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Original Research Article

MRI CSF Flowmetry in Evaluation of Different Neurological Diseases

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Abstract

Aim: The aim of the present study was to assess MRI CSF flowmetry in evaluation of different neurological diseases.

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 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%. PDV, PSV, and SV were found significantly higher in cases group.

Conclusion: MRI CSF flowmetry provides an easy, accurate, and non-invasive method for diagnosis of different neurological diseases that cause CSF flow abnormality. Moreover, this diagnostic modality could be helpful in selecting the therapeutic option.

Keywords: Phase contrast MRI, CSF

Introduction

Cerebrospinal fluid (CSF) is a clear, watery fluid that fills the ventricles of the brain and the subarachnoid space around the brain and spinal cord. CSF plays an import- ant role in supporting the brain growth during evolution and protecting it against external trauma. [1] The nor- mal CSF pressure is between 5 and 15 mmHg (65–195 mm H2O) in adults. In children younger than 6 years, normal CSF pressure ranges between 10 and 100 mm H2O. [2] CSF flows through the aqueduct of Sylvius and the foramen magnum is of a pulsatile "to and fro" nature. During systole, CSF flows through the aqueduct and foramen magnum in caudal direction which is reversed in diastole. It is this pulsatile flow which is detected and measured by phase-contrast MRI. [3]

For CSF flow evaluation, two series of phase-contrast im- aging techniques are applied. One in the axial plane with through-plane velocity encoding for flow quantification, and the other is in the sagittal plane, with in-plane velocity encoding for qualitative assessment. Through- plane evaluation is performed in axial oblique plane perpendicular to the long axis of the aqueduct, and it is more accurate for quantitative analysis because the partial volume effects are minimized. [4]

Qualitative assessment is most beneficial in assessment of communication between the arachnoid cyst and subarachnoid CSF spaces. The plane of imaging is adjusted according to the expected point of communication; it may be in axial, sagittal, or coronal planes for detection pulsatile flow (black and white shades) at the neck of the cyst in phase images as evidence of communication with the subarachnoid spaces, as the pulsatile movement of the CSF in the subarachnoid spaces is transmitted to the neck of the cyst through the point of communication. Absence of such signal is an indicator of non-communication. [5] Finally, im- ages obtained from phase-contrast (PC) MRI can be displayed in closed loop cine format or displayed as separate images. Post processing technique starts with manual drawing of a circular region of interest (ROI) on the phase images to include the whole pixels that represents the flow at the aqueduct. Direct measure of the velocity (cm/s) and volume flow rate (ml/min) of the moving spins can be extracted from velocity- time curves and flow-time curve. [6,7]

The aim of the present study was to assess MRI CSF flowmetry in evaluation of different neurological diseases.

Materials and Methods

The present study was conducted at Department of Radiodiagnosis, Shri Ramkrishna Institute of Medical Sciences, Durgapur, West Bengal, India 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 sagittal 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: Analysis of difference between normal pressure hydrocephalus

	Cases (mean ± SD)	Control group, *N* = 9 (mean ± SD)	*P*
PDV (cm/s)	4.20 ± 1.16	2.11 ± 0.37	0.0004*
PSV (cm/s)	4.96 ± 1.55	2.73 ± 0.50	0.0008*
Vmax (cm/s)	4.58 ± 1.28	2.42 ± 0.26	0.0005*
SV (ML)	83.23 ± 27.45	25.33 ± 5.30	0.009*
Aqueduct area (cm^2)	0.08 ± 0.02	0.04 ± 0.01	0.008*
Maximum flow (cm^3/s)	0.35 ± 0.13	0.12 ± 0.04	0.004*

PDV, PSV, and SV were found significantly higher in cases group.

Discussion

Phase-contrast MRI also can detect if there is communication with CSF or not in cases with arachnoid cysts which in turn provide the clinician with valuable data that allow him to choose the suitable method of treatment. [5] This imaging method can also help in determination of the severity of CSF flow abnormality that results from tonsillar herniation in Chiari 1 malformation. This may be guidance for the clinician to follow-up those patients after treatment. [8,9] Normal pressure hydrocephalus (NPH) is a clinical syndrome characterized by gait disturbance, urinary incontinence, and dementia with normal CSF pressure. Hydrocephalus is a main finding in imaging. It is a rare disease but a treatable cause of dementia. Brain atrophy (BA) is a common feature of many dis- eases affecting the brain, which results in symptoms close to that of NPH; PC MRI is believed to be a re- liable method in the diagnosis of NPH and differentiating it from brain atrophy. [10]

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 [11] 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. [12,13] Ahlberg J et al. observed Urinary incontinence as the third primary symptom of INPH. [14] PDV, PSV, and SV were found significantly higher in cases group.

Phase contrast MRI was studied at the level of aque- duct in 12 patients with NPH; all parameters were found significantly higher in NPH group compared to the con- trol group indicating hyperdynamic CSF flow in NPH patients. This was in agreement with Giner et al. who found that there was significant increase in PDV and SV in NPH patients compared with control group. [15] Hydrocephalus is classified into communicating and non-communicating (obstructive) and hence PC MRI can be used for such classification. Also, it can be used to determine the cause of obstruction in obstructive hydrocephalus if ordinary MRI sequences could not accurately detect it. [16] Idiopathic increased intracranial hypertension (IIH) is characterized by increased intracranial tension in absence of detectable cause. The diagnosis depends on clinical base (presence of papilledema on fundus examination and high CSF opening pressure done by lumber puncture). [17] The same technique of PC MRI at the level of the aqueduct was applied on seven patients with IIH; a statistically significant in- crease was observed in all parameters (apart from the aqueduct area).

Conclusion

MRI CSF flowmetry provides an easy, accurate, and non-invasive method for diagnosis of different neurological diseases that cause CSF flow abnormality. Moreover, this diagnostic modality could be helpful in selecting the therapeutic option.

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