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Original Research Article

To Calculate Aqueductal Systolic Stroke Volume, Peak Systolic Velocity, Mean Systolic Velocity, Forward Flow and Backward Flow by Phase Contrast Mri CSF Flowmetry in Patients with Symptoms of Normal Pressure Hydrocephalus and Controls and to Evaluate the Significance of These Parameters

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Abstract

Aim: The aim of the present study was to calculate Aqueduct systolic stroke volume, Peak systolic velocity, Mean systolic velocity, Forward flow and Backward flow by Phase contrast MRI CSF Flowmetry in patients with symptoms of Normal pressure hydrocephalus and controls and to evaluate the significance of these parameters.

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. The mean aqueduct stroke volume (ASV) in control group of our study (n= 30) was31.4µl with a standard deviation of 11.38µl. The stroke volume in cases in our study was 141.3µl ± 53.56µl. The P value was (0.0001) suggesting that the difference in the values of ASV in cases and controls were statistically significant. So ASV can be used as a parameter to differentiate cases from controls.

Conclusion: These various parameters ASV, PSV, MSV, FF and BF of CSF flow in phase contrast MRI were included in our study. These all parameters reliably differentiated NPH patients from normal volunteers in our study. CSF wave form obtained from Phase contrast MRI were analyzed 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

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 important role in supporting the brain growth during evolution and protecting it against external trauma. [1] The normal 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 imaging 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, images 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] 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 diseases affecting the brain, which results in symptoms close to that of NPH; PC MRI is believed to be a reliable method in the diagnosis of NPH and differentiating it from brain atrophy. [10]

The aim of the present study was to calculate Aqueduct systolic stroke volume, Peak systolic velocity, Mean systolic velocity, Forward flow and Backward flow by Phase contrast MRI CSF Flowmetry in patients with symptoms of Normal pressure hydrocephalus and controls and to evaluate the significance of these parameters.

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 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: Stroke volume in control groups and cases

Groups	STROKE VOLUME (µl)
Control	31.4 ± 11.38
Cases	141.3 ± 53.56

The mean aqueduct stroke volume (ASV) in control group of our study (n= 30) was31.4µl with a standard deviation of 11.38µl. The stroke volume in cases in our study was 141.3µl ± 53.56µl. The P value was (0.0001) suggesting that the difference in the values of ASV in cases and controls were statistically significant. So ASV can be used as a parameter to differentiate cases from controls.

Table 4: Comparison of MSV and PSV in controls in various studies

MSV (cm/s)	PSV (cm/s)
3.0600±1.40457	4.1600± 1.62600
FF	BF
0.0228ml ±0.01531ml	0.0213 ml ±0.0921ml

In our study, the peak systolic velocity of CSF at the cerebral aqueduct had a mean value of 4.1600 cm/s with a standard deviation of 1.62600 cm/s in normal volunteers. While the mean systolic velocity (MSV) of CSF at the cerebral aqueduct in control group was 3.0600 cm/s with a standard deviation of 1.40457 cm/s. In our study, cranial volume were 0.0228 ±0.01531ml and caudal volume were 0.0213 ml ±0.0921 ml.

Discussion

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. [11] 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. [12]

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. [14,15] Ahlberg J et al. observed Urinary incontinence as the third primary symptom of INPH. [16]

The mean aqueduct stroke volume (ASV) in control group of our study (n= 30) was31.4µl with a standard deviation of 11.38µl. The stroke volume in cases in our study was 141.3µl ± 53.56µl. The P value was (0.0001) suggesting that the difference in the values of ASV in cases and controls were statistically significant. So ASV can be used as a parameter to differentiate cases from controls. Schroeder et al in their study reported a stroke volume of 28 µl in normal individuals. [17] Abdallah et al and Yousef et al observed a stroke volume of 27.26µl (+/- 3.05) in their study. [18,19]

In our study, the peak systolic velocity of CSF at the cerebral aqueduct had a mean value of 4.1600 cm/s with a standard deviation of 1.62600 cm/s in normal volunteers. While the mean systolic velocity (MSV) of CSF at the cerebral aqueduct in control group was 3.0600 cm/s with a standard deviation of 1.40457 cm/s. Bhadelia's et al in their study on 17 healthy volunteers using cine phase contrast MR images with the axial aqueduct technique, observed a PSV of 1.9cm/s and a MSV of 0.93cm/s. [20] In our study, cranial volume were 0.0228 ±0.01531ml and caudal volume were 0.0213 ml ±0.0921 ml. Quantitative analysis of CSF flow seems to be only way to differentiate between abnormal ventricular pulstality with high intracranial pressure and abnormal CSF flow with only increase in ventricular size. [21]

Conclusion

These various parameters ASV, PSV, MSV, FF and BF of CSF flow in phase contrast MRI were included in our study. These all parameters reliably differentiated NPH patients from normal volunteers in our study. CSF wave form obtained from Phase contrast MRI were analyzed in our study it appeared to be reliable, reproducible, and sensitive tool for

differentiation of NPH patients and normal volunteers.

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