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Original Research Article

# To Study the Role of CSF Flow Indices in Patients with Symptoms of Normal Pressure Hydrocephalus and to Establish its Diagnostic Value

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**Abstract**

**Aim:** The aim of the present study was to assess the role of CSF flow indices in patients with symptoms of normal pressure hydrocephalus and to establish its diagnostic value.

**Methods:** The present study was conducted at Department of Radiodiagnosis, Shri Ramkrishna Institute of Medical Sciences, Durgapur, West Bengal, India for one year. Total no of 60 participants age range was between 38 to 88 were enrolled into the study.

**Results:** 58.3% population was >60 years, 26.7% population group was in between 51-60 years and 15% population was < 50 years age. Overall gender distribution in case group (n=30) 25 was male and 5 was female and in control group( n=30) 22 was male and 8 was female. Gait Disturbances was present in 86.7%, Dementia was present in 73.3% and Urinary Incontinence was present in 70% in Case Population. Ventriculomegaly was present in 93.3%, Symmetrical trans ependymal edema was present in 90%, Sulcus effacement was present in 90%, Corpus callosal thinning was in 83.3%, Corpus callosal angle was between 50 -80 degree in 83.3% and Flow Void at cerebral aqueduct was present in 62.2%. Grade I was present in 66.7%, Grade II was present in 16.7% and Grade III was in 16.7 cases population.

**Conclusion:** CSF wave form obtained from Phase contrast MRI were analysis in our study its appeared to be reliable, reproducible, and sensitive tool for differentiation of NPH patients and normal volunteers.

**Keywords:** CSF Flow Indices, Symptoms, Normal Pressure Hydrocephalus, Diagnostic Value.

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## Introduction

Cerebrospinal fluid (CSF) acts as a cushion for the brain. In humans, the normal pressure of CSF in the recumbent position by lumbar puncture varies from 25 to 70 mm water in infants and from 65 to 195 mm water in adults. An increase in intracranial pressure can cause characteristic symptoms of hydrocephalus, though they also may occur with normal pressure. [1] CSF flows in oscillatory motion resulting from cardiac pulsations. Cardiac systole transmits pressure wave to intracranial arteries and capillaries causing caudal flow of CSF (CSF systole) through the ventricular system, basal cisterns, and foramen magnum into the cervical subarachnoid space. Following cardiac diastole, there is reversal of flow with cephalad movement of CSF. [2] CSF flow may be altered in many intracranial and intraspinal pathologies. Changes have been seen in CSF hydrodynamics with meningitis, hydrocephalus, and cerebral edema. [3] In normal pressure hydrocephalus (NPH), aqueduct stenosis, or Chiari malformation certain CSF flow parameters can deviate strongly from normal values. [4]

The abnormal values not only help in diagnosing these conditions but also act as a guide to treatment. Accordingly, Bradley et al set increased aqueduct systolic stroke volume (SV) >42 µL/cycle as a threshold value for NPH patients who benefited from surgery [5] but we found that many of our elderly subjects not having NPH had CSF SV in the range of 40–45 µL/cycle. Hence, a need was felt to study normal CSF SV in our population. For this purpose, five parameters were defined.

Peak systolic velocity is the maximum CSF velocity through the cerebral aqueduct during cardiac systole, and this CSF flow is directed caudally (during cardiac systole, blood flow is directed cranially and CSF is directed caudally to maintain total intracranial fluid volume); peak diastolic velocity (PDV) is the maximum CSF velocity through the cerebral aqueduct during cardiac

diastole and this CSF flow is directed cranially; systolic flow (SF) is the total volume of CSF flowing through aqueduct over cardiac systole; diastolic flow (DF) is the total volume of CSF flowing through aqueduct over cardiac diastole; and stoke volume is the average of systolic and diastolic flow.

The aim of the present study was to assess the role of CSF flow indices in patients with symptoms of normal pressure hydrocephalus and to establish its diagnostic value.

**Materials and Methods**

The present study was conducted at Department of Radiodiagnosis, Shri Ramkrishna Institute of Medical Sciences, Durgapur, West Bengal, India for one year. Total no of 60 participants age range was between 38 to 88 were enrolled into the study. All 60 cases were referred to the department of radiology from neurosurgery and neurology outpatient clinics , 30 patients refereed with symptoms of normal pressure hydrocephalus .30 healthy volunteers without neurological symptoms and with normal MRI imaging findings, were included as the control. These normal volunteers were in good health and denied any present or previous spinal or neurologic problems or hypertension.

**Inclusion Criteria**

1. Patients clinically diagnosed as idiopathic normal pressure hydrocephalus (NPH)

2. Patients with MRI features of NPH.

**Exclusion Criteria**

1. All the patients whose MR images were degraded by artefacts making evaluation impossible.
2. Deviation of image planning from study protocol.
3. Lack of cooperation to complete the MRI examination.

**Methodology: -**

**Phase Contrast Mrimage Acquisition**

The study was conducted using MRI machine3 Tesla , (PHILIPS MR SYSTEMS Ingenia , - Release 4.1.3.2 2014 -05- 01 SRN : 42407). A circular polarized head-array coil and ultra-gradients were chosen. First conventional magnetic resonance imaging of the brain was Performed. Standard axial T1 WI (TR = 2000 − TE = 20 /slice thickness = 5 mm/Number of acquisition = 2), axial and sagittal T2WI (TR = 3000 − TE = 80 /slice thickness = 5 mm/Number of acquisition = 2) and axial FLAIR (TR = 11000 − TE = 125 /slice thickness =5mm) images were obtained before CSF flow measurements were made.

**Phase-contrast MR imaging: -** It divided in to three group based on MRI sequence.

(1)CSF Drive( 2) Phase contrast and ( 3) CSF Q flow. Velocity encoding ( VENC )5 cm/s was taken for control group and VENCs (up to 20 cm/s) for case group .CSF flow velocities greater than VENC can produce aliasing artefacts, whereas velocities much smaller than VENC result in a weak signal. Pulse oximetry was used to get MRI images synchronous to cardiac cycle of patient.

**1. CSF Drive**

It is 3D T2Weighted turbo spin echo sequence in the sagital plane. It is small volume with very high in plane resolution. Image sequence is used to visualize CSF in aqueduct of Sylvius.

**2. Phase contrast**

It is In plane, sagittal weighted image, perpendicular to the proximal 1/3 of the cerebral aqueduct, Cardiac gated (ECG being used for cardiac synchronization) were used, 15 phase images were calculated. Single slice phase contrast angiography was used to visualize CSF flow. Based on the flow differences of flowing spins compared to static spins, images were typically presented in 3 sets:

a. **Re-phased image** (magnitude of flow compensated signal) flow is of high signal, background is visible

b. **Magnitude image** (magnitude of difference signal) flow is of high signal (regardless of direction), background is suppressed

c. **Phase image** (phase of difference signal) signal is dependent on direction: forward flow is of high signal: reverse flow is of low signal , background is mid-grey

**3.CSF Q flow**

It is a high resolution axial weighted image perpendicular of the cerebral aqueduct, cardiac gated (ECG being used for cardiac synchronization),12 images were obtained. Images were presented in sets of 3 (a. Re-phased image b. Magnitude image c. Phase image). Transverse single slice quantitative flow measurement information on flow direction and velocity based on flow differences of flowing spins compared to static spins.

CSF flow quantification process

A circular (ROI) Region of interest was placed in the aqueduct with the aid of a mouse driven cursor shown on a magnified image and was substituted for the diameter of the aqueduct, because the phase images did not show the real anatomical lumen of the aqueduct, but only the CSF flow. The area of the circular ROI was controlled to be between 1 and 5 $mm^2$ it was slightly smaller than the diameter of the

aqueduct . Phase contrast images were displayed on a gray scale, where low signal intensity indicated caudal flow and bright signal intensity represented cranial flow.

**Post Processing Calculations**

Following the acquisition of the CSF flow velocity curves in cases of NPH and control where the mean velocity was automatically determined from the mean value of the measured velocities of each cardiac phase and the area of ROI measured by the MR unit. Temporal parameters evaluation involved determination of R-S interval (on set of CSF systole), R-PS interval (time of CSF peak systole), and duration of CSF systole.

Finally systolic stroke volume was calculated from the following equation: -Systolic stroke volume = mean systolic flow (flux) x duration of CSF systole

**Statistical analysis: -**

All the continuous variables were assessed for normality using Shapiro wilk's test.

If the variables were normally distributed, they were being expressed as mean ± standard deviation. All the categorical data were expressed as percentages comparison of normally distributed continuous variables were done by independent sample t test. Comparison off categorical variables were done by chi square test. Data entry was done in MS – excel spread sheet data analysis was carried out by SPSS version 16.0 all p value < 0.05 was considered as statistically significant.

**Results**

**Table 1: Demographic data**

| **Age** | **Cases** | **Control** |
|---|---|---|
| <= 50 yrs | 9 | 15.0 |
| 51-60 yrs | 16 | 26.7 |
| >60 yrs | 35 | 58.3 |
| **Sex** | | |
| Male | 25 | 83.3 |
| Female | 5 | 16.7 |

58.3% population was >60 years, 26.7% population group was in between 51-60 years and 15 % population was < 50 years age. Overall gender distribution in case group (n=30) 25 was male and 5 was female and in control group( n=30) 22 was male and 8 was female.

**Table 2: Symptoms**

| Symptoms | % |
|---|---|
| Gait disturbances | 86.7 |
| Dementia | 73.3 |
| Urinary Incontinence | 70 |

Gait Disturbances was present in 86.7 %, Dementia was present in 73.3% and Urinary Incontinence was present in 70 % in Case Population.

**Table 3: MRI findings**

| MRI FINDINGS | % |
|---|---|
| Ventriculomegaly | 93.3 |
| Symmetrical transependymal edema | 90 |
| Sulcus effacement | 90 |
| Symmetrical transependymal edema | 90 |
| Corpus collasal angle | 83.3 |
| Corpus collasal thinning | 83.3 |
| Flow void at cerebral aqueduct | 63.3 |

Ventriculomegaly was present in 93.3 %, Symmetrical transependymal edema was present in 90 %,Sulcus effacement was present in 90 %,Corpus collasal thinning was in 83.3 % ,Corpus collasal angle was between 50 -80 degree in 83.3 % and Flow Void at cerebral aqueduct was present in 62.2%.

**Table 4: Evan index ratio in studied Case population**

| Evan Index | Frequency | Percent |
|---|---|---|
| Grade I (0.3-0.4) | 20 | 66.7 |
| Grade II (0.41-0.5) | 5 | 16.7 |
| Grade III (0.51-0.6) | 5 | 16.7 |
| Total | 30 | 100 |

Grade I was present in 66.7 %,Grade II was present in 16.7 % and Grade III was in 16.7 cases population.

## Discussion

NPH was initially considered to be idiopathic[6,7] although at present, commonly used terms includes any form of chronic, communicating hydrocephalus [8,9] and even a few noncommunicating forms such as aqueductal stenosis. [10] Because all these patients may present with a similar clinical triad ( gait disturbance, dementia and urinary incontinence) and they may all be treated with a ventriculoperitoneal (VP) shunt, this expansion of the definition is probably appropriate, although certain secondary features distinguish the idiopathic form from communicating hydrocephalus with known causes, the idiopathic form of NPH tends to present in the elderly [11], whereas patients with chronic communicating hydrocephalus from prior subarachnoid hemorrhage, meningitis, neurosurgery, or head trauma tend to present at an earlier age.

58.3% population was >60 years, 26.7% population group was in between 51-60 years and 15 % population was < 50 years age. Dixon et al [7] studied forty nine patients with NPH. The mean age of patients in their study was 72.9 years with a range of 54 to 88 years. Bradley et al [12] studied eighteen patients with NPH. Their mean age was 73 years with a range between 54 to 83 years. Overall gender distribution in case group (n=30) 25 was male and 5 was female and in control group( n=30) 22 was male and 8 was female. Gait Disturbances was present in 86.7 %, Dementia was present in 73.3% and Urinary Incontinence was present in 70 % in Case Population. Boon AJ et al and Mori K observed Gait disturbances are typically the first signs of INPH. [13,14] Ahlberg J et al. observed Urinary incontinence as the third primary symptom of INPH. [15]

Grade I was present in 66.7 %,Grade II was present in 16.7 % and Grade III was in 16.7 cases population. Relkin N et al and Evans WA et al observed a frontal horn ratio (Evans' index), defined as the maximal frontal horn ventricular width divided by the transverse inner diameter of the skull, which signifies ventriculomegaly if it is 0.3 or more. [16] Ishi k et al observed Evan index in INPH 0.338±0.025. [17] In our study, Evan's index ranged from 0.33 to 0.62.

## Conclusion

CSF wave form obtained from Phase contrast MRI were analysis in our study its appeared to be reliable, reproducible, and sensitive tool for differentiation of NPH patients and normal volunteers.

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