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STUDY OF CSF FLOW PHYSICS AND ITS PARAMETERS AT THE LEVEL OF AQUEDUCT IN NORMAL INDIVIDUALS

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Phase-contrast MRI (PC-MRI) is a rapid, simple, and non- invasive technique, and is sensitive to CSF flow. It has been available for some time and been used in the past decade in the evaluation of cranial and spinal CSF flow, demonstrating a mechanical 'coupling between cerebral blood and CSF flows throughout the cardiac cycle and the temporal coordinated succession of these flows' in normal people. The technique led to a better understanding of the pathophysiological basis of diseases with dysfunction of CSF flow.
The aim of the study is to study the physics of the CSF flow and to establish the normal parameters of the CSF flow at the level of aqueduct. MRI brain with CSF flow study was done in 40 patients. These patients were in age group of 20-60 years and came with no significant clinical complaints.
Phase contrast MRI scanning was used following the CSF Quantitative flow protocol and CSF_ DRIVE protocol was followed. Forward flow volume, Backward flow volume, regurgitate fraction, absolute stroke volume, Stroke volume were calculated at the level of cerebral aqueduct provides the best understanding of CSF flow physics and normal CSF parameters.
Stroke volume of 55 % of individuals was seen in the range of the 2.0 to 3.0 and 45% of individuals was seen in the range of 1.0 to 2.0 and Absolute stroke volume of maximum individuals i.e. 72.5% was seen in the range of the 3.6 to 4.5 ml/min.

INTRODUCTION:

The brain and the central canal of the spinal cord are both surrounded by cerebrospinal fluid (CSF). It acts as a chemical buffer for immunological protection, a transport system for waste products and nutrients, a diffusion medium for the transport of neurotransmitters and neuroendocrine substances, as well as a diffusion medium for the transport of neurotransmitters and neuroendocrine substances.[1]

New MRI applications are constantly being developed, allowing for a more accurate assessment of CNS illnesses and their treatment response. CSF movement is one topic that has gotten a lot of attention, but with mixed results. When CSF movement is disrupted, it is associated with a slew of clinical problems, including hydrocephalus (even normal pressure hydrocephalus), cystic CSF collections, and Chiari malformations.[2,3,4]

CSF flow pulse analysis was difficult until recently. The emergence of non-invasive magnetic resonance phase-contrast imaging, on the other hand, has made assessing the CSF flow pulse easier.

To examine the complex physiologic aspects of the CSF flow, phase-contrast pictures alone are inadequate. PC-MRI (phase-contrast magnetic resonance imaging) is a rapid, simple, and non-invasive technique that detects CSF flow.[5,6]. The approach helped researchers better grasp the pathophysiology of disorders involving CSF flow disruption.

The CSF flow research has several uses in both adults and children.

CSF flow MRI can be used to distinguish between communicating and non-communicating hydrocephalus, to localize the level of obstruction in obstructive hydrocephalus, to determine whether arachnoid cysts communicate with the subarachnoid space, to differentiate between arachnoid cysts and subarachnoid space, to distinguish between syringomyelia and cystic myelomalacia, and to assess flow patterns of posterior fossa cystic.[7,8,9,10,11,12]

This imaging modality can also be useful in the pre-operative evaluation of Chiari 1 malformation[13] and normal pressure hydrocephalus, as well as the post-operative monitoring of patients who have had a Neuroendoscopic third ventriculostomy (NTV)[14] or a ventriculoperitoneal (VP) shunt.

As a result, we evaluated CSF flow characteristics and patterns at the aqueduct level in this study to determine typical parameters in adults.

AIMS & OBJECTIVES:

- To study the physics of the CSF flow.
- To establish the normal parameters of the CSF flow at the level of aqueduct.

MATERIALS & METHOD:

In a year, 40 patients had an MRI brain with CSF flow investigation at the radiology department of our tertiary care institution in Mumbai, utilising a Philips 1.5 TESLA PHILIPS ACHIEVA MRI machine.

Patients were chosen among individuals who were referred by clinicians to our facility. These patients were between the ages of 20 and 60 and had no notable clinical concerns. The respiratory rate was assessed while cardiac gating was performed using MRI compatible leads. Patients with any cardiac anomalies or any devices for cardiac stimulation were not selected for the study. Pregnancy of less than 12-week duration and uncooperative patients with claustrophobia were contraindicated

CSF_ DRIVE protocol was followed with the following specifications. 3D T2-wieghted turbo spin echo sequence in the sagittal plane. Small volume with very high in plane resolution. Images can be used to visualize CSF in the aqueduct of Silvius.

In this sequence TR is relatively short to reduce scan time. Heavy T2- weighting was obtained using *DRIVE.*

TE was very long for heavy T2-weightening visualization of the CSF only. High TSE factor for small echo spacing in combination with long TE. *HALFSCAN* was used to reduce scan time.

CSF QF protocol was followed for transverse single slice quantitative flow measurement

Information on flow direction and velocity is based on flow differences of flowing spins compared to static spins. A cardiac synchronization method was needed.

PC velocity adjusted to the flow velocity of the CSF throughout the aqueduct of the Silvius.

PC direction FH to obtain information on flow in the FH-direction only. *Retrospective cardiac synchronization was* used to gather flow information within the complete cardiac cycle. *PPU triggering* was used.

For quantitative flow measurement, PC velocity was slightly higher than the maximum expected velocity to avoid aliasing.

Q-flow measurements was planned perpendicular to the vessel of interest.

HALFSCAN and partial echo are better not be used as phase information is less complete. *VCG triggering* was preferred

CSF Q-flow parameters

- Total scan duration: 02:23.8
- Rel. Signal level (%): 100
- Act. TR (Ms): 3596
- Act. TE (ms): 120
- ACQ. Matrix M x P: 136 x 88
- ACQ voxel MPS (mm): 1.10/1.70/4.00
- REC voxel MPS (mm): 0.47/0.47/4.00
- Scan percentage (%):64.7
- Packages: 4
- Min. Slice gap (mm): 4
- WFS (pix) /BW (Hz): 0.658 /330.1
- TSE es /shot (ms): 5.3/235
- SAR /whole body: <100% / 4.0 W/kg
- Whole body/ level: <4.0 W/kg/1st level
- B1 rms [uT]: 4.5
- PNS/level: 49 % / normal
- Sound pressure level: 13.9

Following the scan, axial images at the level of the Silvius aqueduct were obtained in various cardiac phases. The images are opened in Q-flow, which is provided by the manufacturer. This software evaluates the photos by drawing ROI.

The first ROI was created at the level of the Silvius, with care taken to ensure that the ROI did not touch the aqueduct's walls. It was chosen as the first vessel ROI, and it has been passed on to subsequent phases. The ROI was carefully placed such that it did not come into contact with the wall.

A second ROI, designated the second vessel ROI, was drawn at the peripheral of the aqueduct with no evidence of any involvement of the Silvius aqueduct's wall. (fig 1, fig 2 and 3)

After drawing the ROI, the software computes the CSF flow at different phases and plots the graph with also the absolute stroke volume and other parameters (fig 4 and 5)

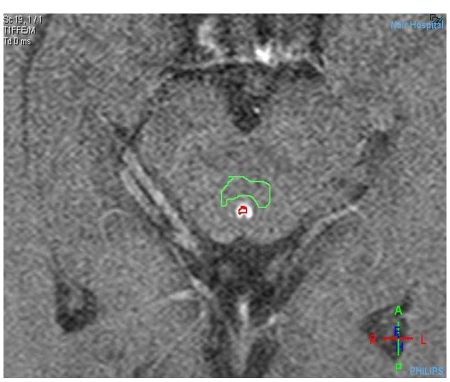


Fig 1: ROI drawn in the axial images.

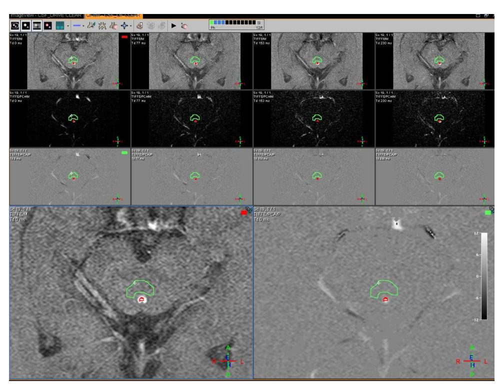


Fig 2: Propagation of the ROI to all phases

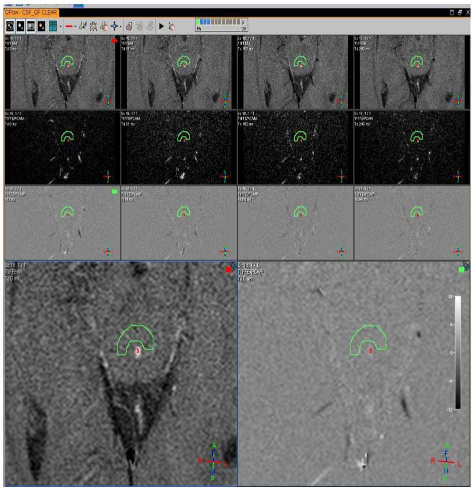


Fig 3: Propagation of ROI to all phases

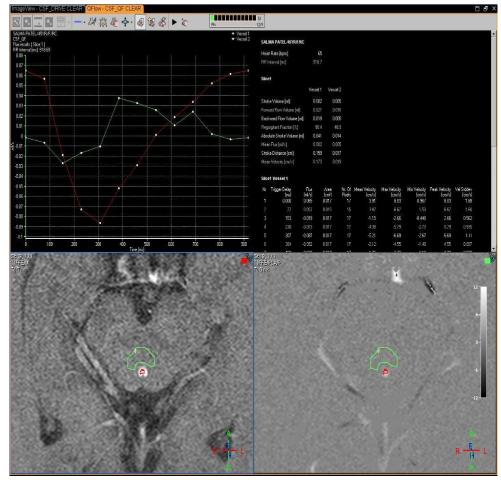


Fig 4: Tabulation of the CSF graph and volume using software.

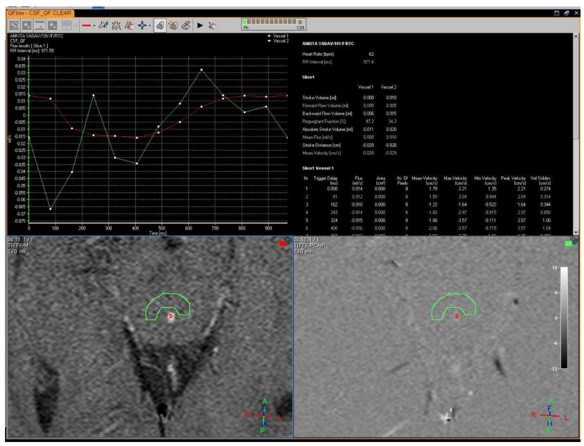


Fig 5: Tabulation of the CSF graph and volume using software.

Parameters calculated in CSF Flow

"Forward flow volume (ml/min)": caudocranial CSF flow volume during diastole.

"Backward flow volume (ml/min)": craniocaudal CSF flow volume during systole.

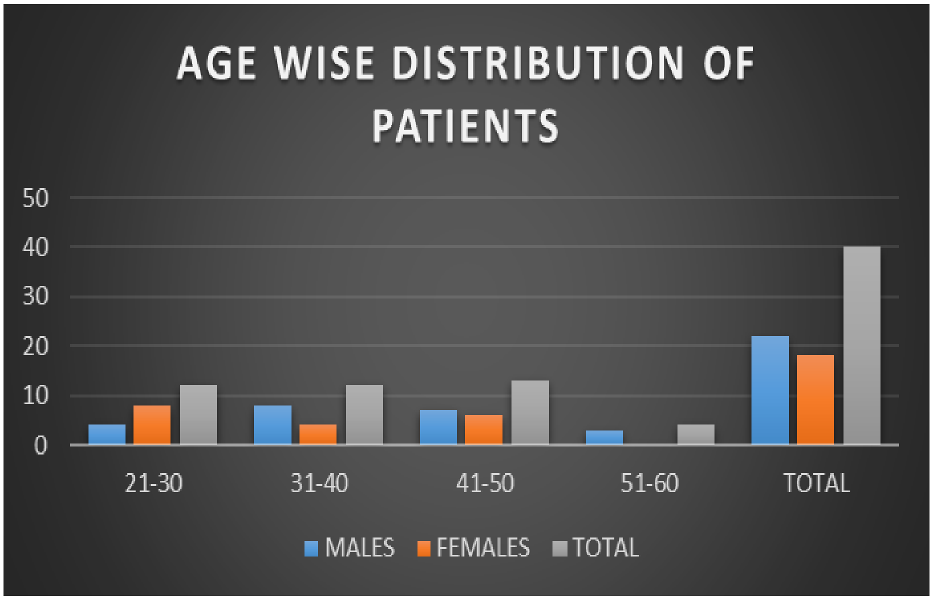
"Regurgitant fraction (%)": the ratio of the smaller to the larger value, between the "backward flow volume" and "forward flow volume", however, in the present study this parameter was defined as the ratio of the caudocranial CSF flow volume to the craniocaudal CSF flow volume.

Absolute stroke volume (ml/min)": the sum of "backward flow volume" and "forward flow volume", meaning total CSF volume passing through the cerebral aqueduct.

Stroke volume (ml/min)": This parameter is calculated as the mean of the absolute value of the caudocranial and craniocaudal CSF flow volumes. but in our study, it was defined as net CSF flow volume (i.e. the difference between "forward flow volume" and "backward flow volume")

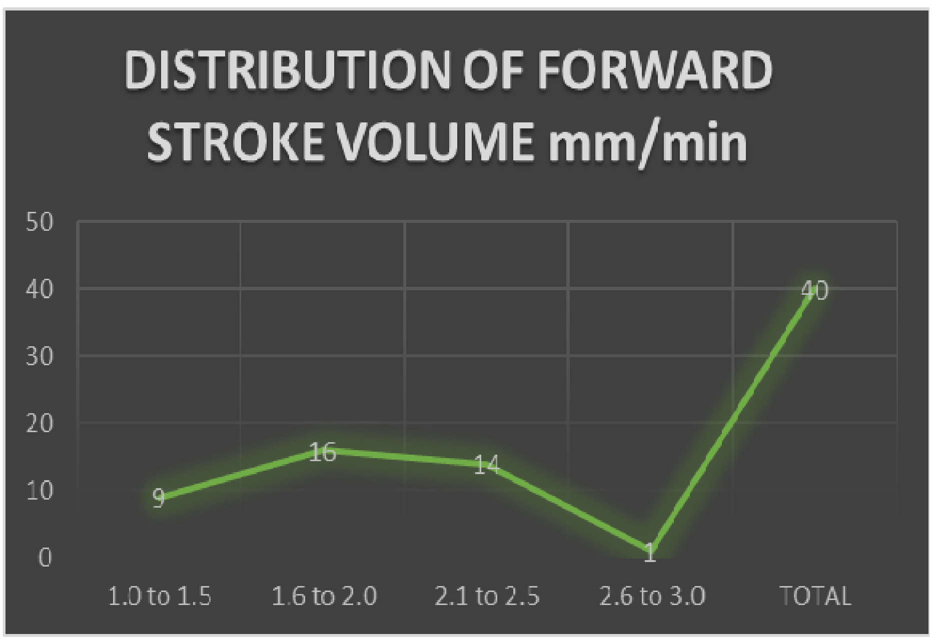
RESULTS AND OBSERVATIONS

This study includes 40 cases of normal patients from time span of 1 year. The study was carried in the department of Radiodiagnosis. The following observations were made.



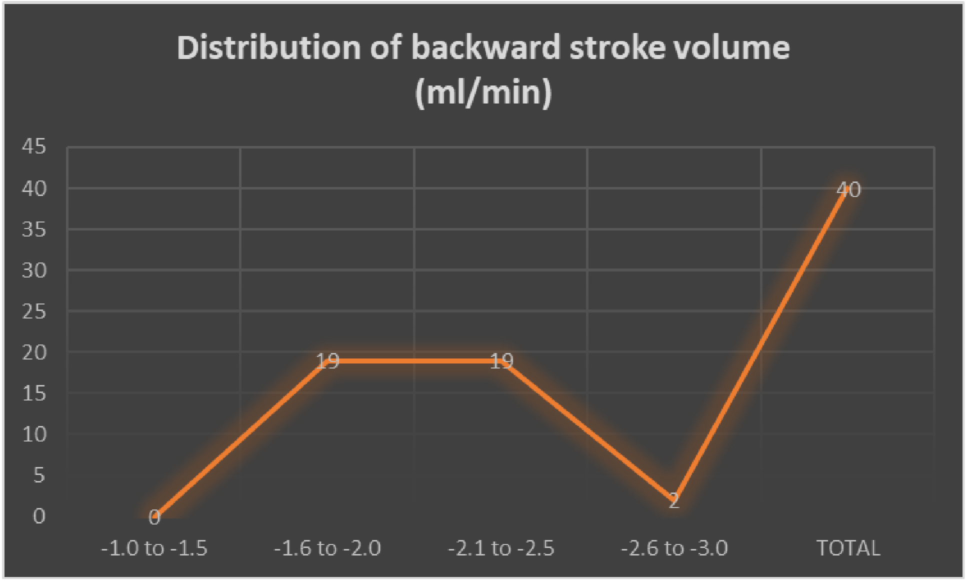
Graph 1: Chart depicting age and sex wise distribution of the subjects with age groups plotted on x-axis and number of males and females plotted on the y-axis.

In our study it was observed that 60% of the individuals included belonged to the age group of 21-30 and 31-40. Number of male subjects were 55% and number of females were 45%.



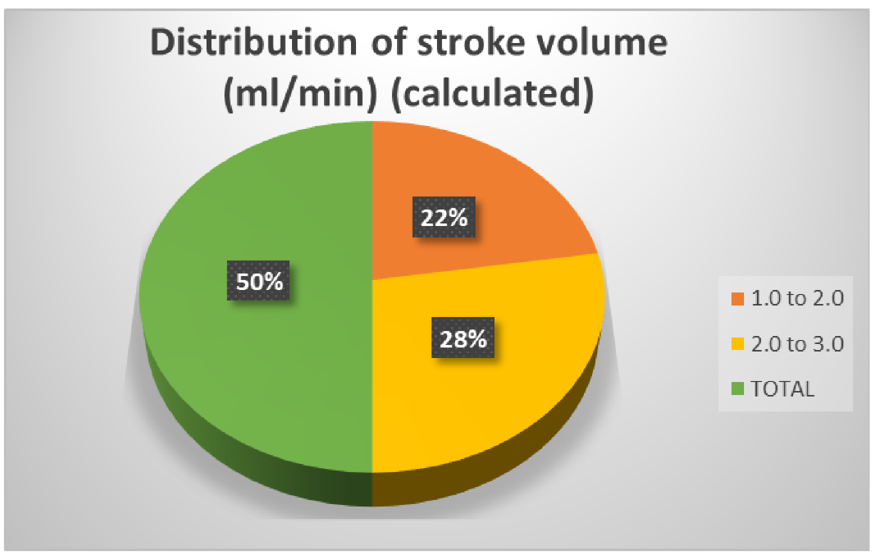
Graph 2: Line diagram depicting the forward stoke volume.

In our study the forward volume of the 30 individuals was seen in the range of to 2.0 ml /min & by 2.1 to 2.5ml/min. Maximum number of individuals 40% was seen in the range of the 1.6 to 2.0 ml/min. Followed by 35% in the range of the 2.1 to 2.5 ml/min



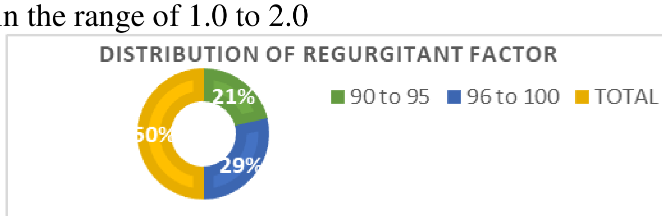
Graph 3: Line diagram depicting the backward stoke volume.

In our study the backward volume of the 38 individuals was seen in the range of -1.6 to -2.0 ml /min & by -2.1 to -2.5ml/min. Equal number of individuals 47.5% was seen in the range of the -1.6 to -2.0 ml/min and -2.1 to -2.5 ml/min.



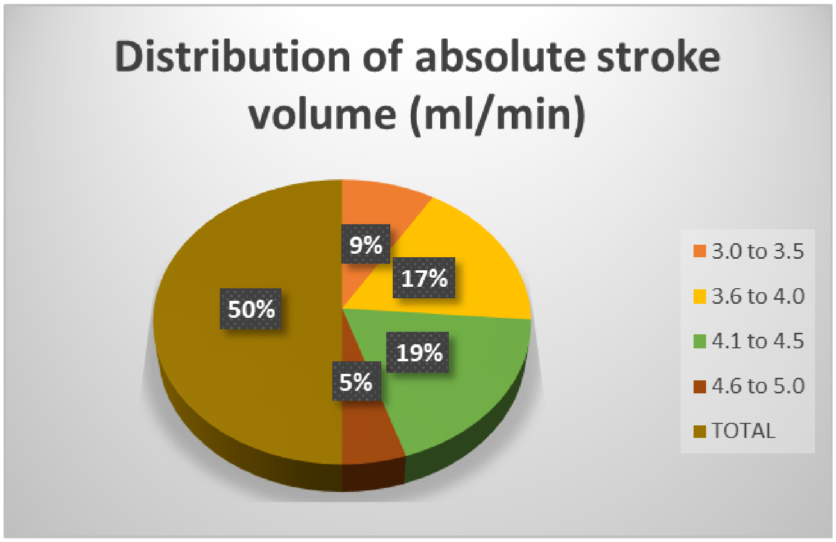
Graph 4: Pie chart depicting the distribution of stoke volume.

In our study the stroke volume of 55 % of individuals was seen in the range of the 2.0 to 3.0 and 45% of individuals was seen in the range of 1.0 to 2.0



Graph 6: Chart depicting the distribution of regurgitant factor.

In our study the regurgitant factor the 57.5 % of the individuals was seen in the range of the 96 to 100. Followed by 43.5% in the range of the 90 to 95.



Graph 7: Pie chart depicting the distribution of absolute stroke volume in ml/min.

In our study the absolute stroke volume of maximum individuals i.e. 72.5% of as seen in the range of the 3.6 to 4.5 ml/min.

STATISTICAL ANALYSIS

Forward volume of the 30 individuals was seen in the range of 1.6 to 2.0 ml /min & by 2.1 to 2.5ml/min. Maximum number of individuals 40% was seen in the range of the 1.6 to 2.0 ml/min. Followed by 35% in the range of the 2.1 to 2.5 ml/min.

Backward volume of the 38 individuals was seen in the range of -1.6 to -2.0 ml /min & by -2.1 to -2.5ml/min. Equal number of individuals 47.5% was seen in the range of the -1.6 to -2.0 ml/min and -2.1 to -2.5 ml/min.

Stroke volume of 55 % of individuals was seen in the range of the 2.0 to 3.0 and 45% of individuals was seen in the range of 1.0 to 2.0

Regurgitant factor the 57.5 % of the individuals was seen in the range of the 96 to 100. Followed by 43.5% in the range of the 90 to 95.

Absolute stroke volume of maximum individuals i.e. 72.5% was seen in the range of the 3.6 to 4.5 ml/min.

DISCUSSION

The MRI CSF flow study is a non-invasive tool for determining the amount of CSF in the body at different levels. The vast physiological range of the timing, velocity, and flow parameters is noticeable when measuring CSF flow using 2D phase-contrast MR imaging. The size and structure of the CSF spaces, the size of the blood vessels, systolic and diastolic arterial blood pressure, heart rate, jugular venous flow, compliance of surrounding brain tissue, and respiration all contribute to this generally large variance.

Because the diastole is primarily driven by alterations in the R-R interval, the systolic temporal parameters are less changeable than the diastolic temporal characteristics. Despite the use of high-resolution imaging units, there is still a significant amount of inaccuracy in the velocity data because to gradient nonlinearity, eddy currents, partial volume effects, and ROI placement.[51]

Eddy currents disrupt the gradient profile, lowering the integrity of the encoded image as a result. The estimated inaccuracy as a result of these factors is claimed to be between 10% and 15%.[52] Because noise and poor contrast make placement of the ROI problematic in very narrow aqueducts, this error may be substantially larger.

Bidirectional oscillatory movement of cerebrospinal fluid (CSF) within the craniospinal axis is caused by cardiac cycle-related cerebral blood volume fluctuations. The net influx of blood during systole raises intracranial volume and causes craniocaudal (systolic) CSF flow.

The net outflow of blood during diastole decreases intracranial volume and enhances caudocranial (diastolic) CSF flow. This pulsatory CSF motion can be visualised non-invasively using phase-contrast magnetic resonance imaging (MR imaging) and its amplitude can be measured. This method makes MR images more sensitive to changes in velocity in one direction while cancelling out signals from stationary protons and motion in other directions. A disruption of the CSF hydrodynamics causes hydrocephalus. Using phase-contrast MR imaging, pathological CSF flow dynamics in obstructive and non-obstructive hydrocephalus have been extensively studied.

Patients with normal pressure hydrocephalus who responded to ventriculoperitoneal shunting have also seen increased CSF flow through the cerebral aqueduct. Despite this, due to the large range of CSF flow values reported in normal people, the clinical relevance of CSF flow velocity studies has remained limited.

In our study of 40 individuals belonging to age group of 20 to 60 years and including both sexes were taken. In all patients retrograde respiratory gating was performed. The CSF Drive sequences was used to locate the cerebral aqueduct and then the CSF Q Flow technique was used to gain images.

The CSF was measured using Q Flow software provided by the vendor at all cardiac stages. The ROI was manually established and transmitted to all sequences, and the results were then computed by the software and recorded. The absolute stroke volume mean is calculated and used as the Stoke volume parameter.

We discovered that 60 percent of the participants in our survey were between the ages of 21 and 40. Male individuals accounted for 55% of the total, while females accounted for 45%. The remaining 30% of people are between the ages of 21 and 40, while 10% are between the ages of 51 and 60.

In our study forward volume of the 30 individuals was seen in the range of 1.6 to 2.0 ml /min & by 2.1 to 2.5ml/min. Maximum number of individuals 40% was seen in the range of the 1.6 to 2.0 ml/min. Followed by 35% in the range of the 2.1 to 2.5 ml/min. Normal range of the forward volume is seen in range of the 2.4 +/- 0.9 ml/min by study conducted by Jeong et al [53]

This study revealed backward volume of the 38 individuals was seen in the range of -1.6 to -2.0 ml /min & by -2.1 to -2.5ml/min. Equal number of individuals 47.5% was seen in the range of the -1.6 to -2.0 ml/min and -2.1 to - 2.5 ml/min. In the study conducted by Jeong et al[53] the normal range was -2.5 +/- 1.01.

Regurgitant factor the 57.5 % of the individuals was seen in the range of the 96 to 100. Followed by 43.5% in the range of the 90 to 95.

Absolute stroke volume of maximum individuals i.e. 72.5% was seen in the range of the 3.6 to 4.5 ml/min which was seen within the normal range. Stroke volume was calculated by taking mean of the absolute stroke volume. Stroke volume of 55 % of individuals was seen in the range of the 2.0 to 3.0 and 45% of individuals was seen in the range of 1.0 to 2.0ml/min. It was calculated by taking mean of the absolute stroke volume.

CONCLUSION

In our study CSF flow study was done in 40 normal individuals. The CSF Q flow technique at the level of cerebral aqueduct and axial images were achieved at different cardiac phases. ROI was plotted manually and propagated to other cardiac phases. The forward stroke volume, backward stroke volume, regurgitant factor, absolute stroke volume & mean velocity is computed by software. The stroke volume which is calculated by taking mean of the absolute stroke volume.

Calculation of the CSF flow at the level of cerebral aqueduct provides the best quantification of the CSF volume. The study was conducted to establish the normal range of the values of the CSF in the normal individuals.

Stroke volume was seen in range of the 1.0 to 3.0 ml/min. It was calculated by taking mean of the absolute stroke volume. It was seen in the normal range of the 2.4+/- 0.9 ml/min as described in other studies.

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