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Original article

Role of MRI CSF Flowmetry in Evaluation of Hydrocephalus in Pediatric Patients with Correlation between Thin Cuts T2, Heavy T2 and Phase Contrast

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Abstract:

Background and Aim: flow-sensitive MRI techniques have been applied to quantitatively and qualitatively assess CSF flow dynamics to discriminate between communicating and non-communicating hydrocephalus. So, we aimed to Correlate between thin cuts T2 ,3D- heavy T2 {CISS, sampling perfection with application-optimized contrasts using different flip angle evolutions (SPACE) with variable flip angle mode (VFAM) & constant angle} & phase contrast (PC) Sequences in pediatric hydrocephalus **Patient & methods**: 20 Patients with age below 18yrs old with evidence of hydrocephalic changes by clinical examination and by previous U/S,CT or MR scan with ventriculomegaly were included. 2D-T2-TSE, 3D-heavy T2 & PC-MRI were analyzed qualitatively by evaluating the capabilities of visualization of the obstructive pathology, overall image quality, severity of artifacts, and delineation of the CSF pathways. **Results**: showed that 3D heavily T2WI were superior to T2-TSE, 3D-SPACE showed fewer artifacts than 3D-CISS or T2-TSE sequences. 3D-SPACE VFAM is considered as a highly accurate alternative to PC-MRI for physiological and morphological evaluation of aqueductal patency compared to T2-TSE. **Conclusion:** 3D heavily T2 sequences are necessary for the assessment of CSF pathways in patients with hydrocephalus when compared with T2-TSE. 3D-SPACE VFAM is considered as a highly accurate alternative to PC-MRI for physiological and morphological evaluation of aqueductal patency.

Key words: Hydrocephalus, 3D-SPACE, variable flip angle, phase contrast.

Abbreviations: CSF; Cerebrospinal fluid, CISS; Constructive interference in steady state, SPACE; sampling perfection with application optimis contrasts using different flip angle evolutions, VFAM; variable flip angle mode, TSE; Turbo spin echo, PC; phase contrast.

Introduction

Hydrocephalus could be defined as disturbance of formation, flow or absorption of Cerebrospinal fluid (CSF). In infants, it leads to progressive macrocephaly, while in childhood the patient may present with signs of increased intracranial tension. It's classified into communicating and non-communicating/obstructive hydrocephalus **(1)**.

During the last two decades, flow-sensitive MRI techniques have been increasingly applied to quantitatively and qualitatively assess CSF flow dynamics. CSF flow MRI can be used to discriminate between communicating hydrocephalus and non-communicating hydrocephalus, to localize the level of obstruction in obstructive hydrocephalus, to determine whether arachnoid cysts communicate with the subarachnoid space, to discriminate between syringomyelia and cystic myelomalacia, and to evaluate flow patterns of posterior fossa cystic malformations **(2)** **.**PC-MRI aids in evaluating aqueductal patency. Axial and sagittal images are beneficial when performing PC-MRI. Axial plane images encode in the craniocaudal direction for flow quantification and sagittal plane images encode craniocaudal images for qualitative evaluation. The aqueductal web may be accurately visualised on 3D heavily T2W images These sequences have also be enreported to be useful in the assessment of the treatment response (3) .

Recent studies have shown that 3D-SPACE with VFAM technique alone is usually sufficient for the diagnosis of Aqueductal stenosis (AS) by itself. Furthermore, a heavily T2W 3D-SPACE sequence with constant flip-angle images is beneficial in demonstrating luminal morphology .Compared to the other fully balanced techniques, such as 3D-CISS and other flow compensated gradient echo sequences, the 3D-SPACE technique is less sensitive to artifacts while providing images with similar contrast and geometric resolution ***(3)***

Patients and Methods

Study population:

Our study is prospective study done at MRI unit (Seimens 1.5 Tesla SE, Germany), was used at department of diagnostic radiology, faculty of medicine, Benha university includes a total of 20 participants age group below 18 years old patients with evidence of hydrocephalic changes by clinical examination including headache vomiting initially morning poor feeding, irritability, deterioration of motor or mental activity, urine incontinence, and gait disturbances) +/-papilledema and by previous scan using U/S,CT or MR imaging criteria which include the presence of ventriculomegaly aiming to asses CSF flow abnormalities , 11 patients were known to have obstructed hydrocephalus refereed to us by the clinician due to progression of manifestation for advanced MRI assessment, 3 patients were refereed to us by the clinician after MR/CT brain examination and confirmation of hydrocephalus& 6 patients were refereed by the clinician due to clinical suspicious of hydrocephalus for routine and advanced MR assessment without previous radiological study.

They were enrolled into this study in a period extending from April 2018 to August 2019, صe used sedative drug as (oral administration of Chloral hydrate, a sedative, is used in the short-term sedation to relieve anxiety and induce sleep before the scan, its dose is. 50 mg for every kilogram of body weight , 30 minutes before the study start, the study approved by ethical committee & written consent of the patient.

MRI techniques:

First conventional magnetic resonance imaging of the brain was performed including :Axial & coronal T2WI (TR=6610, TE=112, slice thickness=3.4 mm, interval 2mm, Number of acquisition =2),Axial FLAIR (TR=7000-9000, TE=110, slice thickness=5mm, interval 2mm, Number of acquisition =2) ,Axial (2mm slice thickness) SagittalT1WI (5mm slice thickness) (TR=400-600, TE=15-25, interval 2mm, Number of acquisition =2),four different high-resolution T2W pulse sequences were employed to cover the aqueduct of sylvius & ventricular region. The 2D-TSE-T2W, 3D-CISS, and 3D-SPACE with variable flip angle mode & 3D-SPACE with constant flip angle images were in the sagittal plane. The details of the T2W pulse sequences are summarized in Table 1. All patients also had PC-MRI and T2W 3D-SPACE with variable flip angle mode sequences for confirmation of the obstructive character of the pathologic condition. Midline sagittal and axial-oblique cine PC-MRI, in which the axial-oblique images were taken in a plane perpendicular to the aqueduct, were also obtained.

Table 1 Sequence parameters for 2D-TSE-T2, 3D-SPACE, and 3D-CISS

	2D-TSE-T2	**3D-SPACE**	**3D-CISS**
Repetition time (ms)	4240	3200	5.53
Echo time (ms)	119	380	2.4
Flip angle	150	Constant or variable	50
Field of view (mm)	250	270	250
In-plane voxel size (mm)	1.5x1.5x1.5	1x1x1	1 × 1× 1
Slice thickness	1.5mm	1mm	1mm

Qualitative image analysis

All T2W images were evaluated retrospectively, Differences were resolved by consensus a 4-point scale was used to evaluate the visibility of the underlying cause of the obstructive pathology and the contrast between the lesion and parenchyma, overall image quality, severities of artifacts, and delineation of morphologic features of the CSF pathways, including the foramen of Monro, the cerebral aqueduct, and the outlet of the fourth ventricle foramina. The visualization of the obstructive pathology

and contrast change were graded as follows: (1) non-diagnostic; (2) difficult to determine, low confidence; (3) mildly difficult, good confidence; (4) not difficult, high confidence. Overall image quality was graded as follows: (1) unreadable, poor;(2) moderate; (3) good; (4) excellent. Severities of all artifacts were graded as follows: (1) severe artifacts and unreadable;(2) moderate artifacts; (3) mild artifacts; (4) no artifacts. The following scale was used for delineation of the CSF pathways:(1) no or poor delineation; (2) moderate delineation; (3) good delineation; (4) excellent delineation.

Quantitative assessment:

CSF flow quantification was performed on phase contrast images using the region of interest (ROI) measurements and a CSF flow wave form was generated. A circular ROI was drawn so to include those pixels that reflected the CSF flow signals of the cerebral aqueduct on the phase images.

Statistical analysis:

Data management and statistical analysis were done using SPSS vs.25. (IBM, Armonk, New York, United states). Numerical data was summarized as means and standard deviations. Categorical data was summarized as numbers and percentages. Comparisons between different approaches as regard visibility pathology, quality of image, artifacts and delineation CSF were done using Cochrane's Q test. Total scores of all approaches were compared using Friedman's test. Pairwise analysis was done and all pairwise comparisons were adjusted for multiple comparisons. All P values were two sided. P values less than 0.05 were considered significant.

Results:

Table (2) Cause of hydrocephalus in relation to gender & Age in our study.

	Female N	Male N	Age	Total	%
AS	6	5	3mon.-11yrs	11	55.0
Chiari malformation	1	3	4yrs-12yrs	4	20.0
Dandy Walker malformation	0	1	3months	1	5.0
Arachnoid cyst	0	1	1.5yrs	1	5.0
Post-meningitis sequale	0	3	2yrs-9yrs	3	15.0

N= number ,AS =aqueductal stenosis

T2 characteristics

Table (3) T2 characteristics in the whole study population

		N	%
Visibility pathology	Non diagnostic	5	25.0
	Low confidence	14	70.0
	Good confidence	1	5.0
	High confidence	0	0.0
Quality image	Poor	1	5.0
	Moderate	19	95.0
	Good	0	0.0
	Excellent	0	0.0
Artifacts	Severe	3	15.0
	Moderate	10	50.0
	Mild	7	35.0
	No artifacts	0	0.0
Delineation CSF	Poor	5	25.0
	Moderate	12	60.0
	Good	3	15.0
	Excellent	0	0.0

CISS characteristics

Table (4) CISS characteristics in the whole study population

		N	%
Visibility pathology	Non diagnostic	0	0.0
	Low confidence	0	0.0
	Good confidence	15	75.0
	High confidence	5	25.0
Quality image	Poor	0	0.0
	Moderate	1	5.0
	Good	18	90.0
	Excellent	1	5.0
Artifacts	Severe	1	5.0
	Moderate	2	10.0
	Mild	16	80.0
	No artifacts	1	5.0
Delineation CSF	Poor	0	0.0
	Moderate	0	0.0
	Good	10	50.0
	Excellent	10	50.0

Space C characteristics

Table (5) Space C characteristics in the whole study population

		N	%
Visibility pathology	Non diagnostic	0	0.0
	Low confidence	2	10.0
	Good confidence	9	45.0
	High confidence	9	45.0
Quality image	Poor	0	0.0
	Moderate	0	0.0
	Good	19	95.0
	Excellent	1	5.0
Artifacts	Severe	0	0.0
	Moderate	3	15.0
	Mild	11	55.0
	No artifacts	6	30.0
Delineation CSF	Poor	0	0.0
	Moderate	0	0.0
	Good	6	30.0
	Excellent	14	70.0

Space V characteristics

Table (6) Space V characteristics in the whole study population

		N	%
Visibility pathology	Non diagnostic	0	0.0
	Low confidence	1	5.0
	Good confidence	5	25.0
	High confidence	14	70.0
Quality image	Poor	1	5.0
	Moderate	0	0.0
	Good	4	20.0
	Excellent	15	75.0
Artifacts	Severe	0	0.0
	Moderate	3	15.0
	Mild	10	50.0
	No artifacts	7	35.0
Delineation CSF	Poor	0	0.0
	Moderate	0	0.0
	Good	5	25.0
	Excellent	15	75.0

Table (7)& Fig.(1): Total score percent in different approaches

	Mean ±SD	P value
T2	49.06 ±9.13 [a]	<0.001
CISS	78.75 ±8.21 [b]	
Space C	82.81 ±9.91 [b]	
Space V	89.06 ±11.97 [b]	

According to PC –MRI :

It provides only physiological data about the aqueductal patency & quantitative assessment for CSF flow through the aqueduct, but no anatomical data, more liable to artifact**. Table (3)**

Table (8) : Advantages and disadvantages of PC-MRI Sequences were given when compared to T2W 3D-SPACE with variant FAM imaging turbo spin-echo-based heavily T2W 3D-SPACE with constant FAM imaging, gradient-echo-based heavily T2W 3D-CISS data.

Sequences /parameters	3D-SPACE V	3D-SPACE C	3D-CISS	PC-MRI
Physiological data	Yes	No	No	Yes
Morphological data	Yes	Yes	Yes	NO
Artifact susceptibility	No	No	Yes	Moderate
Fluid- tissue discrimination	Good	Perfect	Perfect	Poor

- ❖ According to PC-MRI we have 11 patient had aqueductal stenosis & 9 patients had aqueductal patency.
- ❖ T2-TSE in agreement with PC-MRI in 16 out of 20 patient =80% ,while SPACE variable in agreement with PC-MRI in 20 out of 20 patient=100% ,T2-TSE demonstrate aqueductal occlusion in 4 patients (false-ve),while SPACE V & PC-MRI revealed patent aqueduct**.**(Table4)

Table (9): Diagnostic Values of T2W 2D-TSE and T2W 3D-SPACE V for Diagnosis of Aqueductal Patency using Cine PC-MRI as Reference Standard.

	T2W 2D-TSE	SPACE V
True-positive (No.)	5	9
False-positive (No.)	0	0
True-negative (No.)	11	11
False-negative (No.)	4	0
Sensitivity (%)	55%	100%
Specificity (%)	100%	100%
Negative predictive value (%)	73%	100%
Positive predictive value (%)	100%	100%

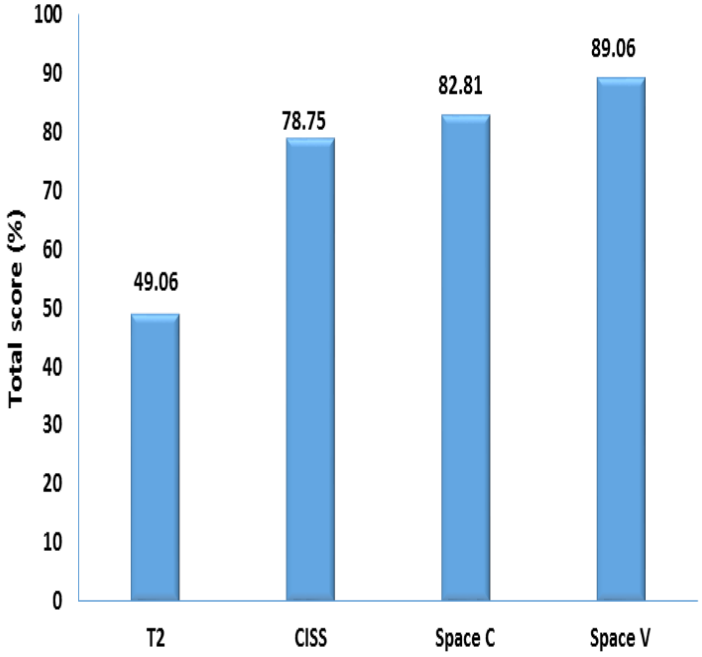

Fig.(1): Total score percent in different approaches

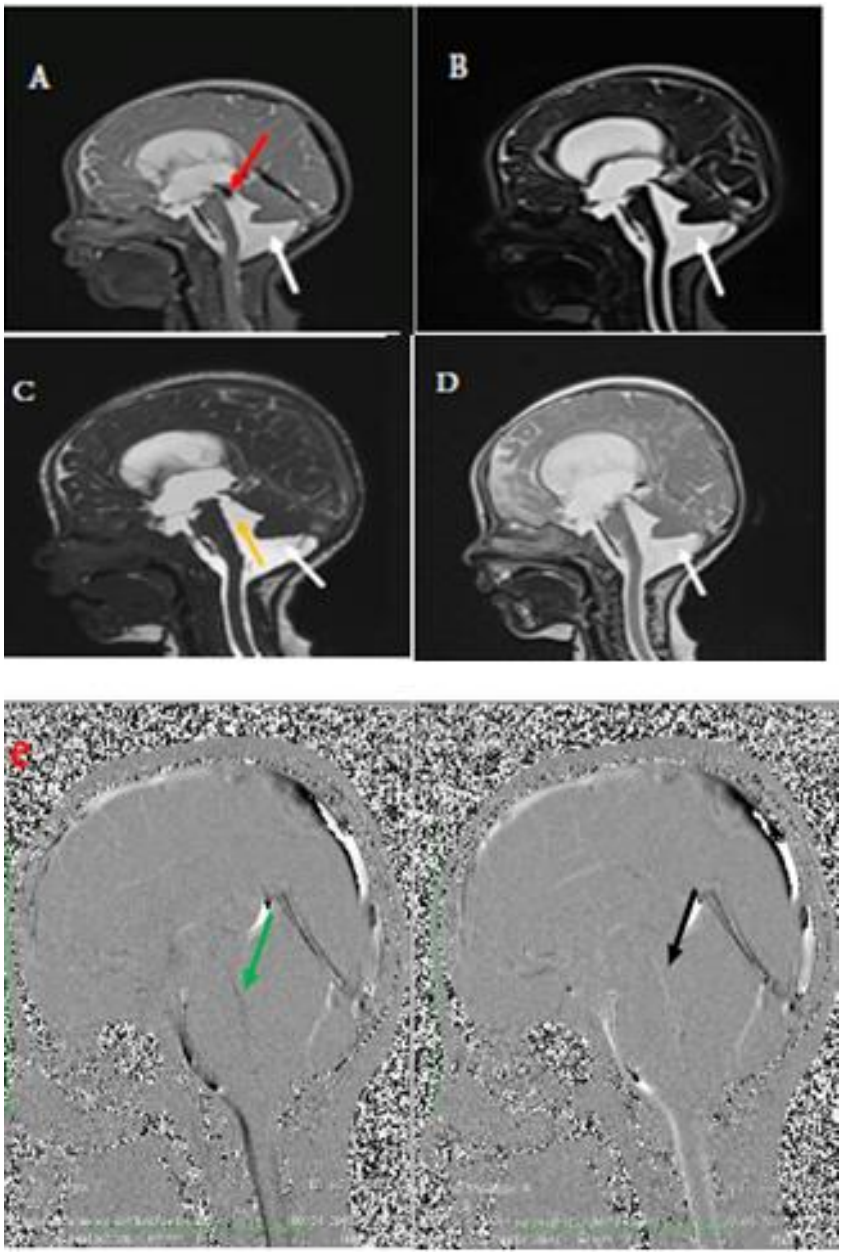

Fig.(2) a, 3D space with VAM **b,** 3D-space constant **c,** 3D- CISS **d,** T2-TSE sequence shows Communicating hydrocephalus with cystic posterior fossa **(white arrow)**& patent aqueduct is more obvious at **a,** 3D space with VAM **b,** 3D-space constant as well as **c,** 3D- CISS while no obvious sign of aqueductal patency in **d,**T2-TSE sequence, presence of signal void **(red arrow)** in 3D-space VAM ensure the patency, with notable artefact in 3D-CISS **(yellow arrow) e,** mid-sagittal phase contrast show hypo-intense signal in systole**(green arrow)**, hyper-intense signal in diastole **(black arrow)** with no anatomical data.

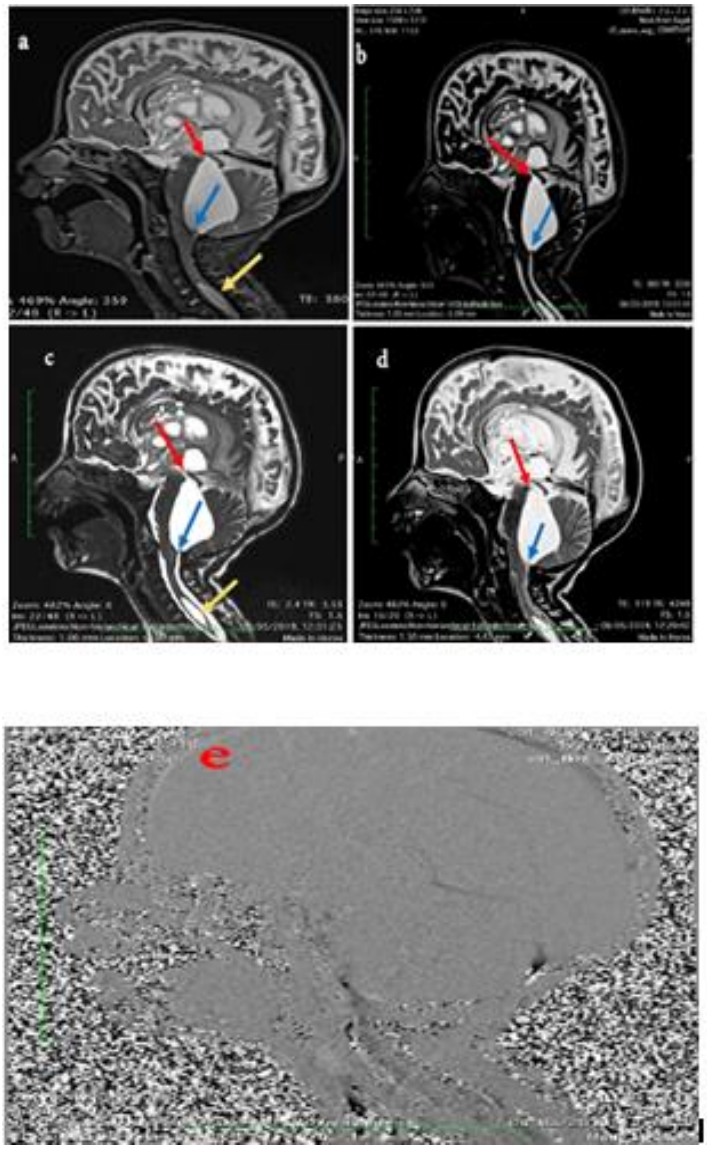

Fig.(3) a, 3D space with VAM **b,** 3D-space constant **c,** 3D- CISS **d,** T2-TSE sequence Obstructive hydrocephalus with notable web obstructing the aqueduct**(red arrow)**& another membrane is seen obstructing CSF pathway at 4th ventricle outlet **(blue arrow)** are more obvious at**a**,3D-space with VFAM **b**, 3D-space constant and**C**,3D-CISS sequences than **d**,T2-TSE, 3D space with VFAM adding more value by absence of signal void through the aqueduct ensuring the aqueductal obstruction ,entrapped 4th ventricle ,upper cervical syrinx is detected**(yellow arrow) e**, mid-sagittal phase contrast image show absence of CSF flow the aqueduct with no anatomical data.

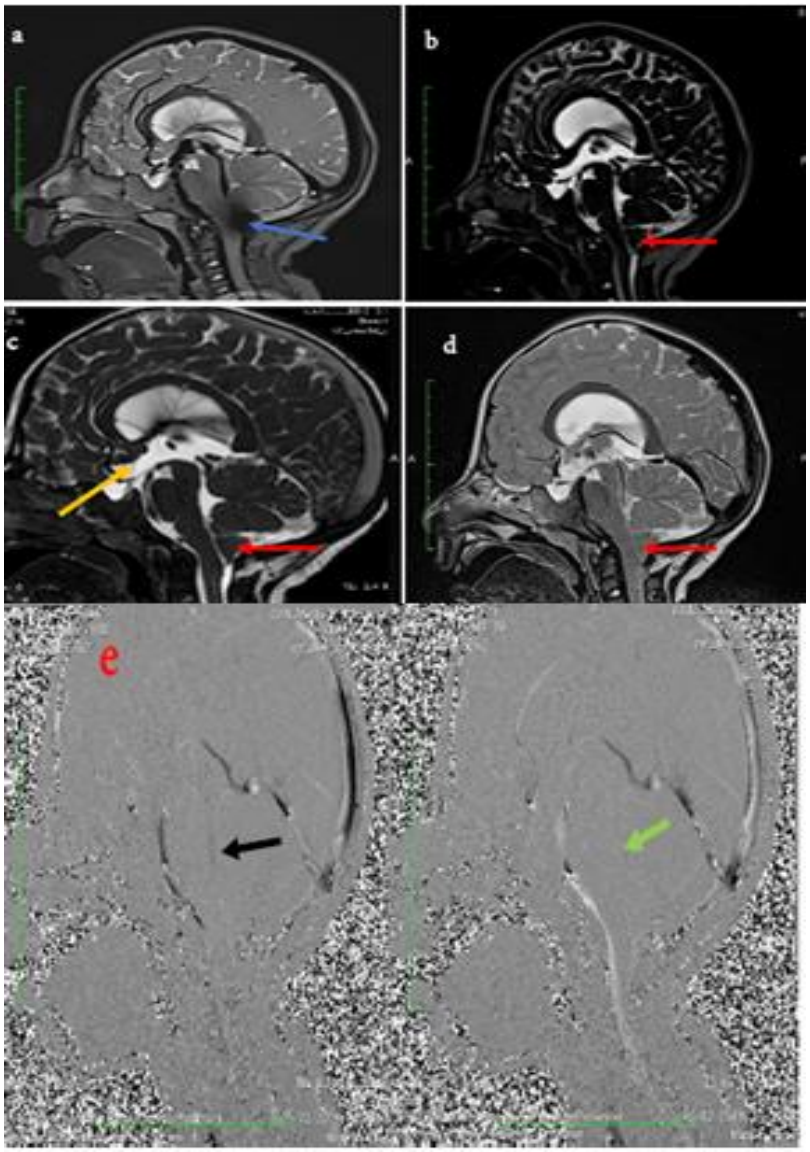

Fig.(4) a, 3D space with VAM **b,** 3D-space constant **c,** 3D- CISS **d,** T2-TSE sequence shows mild downward tonsillar herniation measures 6.33 mm below level of foramen magnum (**red arrow)**suggesting Chiari I could be detected in **a**, 3D-space variable **b,** 3D space constant **c**, 3D-CISS **d,** T2-TSE with notable turbulent flow at 4th ventricle outlet (lushka & Magendie foramina),**(blue arrow)**, detected by 3D space with VFAM ensuring the diagnosis, banding artifact is more obvious in 3D- CISS(**yellow arrow) e,** mid sagittal phase contrast images shows CSF flow through aqueduct with hyper-intense signal at diastole **(green arrow) &**hypo-intense signal at systole **(black arrow)**

Fig.(5) Quantitative assessment for chiari I shows CSF flow curve & results with high CSF peak systolic and diastolic velocity and high CSF systolic flow through the aqueduct with elevated stroke volume indicating hyper-dynamic circulation with stroke volume =36microlitre/cycle.

Discussion:

Hydrocephalus could be defined as disturbance of formation, flow or absorption of CSF. In infants, it leads to progressive macrocephaly, while in childhood the patient may present with signs of increased intracranial tension. It is classified into communicating and non-communicating/obstructive hydrocephalus **(1)**.

In agreement with **researchers** **(1)** , among causes of hydrocephalus, aqueduct stenosis(AS) is the commonest that could be idiopathic or secondary to inflammatory pathologies, In different studies , it was found that 14 out of 25 patients (4) and 9 out of 20 patients (1) were AS while in this present study it was 11 out of 20 patients have AS.

In the current study, the age of cases with aqueductal stenosis (AS) ranged from 3 mons. to 11yrs old, is relatively similar to those reported in other studies **(4 & 1)** *with age*

of 2mon. to 11yr & 2mon to 12 yrs old respectively.

Regarding sex , in the current study, AS is more predominant in females, (6 females & 5 males) and this is in agreement with the study done before [4] being (8 females & 6 males)

New MRI sequences including phase-contrast magnetic resonance imaging (PC-MRI), 3D-heavily T2W {3D-CISS and 3D-SPACE} enable evaluation of CSF-related pathologies with higher sensitivity and specificity [5].

In the current study, three different 3D heavily T2W sequences(CISS, SPACE with variable flip angle & SPACE with constant flip angle), a 2D-TSE-T2W as well as PC-MRI were evaluated in 20 patients with proven hydrocephalus.

It was stated that the most important advantage of the T2W 3D-SPACE over T2W 2D-TSE sequence was sensitivity of the aqueductal patency evaluation when compared to the T2W 2D-TSE sequence [6].

In comparing the visualization of the underlying cause of the obstructive pathology and contrast between the lesion and parenchyma, quality of image, artifacts as well as CSF pathways delineation using the three techniques, it was found that 3D heavily T2W sequences were superior to 2D-TSE-T2W sequences in all parameters ($P < 0.001$) with total score percent in 2D-TSE-T2W is 49% compared to 78% ,82% & 89% in CISS ,Space constant & variable respectively. These findings show high agreement with others [6, 7 & 8] who proved that 3D-CISS is more sensitive than conventional sequences in demonstrating fine anatomical details and obstructive membranes within the CSF pathways.

In the current study, the visualization of the obstructive pathology, overall image quality, and delineation of the CSF pathways with the 3D-SPACE images was comparable with 3D-CISS. We found that the 3D-CISS sequence is prone to ghosting and banding artifacts that result from motion of CSF flow and inhomogeneity in the main magnetic field, our result yielding that CISS has no artifacts in only 5% of our patient compared to 30% & 35% in SPACE constant & variable respectively. The 3D-SPACE sequence provided excellent images of the CSF pathways without artifacts & high CNR values between the CSF and parenchyma compared with the other techniques. This is in agreement with many other studies [6, 8, 9, 10 &11]

The 3D-T2-SPACE sequence is based on the TSE sequence that is less sensitive to motion and main magnetic field in-homogeneities [12].

The SPACE sequence with 3D acquisition can supply standardization of MR imaging protocol in patients with AS and/or obstructive hydrocephalus. Another advantage of 3D-SPACE is its capability to decrease MR imaging examination time significantly [12].

In disagreement with that [6] the T2W 3D-SPACE did not show the same benefit in the morphological evaluation of the CSF pathways, and the 3D-CISS was found to be

superior to both the T2W 2D-TSE and T2W 3D-SPACE sequences in assessment of the aqueduct morphology.

In agreement our study, some researchers [9] proved that 3D SPACE has higher resolution than 3D CISS, better delineates the morphology of CSF containing spaces, CSF-related tiny membranes &CSF hydrodynamics. We found that quality of images & delineation of CSF pathways is excellent in 75 % for each in our patients in space with VFA, 5% & 70% respectively in space constant compared to 5% & 50%respectively with CISS, so SPACE with VFAM adding more image quality & CSF delineation than SPACE constant & CISS.

The 3D SPACE sequence has been proposed as rapid and most efficient sequence for evaluating hydrocephalus [9] this is because of their effectiveness in detecting thin membrane as the cause of obstruction and better localization of obstruction. In the current study, space with VFA & constant show high confidence on visibility of pathology by ration of 70% & 45% respectively compared to 25% in CISS while 2D-TSE shows low confidence in majority of patients. This is mainly because of the insensitive conventional sequence in detecting obstructive causes like thin membranes giving a spurious result of large number of communicating hydrocephalus. T2W 3D-SPACE VFAM imaging helps to determine the etiology and location of blockage in obstructive hydrocephalus as T2W-VFAM 3D-SPACE imaging demonstrates the morphologic features of hydrocephalus [11].

It was found that the 3D-SPACE and 3D-CISS were nearly similar in their capabilities to visualize the obstructive pathology, overall image quality, and delineation of the CSF pathways [8] in agreement with our results as the total score percent of the four parameters (visibility of pathology ,image quality ,severity of artifact & CSF pathway delineation) are 78% in CISS ,82.8% in space constant & 89% in space variable respectively .which shows no significant differences were found between the 3D heavily T2W techniques.

Cine PC-MRI is the only non-invasive imaging method presently available to quantify the CSF flow. However, several drawbacks have limited the use of cine PC-MRI for evaluation of CSF flow imaging. First, PC-MRI can be incorrect in the presence of turbulent-complex flow or if the velocity encoding value is not correctly chosen. Second, this sequence is two-dimensional and demonstrates only selected plane in a slice, and the multiple slices require long acquisition times. Sometimes inadequate or false results may be seen due to partial volume effect. Although cine PC-MRI is very sensitive to demonstrate flow, it cannot provide adequate anatomical information **[6].**

The T2W 3D-SPACE may hold promise as a highly accurate alternative to PC-MRI for physiological and morphological evaluation of aqueductal patency [8].

In the current study it was found that T2W 3D-SPACE yielded the same sensitivity as the PC-MRI, which is known

to have very high sensitivity for aqueductal patency. 3D-SPACE with VFAM could provide all the information about CSF flow dynamics with a single-station image acquisition. In this sequence, restricted CSF proximal to the obstruction appeared hyper-intense, and freely floating unrestricted CSF was observed as a hypo-intense signal intensity which is called (flow void sign). 3D-SPACE with VFAM provides non-invasive evaluation of CSF hydrodynamics similar to that in PC-MRI. In addition, it can give all the morphologic information that can be obtained from other sequences in high resolution. Those features of 3D-SPACE are a great advantages for evaluation of AS and obstructive hydrocephalus. Moreover, the sequence can be applied in 3D T2-weighted and PC-MRI sequences are needed in multiple planes for the evaluation of hydrocephalus. However, 3D-SPACE could supply the same morphologic and physiologic information alone & all of this is also was confirmed by others **(9,10,12 & 13)**

The current study has several limitations. First, the main purpose of this study was to compare different sequences and the readers' subjective perception of image quality. Second, the readers of the study were not fully blinded as to which pulse sequence was being evaluated because the differentiation of CSF, parenchymal signals, and artifact distortions were different between all Sequences. Thus, they knew the sequence during the evaluation and image analysis. Third, the MRI examination was done with sedation of non- cooperative children& infants.

Conclusion:

3D heavily T2W sequences are necessary tools for the assessment of CSF pathways in patients with hydrocephalus when compared with 2D-T2-TSE weighted sequences. 3D-SPACE VFAM is considered as a highly accurate alternative to PC-MRI for physiological and morphological evaluation of aqueductal patency.

References:

1-Abdelhameed, A. M., Darweesh, E. A. F., & Bedair, M. H. (2017):. Role of MRI CSF Flowmetry in Evaluation of Hydrocephalus in Pediatric Patients. *Egyptian Journal of Hospital Medicine*, *68*(2).

2- Battal B, Kocaoglu, bulakbasi,Husman G,Tuba H, Tayfun C (2011):
Cerebrospinal fluid flow imaging by using phase-contrast MR technique The British Journal of Radiology, 84, 758–765

3-Kartal MG, Algin O (2014): Evaluation of hydrocephalus and other cerebrospinal fluid disorders with MRI: an update. Insights Imaging ;6:531–41.

4- Mohammad, S. A., Osman, N. M., & Ahmed, K. A. (2019). The value of CSF flow studies in the management of CSF disorders in children: a pictorial review. *Insights into imaging*, *10*(1), 3.

5- Yılmaz, T. F., Aralasmak, A., Toprak, H., Mehdi, E., Kocaman, G., Kurtcan, S.,etal. (2019): Evaluation of CSF flow metrics in patients with communicating hydrocephalus and idiopathic intracranial hypertension. *La radiologia medica*, *124*(5), 382-391.
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6- Ucar, M., Guryildirim, M., Tokgoz, N., Kilic, K., Borcek, A., Oner, Y., etal. (2014): Evaluation of aqueductal patency in patients with hydrocephalus: three-dimensional high-sampling-efficiency technique (SPACE) versus two-dimensional turbo spin echo at 3 Tesla. *Korean journal of radiology*, *15*(6), 827-835.

7-Dinçer A, Kohan S, Ozek MM.(2009): Is all "communicating" hydrocephalus really communicating? Prospective study on the value of 3D-constructive interference in steady state sequence at 3T. AJNR Am J Neuroradiol.;30:1898–1906.

8-Ucar, M., Tokgoz, N., Damar, C., Alimli, A. G., & Oncu, F. (2015):Diagnostic performance of heavily T2-weighted techniques in obstructive hydrocephalus: comparison study of two different 3D heavily T2-weighted and conventional T2-weighted sequences. *Japanese journal of radiology*, *33*(2), 94-101.

9-Chellathurai, A., Subbiah, K., Ajis, B. N. A., Balasubramaniam, S., & Gnanasigamani, S. (2018): Role of 3D SPACE sequence and susceptibility weighted imaging in the evaluation of hydrocephalus and treatment-oriented refined classification of hydrocephalus. *The Indian journal of radiology & imaging*, *28*(4), 385.

10-Algin, O. (2015). Prediction of endoscopic third ventriculostomy (ETV) success with 3D-SPACE technique. *Neurosurgical review*, *38*(2), 395-397.

11-Algin, O. (2018). Evaluation of hydrocephalus patients with 3D-SPACE technique using variant FA mode at 3T. *Acta Neurologica Belgica*, *118*(2), 169-178.

12- Algin, O., & Turkbey , B. (2012). :Evaluation of aqueductal stenosis by 3D sampling perfection with application-optimized contrasts using 108 different flip angle evolutions sequence: preliminary results with 3T MR imaging. *American Journal of Neuroradiology*, *33*(4), 740-746.

13-Algin, O., Turkbey, B., Ozmen, E., Ocakoglu, G., Karaoglanoglu, M., & Arslan, H. (2013). Evaluation of spontaneous third ventriculostomy by three-dimensional sampling perfection with application-optimized contrasts using different flip-angle evolutions (3D-SPACE) sequence by 3 T MR imaging: Preliminary results with variant flip-angle mode. *Journal of Neuroradiology*, *40*(1), 11-18.

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