International Journal of Multidisciplinary Research and Development
www.allsubjectjournal.com
Online ISSN: 2349-4182, Print ISSN: 2349-5979
Received: 28-11-2021, Accepted: 13-12-2021, Published: 29-12-2021
Volume 8, Issue 12, 2021, Page No. 106-113

Role of MRI CSF flowmetry in differantiation between normal pressure hydrocephalus and invoultional brain changes

Ahmed Metwali Hamza Ahmed[1*], Hoda Abdelkareem Abdalsamie[1], Mohammed Sayed I Elshandawely[2]
[1] Department of Radiodiagnosis, Faculty of Medicine, Al-Azhar University, Assiut, Egypt
[2] Department Neurosurgery, Faculty of Medicine, Al-Azhar University, Assiut, Egypt

Abstract
Background: Phase contrast MR imaging is a quick and non- invasive method for its ability to distinguish between normal pressure hydrocephalus and involutional brain abnormalities.
Patient and Methods: The descriptive case-control study was conducted at Al-Azhar University, Assiut, Egypt from December 2020 to October 2021, and comprised patients with normal pressure hydrocephalus and involutional brain changes. Healthy volunteers were included as controls. Conventional magnetic resonance imaging of the brain was performed followed by the assessment of cerebrospinal fluid flow dynamics, was done at the level of the aqueduct of Sylvius.
Results: Of the 50 subjects with a mean age of 47.2 ±18.19 years (range: 18-77 years), There were 28(56%) males and 22(44%) were females. Among the patients, 20(40%) had brain atrophic changes based on magnetic resonance imaging, and 18(36%) had normal pressure hydrocephalus This study revealed that CSF flowmetry can differentiate between NPH and atrophic brain changes by the value of stroke volume, where the normal range was (15-27 ul),, and all cases of atrophic brain changes showed stroke volume between (2.7-15.9ul), where all cases of NPH showed stroke volume between (35-155ul),. This study can also confirm the diagnosis of aqueductal stenosis and differentiate it from communicating hydrocephalus (case of aqueductal stenosis showed stroke volume less than 11 µl, where communicating hydrocephalus showed stroke volume is between (11-18 ul),, signs clinically and scanning criteria.
Conclusion: In order to distinguish between normal pressure hydrocephalus and age-related brain atrophy, phase-contrast magnetic resonance imaging was proven to be a beneficial tool.

Keywords: normal pressure Hydrocephalus, MRI-CSF flowmetry, brain atrophy

Introduction
The CSF is created largely in the choroid plexus of the lateral and third ventricles, then flows into the cranial and spinal subarachnoid spaces, where it is absorbed into the blood circulatory system [1]. In the normal condition, the balance between CSF production and resorption is a constant value, therefore hydrocephalus is an excessive accumulation of CSF in the cerebral CSF spaces due to an imbalance of its production and resorption. Hyperproduction of CSF is only seen in patients with papillomas of the choroid plexus who have subsequent hydrocephalus. In the rest of the patients, hydrocephalus is caused by a lack of CSF resorption or an obstruction of CSF routes. On the one hand, arachnoid villi blockage may cause a decrease in resorption [2]. Normal-pressure In a patient with communicating hydrocephalus, the clinical triad of gait instability, dementia, and urine incontinence is known as hydrocephalus (NPH) [3].
Normal pressure hydrocephalus (INPH) can be idiopathic or develop from subarachnoid bleeding, as in tuberculoma meningitis, cranial traumas, or intracranial surgery [4]
CSF flow across the cerebral aqueduct has been quantified using cine phase-contrast MR techniques, and greater flow rates have been linked to NPH. Four phases were involved in the quantitative analysis of PC-MRI scans: (a) segmentation of Sylvius' aqueduct; (b) extraction of CSF flow-vs.-time curves; (c) aliasing correction; and (d) quantitative CSF parameter calculation [5]. Patients with idiopathic normal-pressure hydrocephalus (INPH) have been suggested as candidates for shunt surgery using aqueductal CSF stroke volume (ACSV) evaluated by phase-contrast MR imaging [6].

Aim of the work
To assess the value of phase contrast magnetic resonance imaging cerebrospinal fluid flowmetry in differentiating between normal pressure hydrocephalus and involutional brain changes.

Patient and Methods
Patient selection and evaluation
Patients group
This study included fifty individuals (28 males and 22 females) ranging in age from 18 to 77 years old who had been diagnosed with ventriculomeglly and probable hydrocephalus based on a previous radiological examination. They were referred to the radiodiagnosis department at Alazhar University Hospitals after being selected from outpatient clinics. The research was carried out between December 2020 and October 2021.

Inclusion criteria
- patient clinically diagnosed as NPH
- Patients above the age of 18 who have been diagnosed with ventriculomegaly with hydrocephalus (clinically and radiologically)

- There is no preference for one gender over another.

Exclusion criteria

Patients with established MRI contraindications, such as pacemakers, implanted magnetic devices, or claustrophobia. Patients under the age of 18 Patients with V-P shunts should have their measurements double- checked to eliminate measuring errors caused by the shunts.

Methods

All patients were subjected to

- History taking and Clinical examinations.
- Conventional MRI, All patients underwent routine MR brain imaging, including, Axial T1, FLAIR, T2 WI AND Diffusion WI, sagittal T2 WI. Mid line-sagittal FIESTA image. AllMRI scans were performed by a 1.5 Tesla Philips MACHINE & 1.5 Tesla using a head coil at MRI unit at Radio diagnosis and medical imaging department, AL-Azhar University Assiut Hospital.

Cine Phase contrast MR technique

- Cine phase contraset MR technique in all cases cardiac, gating was performed with MR compatible electrodes. Phase contrast MR images were gated to the cardiac cycle by ECG, so that the frames obtained covers the entire cardiac cycle and Sagittal and axial phase contrast MR imaging was performed Sagittal and axial phase contrast MR imaging was performed with the following acquisition parameters, Flip angle: 10 degrees, TR/TE: 21/6.8 Section thickness: 10 mm, FOV: AP 190, Matrix size: 236x182, Velocity Encoding (VENC): ranged between 5- up to 25 cm/s(average 15 cm/s), and if aliasing was observed, we decreased the encoding velocity in increments of 5-cm/sec until aliasing resolved and Encoding direction: cranio-caudal or caudo-cranial.
- For sagittal phase contrast MR imaging, the midline sagittal plane which clearly shows the aqueduct of Sylvius, and the anterior and posterior CSF spaces atthe cranio-cervical junction will be chosen from regular imaging.
- Quantitative CSF flow measurments were obtained by performing axial phase contrast MR imaging. Traditionally, axial images are acquired in a plane perpendicular to the presumed direction of CSF flow at the level of aqueduct of Sylvius.

Velocity parameters

- Peak systolic velocity (cm/sec) highest CSF velocity of the obtained measurement during the systole.
- End diastolic velocity (cm/sec) highest CSF velocity of the obtained measurement during the diastole.
- Mean (average) velocity (cm/sec) during both systole and diastole.

Volumetric flow parameters

- Mean flow rate (ml/min) = Summation of flow values/Their Numbers)
- Stroke volume (microliter) defined the mean volume of CSF passing the aqueduct during the systole = mean systolic flow X CSF duration during the systole.

Results

This study included 50 patients and 10 healthy volunteers who had normal MRI scans as a control group. Males outnumbered females in the study groups, with 56 percent of males and 44 percent of females. The patients' age ranged from 18 years to 77 years. in 10 healthy volunteers(seven males and three females) with normal conventional MRI. the systolic stroke volume in control group ranged between (15-27 ul). cine-PC MRI was also used to study the aqueductal CSF flow in the patient group (28 males and 22 females).Their ages ranged from 18 to 77 years, with mean ± SD age of 47.2 ±18.19 years and median age of 50 years. Quantitative analysis of CSF flow at the cerebral aqueduct by phase-contrast technique was done and revealed patients subdivided our patients into 5 [five] groups [Table1]

Table 1: Distribution of patients according to diagnosis.

Patient group	Diagnosis	No of patients (50)
Group I	Hyperdynamic circulation(NPH)	**18**
Group II	hypodynamic circulation (atrophic brain changes)	**20**
Group III	communicating hydrocephalus with normal flowmetry	**8**
Group IV	Arnold chiari type 1	**3**
Group V	Aqueduct stenosis	**1**

First group with hyperdynamic flow (stroke volume more than the maximum normal value), those with normal flow (stroke volume within normal values), and second group with hypodynamic flow (stroke volume less than the lowest normal value).

patients with Arnold Chiari type 1 and patients with Aqueductal stenosis Hyperdynamic flow group contained 18 individuals (12 males and 6 females).. Their ages ranged from 38 to 77 years, with mean ± SD age of 53 ± 8 years and median age of 52 years. Their clinical presentation and conventional MRI were in favor of the diagnosis of NPH (Table No 1).

The cutoff value of stroke volume in the diagnosis of hyperdynamic flow (NPH) according to our study was around 37.5 µl. The PSV, mean systolic flow, and stroke volume were significantly higher in hyperdynamic flow group than in the control group (Table 1).

Hypodynamic CSF flow was noted in patients with involutional brain changes and also in patients with aqueductal stenosis; both groups were differentiated from each other by clinical presentation and conventional MRI findings. The stroke volume in patients with involutional brain changes in our study ranged between (2.7-15.9ul),, with an average of 6.15 ± 3 µl (mean ± SD). The PSV and stroke volume were significantly lower in patients with involutional brain changes than in the control group (CASEN 2).

Patients with aqueductal stenosis showed reverberated appearance of CSF velocity curve owing to turbulence of CSF flow through the aqueduct of Sylvius caudal to the stenotic membrane, with stroke volume ranged between 1 and 7 µl, with an average of 4.8 ± 2 µl (mean ± SD). The PSV and stroke volume were significantly lower in patients with aqueductal stenosis than in the control group.

The stroke volume in patients with communicating hydrocephalus and normal flow in our study ranged between 11 and 18 µl, with an average of 13 ± 2 µl (mean ± SD). The CSF flowmetry study showed weak flow and low stroke volume within the aqueduct of Sylvius as well as the

anterior and posterior subarachnoid spaces at the cranio cervical junction in patients with Chiari malformation.

Table 2: Comparison between the control and Normal Pressure Hydrocephalus groups. regarding PSV, PDV and SSV.

	Control	NPH
PSV (cm/S)	4.49±1.33	8.6±5.6
PDV (cm/S)	2.01±1.02	3.27±2.18
SV (microliter/sec)	(15-27 ul),,	(35-155ul)

Table 3: Comparison between the control and brain atrophic changes groups.

	Control	Brain Atrophy
PSV (CM/S)	4.49±1.33	2.036±0.53
PDV (cm/S)	2.01±1.02	2.045±.087
SV(microliter/sec)	(15-27 ul),,	2.7-15.9ul

Case No 1: Fifty Five years old male presented with dementia, loss of memory, headache, urine incontinences and unstable gait.

Conventional MRI imaging: Axial (A) and Sagittal (B) T2 W images as well as flair (C) showing:

- Supra and infra tentorial ventricular dilatation
- Leukoaraiosis
- Central and peripheral involutional changes
- White matter lacunar infarction

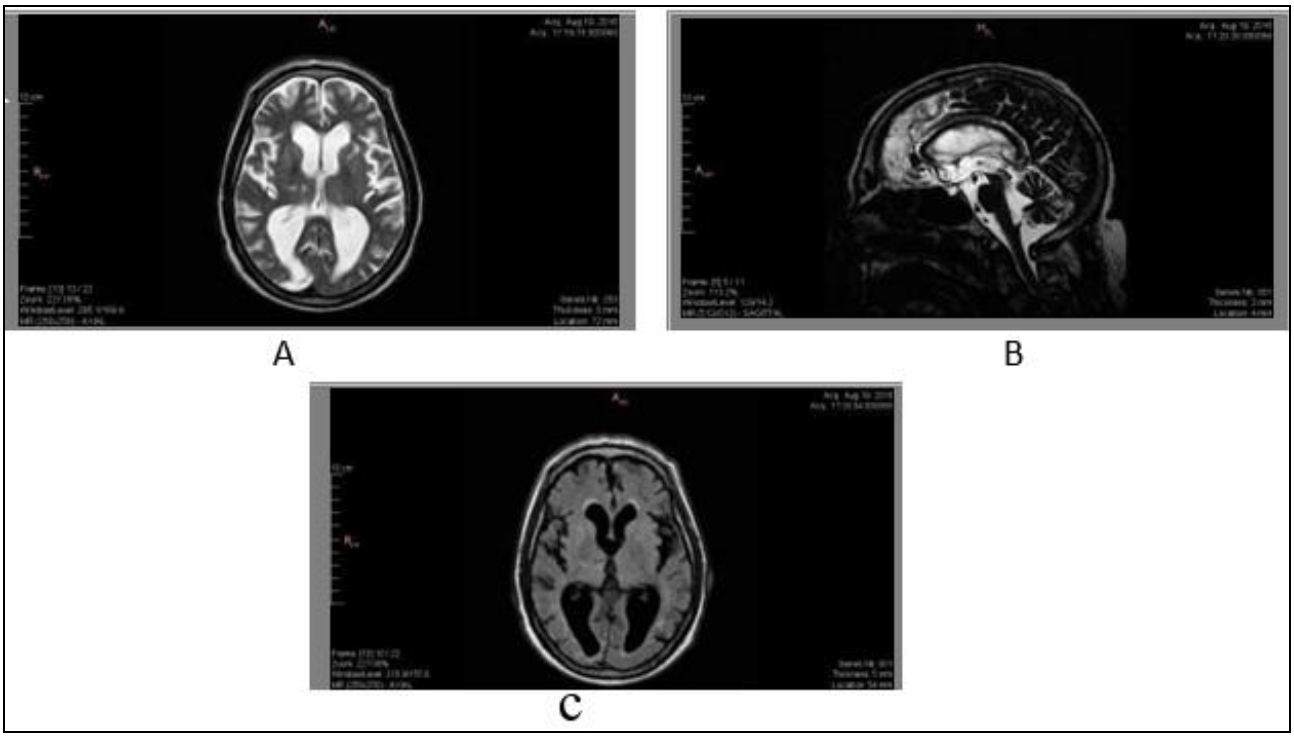

Fig 1

MRI CSF flowmetry study: Photographs showing in-plane rephrased (A), magnitude (B) and Photographs showing in-plane rephrased (A), magnitude (B) and phase images (C) of CSF flow MRI scans

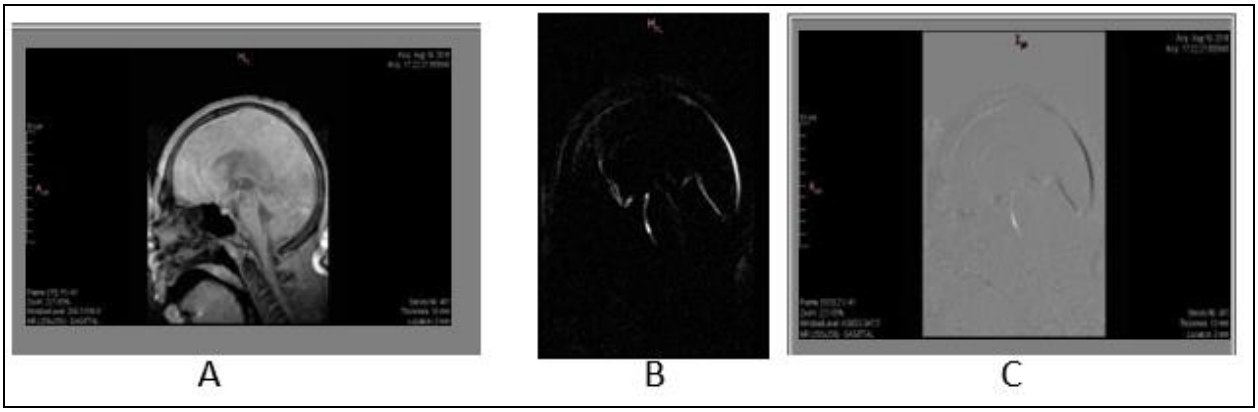

Fig 2

Quantitive analysis of CSF flowmetry by velocity curve & table show velocity and flow parameters

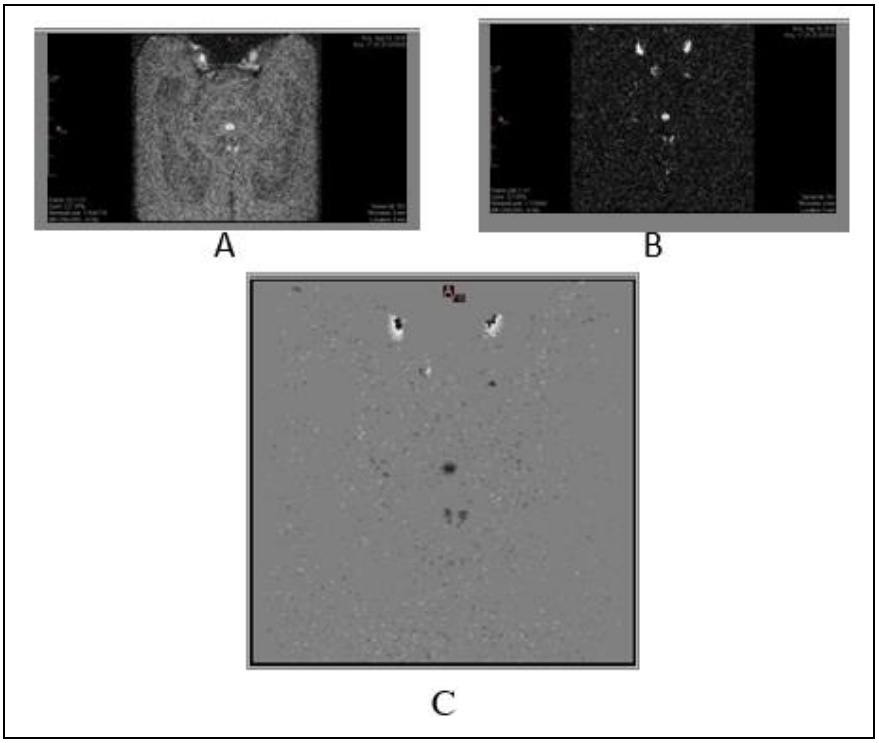

Fig 3

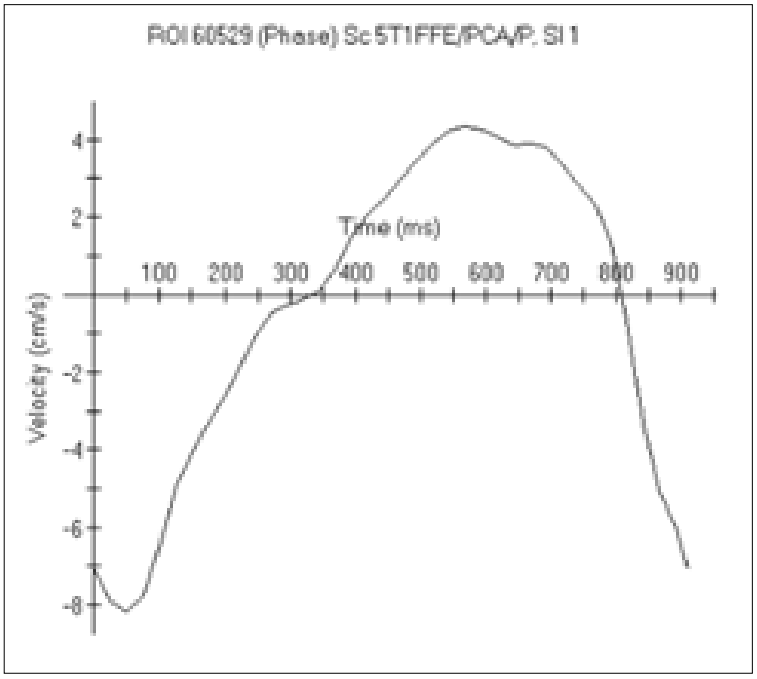

Table For ROI 60529

ROI 60529 (Phase) Sc 5T1FFE/PCA/P, SI 1

Phase	Time (ms)	Velocity (cm/s)	Flux (ml/s)	Cumul.Vol.(ml)
1	0.0	-7.07	-0.10	0.0
2	25.0	-7.89	-0.11	-0.0
3	49.0	-8.16	-0.11	-0.0
4	74.0	-7.76	-0.11	-0.0
5	99.0	-6.53	-0.09	-0.0
6	124.0	-4.97	-0.07	-0.0
7	148.0	-4.10	-0.06	-0.0
8	173.0	-3.38	-0.05	-0.0
9	198.0	-2.64	-0.04	-0.0
10	223.0	-1.93	-0.03	-0.0
11	247.0	-1.07	-0.01	-0.0
12	272.0	-0.48	-0.01	-0.0
13	297.0	-0.31	-0.00	-0.0
14	322.0	-0.12	-0.00	-0.0
15	346.0	0.11	0.00	-0.0
16	371.0	0.71	0.01	-0.0
17	396.0	1.58	0.02	-0.0
18	421.0	2.10	0.03	-0.0
19	445.0	2.47	0.03	-0.0
20	470.0	2.97	0.04	-0.0
21	495.0	3.47	0.05	-0.0
22	519.0	3.91	0.05	-0.0
23	544.0	4.26	0.06	-0.0
24	569.0	4.33	0.06	-0.0
25	594.0	4.26	0.06	-0.0
26	618.0	4.08	0.06	-0.0
27	643.0	3.87	0.05	-0.0
28	668.0	3.88	0.05	-0.0
29	693.0	3.82	0.05	-0.0
30	717.0	3.39	0.05	-0.0
31	742.0	2.82	0.04	-0.0
32	767.0	2.32	0.03	0.0
33	792.0	1.33	0.02	0.0
34	816.0	-0.63	-0.01	0.0
35	841.0	-3.33	-0.05	0.0
36	866.0	-5.05	-0.07	-0.0
37	891.0	-6.02	-0.08	-0.0
Strk Vol	909.1	-7.07	-0.10	-0.0

Fig 4

Parameters of CSF flowmetry (case 2)

Table 4

1-End diastolic peak velocity	8.16 cm/sec
2-Systolic peak velocity	-4.3 cm/sec
3-Onset of CSF.systole (RS)	346 ms
4-Time for CSF peak systole (R-PS)	275 ms
5-Duration of CSF systole	486 ms
6-systolic stroke volume	73.7 µl
7-aqueduct area	3.9mm

The CSF flowmetry study show increase flow, velocity and stroke volume within the aqueduct of sylvius denoting hyperdynamic circulation (NPH)

Case No 2: Sixty seven years old male patient presented with dementia, headache and urine incontinence by Conventional MRI Imaging**:**Axial (A) and sagittal (B) T2 W images showing supra and infra tentorial ventricular dilatation.

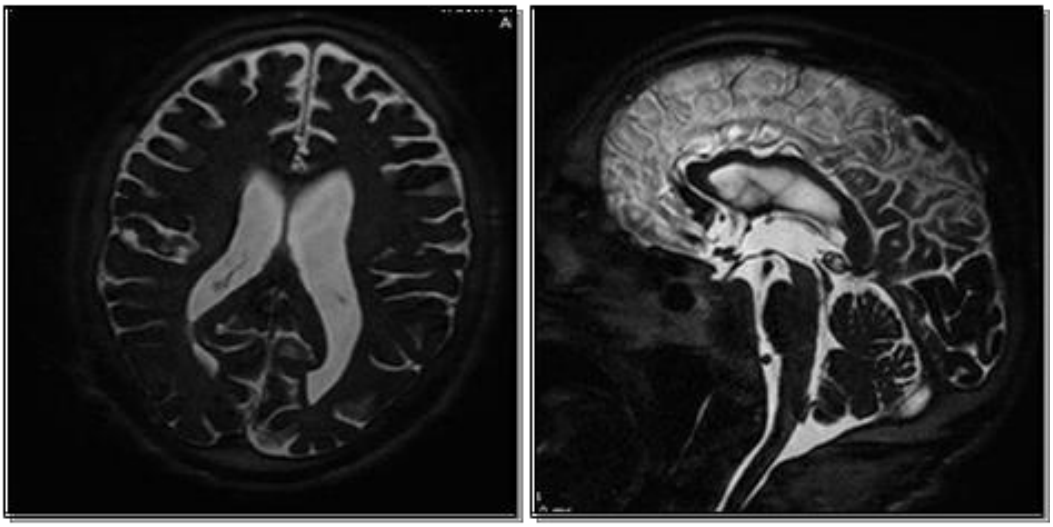

Fig 5

MRI CSF flowmetry study

Photographs showing in-plane rephrased (A), magnitude (B) and phase images (C) of CSF flow MRI scans

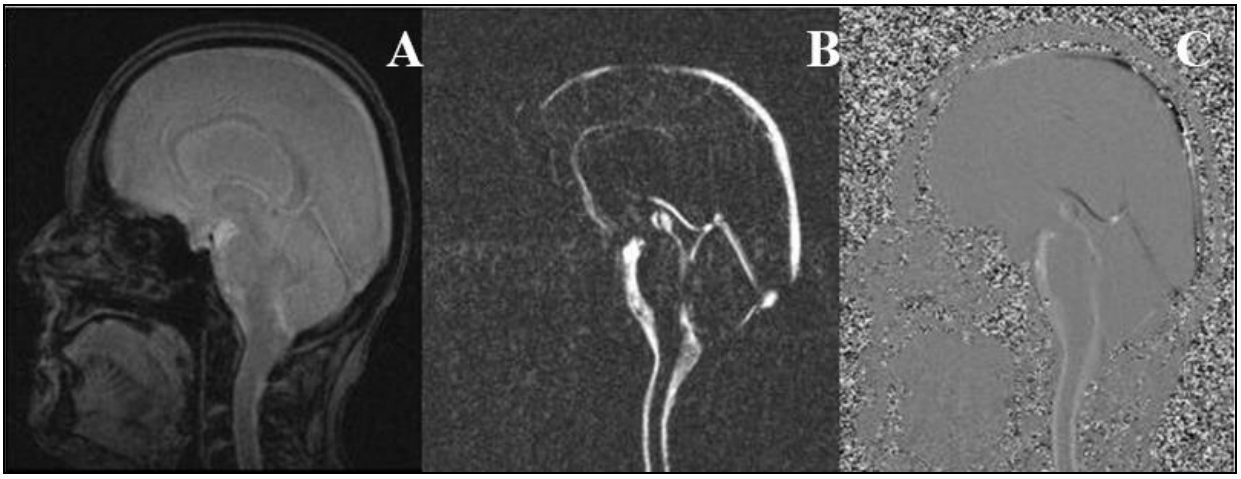

Fig 6

Photographs showing the through-plane rephrased (A), magnitude (B) and phase images (C) of CSF flow MRI scans. The red circle indicates the cross-section of aqueduct in each picture

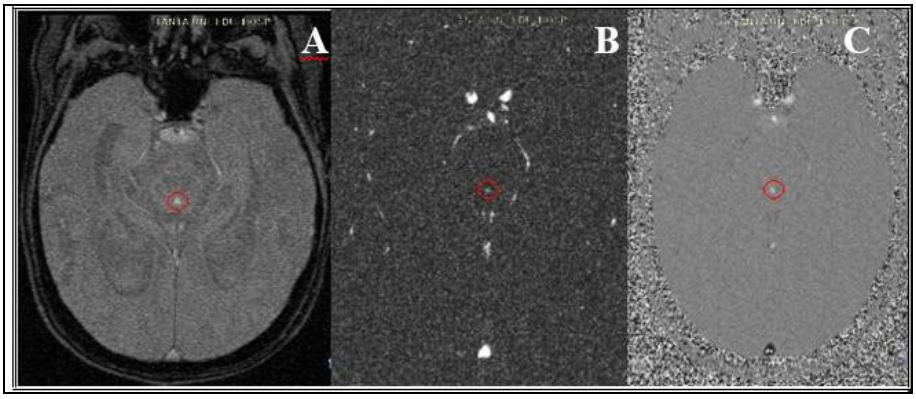

Fig 7

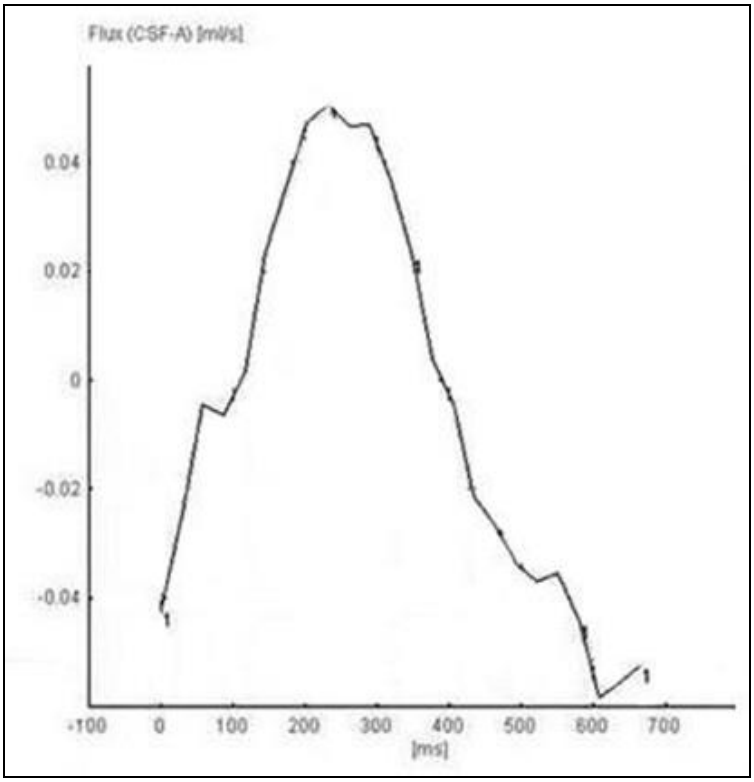

Fig 8: Quantitative analysis of CSF flowmetry by flow curve

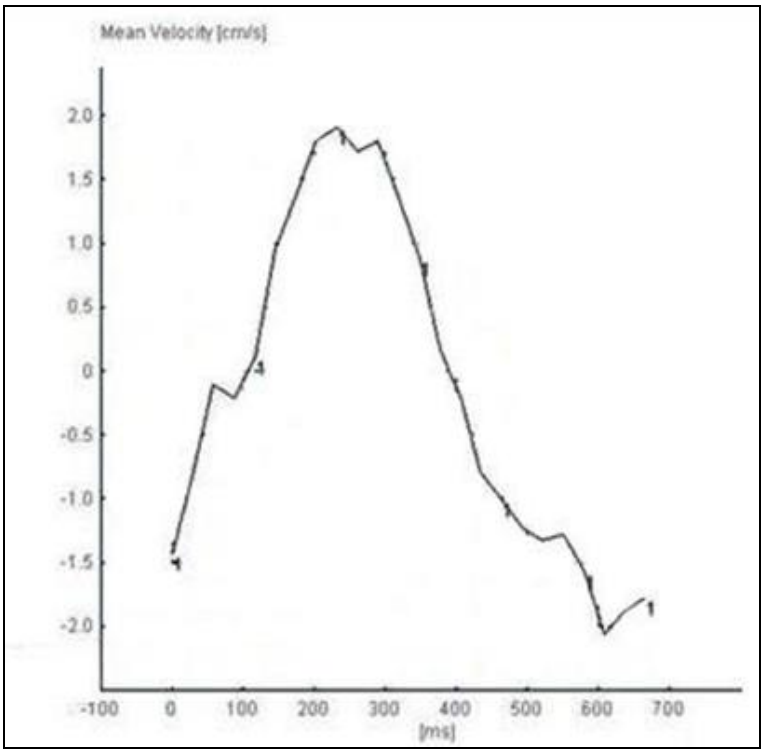

Fig 9: Quantitative analysis of CSF Flowmetry by velocity curve

Parameters of CSF flowmetry (case No 1)

Table 5

1-End diastolic peak velocity	1.8 cm/sec
2-Systolic peak velocity	-2 cm/sec
3-Onset of CSF.systole (RS)	400 ms
4-Time for CSF peak systole (R-PS)	600 ms
5-Duration of CSF systole	370 ms
6-systolic stroke volume	11.6 ul
7-Aqueduct area	2.5mm

CSF flowmetry study showing decreased flow, velocity and stroke volume within the aqueduct of sylvius denoting hypodynamic circulation (atrophy)

Discussion

This prospective, analytical study included 50 patients who had a clinical suspicion of hydrocephalus and a control group of 10 people who appeared to be healthy. By employing phase contrast MRI CSF flowmetry, we were able to assess the diagnostic value of CSF flowmetry using

its various flow indices in patients with normal pressure hydrocephalus from patient with involutional ventriculomegaly.

The systolic peak velocity and systolic stroke volume were considerably higher in pathological CSF flow dynamics in NPH patients than in controls, indicating that NPH patients exhibited hyper-dynamic aqueduct CSF flow. Blood flow to the brain is reduced in cerebral atrophy, and there were significantly lower systolic peak velocity, systolic mean velocity, and stroke volume values compared to controls, indicating a hypodynamic CSF circulation in the former. There was a substantial discrepancy between certain MRI flowmetry parameters and patient diagnosis in the current investigation, which was consistent with a previous study [7].

In the current study, the control group showed that the stroke volume was averaged 20.61±3.82 (mean±SD), range between (15-27 ul) and the peak systolic velocity was 4.49±1.33.

This was matched with Abdalla *et al* 2019 results (8) that revealed: the stroke volume was averaged 15.75±3.5, ranged between (10-21 ul) and the peak systolic velocity was 4.49±1.33(2.8-7) in control group.

Our results were very close with a study performed by Abbey *et al* 2009(9) which showed that the stroke volume was (17.41±10.11ul) in their control group.

Our result correlate with a study performed by Abdallah 2015 [10] who reported that quantitative analysis aqueductal systolic stroke volume in healthy volunteersa mean value was 27.26microliters (+/- 3.05).

Our studied Group I (NPH patients with high stroke volume) were reported marked elevation of the systolic peak and mean velocity as well as stroke volume in comparison with healthy volunteers, indicating a hyperdynamic CSF circulation. The systolic peak velocity had a mean value of 8.6cm/s (±5.6) in NPH patients compared to 4.49cm/s (±1.33) in normal volunteers with a statistical significance of (P value = 0.038*). The stroke volume was also higher in NPH patients (60.47± 25.96) compared to (20.6 ±3.82) in normal volunteers which was also statistically significant (P value =0.001*). However, the systolic mean flow was around 0.18±0.09 in NPH patients compared to 0.05±0.01 in normal individuals with statistical significance (P value = 0.001*).

In agreement with our results the study by Abdalla *et al* 2019(8) results in the NPH group reported showed that the mean Peak systolic velocity(cm/Sec.) 8.6±5.6 and stroke volume (Microliter) 60.47±25.96

As well the study by Youssef *et al*.2021, [11] reported that in the NPH group the mean Peak systolic velocity (cm/Sec.) was 10.4±3.8 and stroke volume (Microliter) was 109.5±68.4 and Dlouhy *et al* 2017 [14] found that in the NPH group the mean Peak systolic velocity (cm/Sec.) was 4.20 ± 1.16 and the stroke volume (Microliter) was 83.23 ± 27.45.

We also found that the stroke volume in group II patients in our study was averaged 8.77±4.59, range between (2.7-15.9ul) and the Peak systolic velocity was 2.0±5.3 (1.4-3.2).

In agreement with our results the study of Abdalla *et al* 2021 [12] in the atrophic brain group reported that the mean Peak systolic velocity (cm/Sec.) 2.036±0.53and stroke volume (Microliter) 6.15±3.

While in study of Abdalla *et al*.2019 [8] in the atrophic brain group revealed that the mean Peak systolic velocity (cm/Sec.) was 0.9 ± 0.3 and Systolic stroke volume (Microliter) was 9.1 ± 2.8.

As well the study by Youssef *et al* 2021(11) reported that in the atrophic dilatation group the mean Peak systolic velocity(cm/Sec.) was 4.3± 1.2and stroke volume (Microliter) was 16.2± 7.4.

Also in our study tHREE patients with chiari malformation show complete absence of CSF flow behind cervicomedullary junction our result correlate also with a study performed by (Forner, 2013) (13). From the ten patients, six cases showed flow absence at the posterior CSF column at C1 level and increased flow at the anterior column.

Also in our study ONE patients with aqueduct stenosis show Reduced CSF flow & velocity through the aqueduct by cine phase contrast image caudal to the obstruction. These findings are compatible with a study performed on 16 patients by (kim in 1999) (14). In the 16 cases, the aqueductal CSF flow maximum systolic velocity was reduced.

In conclusion

MRI CSF flowmetry is a simple and non-invasive tool for diagnosing and monitoring a variety of neurological illnesses that might produce aberrant

CSF flow. NPH can be distinguished from brain atrophy using MRI CSF flowmetry, which is a simple, quick, and cost-effective approach that improves the overall accuracy of a traditional MRI scan. CSF FLOMETRY adds to the confidence of the diagnosis by eliminating the necessity of previously utilised invasive procedures such as external lumbar drainage, lowering the risk of complications and predicting shunt responsiveness.

References

1. Craven J. cerebrospinal fluid and its circulation, anesthesia and intensive care medicine. Neurosurgery,2010:10(8):405-406.
2. Kornienko, Valery N, Pronin IN. Hydrocephalus in “Diagnostic Neuroradiology” AJNR,2009:30(9):E136-E136.
3. Adams RD, Fisher CM, Hakim S *et al*. Symptomatic occult hydrocephalus with "normal" cerebrospinal fluid pressure: a treatable syndrome. N Engl J Med,1965:273(3):117-126.
4. Algin O, Hakyemez B, Ocakoğlu G *et al*. MR cisternography: Is it useful in the diagnosis of normal-pressure hydrocephalus and the selection of good shunt responders. Diagn Interv Radio,2011:l7(2):105-111.
5. Florez YN, Moratal D, Forner J *et al*. Semiautomatic analysis of phase contrast magnetic resonance imaging of cerebrospinal fluid flow through the aqueduct of Sylvius. Magn Reson Mater Phy,2006:19(2):78-87.
6. Arif ID, Selim R. Normal Pressure Hydrocephalus. Estimated incidence of normal pressure hydrocephalus and shunt outcome in patients residing in assisted-living and extended care facilities. Neurosurg Focus,2013:22(4):5-9.
7. Abdallah AEA, Shabaan MH, Hassan MA, Yassin AN. The role of MRI-CSF flowmetry in differentiation between NPH and involutional brain changes. European Congress of Radiology. [Online] [Cited 2017 December 15]. Available from URL, 2015.
8. Rasha Najim Abdalla M, Zghair *et al*. The role of magnetic resonance imaging cerebrospinal fluid flowmetry in differentiation between normal flow

hydrocephalus and in volutional brain atrophy The 14th Scientific International Conferenc, 2019, 69(3).
9. Abbey P, Singh P, Khandelwal N *et al*. Shunt surgery effects on cerebrospinal fluid flow across the aqueduct of Sylvius in patients with communicating hydrocephalus. J Clin Neurosci,2009:16(4):514-518.
10. Abdallah A, Shabaan M, Hassan M *et al*. The role of MRI-CSF flowmetry in differentiation between NPH and involutional brain changes. European society of radiology,2015:6:1-21.
11. Youssef AT, Magdy AM, Amal A Abdul-Rahman *et al*. The role of MRI-CSF flowmetry in the diagnosis of idiopathic normal pressure hydrocephalus, Fayoum University Medical Journal,2021:(1):1-12
12. Abdulla MS, Hala H Mohamed, Alghannam MB *et al*. Evaluation of cerebrospinal fluid flow by phase-contrast technique, Menoufia Medical Journal,2021:34:1041-1047
13. forner J, Sanz-Requena R, Costa S *et al*. CSF circulation alterations in Chiari I patients: evaluation with phase-contrast MRI before and after surgery. European society of radiology, 2013, 1-6.
14. Kim DS, Choi JU, Huh R *et al*. Quantitative assessment of cerebrospinal fluid hydrodynamics using a phase-contrast cine MR image in hydrocephalus. Childs Nerv Syst,1999:15(9):461-467.