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# Evaluation of normal CSF velocities at the level of aqueduct amongst Indian rural adults using 1.5 Tesla MRI

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## Abstract

Rapid advances in imaging techniques have remarkably improved the diagnosis and treatment of central nervous system (CNS) disorders, with magnetic resonance imaging (MRI) being the most recent. New MRI applications are continually being developed, providing improved assessment of CNS disorders and their response to treatment, such as cerebrospinal fluid (CSF) movement, the alteration of which results in many clinical disorders with hydrocephalus (including normal pressure hydrocephalus), cystic CSF collections, and Chiari malformations being more common. CSF flow MRI can be used to discriminate between several disorders and provide information in the pre and postoperative evaluation of clinical disorders and surgical intervention. The aim of the study is to calculate and evaluate CSF flow velocities at the level of the aqueduct. MRI brain with CSF flow study was done in 40 patients. These patients were in the 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. A transverse single slice quantitative flow measurement was used to calculate the mean CSF flow velocity. Calculation of the CSF flow at the level of the cerebral aqueduct provides the best quantification of the CSF volume. It concluded that the normal range of the values of the CSF in normal individuals comes out to be 0.05 ±0.12 cm/sec.

KEYWORDS: Cerebrospinal fluid flow; Phase contrast MRI scanning; CSF volume

## Introduction

Alcoholism The brain and the central canal of the spinal cord are both surrounded by cerebrospinal fluid (CSF). It acts similarly to a shock absorber in helping to cushion the central nervous system (CNS). As a chemical buffer, it protects the body's immune system and moves waste and nutrition from one place to another.

It stops the brain tissue from deforming under its own weight due to its buoyancy action. It helps neurotransmitters and neuroendocrine chemicals move from one place to another by acting as a diffusion medium [1].

Rapid advances in imaging techniques have remarkably improved the diagnosis and treatment of CNS disorders and their response to treatment, with magnetic resonance imaging (MRI) being the most recent.

CSF movement is one topic that has gotten a lot of research, although with mixed results. Hydrocephalus, cystic CSF collections, and Chiari malformations are some of the most common diseases caused by changes in the movement of CSF [2,3].

The cerebrospinal fluid (CSF) pulsates within the craniospinal axis in response to rhythmic cerebral blood volume variations during the cardiac cycle. The CSF pulsations, like the

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arterial pulsations, have a pressure and a flow pulse in the same way [4]. The configuration and amplitude of the normal and pathologic CSF pressure pulses, recorded as a waveform, have been extensively investigated. Until recently, the simultaneously occurring CSF flow pulse was difficult to analyze. However, the introduction of non-invasive magnetic resonance phase-contrast imaging has facilitated the assessment of the CSF flow pulse. Phase-contrast images alone aren't enough to tell you about the subtle physiologic details of the CSF flow.

Phase-contrast MRI (PC-MRI) is a rapid, simple, and non- invasive technique that is sensitive to CSF flow [5,6]. It has 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. 5. The technique lead to a better understanding of the pathophysiological basis of diseases with dysfunction of CSF flow [6].

The applications of the CSF flow study are numerous in both adults and children.

CSF flow When there's a lot of water in the brain, it can be hard for doctors to tell if the water is coming from the brain or from the body. MRI can help doctors figure out which is which. It can also help them figure out how water moves through the brain [7-12].

This imaging method can also provide significant information in the pre-operative evaluation of Chiari 1 malformation [13], normal pressure hydrocephalus, and post-operative follow-up of patients with neuroendoscopic third ventriculostomy (NTV) [14] and ventriculoperitoneal (VP) shunt.

As a result, in this study, we evaluated the CSF velocities at the level of the aqueduct to establish normal parameters in the adults.

Objectives of study: To calculate and evaluate CSF flow velocities at the level of the aqueduct in patients in the age group of 20-60 years. To determine normal parameters for the mean velocity of CSF flow at the aqueduct level in adults.

## Material And Methodology

**Ethical approval:** Study was approved by the Institutional Ethics Committee of our institute.

**Study location:** Study was conducted at radiology department of our tertiary care center, Mumbai.

**Study duration:** 12 months

**Inclusion criteria:** Patients were selected based on those who were referred to our hospital by clinicians. These patients were in the age group of 20-60 years and came with no significant clinical complaints.

**Exclusion criteria:** Patients with

1. Patients with cardiac pacemakers, heart valve replacement, vascular aneurysmal clips, electrical implants, neurostimulators, electrodes, prosthesis, ear implants, gunshot/shrapnel injury, metallic foreign body, drug infusion devices, and other contraindications for MRI.
2. Pregnancy of less than 12 weeks' duration.
3. Uncooperative patients (claustrophobic)

**Sample size:** Fourty

**Methodology:** A MRI brain with CSF flow study was conducted in 40 patients using a Philips 1.5 TESLA PHILIPS ACHIEVA MRI machine.

Cardiac gating was performed using MRI compatible leads, and respiratory rate was measured.

The CSF QF protocol was followed. Transverse single slice quantitative flow measurement Information on flow direction and velocity was based on the flow differences of flowing spins compared to static spins. A cardiac synchronization method was needed.

PC velocity is 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.

To avoid aliasing, the PC velocity should be slightly higher than the maximum expected velocity to avoid aliasing.

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

HALFSCAN and partial echo should not be used as phase information is less complete.

VCG triggering is preferred.

After running the scan, the axial images at the level of the aqueduct of Silvius are obtained in different cardiac phases. The images are opened in the software provided by the vendor, i.e., Q-flow. The images are evaluated in this software by drawing ROI.

The first ROI is drawn at the level of the Silvius. Taking care that the ROI is not touching the walls of the aqueduct. It is taken as the first vessel ROI and it propagates to other phases. It is taken care of so that the ROI doesn't touch the wall.

Table 1: 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 |

Another ROI, labelled as the second vessel ROI, is drawn on the periphery of the aqueduct with no evidence of any involvement of the wall of the aqueduct of the Silvius [fig 1]. The same ROI was propagated to other phases with the precaution that it wouldn't touch the wall. (fig 2 and 3)

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

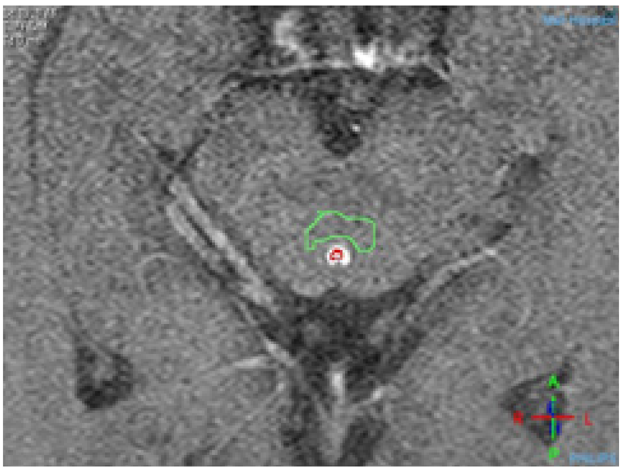

**Fig 1: ROI drawn in the axial images**

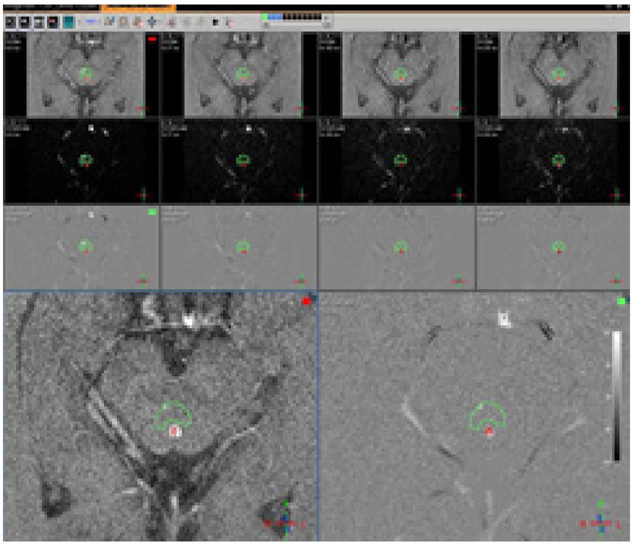

**Fig 2 : Propagation of the ROI to all phases**

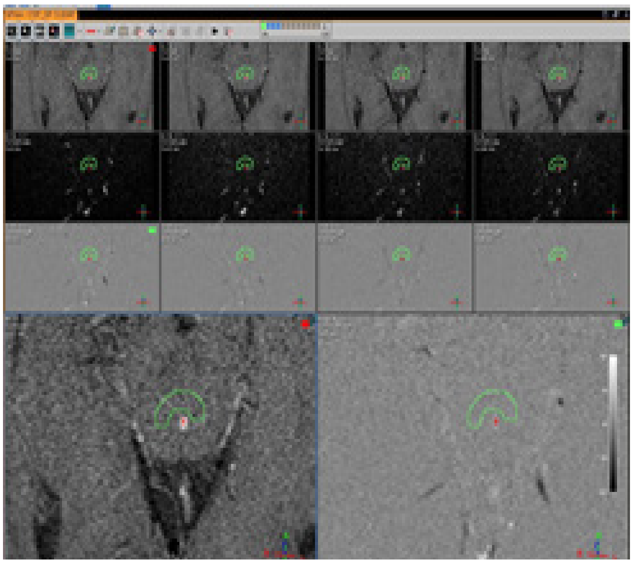

**Fig 3: Propogation of ROI to all phases using software.**

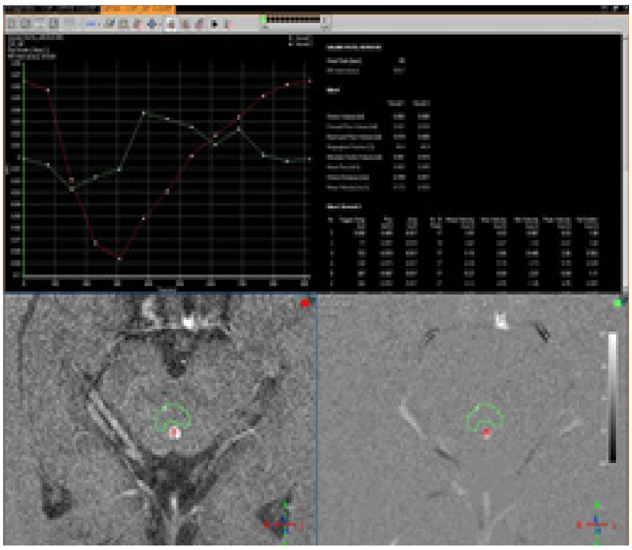

**Fig 4 : Tabulation of the CSF graph and volume**

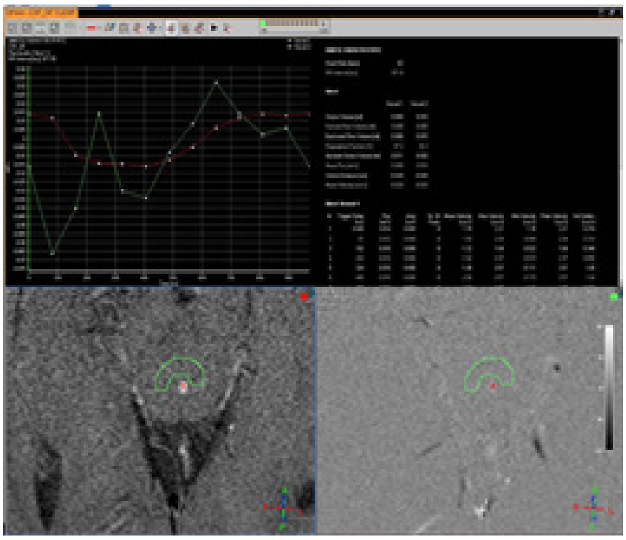

**Fig 5 : Tabulation of the CSF graph and volume using software.**

## Results

This study includes 40 cases of normal patients from a 1-month span. The study was carried out in the department of radiodiagnosis. The following observations were made.

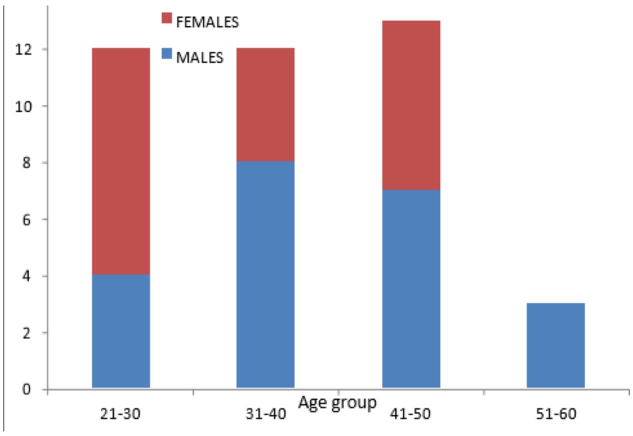


**Fig 6: Age and gender distribution of subjects**

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%.

Table 2: Distribution of mean velocity (cm/sec)

| Mean Velocity (cm/sec) | N |
|---|---|
| 0.01 to 0.05 | 28 |
| 0.06 to 0.10 | 12 |
| TOTAL | 40 |

In our study the mean velocity of the 28 individuals i.e 70% was seen in the range of 0.01 to 0.05 cm/sec. Remaining 30% was seen in the range of the 0.06 to 0.1.

## Discussion

An MRI CSF flow study is a noninvasive method for the quantification of the CSF at various levels. CSF flow quantification using 2D phase-contrast MRI. The wide physiological range of the temporal, velocity, and flow parameters is striking. CSF space size and anatomy, blood vessel size, heart rate, jugular vein flow, compliance of surrounding brain tissue, and respiration are the main reasons for this wide range of variation.

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 error in the velocity data due to gradient nonlinearity, eddy currents, partial volume effects, and ROI [15] placement. Eddy currents disrupt the gradient profile, lowering the integrity of the encoded picture as a result. According to reports, the estimated inaccuracy due to these variables is between 10% and 15% [16]. Because very small aqueducts are hard to place the ROI because of noise and poor contrast, this error may be much bigger.

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. During diastole, there is less blood in the brain, making it simpler for cerebrospinal fluid (CSF) to go from the brain to the spinal cord.

Phase-contrast magnetic resonance (MR) imaging can display this pulsatory CSF motion non-invasively and allows the assessment of its amplitude. This technique sensitizes MR images to velocity changes in a specific direction, while cancelling signals from stationary protons and from motion in other directions. Hydrocephalus is caused by a disturbance of the CSF hydrodynamics. Pathological CSF flow dynamics in obstructive and non-obstructive hydrocephalus have been extensively analyzed using phase-contrast MRI. 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 [17].

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

The Q-Flow software provided by the vendor was utilized to quantify the CSF at all cardiac phases. The ROI was placed manually and propagated to all sequences. The findings were then computed by the software were taken.

We observed that in our study, 60% of the individuals included belonged to the age groups of 21-30 and 31–40. The number of male subjects was 55% and the number of females was 45%. The remaining 30% of the individuals belong to the age group of 21–40, and 10% belong to the age group of 51–60.

The mean velocity of the 28 individuals, i.e. 70%, was seen in the range of 0.01 to 0.05 cm/sec. The remaining 30% was seen in the range of 0.06 to 0.1. The normal range was cited to be 0.05 +/- 0.12.

## Conclusion

In our study, CSF flow was studied in 40 normal individuals. At different cardiac phases, the CSF Q flow technique at the level of the cerebral aqueduct and axial images were achieved. The ROI was plotted manually and propagated to other cardiac phases. The mean velocity is computed by software. Calculation of the CSF flow at the level of the 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 normal individuals, which comes out to be 0.05 (+/-) 0.12 cm/sec.

**Conflict of interest :** Nil
**Source of funding :** Nil

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