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Role of CSF Flowmetry in prognosis of normal pressure hydrocephalus

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Abstract: Background: Background: During the last two decades, flow-sensitive MRI techniques have been applied widely for quantitative and qualitative assessment of CSF flow dynamics. **Objective**: to detect the accuracy of CSF flowmetry in diagnosis of normal pressure hydrocephalus and its use in prognosis for better selection of patients benefiting from VP shunt. **Methods**: Our cross-sectional study included 20 patients (13 males and 7 females, age range 40-85 years old), who visited the neurology and neurosurgery outpatient clinics at Kasr El-ainy hospital. Patients present with at least 2 of the classic symptoms from the clinical triad of normal pressure hydrocephalus: dementia, urinary incontinence, gait disorders. Conventional MRI and MRI CSF flowmetry examinations were done in the Kasr El Ainy hospital radiology department. MRI CSF flowmetry was done before and after CSF tapping **Results**: patients with mean systolic velocity more than 34.7 mm/sec have better chance for clinical improvement after CSF tapping and can be used to predict clinical improvement after shunt surgery with sensitivity (83 %) and specificity (75 %). This was statistically significant ($p>0.05$). Both White matter changes (low Fazekas score I/II) and widening of sylvian fissure showed high sensitivity in prediction of shunt responsiveness when compared with other morphological findings; 100 (59 – 100). Both bowing of corpus callosum and Evan index (>3) were considered of moderate sensitivity, they both showed 71% sensitivity. On the other hand, both widening of sylvian fissure and Evan index showed 0 specificity **Conclusion**: Both conventional MRI white matter changes and quantitative findings can be used in diagnosis and prognosis of iNPH patients and prediction of shunt responsiveness

Keywords: Normal Pressure Hydrocephalus, CSF Flowmetry

Introduction

Normal Pressure Hydrocephalus (NPH) is considered remarkable as it is one of the few treatable dementia causes, and neuroradiologists are involved in the diagnosis (1).

The clinical diagnosis of NPH was based on the following criteria: a history of gait disturbance, progressive mental deterioration, and urinary urgency in presence of cerebral hydrocephalic changes (2).

Normal Pressure Hydrocephalus (NPH) is a diagnostic and therapeutic challenge, thus the usefulness of a shunt remains questionable(3).

Normal Pressure Hydrocephalus (NPH) is considered to be both over-suspected clinically and underconfirmed when based on immediate and longterm response to cerebrospinal fluid diversion (4).

Conventional brain MRI (with CSF voiding sign in the aqueduct) was considered to have doubtful additional predictive value (5). Phase contrast cine MR is a useful imaging technique in evaluating CSF dynamics that affects various disease processes. Phase contrast cine MR can provide valuable additional information to conventional MRI in evaluation; surgical decision and post-operative follow up of these disease processes. CSF pulsatility and stroke volume through the aqueduct has been correlated with a positive response to shunting in patients with normal pressure hydrocephalus (6).

Patients and Methods

This is a cross-sectional trial that was conducted in Cairo university, We included 20 patients (13 males and 7 females, age range 40-85 years old), who visited the neurology and neurosurgery outpatient clinics.

Inclusion Criteria:

Patients presenting with at least 2 of the classic symptoms from the clinical triad of normal pressure hydrocephalus: dementia, urinary incontinence, gait disorders. Patients with radiological features suggestive of a diagnosis of normal pressure hydrocephalus on conventional MRI images

Exclusion criteria:

Non-compliant patients., Patients with contraindications for MRI, Patients with a cardiac pacemaker, Patients with severe claustrophobia.

Conventional MRI and MRI CSF flowmetry examinations were done.

An informed consent was obtained from all patients after discussing the management plan with them before performing the study.

All patients were subjected to detailed history taking and clinical assessment regarding their clinical symptoms including gait disturbances, dementia, urinary incontinence and any other associated symptoms or diseases.

Brief clinical examination and heart rate assessment were done for the patients before doing the radiological studies.

All patients were subjected to:

1. MRI examination:

Conventional MRI and MRI CSF flowmetry were performed on a 1.5 Tesla Achieva MRI machine.

Conventional MRI brain sequences included: axial T2, FLAIR , sagittal T2 WIs of the brain and 3D sagittal T2WIs over the aqueduct of Sylvius.

Appropriate encoding velocity (VENC) was entered into the pulse sequence protocol before obtaining CSF flowmetry phase contrast images.

Phase contrast MRI pulse sequences were ECG gated.

Images were analyzed quantitatively through quantification of multiple velocity and flow parameters obtained at different phases of CSF flow at regions of interest (e.g. cross-sectional area of the aqueduct of Sylvius), these parameters include: Mean systolic velocity (MSV), Mean systolic flow (MPF), Stroke volume (SV).

The data were represented graphically with CSF velocity or flow depicted on the y axis over the time of the cardiac cycle on the x axis.

The average duration of the MRI examination was about 15 to 20 minutes.

Patients whom CSF flowmetry study findings confirmed normal pressure hydrocephalus were referred to the neurosurgery department to perform tap test.

2. Tap test:

CSF from the subarachnoid space lowers the ICP for several hours with a possible partial normalization of CSF hydrodynamics.

3. Data analysis:

Assessment of clinical symptoms before and after CSF tap test was carried out using various clinical tests .the patients were subjected to another MRI CSF flowmetry study with both qualitative and quantitative assessment.

Statistical analysis

Data were coded and entered using the statistical package for the Social Sciences (SPSS. Data were summarized using mean, standard deviation, minimum and maximum in quantitative data. Comparisons between quantitative variables were done. Exact test was used instead when the expected frequency is less than 5. Survival curves were plotted by the Kaplan – Meier method**.**

Results

20 patients were eligible to participate in the study. Their ages ranged from 40 to 85 years old, with only two patients younger than 60 years old. Their mean age was 64.5 ± 7.85 years old. 60% of them (13 patients) were males while 40% of them (7 patients) were females. A total of 20 patients were evaluated in our study; associated diseases were present in 15 patients. All of the 20 patients had gait disturbances of different grades (100 %), while cognitive dysfunction was found in 17 patients only (90 %) and bladder symptoms were found in 17 patients (90 %). The classic triad symptoms (gait disturbance, cognitive dysfunction and bladder symptoms) were present in 14 patients (80 %).

CSF tapping was done in all 20 patients, with 11 patients showing clinical improvement after tap test (70 %) while 9 patients showed no improvement regarding their clinical symptoms (30 %). Of the 11 patients who showed clinical improvement after CSF tapping: 11 patients showed improvement as regards to all three symptoms of the clinical triad (57.14 %), 8 patients showed clinical improvement as regards to their gate disturbances (85.7 %), 8 patients reported improved mental capabilities (85.7 %) and 8 patients showed clinical improvement of their bladder symptoms (85.7%). On following up the prognosis of patients, we found that 60% of patients reported improvement concerning gait disturbance after CSF tapping.

A) CSF flowmetry quantitative parameters:

1. Mean systolic velocity (MSV)

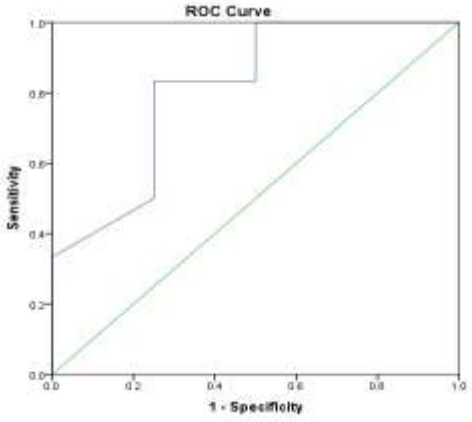


Figure (1): showing the ROC curve for measuring the accuracy of MSV as a prognostic measuring tool for clinical improvement of NPH patients.

In our study, we found that patients with mean systolic velocity more than 34.7 mm/sec have better chance for clinical improvement after CSF tapping and can be used to predict clinical improvement after shunt surgery with sensitivity (83 %) and specificity (75 %). This was statistically significant ($p<0.05$) as shown in the table below.

B) Morphological MRI findings parameters:

As regards to the conventional MRI findings, Evans index was found to be more than 0.3 in 24 patients, white matter changes (Fazekas score) were found to be mild (grade I) in 3 patients only, moderate (grade II) in 18 patients and severe (grade III) in 9 patients, widening of the sylvian fissures was found in all 30 patients while bowing of corpus callosum was found in 21 patients and narrowed posterior part of cingulate sulcus was found in 12 patients.

Table (1): showing correlation between morphological MRI findings and clinical improvement after CSF tapping:

Conventional MRI finding	Total number of patients showing this conventional MRI finding	Clinically improved patients after CSF tapping showing this conventional MRI finding	Patients showing no clinical improvement after CSF tapping showing this conventional MRI finding	Clinically improved patients after CSF tapping not showing this conventional MRI finding
Widening of sylvian fissure	20	11	9	0
Bowing of corpus callosum	20	8	6	6
Narrowed posterior part of cingulated sulcus (cingulated sulcus sign)	12	12	0	9

We tested the diagnostic accuracy for each of the morphological MRI findings in predicting the clinical improvement of patients with NPH after CSF tapping and found the following:

widening of sylvian fissure showed high sensitivity in prediction of shunt responsiveness when compared with other morphological findings; 100 (59 – 100).

bowing of corpus callosum was considered of moderate sensitivity, they both showed 71% sensitivity.

Concerning specificity, we found that cingulate sulcus sign showed the highest specificity as a predictor for clinical improvement of NPH patients after CSF tapping /shunt surgery when compared with others (100; 95 CI : 59 – 100). On the other hand, both widening of sylvian fissure and Evan index showed 0 specificity as shown in the table below.

Disproportionate enlarged subarachnoid space hydrocephalus (DESH) finding:

It is a specific pattern of communicating hydrocephalus characterized by crowding of the sulci superiorly near the vertex accompanied by enlargement of CSF spaces more inferiorly, particularly in the Sylvian fissure. The combination of ventriculomegaly, Sylvian fissure widening, and cortical sulci crowding at the vertex is known as DESH.

A 63-year-old female presented with gait disturbances in the form of shuffling gait, repeated falling to the ground, and cognitive impairment in the form of short-term memory loss for recent events and a recent onset of urinary incontinence. This patient showed clinical improvement as regards to the gait related symptoms and the urinary incontinence after CSF tapping (Figure 2:5).

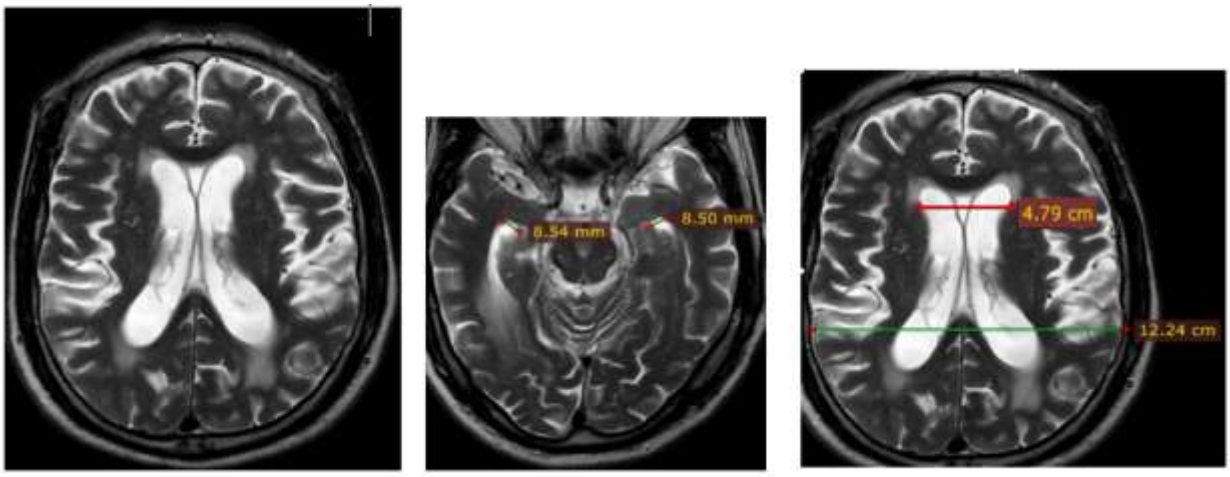
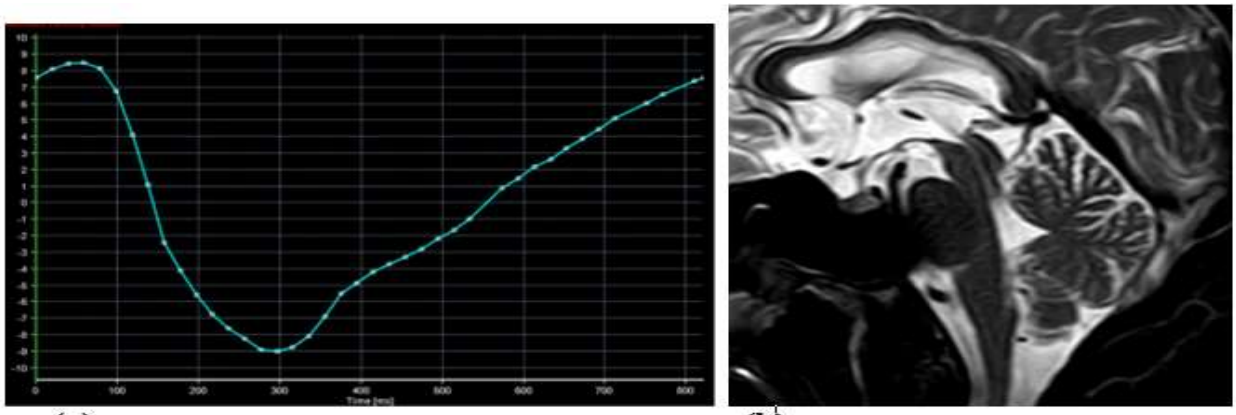


Figure (2): (a) Axial T2WIs show bilateral rather symmetrical dilatation of the lateral ventricles out of proportion to the extra axial CSF spaces with (b) widening of the temporal horns of the lateral ventricles (8.5 mm) and (c) increased Evans' index (0.39).



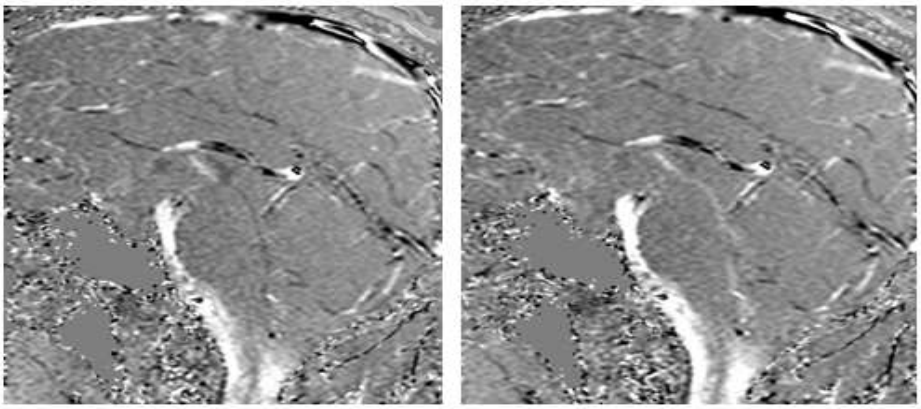


Figure (3): (a) Graph demonstrating CSF flow velocity over time along the cerebral aqueduct in phase-contrast images obtained: there is significant increase of CSF flow velocity during systole and diastole (PSV= 8.99 cm/sec, MSV=4.37 cm/sec). (b) Sagittal T2WI over the aqueduct of sylvius showing flow void across it denoting hyperdynamic CSF flow. (c) Sagittal phase contrast images showing change in signal of CSF flow across the aqueduct during the cardiac cycle, denoting free flow with no obstruction. The estimated stroke volume is 89.3 micro liter

After tap test

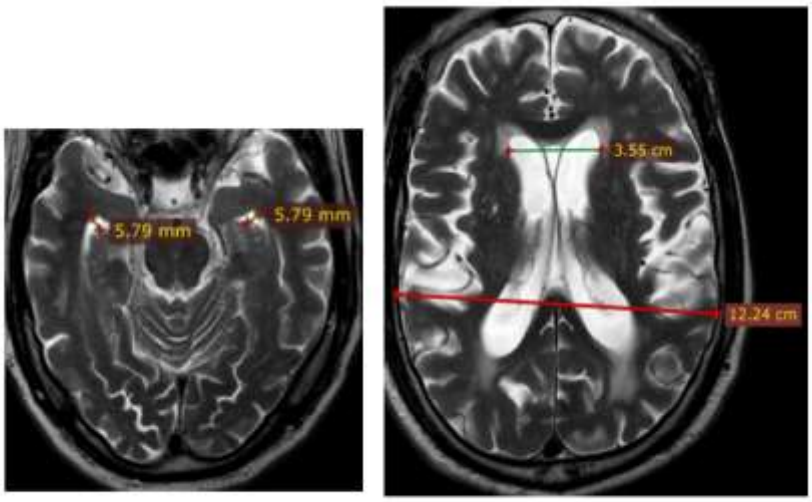


Figure (4): (a) Axial T2WIs show reduced diameter of the temporal horns of the lateral ventricles after CSF tapping (5.7 mm). (b) Decreased Evans' index back to normal (0.29).

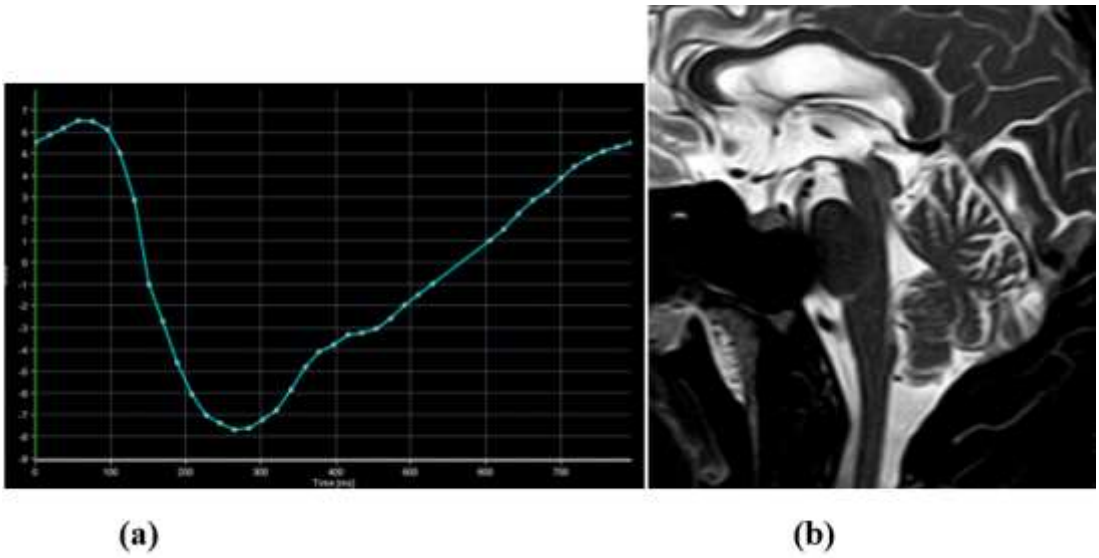


Figure (5): (a) The CSF flow graph shows relative reduction of CSF flow velocity during systole and diastole (PSV= 7.67 cm/sec, MSV=4.05 cm/sec). (b) Sagittal T2WI over the aqueduct of sylvius shows less pronounced flow void signal across it. The estimated stroke volume is 58.8 micro liter (significant reduction of SV). This patient showed clinical improvement as regards to the gait related symptoms and the urinary incontinence after CSF tapping

Discussion

Normal pressure hydrocephalus (NPH) is a syndrome characterized by the clinical triad of gait disturbance, mental deterioration and urinary incontinence, associated with ventricular enlargement and rather normal cerebrospinal fluid (CSF) pressure. The clinical presentation may be atypical and mimicked by other diseases, hence complementary tests are needed, particularly to predict post shunting outcomes and help in selection of shunt-responsive patients (8).

NPH clinical symptoms can be reversed by CSF shunting surgery. Shunting usually results in symptoms improvement with low complication incidence in patients with NPH. Definitive diagnosis is made only when there is clinical improvement after shunt surgery therefore it is essential to preoperatively select the patients who would get benefit from CSF shunting to prevent unnecessary surgery complications (9).

The purpose of this study is to evaluate the role of CSF flowmetry in diagnosis and selection of NPH patients for shunt surgery, to detect stroke volume cutoff value for choosing the patients who would benefit from VP shunt to minimize the need for unnecessary shunt surgeries with its related complications in order to improve the clinical outcomes for shunt surgeries , also the added value of post tap test CSF flowmetry in prediction of VP shunt success can be assessed.

All patients were subjected to brief clinical examination and heart rate assessment, conventional MRI and MRI CSF flowmetry before and after spinal Tap test.

During the last two decades, flow-sensitive MRI techniques have been applied widely for quantitative and qualitative assessment of CSF flow dynamics. It was also used to diagnose NPH and to discriminate it from cerebral atrophy/involution: In cerebral atrophy, blood flow to the brain is decreased, and there was markedly lower systolic peak velocity, systolic mean velocity and stroke volume values which reflect a hypodynamic CSF circulation whereas in normal pressure hydrocephalus hyperdynamic CSF flow is observed (11).

Ahmed et al, (12) in their study suggested that MRI CSF flowmetry provides an easy and non-invasive method for diagnosis, follow-up of patients with normal pressure hydrocephalus and discrimination of NPH from brain atrophy (8) .

We have confirmed the fact that MRI CSF flowmetry is one of the most important tools in diagnosis of patients with normal pressure hydrocephalus using both morphological and quantitative parameters to differentiate it from other causes of hydrocephalus , it also helps in selection of patients for shunt surgery as patients with positive response (clinical improvement) after spinal tap test showed specific radiological features in the pre and post tap test CSF flowmetry that can be used to assess patients before shunt surgery to select patients who would benefit most from shunt surgery .

We found that patients age and sex are not dependant factors for prediction of shunt response in our study as we found no significant statistical differences for tap test response among both males, females , older and younger patients.

This is also agreed with Halperin et al, (14) study which suggested that positive response to external lumbar drainage increases the chance of response to shunting, and the chance of successful shunting does not decrease with increasing patient age.

In our study we found no correlation between underlying diabetes mellitus, hypertension and clinical improvement after CSF tapping as there was no statistical significance of these diseases among both the positive and negative tap test responders .

As regards the morphological MRI features in NPH patients**:**

As regards CSF assessment we found that peak systolic velocity (PSV), mean systolic velocity (MSV) and stroke volume (SV) are significantly elevated in all tap test positive responders patients.

This was found concordant with Ahmed et al, (12) study where they found that all the CSF flow quantitative parameters were significantly higher in NPH group as compared to the control group denoting hyperdynamic CSF flow in NPH patients.

In our study we found that patients with mean systolic velocity more than 34.7 mm/sec have better chance for clinical improvement after CSF tapping and can be used to predict clinical improvement after shunt surgery with sensitivity (83 %) and specificity (75 %).

Conclusion

MRI CSF flowmetry study can be used as a tool to diagnosis and prognosis of the clinical outcome of VP shunt placement in normal pressure hydrocephalus patients. Both conventional MRI white matter changes and DESH findings can be used in diagnosis of iNPH patients and prediction of shunt responsiveness.

References:

1. Bradley W G. (2000). Normal pressure hydrocephalus: new concepts on etiology and diagnosis. American Journal of Neuroradiology, 21(9), 1586-1590.
2. Vanneste,JAL.(2000).Diagnosis and management of normal pressure hydrocephalus. Journal of neurology, 247(1), 5-14.
3. McGirt M J, Woodworth G, Coon A L, Thomas G, Williams M A, Rigamonti D. (2005). Diagnosis, treatment, and analysis of long-term outcomes in idiopathic normal- pressure hydrocephalus. Neurosurgery, 57(4),699-705.
4. Espay AJ, DaPrat GA, Dwivedi AK, Rodriguez Porcel F, Vaughan JE, Rosso M, Mandybur G T. (2017). Deconstructing normal pressure hydrocephalus: ventriculomegaly as early sign of neurodegeneration. Annals of neurology, 82(4), 503- 513.
5. Duinkerke A, Williams M A, Rigamonti D, Hillis A E. (2004). Cognitive recovery in idiopathic normal pressure hydrocephalus after shunt. Cognitive and behavioral neurology, 17(3),179-184.
6. Bradley W G, Quencer R M. (2000). Hydrocephalus and cerebrospinal fluid flow. Magnetic resonance imaging, 3,1483-1506.
7. Senger K P S, Singh R K, Singh A K, Singh A, Dashottar S, Sharma V, Mishra A. (2017). CSF flowmetry: an innovative technique in diagnosing normal pressure hydrocephalus. Int J Adv Med, 4,682-687.
8. Damasceno, B. P. (2015). Neuroimaging in normal pressure hydrocephalus. Dementia & neuropsychologia, 9, 350-355.
9. Ammar, A., Abbas, F., Al Issawi, W., Fakhro, F., Batarfi, L., Hendam, A., ... & Al Jehani, H. (2017). Idiopathic Normal-Pressure Hydrocephalus Syndrome: Is It Understood? The Comprehensive Idiopathic Normal-Pressure Hydrocephalus Theory (CiNPHT). In Hydrocephalus (pp. 67-82). Springer, Cham.
10. Mori, E., Ishikawa, M., Kato, T., Kazui, H., Miyake, H., Miyajima, M., ... & Arai, H. (2012). Guidelines for management of idiopathic normal pressure hydrocephalus. Neurologia medico-chirurgica, 52(11), 775-809.
11. Tawfik, A. M., Elsorogy, L., Abdelghaffar, R., Naby, A. A., & Elmenshawi, I. (2017). Phase-contrast MRI CSF flow measurements for the diagnosis of normal-pressure hydrocephalus: observer agreement of velocity versus volume parameters. American Journal of Roentgenology, 208(4), 838-843.
12. Ahmad, N., Salama, D., & Al-Haggar, M. (2021). MRI CSF flowmetry in evaluation of different neurological diseases. Egyptian Journal of Radiology and Nuclear Medicine, 52(1), 1-10.
13. Oertel, J. M., & Huelser, M. J. (2021). Predicting the outcome of normal pressure hydrocephalus therapy—where do we stand?. Acta Neurochirurgica, 163(3), 767-769.
14. Halperin, J. J., Kurlan, R., Schwalb, J. M., Cusimano, M. D., Gronseth, G., & Gloss, D. (2015). Practice guideline: Idiopathic normal pressure hydrocephalus: Response to shunting and predictors of response: Report of the Guideline Development, Dissemination, and Implementation Subcommittee of the American Academy of Neurology. Neurology, 85(23), 2063-2071
15. Witthiwej, T., Sukeeyamanon, W., Songsaeng, D., Ngamsombat, C., Charnchaowanish, P., Itthimathin, P., ... & Chawalparit, O. (2017). MRI study of morphologic features and CSF hydrodynamics to predict ventriculoperitoneal shunt responsiveness in normal pressure hydrocephalus. J Med Assoc Thai, 100(4), S32-S40.
16. Hashimoto, M., Ishikawa, M., Mori, E., & Kuwana, N. (2010). Diagnosis of idiopathic normal pressure hydrocephalus is supported by MRI-based scheme: a prospective cohort study. Cerebrospinal fluid research, 7(1), 1-11.