ORIGINAL ARTICLE

Role of MR CSF flowmetry in post ETV assessment in pediatric age group

Fadila M. Elsayed [a,*], Hanan E. Abd El-Razik [a], Usama M. El Shokhaiby [b]

[a] Department of Diagnostic and Interventional Radiology, Faculty of Medicine for Girls, Al-Azhar University, Cairo, Egypt
[b] Department of NeuroSurgery, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt

Abstract

Background: ***The qualitative and quantitative assessment of cerebrospinal fluid flow abnormalities in certain neurological diseases can be achieved through the utilization of phase contrast MRI cerebrospinal fluid (CSF) flowmetry.***

Aim of work: ***The objective of this investigation is to detect the role of MRI CSF flowmetry in post-endoscopic third ventriculocisternostomy (ETV) assessment in the pediatric age group.***

Patients and methods: ***This prospective investigation was conducted from October 2022 to April 2024. A total of sixteen cases participated in this investigation. They were referred from the pediatric department to the MRI department at Al Zahraa University Hospitals. The MRI 1.5 Tesla (Philips Ingenia) machine (closed magnet) has been utilized to conduct all MRI examinations on all included individuals, with a standard head coil. The cases were categorized into the following subgroups depending on a conventional clinical MRI, as follows: Two cases underwent ETV for communicating hydrocephalus, while fourteen cases underwent ETV for non-communicating hydrocephalus caused by aqueductal stenosis.***

Results: ***The patients who had ETV are 16 patients, 12 patients have jet of CSF flow through ventriculostomy and 4 patients have inadequate CSF flow through the stoma that can be detected by PC-MRI. Conventional MRI had sensitivity of 0% and specificity of 100% for the recognition of ETV.***

Conclusion: ***We suggest utilizing phase-contrast MR images in all patients who have ETV, as it can detect its function, that is the gold stander role of our recommended technique.***

Keywords: Phase contrast MRI; Hydrocephalus; CSF flowmetry; Aqueductal stenosis

1. Introduction

A clear, colorless ultrafiltrate of plasma, cerebrospinal fluid is situated in the subarachnoid spaces of the spine & cranium, among the pia mater and arachnoid mater.[1]

The ventricles contain twenty-five milliliters of cerebrospinal fluid, while the subarachnoid spaces contain 125 milliliters. The average volume of cerebrospinal fluid is 150 milliliters. Intracranial pressure is determined by cerebrospinal fluid pressure, which is physiologically between three and four millimeters of mercury prior to the age of one year and ten to fifteen millimeters of mercury in adults. The cerebrospinal fluid space is a dynamic pressure system.[1,2]

Cerebrospinal fluid is derived from blood plasma & is largely comparable to it, with the exception of its nearly protein-free composition and slightly varying electrolyte concentrations. The composition of cerebrospinal fluid is rigorously regulated.[3]

Cerebrospinal fluid produced in the lateral ventricles will pass through the interventricular foramina, the cerebral aqueduct, and the 4th ventricle prior to entering the subarachnoid space at the base of the brain through the median aperture, additionally referred to as the foramen of Magendi.[4]

The symptomatic accumulation of cerebrospinal fluid within the cerebral ventricles is what is known as hydrocephalus. It is possible that this accumulation is the result of a blockage in the normal passage of cerebrospinal fluid, overproduction of cerebrospinal fluid or problems with absorption into the venous system by the Pacchionian arachnoid granulations.[5]

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* Corresponding author at: Diagnostic and Interventional Radiology, Faculty of Medicine for Girls, Al-Azhar University, Cairo, Egypt.
E-mail address: Fadilaeed1999@azhar.edu.eg (M. H. A. Dahashan).

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The cause of hydrocephalus is the 1ry focus of the initial therapy. Operative evacuation might alleviate hydrocephalus in instances of subarachnoid bleeding or cancers.[5]

The diversion of cerebrospinal fluid flow is an essential aspect of the surgical treatment of hydrocephalus, which is intended to reestablish intracranial fluid equilibrium.[6]

Ventricular-peritoneal (VP) shunting is the common and traditional method of managing the increased intracranial pressure due to hydrocephalus. VP shunts have potential risks and many complications, such as infection and shunt obstruction that results in shunt failure requiring another surgery, like revision or new ventriculoperitoneal shunt insertion.[7] Endoscopic third ventriculostomy has become a public alternative to cerebrospinal fluid shunt placement in hydrocephalus due to aqueductal stenosis, but there is still some debate related to the monitoring and imaging for assessment of success after the procedure.[8]

Endoscopic third ventriculocisternostomy (ETV) is a neuro-endoscopic procedure that involves the creation of a small perforation in the floor of the 3rd ventricle. It must be the 1st management option for all cases having congenital aqueductal stenosis.[9]

The 1ry goals of this operation are to establish a conduit between the interpeduncular cistern and the third ventricle in order to redirect cerebrospinal fluid away from the occlusion.[9] The success rate of ETV varies from 69 to 95%. However, different percentages of failed cases were reported in scientific studies,[10]

The objective of this investigation was to detect the importance of MRI CSF flowmetry in post-ETV assessment in the pediatric age group.

2. Patients and methods

Between October 2022 and April 2024, this prospective investigation was conducted. The investigation included a total of sixteen cases, with eleven females and five men. Their mean ages varied from four months to fifteen years. The pediatric department referred them to the MRI department at Al Zahraa University Hospitals. The MRI 1.5 Tesla (Philips Ingenia) machine (closed magnet) has been utilized to conduct all MRI examinations on all involved individuals, with a standard head coil. The cases have been categorized into the following subgroups depending on conventional and clinical magnetic resonance imaging, as follows: Two cases underwent ETV for communicating hydrocephalus, while fourteen patients underwent ETV for non-communicating hydrocephalus caused by aqueductal stenosis.

Statistical Analysis

The data had been gathered, coded, revised, & entered into the Statistical Package for Social Science (IBM SPSS) version 27. The qualitative parameters have been represented as percentages and numbers. The Kolmogorov-Smirnov test may be utilized to determine whether the parameter is normally distributed in a single sample. The Chi-square test and/or Fisher's exact test were utilized to compare the qualitative data of the groups when the predicted count in any cell was below five. In the context of conventional MRI, the receiver operating characteristic curve (ROC) was utilized to provide an evaluation of the appropriate cut-off point regarding its specificity, negative predictive value, sensitivity, positive predictive value, and area under the curve (AUC). This evaluation was conducted to identify ETV. The accepted margin of error was five percent, and the confidence interval has been established at ninety-five percent. Therefore, the p-value has been deemed significant at a level of 0.05.

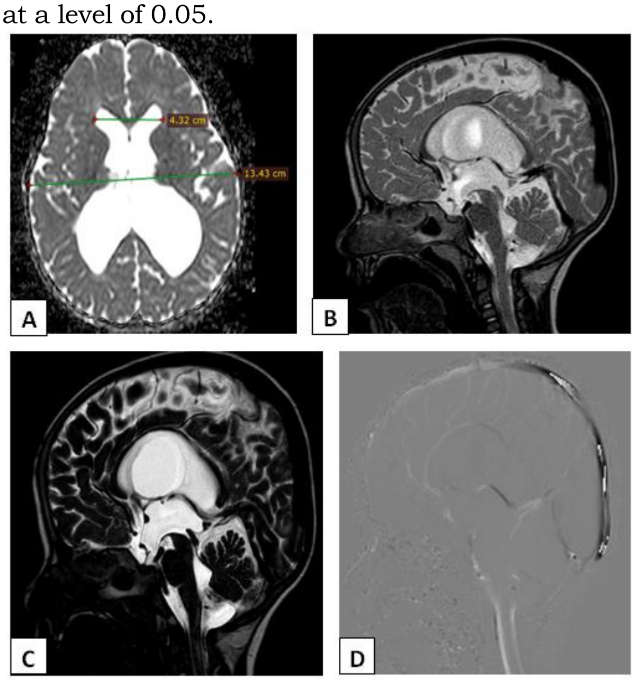

Figure 1. A four-year-old male case with a history of aqueductal stenosis had ETV for monitoring. MRI (a) axial T2 WI at lateral ventricle level demonstrating hydrocephalus (Evan index =0.32). b) Sagittal T2 WI demonstrating the absence of the typical aqueductal signal lacuna. (C) 3D DRIVE image illustrating an obstructed aqueduct. (d) A sagittal phase image in the systole demonstrates insufficient cerebrospinal fluid flow at ETV and no flow of cerebrospinal fluid in the aqueduct.

Phase contrast MRI protocol

The magnetic resonance imaging protocol needs to include imaging of the brain with T2-weighting in both coronal & axial planes, axial fluid attenuation inversion recovery (FLAIR), & sagittal T1-weighted image (T1-WI). A highresolution, extensively T2-weighted volumetric sequence is obtained in the sagittal plane, and it is referred to as the 3-dimensional driven equilibrium, or 3D-DRIVE. The field of view extends from the left foramen of Luschka to the right foramen. In cases of intracranial tumors or suspected inflammatory processes, a post-contrast T1-weighted image might be acquired in 3 planes. The acquisition of axial T2*-WI might be beneficial for the more accurate identification of intracranial bleeding as a contributing factor to hydrocephalus.[11]

A localizer has been positioned perpendicular to the Sylvius aqueduct in the midsagittal image. The localizer must pass through the aqueduct in the axial plane.[12]

Cine phase-contrast sequences may illustrate the pulsatile flow of cerebrospinal fluid during the cardiac cycle. It may be obtained in sagittal section to follow up the flow of cerebrospinal fluid through the aqueduct & basal subarachnoid spaces (qualitative evaluation). Additionally, it may be obtained in an axial section for the quantitative evaluation of Cerebrospinal fluid flow.[11]

Following the acquisition of the sequence, the images are retrieved in sets of 3 distinct contrasts for each plane: phase image (phase of distinction signal), re-phased image (magnitude of flow compensated signal), & magnitude (magnitude of distinction signal). The phase image is more sensitive to the identification of cerebrospinal fluid flow compared to the magnitude image, as it indicates the phase shift.[11]

The magnitude image illustrates the flow of cerebrospinal fluid as a bright signal, whereas stationary tissues are suppressed and represented as a black background. The white signal and black signal indicate forward and backward flows, respectively, as the phase image is phase-shift encoded (through-plane or in-plane). As it is phase-dependent, it includes velocity data that may be quantitatively evaluated. The pulsatile cerebrospinal fluid flow may be observed in both types of images as a result of the PC MRI gating with the cardiac cycle.[13]

All phase contrast images have been taken during 1 cardiac cycle. A series of phase & magnitude images has been taken during various cardiac phases. All images have been transferred to the workstation apparatus using Q-flow software following the data acquisition. Following the phase, images were magnified to explain the flow, and a region of interest was manually drawn to encompass all pixels that indicate a flow signal of cerebral spinal fluid. Subsequently, the cerebral spinal fluid parameter values have been automatically extracted.[12]

3. Results

Table (1) shows that the median and inter-quartile range of age of the patients was 4.5 (1 – 9.5) and range of 0.33 – 15 years. The patients were classified according to the sex to 21female patients (75.0%) and 7 male patients (25.0%).

Table 1. Age and sex of the studied patients

		NO. = 28
AGE (YEARS)	Median(IQR)	4.5 (1 – 9.5)
	Range	0.33 – 15
SEX	Female	21 (75.0%)
	Male	7 (25.0%)

Table (2) shows that 16 patients were classified according to the CSF flowmetry assessment of ETV to 12 patients have patent ETV (75.0%) and 4 patients have occluded ETV (25.0%).

Table 2. CSF flowmetry assessment of ETV among the studied patients

		NO. = 16
ETV IN MRI CSF FLOWMETRY	Patent	12 (75.0%)
	Occluded	4 (25.0%)

Table (3) shows that 4 patients were classified according to the Conventional MRI assessment of shunt to one patient has a shunt Out of its normal place (25%) and 3 patients have shunts at its normal place (75%).

Table 3. Conventional MRI assessment of shunt among the studied patients

		NO. = 4
VP SHUNT IN CONVENTIONAL MRI	Out of its normal place	1 (25%)
	At its normal place	3 (75%)

Table (4) shows that 3 patients were classified according to the CSF flowmetry assessment of VP shunt to one patient has a patent shunt (33.3%) and 2 patients have occluded shunts (66.7%).

Table 4. CSF flowmetry assessment of VP shunt among the studied patients

		NO. = 3
VP SHUNT IN FLOWMETRY	Patent	1 (33.3%)
	Occluded	2 (66.7%)

There was significant variance between conventional MRI and cerebral spinal fluid flowmetry regarding detection of ETV (Table 5).

Table 5 Comparison between conventional MRI and CSF fl.owmetry to detect ETV among the studied patients

		CONVENTIONAL MRI	MRI CSF FLOWMETRY	TEST VALUE	P-VALUE	SIG.
		No. = 16	No. = 16			
ETV	Patent	16 (100.0%)	12 (75.0%)	4.571*	0.033	S
	Occluded	0 (0.0%)	4 (25.0%)			

P-value more than 0.05: Non-significant; P-value below 0.05: Significant; P-value less than 0.01: Highly significant, *: Chi-square test

There was insignificant relation between detection of ETV in MRI CSF flowmetry and detection of ETV in conventional MRI (Table 6)

Table 6. Relation between conventional MRI and CSF flowmetry in detection of ETV among the studied patients

		ETV IN MRI CSF FLOWMETRY (GOLD)		TEST VALUE	P-VALUE	SIG.
		Patent	Occluded			
		No. = 12	No. = 4			
ETV IN CONVENTIONAL MRI	Patent	12 (100.0%)	4 (100.0%)	–	–	–
	Occluded	0 (0.0%)	0 (0.0%)			

Conventional MRI had sensitivity of 0% and specificity of 100% for the identification of ETV (Table 7).

Table 7. ROC analysis for the detection of ETV by conventional MRI.

	TP	TN	FP	FN	SENSITIVITY	SPECIFICITY	PPV	NPV	ACCURACY
ETV	0	12	0	4	0.0%	100.0%	0.0%	75.0%	0.750

TP: True positive; PPV: Positive predictive value; FN: False negative; FP: False positive; TN: True negative; NPV: Negative predictive value

4. Discussion

A variety of neurological illnesses induce abnormalities in the dynamics of cerebrospinal fluid, which subsequently result in the development of numerous neurological signs and symptoms.[14]

These diseases include communicating hydrocephalus and non-communicating hydrocephalus.[12] ETV is regarded as the 1st choice of management in all cases of congenital aqueductal stenosis.[15]

The diagnosis of hydrocephalus has been established in sixteen cases in this investigation. The age range of the individuals is four months to fifteen years, with five men and eleven women.

The evaluation of flow through the floor of the 3rd ventricle with the appropriate detection of ventriculostomy malfunction is highly confident in the phase-contrast & 3-dimensional driven equilibrium sequences. PCMRI was determined to be a dependable indicator for the functional evaluation of 3rd ventriculostomy, in addition to the existence of a flow vacuum across the floor of the 3rd ventricle.[12]

The median and inter-quartile range of age of the patients was 4.5 (1 – 9.5) and range of 0.33 – 15 years. The patients were classified according to the sex to 21female patients (75.0%) and 7 male patients (25.0%).

In the present study, all the patients with suspected aqueductal stenosis showed supraventricular dilatation by conventional MRI, all of them showed absence of flow void at aqueduct of Sylvius by 3D-Drive and no CSF flow at the aqueduct of sylvius by PCMRI.

These findings are consistent with those of El-Sayed Sakr et al.[14] and Ahmad et al.[12], who diagnosed aqueductal stenosis in their studies by conventional MRI findings, and by no CSF flow through the aqueduct of Sylvius on phase-contrast images.

Phase-contrast and 3D-DRIVE sequences have high confidence in the assessment of the flow through the floor of the third ventricle, with proper identification of ventriculostomy malfunction. Along with the presence of a flow void across the floor of the third ventricle, PCMRI was found to be a reliable indicator for functional assessment of third ventriculostomy.[12]

In our study there are 16 patients underwent ETV. By conventional MRI, All the 16 patients have dilated third ventricle with bulging floor & lamina terminalis as well as opened recesses (evidence of 3rd ventriculostomy opening related to its floor) measuring ranging from 4 – 10 mm. But 12 patients have jet of CSF flow through ventriculostomy and 4 patients have inadequate CSF flow through the stoma that can be detected by PC-MRI.

This is the gold standard role of the PCMRI, as it can detect the CSF dynamics through the ETV.

These outcomes were in accordance with those of Mohammad et al.[12] and Korbecki et al.[13], who examined the patency of ETV.

In our study, there are 4 patients who have VP shunts. By conventional MRI, 3 of the patients' shunts are in their normal place at the right lateral ventricle, and one patient has a VP shunt out of its normal place. But by PCMRI, one of them has a functioning shunt, and the other 2 patients have a non-functioning shunt by detection of CSF flow through the shunt.

And this is also a gold stander role of PCMRI as it can detect the CSF dynamics through the shunt.

These findings were consistent with those of Korbecki et al.[13], who studied the functioning and malfunction of the VP shunts.

Recommendations: The gold stander role of CSF flowmetry utilizing phase contrast MRI in the ETV is to evaluate its patency. To get better results in patients having communicating, non-communicating hydrocephalus underwent ETV we demand additional investigation with more sample size.

4. Conclusion

This investigation revealed that cerebrospinal fluid flowmetry has a gold standard role as it can detect the CSF dynamics through the ETV.

Disclosure

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All authors have a substantial contribution to the article

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