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Original Research Article

CSF Flowmetry: An Innovative Technique in Diagnosing Normal Pressure Hydrocephalus

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Abstract

Aim: The aim of the present study was to analyses aqueduct velocity parameters by phase contrast MRI CSF flowmetry in Idiopathic Normal pressure hydrocephalus patients (NPH).

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. Duration of study for one year.

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%.

Conclusion: MRI CSF flowmetry using phase contrast method is an advanced imaging parameter which can non-invasively and reliably detect NPH. Also, it can be used to follow the response to treatment following shunting and can act as a prognostic marker.

Keywords: CSF flowmetry, Hydrocephalus, NPH, Phase contrast MRI

Introduction

Normal pressure hydrocephalus (NPH) is a gloomy entity with no definite cause know till date. There are various theories of NPH: One theory is related to reduced CSF absorption while the other is based on periventricular ischemic changes which tends to slow CSF outflow through extracellular spaces resulting in back pressure effect causing ventricular enlargement. [1] This entity is first described by Hakin and Adams. The classical clinical trial of gait apraxia, urinary incontinence and dementia is not seen in all patients. Not all patients of NPH have dementia but it is one of the treatable causes of dementia.

The majority of cases of normal pressure hydrocephalus (NPH) are idiopathic. The incidence is much higher in elderly populations. There are several MRI features like ventriculometry, periventricular hyperintensity, crowding of gyri at the vertex and several other signs which point towards NPH. Over a period of time need was felt to evaluate CSF dynamics in patients of hydrocephalus. Phase contrast MRI (PC-MRI) is the most commonly used amongst MRI techniques to evaluate CSF flow dynamics in real time. By using this technique CSF flow is coupled with cardiac cycle and CSF flow dynamics is evaluated using various parameters. Quencer et al was one of the first researcher to evaluate CSF flow dynamics by cine magnitude imaging. [2] Following this phase contrast MRI came into picture which is capable of determining CSF flow velocity (quantitative) in addition to qualitative assessment.

PC-MRI has wide clinical applications ranging from NPH evaluation, follow up, surgical decision and post- surgery and post shunting status, Chiari malformation, syringomyelic cyst, posterior cystic malformation, etc. With more and more research being accumulated, NPH which was initially thought of as an idiopathic entity is now being increasingly recognized as a chronic communicating

hydrocephalus with a potential benefit to patients of this group from VP shunting. The incidence of NPH as quoted in literature by Brean and Eide is 5.5 per 100000 and prevalence is 21.9 per 100000. [3]

The aim of the present study was to analyse aqueductal velocity parameters by phase contrast MRI CSF flowmetry in Idiopathic Normal pressure hydrocephalus patients (NPH).

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. Duration of study for one year. 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 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 trans ependymal edema	90
Sulcus effacement	90
Symmetrical trans ependymal edema	90
Corpus callosal angle	83.3
Corpus callosal thinning	83.3
Flow void at cerebral aqueduct	63.3

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%.

Table 4: Combined study parameters of control and study groups with p values

	Category	Counts	Mean	Std deviation	P value (<0.05 significant)
ASV(ml)	Control	36	0.0321 ml	0.0123 ml	0.0001
	Cases	36	0.152ml	0.0490 ml	
PSV(cm/s)	Control	36	3.99 cm/s	1.56 cm/s	0.0002
	Cases	36	8.12 cm/s	2.53 cm/s	
MSV(cm/s)	Control	36	3.19 cm/s	1.34 cm/s	0.0003
	Cases	36	5.17 cm/s	1.69 cm/s	
FF(ml)	Control	36	0.0312 ml	0.0134 ml	0.003
	Cases	36	0.0692 ml	0.0321 ml	
BF(ml)	Control	36	0.0247 ml	0.0102 ml	0.023
	Cases	36	0.0883 ml	0.0217 ml	

Mean value of ASV for control was .0321 ml std deviation of 0.0123 ml, while for cases mean value of ASV was 0.152ml, standard deviation 0.0490 ml. P value of 0.0001. Mean value of PSV for controls was 3.99 cm/s standard deviation of 1.56 cm/s, while for the cases mean value of PSV was 8.12 cm/s standard deviation of 2.53 cm/s, P value of 0.0002. Mean of MSV for controls was 3.19 cm/s standard deviation of 1.34 cm/s while for cases mean MSV was 5.17 cm/s standard deviation of 1.69 cm/s. P value of 0.0003. Mean of FF for controls was 0.0312 ml standard deviation of 0.0134 ml for cases mean FF was 0.0692 ml standard deviation of 0.0321ml. P value of 0.003. Mean of BF for controls was 0.0247 ml standard deviation of 0.0102 ml for cases mean FF was 0.0883 ml standard deviation of 0.0217 ml. P value of 0.023.

Discussion

CSF is present in all ventricles, CSF subarachnoid spaces, such as cisterns and sulci, and the central canal of the spinal cord. The rate of CSF formation in humans is about 0.3-0.4 ml min-1 (about 500 ml day-1). Total CSF volume is 90-150 ml in adults and 10-60 ml in neonates and it is undergoes resorption and reformation of its entire volume at least three times a day. Potential sites of CSF origin include the choroid plexus, parenchyma of the brain and the spinal cord, and ependymal lining of the ventricles. [4]

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 [5] 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. [6,7] Ahlberg J et al. observed Urinary incontinence as the third primary symptom of INPH. [8]

The diagnosis of NPH is supported by the radiological findings of ventricular dilatation: out of proportion cortical sulcal enlargement, upward bowing of corpus callosum, flattening of the gyri against the calvarium and increased or normal CSF flow void. In properly selected patients, ventricular shunting results in resolution of symptoms and slows progressive deterioration. The aim of ventriculoperitoneal shunting is not to decrease mean pressure, but to dampen the pulse pressure by providing extra capacitance to the ventricular system. [9,10] Mean value of ASV for control was .0321 ml std deviation of 0.0123 ml, while for cases mean value of ASV was 0.152ml, standard deviation 0.0490 ml. P value of 0.0001. Mean value of PSV for controls was 3.99 cm/s standard deviation of 1.56 cm/s, while for the cases mean value of PSV was 8.12 cm/s standard deviation of 2.53 cm/s, P value of 0.0002. Mean of MSV for controls was 3.19 cm/s standard deviation of 1.34 cm/s while for cases mean MSV was 5.17 cm/s standard deviation of 1.69 cm/s. P value of 0.0003. Mean of FF for controls was 0.0312 ml standard deviation of 0.0134 ml for cases mean FF was 0.0692 ml standard deviation of 0.0321ml. P value of 0.003. Mean of BF for controls was 0.0247 ml standard deviation of 0.0102 ml for cases mean FF was 0.0883 ml standard deviation of 0.0217 ml. P value of 0.023.

Conclusion

MRI CSF flowmetry using phase contrast method is an advanced imaging parameter which can non-invasively and reliably detect NPH. Also, it can be used to follow the response to treatment following shunting and can act as a prognostic marker.

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