positive CSF drainage or physiologic tests can strengthen confidence, while negative tests should be interpreted cautiously. Biomarkers may identify mixed neurodegenerative pathology, but no biomarker independently determines candidacy. Future patient-selection tools should integrate clinical, imaging, physiologic, biomarker, comorbidity, and surgical-risk information.

References

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