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ORIGINAL RESEARCH

Assessment of Cerebrospinal Fluid Hydrodynamics Using Magnetic Resonance Imaging in Postcraniospinal Surgery Patients

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ABSTRACT

Background: Phase-contrast MRI (PCMRI) with cardiac synchronism is a dynamic technique used to visualize cerebrospinal fluid (CSF) movement. The present study was conducted to assess Cerebrospinal Fluid Hydrodynamics Using Magnetic Resonance Imaging in Postcraniospinal Surgery Patients.

Materials and Methods: The present case-control study comprising 30 patients and 30 controls, conducted over a period of 2 years in a tertiary-care hospital in India. Healthy subjects formed the control group. Conventional magnetic resonance imaging of the brain was performed before PCMRI. Assessment of clinical signs and symptoms was done pre and postoperatively. Statistical Analysis of data was done in terms of mean (±standard deviation), frequencies (number of cases), and percentages. The p-value of < 0.05 was considered significant. All the analysis was performed on SPSS 16.0 version (Chicago, Inc., United States).

Results: The present case-control study comprising 30 patients and 30 controls. Postoperative imaging follow-up was done in 30 patients after an interval of 1 month. Postoperatively, a majority (17) of the patients showed improvement in clinical symptoms. 7 patients showed no change, while six patients showed deterioration. Phase-Contrast Magnetic Resonance Imaging Quantitative parameters measured at cerebral aqueduct, foramen magnum, C2–3, and D12–L1 vertebral levels, in controls, showed no significant difference in peak CSF velocities. In group I and group II mean change CSF velocity was noted in improved patients was more than the other patients.

Conclusion: The present study concluded that PCMRI can effectively evaluate changes in CSF flow noninvasively both pre- and postoperatively.

Keywords: Cerebrospinal Fluid, Magnetic Resonance Imaging, Postcraniospinal Surgery Patients.

INTRODUCTION

Neuroimaging has a crucial role in depiction of inflammatory changes in the brain and spine and may aid early diagnosis. It also helps in evaluation of subsequent complications and therapeutic response monitoring.[1-3] Cerebrospinal fluid (CSF) shows complex oscillatory flow during the cardiac cycle across different levels with areas of relative change in velocity and flow patterns.[4] CSF flow may be obstructed to a varying degree in different pathologies leading to a wide array of clinical and neuroradiological presentations requiring various surgical interventions.[5] Phase-contrast MRI (PCMRI) with cardiac synchronism is a dynamic

technique used to visualize cerebrospinal fluid (CSF) movement. This technique is non-invasive, highly sensitive even to slowflow and provides precise and reproducible measurement of quantitative parameters.[6] CSF flow may be altered in many intracranial and intraspinal pathologies. Over the past few decades, clinical research has demonstrated associations among changes in CSF hydrodynamics with meningitis, hydrocephalus, and cerebral edema.[7-9] The present study was conducted to assess Cerebrospinal Fluid Hydrodynamics Using Magnetic Resonance Imaging in Postcraniospinal Surgery Patients.

MATERIALS AND METHODS

The present case-control study comprising 30 patients and 30 controls, conducted over a period of 2 years in a tertiary-care hospital in India. Patients with various craniospinal pathologies causing CSF flow alterations undergoing surgeries irrespective of age and gender comprised the study group. Before the commencement of the study ethical approval was taken from the ethical committee of the institute and informed consent was taken from the patient. Healthy subjects formed the control group. Conventional magnetic resonance imaging of the brain was performed before PCMRI. For qualitative PCMRI, a two-dimensional fast low-angle shot (FLASH) sequence was used. T2-weighted sagittal images, phase, rephase, and magnitude images were acquired. Imaging parameters were repetition time/echo time (TR/TE) = 34.45/9.73 ms, field of view (FOV) = 240 mm, flip angle = 10 degrees, and slice thickness = 4.5 mm. CSF flow dynamics were quantitatively studied by using a prospective cardiac-gated (pulse trigger being used for cardiac synchronization) high-resolution axial phase-contrast protocol with an optimal imaging plane depending on surgical site perpendicular to (1) mid one-third of the cerebral aqueduct, (2) foramen magnum, (3) C2–3, and (4) D12–L1 vertebral levels. The imaging parameters were TR/TE = 41.35/4.09 ms, FOV = 320 mm, flip observer was taken angle = 30 degrees, and slice thickness = 5 mm. Velocity encoding was kept at 20 cm/s. Area with maximal alteration of cerebrospinal flow dynamics in patients was selected as the region of interest (ROI) for comparison. The acquired FLASH through-plane images were transferred to Argus Siemens postprocessing program. In all cases, CSF flow was initially evaluated qualitatively following acquisitions of phase, rephase, and magnitude images. A circular ROI was placed carefully on each image manually in one of those series. In all controls and patients, the following parameters were assessed at different levels as follows: (1) area of subarachnoid spaces (SAS), (2) peak velocity, (3) average velocity, (4) forward volume, (5) reverse volume, and (6) stroke volume. Two radiologists, who were blinded to the clinical history, evaluated the images qualitatively and quantitatively. The average values of quantitative parameters calculated by the observers were taken. Assessment of clinical signs and symptoms was done preand postoperatively. Based on clinical examination, patients were categorized into the following groups improved, unchanged, and deteriorated accordingly. Each presenting symptom was scored preoperatively and postoperatively between 1 and 5, with 1 representing no disability and 5 representing complete disability. Complete disability was considered when patients had significant deterioration in activities of daily living or inability to carry out his/her routine occupational job. Cumulative accrued values based on each symptom were averaged. Postoperative assessment in patients was performed 1 month after the surgical intervention, subject to patient availability and informed consent. Statistical Analysis of data was done in terms of mean (±standard deviation), frequencies (number of cases), and percentages. Paired t-test was used to compare the mean change in peak CSF systolic velocity pre- and postoperatively. The p-value of < 0.05 was considered significant. All the analysis was performed on SPSS 16.0 version (Chicago, Inc., United States).

RESULTS

The present case-control study comprising 30 patients and 30 controls. Postoperative imaging follow-up was done in 30 patients after an interval of 1 month. Postoperatively, a majority (17) of the patients showed improvement in clinical symptoms. 7 patients showed no change, while six patients showed deterioration. Phase-Contrast Magnetic Resonance Imaging Quantitative parameters measured at cerebral aqueduct, foramen magnum, C2–3, and D12–L1 vertebral levels, in controls, showed no significant difference in peak CSF velocities. In group I and group II mean change CSF velocity was noted in improved patients was more than the other patients.

Table 1: Disability scoring of clinical symptoms

Group	Number of patients	Preoperative disability score	Postoperative disability score
Improved	17	15.67	9.3
Static	7	13.01	12.09
Worsened	6	14.1	14.7

Table 2: Mean cerebrospinal fluid peak velocity in controls and patients

Region of interest	Peak systolic velocity (cm/s)	
	Control	Patient (preoperative)
Aqueduct	2.12	2.24
Foramen magnum (ventral)	2.64	2.12
Foramen magnum (dorsal)	2.70	2.64
C2–3 (ventral)	2.30	2.80
C2–3 (dorsal)	2.10	2.30
D12–L1 (ventral)	3.00	2.08
D12–L1 (dorsal)	3.20	3.04

Table 3: Correlation of postoperative change in peak CSF velocity with changes in clinical outcome

Patient group	Clinical outcome	N	Mean change in peak CSF velocity (cm/s) Mean±SD
Group I	**Improved**	2	2.22±0.07
	Others	2	0.52±0.01
Group II	**Improved**	17	0.25±0.42
	Others	13	0.02±0.09

DISCUSSION

CSF comprises all intracerebral ventricles, spinal and brain 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. Potential sites of CSF origin include the choroid plexus, parenchyma of the brain and the spinal cord, and ependymal lining of the ventricles.[10]

The PC MRI generates signal contrast between flowing and stationary nuclei by sensitising the phase of the transverse magnetisation to the velocity of motion.[11] To obtain the optimal signal, the CSF flow velocity should be the same as, or slightly less than, the selected VENC. CSF flow velocities greater than VENC can produce aliasing artefacts, whereas velocities much smaller than VENC result in a weak signal.[12,13]

The present case-control study comprising 30 patients and 30 controls. Postoperative imaging follow-up was done in 30 patients after an interval of 1 month. Postoperatively, a majority

(17) of the patients showed improvement in clinical symptoms. 7 patients showed no change, while six patients showed deterioration. Phase-Contrast Magnetic Resonance Imaging Quantitative parameters measured at cerebral aqueduct, foramen magnum, C2–3, and D12–L1 vertebral levels, in controls, showed no significant difference in peak CSF velocities. In group I and group II mean change CSF velocity was noted in improved patients was more than the other patients.

Experimental studies by Scheld et al. and Fuhrmeister et al. have demonstrated marked alterations in CSF hydrodynamics in the acute stage of meningitis with elevation in CSF pressure and outflow resistance. However, their studies also suggested a 5–10-fold reduction in the CSF formation rate at basal intracranial pressure in the presence of meningitis.[14,15]

The patients with tuberculous and bacterial meningitis showed higher average CSF flow parameters as compared to those with viral etiology possibly indicating higher propensity to alter the CSF flow dynamics. In these etiologies, the bacteria have a higher tendency to disrupt the blood–brain barrier, causing the inflammatory cells and proteins to leak into the subarachnoid space and form exudates.[16,17]

Arora P et al to evaluate the effect of craniospinal interventions on cerebrospinal fluid (CSF) flow hydrodynamics and study the correlation of postoperative changes in flow alteration with clinical outcome. Patients in both groups showed a significant change in peak CSF velocity postoperatively (mean change of 1.34 cm/s in group I and 0.28 cm/s in group II) with bidirectional improvement in flow on cine-phase-contrast qualitative images. Regional pain (82%) and headache (46%) were seen in most of the patients preoperatively. Postoperatively clinical symptoms improved in 59.5%, static in 26.2%, and worsened in 14.3%. In both the groups, an improvement in clinical symptomatology had significant correlation with mean changes in peak CSF velocity postoperatively ($p = 0.04$ in both groups).[18]

CONCLUSION

The present study concluded that PCMRI can effectively evaluate changes in CSF flow noninvasively both pre- and postoperatively.

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