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MRI Imaging Technique in Assessment of the Commonest Cerebrospinal Fluid (CSF) Flow Abnormalities

[1]Helal Khalaf H Alnassr, [2]Shahad Nasser Alfowyas

Abstract: **Progressive advancements in magnetic resonance imaging (MRI) innovations allow us to better evaluate CSF blood circulation. Therefore, MRI helps in the medical diagnosis of diseases that result from alterations of the CSF circulation. The aim of this review was to evaluate the role of MRI flow imaging technique in the assessment of the most common CFS flow disorders, we also intended to discuss main two CSF disorders, which are the hydrocephalus, and Spontaneous intracranial hypotension (SIH). A search of literature through databases; MIDLINE, and EMBASE was conducted to identified related articles to our concerned topic (Role of MRI in assessment of CSF flow disorders) we were published up to November 2016, Following Mesh terms were used in our search through the MIDLINE; MRI, PC-MRI, and MR imaging, Combined with CSF, cerebrospinal fluid, disorders, CSF flow, and hydrocephalic. We limited our search to English language published articles with human subject.MRI is not just helpful in the medical diagnosis of CSF-flow conditions, however also helps in therapy planning and post-surgery follow-up of the patients. With the advances in MRI systems, freshly established series and techniques enable precise evaluation of numerous CSF-related disorders, the most essential which is hydrocephalus.**

Keywords: **MRI Imaging technique, Spontaneous intracranial hypotension (SIH).**

1. INTRODUCTION

The CSF volume is around 150 ml in adults; 125 ml is dispersed in the cranial and spine subarachnoid areas and 25 ml is found in the ventricles [1]. A volume of 400-500 ml is secreted and approximately 330-- 380 ml of CSF enters the venous circulation everyday (**Figure 1**) [2]. CSF is produced in the choroid plexus, brain parenchyma, spinal cord, and ependymal lining of the ventricles. The majority of is secreted in the lateral ventricles and leaves the ventricles through the foramen of Monro to go into the 3rd ventricle. From there, the CSF streams into the fourth ventricle through the aqueduct. It leaves the fourth ventricle by the foramen of Magendie and foramina of Luschka and gets in the subarachnoid area. Cerebrospinal fluid is essentially absorbed into the internal jugular system by means of cranial arachnoid granulations (**Figure 1**) [2]. Multiple experiments indicate that movement along nerve roots and leaving vessels likewise plays a function [1,3]. In addition, absorption to the interstitial compartment happens by means of the Virchow-Robin areas [1].

Progressive advancements in magnetic resonance imaging (MRI) innovations allow us to better evaluate CSF blood circulation. Therefore, MRI helps in the medical diagnosis of diseases that result from alterations of the CSF circulation. Hydrocephalus, which constitutes a significant CSF-related disorder, is well demonstrated utilizing MRI. MRI likewise assists to discriminate the aetiology of the disease [1,4]. The supplied data are essential for preparing the management along with follow-up of the patients. MRI is likewise effective in the diagnosis and treatment preparation of other CSF disorders such as CSF leak, arachnoid cysts [4,5].

During the last two decades, flow-sensitive MRI techniques have been significantly applied to quantitatively and qualitatively evaluate cerebrospinal fluid (CSF) flow characteristics [6]. CSF circulation MRI can be utilized to discriminate between interacting hydrocephalus and non-communicating hydrocephalus, to localize the level of obstruction in obstructive hydrocephalus, to identify whether arachnoid cysts interact with the subarachnoid area, to distinguish in between arachnoid cysts and subarachnoid area, to discriminate between syringomyelia and cystic myelomalacia, and to evaluate circulation patterns of posterior fossa cystic malformations. This imaging method can also supply substantial information in pre-operative examination of Chiari 1 malformation and normal pressure hydrocephalus and post-operative follow-up of patients with neuroendoscopic 3rd ventriculostomy (NTV) and ventriculoperitoneal (VP) shunt [6,7,8,9].

The aim of this review was to evaluate the role of MRI flow imaging technique in the assessment of the most common CFS flow disorders, we also intended to discuss main two CSF disorders, which are the hydrocephalus, and Spontaneous intracranial hypotension (SIH).

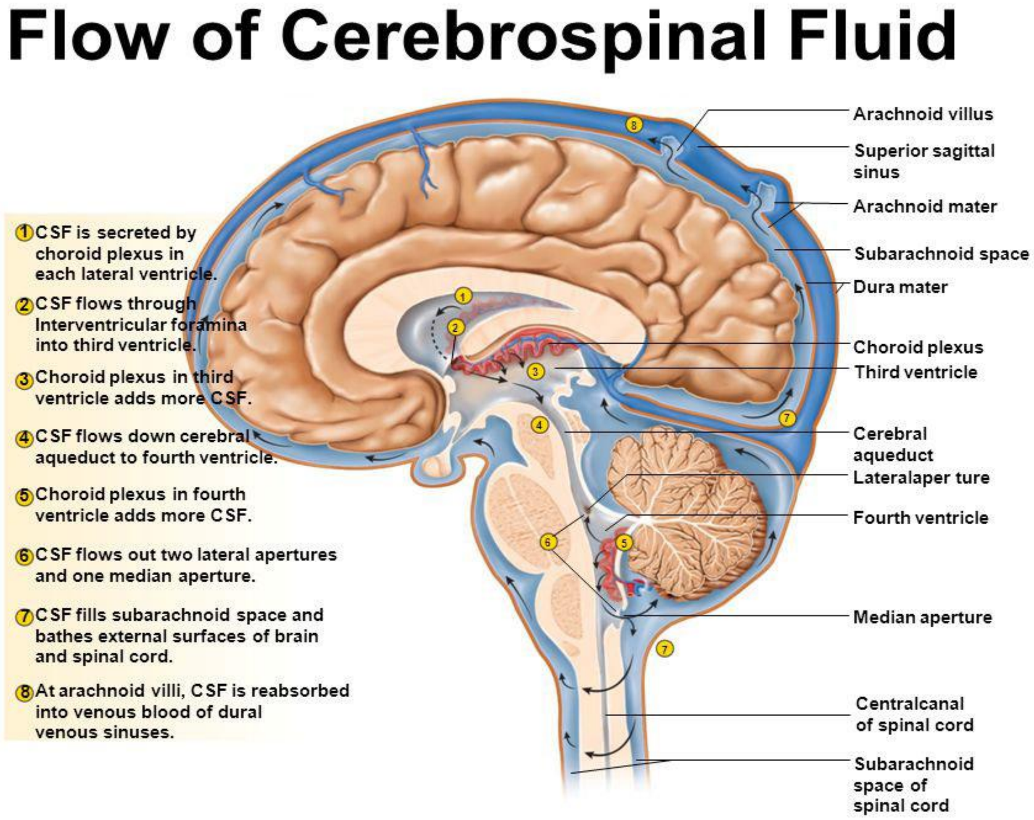

Figure 1: Circulation of CSF [2]

2. METHODOLOGY

A search of literature through databases; MIDLINE, and EMBASE was conducted to identified related articles to our concerned topic (Role of MRI in assessment of CSF flow disorders) we were published up to November 2016, Following Mesh terms were used in our search through the MIDLINE; MRI, PC-MRI, and MR imaging, Combined with CSF, cerebrospinal fluid, disorders, CSF flow, and hydrocephalic. We limited our search to English language published articles with human subject.

3. RESULTS & DISCUSSION

➢ **Most common CSF disorders:**

Hydrocephalus is a complicated condition that can establish for numerous reasons. Dilatation of the ventricular system may result in loss of brain cells leading to a variety of neurological signs, stroke, and sometimes even death due to press used on the brain parenchyma [4]. The causes of CSF boost are often obstructive diseases such as cystic sores, tumours or obstructive membranes [5, 10,11]. Rarely, it may be the outcome of extreme CSF production, which might be because of pathologies at the sites where CSF production takes place. More regularly, it is be because of a blockage in the ventricular system (non-communicating or obstructive type) or interrupted CSF absorption or flow (communicating type) [12]. In young people and kids, obstructive-type hydrocephalus is the most typical type [10,13,14]. In some circumstances, such as meningitis, both absorption and flow may be interrupted, which is specified as complex-type hydrocephalus [15]. There are numerous theories regarding the pathophysiology of hydrocephalus, just recently the most extensively accepted one has been Greitz's hyperdynamic flow theory, which divides hydrocephalus into 2 main groups, severe and hydrocephalus [12].

Spontaneous intracranial hypotension (SIH) is caused by spontaneous cerebrospinal fluid (CSF) leaks and is understood to trigger orthostatic headaches [18]. The precise causes of spontaneous spinal CSF leaks are still unidentified; however, a structural weakness of the spinal meninges is thought to be among them [19]. It has been presumed that a decline in CSF volume is more vital than CSF pressure for explanation of the pathophysiology of SIH. Therefore, an alternative term, "spontaneous CSF hypovolemia," has actually been presented [20]. This is, nevertheless, an oversimplification. For instance, also spontaneous CSF rhinorrhea or otorrhea may cause loss of CSF volume, however the typical imaging and scientific functions of SIH are seldom seen with those conditions. The final typical pathway is most likely a modified circulation of craniospinal elasticity due to spinal loss of CSF, not CSF hypovolemia [21] and "spontaneous back CSF leakage" is used as a descriptive term [18].

- **Phase-Contrast MR Imaging (PC MRI) in diagnosis of CSF flow disturbances:**

The PC MRI generates signal contrast in between streaming and fixed nuclei by sensitising the phase of the transverse magnetisation to the speed of movement [22]. 2 data sets are acquired with opposite sensitisation, yielding opposite stage for moving nuclei and similar phases for fixed nuclei [23]. For stationary nuclei, the net phase is absolutely no, and their signal is eliminated in the final image. However, streaming nuclei move from one position in the field gradient to another between the time of the first sensitization which of the 2nd sensitization. Because stage varies with position in the field, the net phase after subtraction of the two information sets is non-zero, and there is recurring signal from streaming CSF [24]. When the two data sets are subtracted, the signal contribution from fixed nuclei is gotten rid of and only streaming nuclei are seen (**Figure 2**) [26]. Prior to PC MRI data are acquired, the anticipated maximum CSF flow velocity should be entered into the pulse series procedure (velocity encoding (VENC)) [25]. To obtain the optimum signal, the CSF circulation velocity ought to be the same as, or slightly less than, the chosen VENC. CSF flow velocities greater than VENC can produce aliasing artefacts, whereas velocities much smaller sized than VENC lead to a weak signal (24,25). The mean VENC value is 5-8 cm s^{-1} for standard CSF circulation imaging. Low VENC values (2-4 cm s^{-1}) can be valuable in the discrimination of interacting and non-communicating arachnoid cysts, and in the evaluation of the ventriculoperitoneal shunt patency. In typical pressure hydrocephalus, significantly greater VENC worths (20-25 cm s − 1) should be chosen owing to hyperdynamic CSF circulation within the cerebral aqueduct.

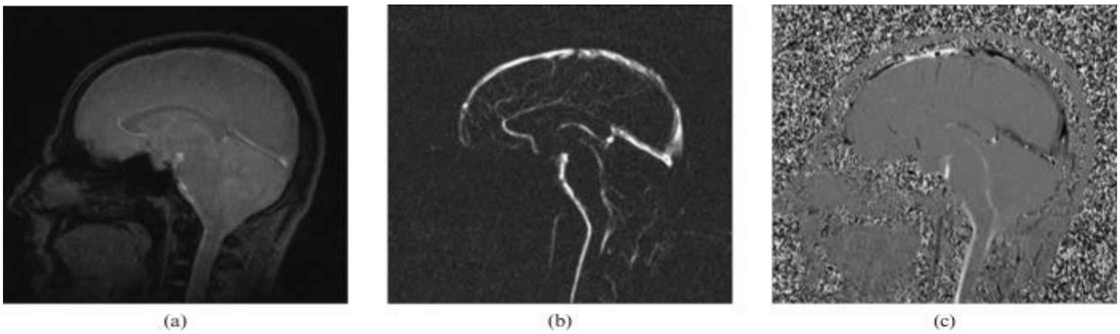

Figure 1: (a) Re-phased image is a magnitude of flow compensated signal, in this image the flow is bright and background is visible, (b) magnitude image is a magnitude of difference signal, in this image the flow is bright and the background is suppressed and (c) phase image is a phase of difference signal, in this image forward flow is bright, reverse flow is black and background is mid-grey. [26]

In previous studies, different PC-MR values were reported for healthy subjects. These variations may result from different magnetic fields, makers, sites of detection, age [27], sex [27,28], or BMI. PV varied significantly with age, and it was much greater in topics below 14 years of ages [27,29]. The stroke volume and flux were substantially higher in males compared to women [28]. Elderly cases had less parenchyma viscoelasticity and lower CSF circulation [28,30]. Since age, sex, and BMI could affect the PC-MR specifications, we adjusted them in our data appropriately.

MRI in normal pressure hydrocephalus:

Normal pressure hydrocephalus (NPH) is a state of chronic hydrocephalus in which the CSF pressure is in physiological variety, but a small pressure gradient continues between the ventricles and the brain parenchyma. This pathology is explained in senior patients and has a traditional symptom triad of gait disturbance, urinary incontinence and dementia [31]. The diagnosis of NPH is supported by the radiological findings of ventricular dilatation: out of proportion cortical sulcal augmentation, up bowing of corpus callosum, flattening of the gyri versus the calvarium and increased or typical CSF flow void. In correctly chosen patients, ventricular shunting leads to resolution of symptoms and slows progressive deterioration. The objective of ventriculoperitoneal shunting is not to decrease mean pressure, but to dampen the pulse pressure by supplying extra capacitance to the ventricular system [8,9]. PC MRI works in selection of patients for shunt placement. Caudal and rostral peak aqueduct CSF circulation was considerably increased in patients with NPH. While a CSF flow measurement of less than 18 ml min^{-1} with a sinusoidal circulation pattern is regular, a flow of greater than 18 ml min^{-1} recommends idiopathic NPH at the cerebral aqueduct [32]. Demonstration of increased pulsatility throughout the cerebral aqueduct has been associated with a favourable action to shunting. CSF velocity imaging is the most sensitive method for finding symptomatic patients with a shunt responsive NPH on the basis of hyperdynamic CSF circulation (**Figure 3**) [9].

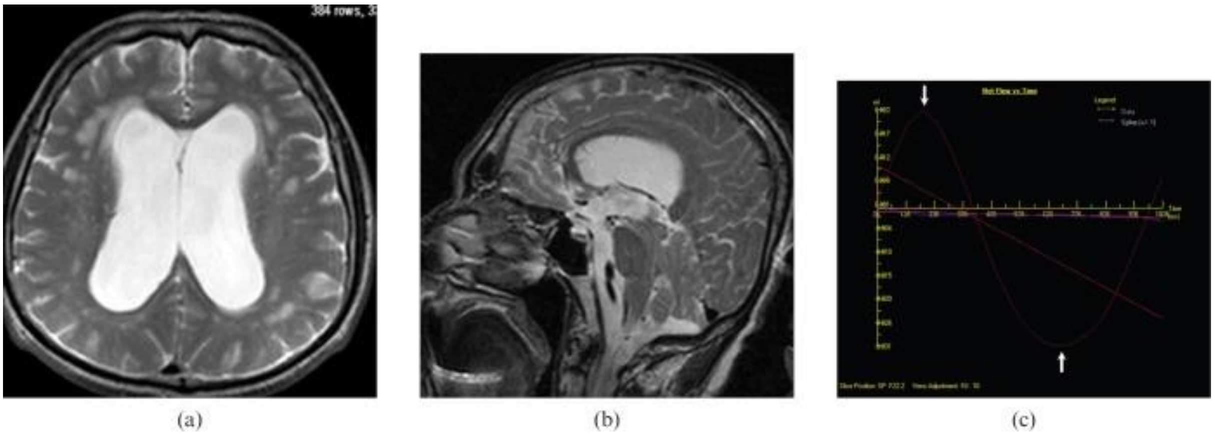

Figure 3: A 73-year-old male with the diagnosis of normal pressure hydrocephalus presented with urinary incontinence and dementia. (a) Axial and (b) sagittal *T*2 weighted images show enlarged ventricles, upward bowing of corpus callosum, periventricular white matter hyperintensities consistent with transependimal CSF leakage/gliosis and normal cerebral sulci. (c) Quantitative cerebrospinal fluid (CSF) flow analysis graphic reveal hyperdynamic flow rates (arrows) in the aqueduct (average flow: 20.34 ml min−1). [9]

Role of MRI in Non-communicating (obstructive) hydrocephalus:

Acute hydrocephalus is an emergency situation condition that should be dealt with urgently. Unless the condition is urgently treated, it may lead to major complications including relentless blindness, cerebral infarct, herniation or death [33]. The most considerable finding on MRI to discriminate between chronic and severe types of hydrocephalus is periventricular hyperintensities on T2W or FLAIR images, which follows intense interstitial oedema [14] (**Figure 4**). Below, the obstruction sited are evaluated regarding pathologies specific to that site and MRI.

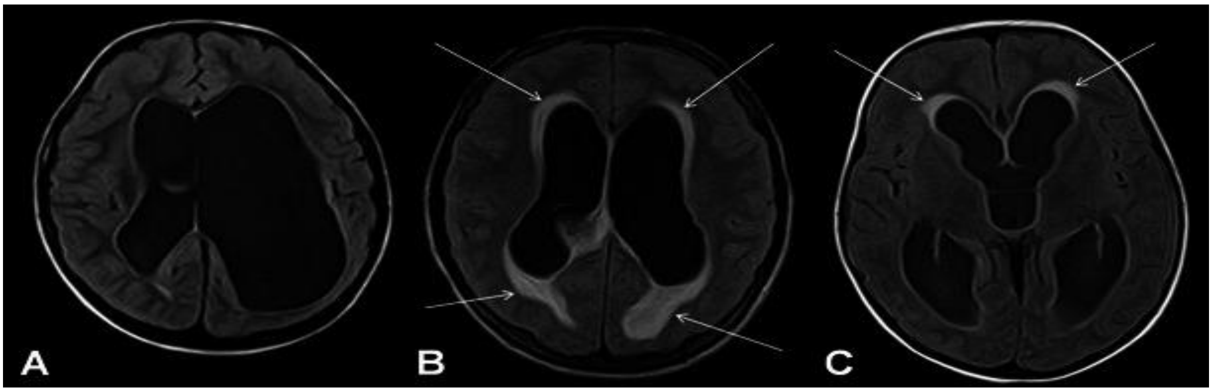

Figure 4: Axial FLAIR images of three different patients with hydrocephalus. In the first patient with chronic compensated hydrocephalus, lack of periventricular CSF resorption is seen (A). In the second patient, periventricular hyperintensity consistent with interstitial oedema due to acute decompansated hydrocephalus is demonstrated (*arrow*, B). Periventricular caps seen in middle aged adults should be differentiated from decompansated hydrocephalus (*arrows*, C) [14]

The role of MRI in other CSF disorder Arachnoid cysts (ACs):

Arachnoid cysts are mainly discovered in the temporal fossa and cerebellopontine angle, but they may likewise be located intra- or periventricularly [34]. Due to CSF secreted from the cyst wall or check-valve mechanism, which allows inflow of CSF however avoids outflow, these sores may grow larger and compress ventricles and foramina [33,34] (**Figure 5**) [35]. Air conditioners look like homogeneous cystic lesions with smooth margins, isointense to CSF in all series [35]. Standard cranial MRI series generally enable medical diagnosis of Air Conditioner, but for those lesions that are controversial, diffusion-weighted and post-contrast T1W images are useful [35]. Showing the communication of ACs with the ventricular and subarachnoid system is necessary in order to plan the treatment. PC-MRI or CE-MRC might be useful to determine the existence of the interaction [33,34].

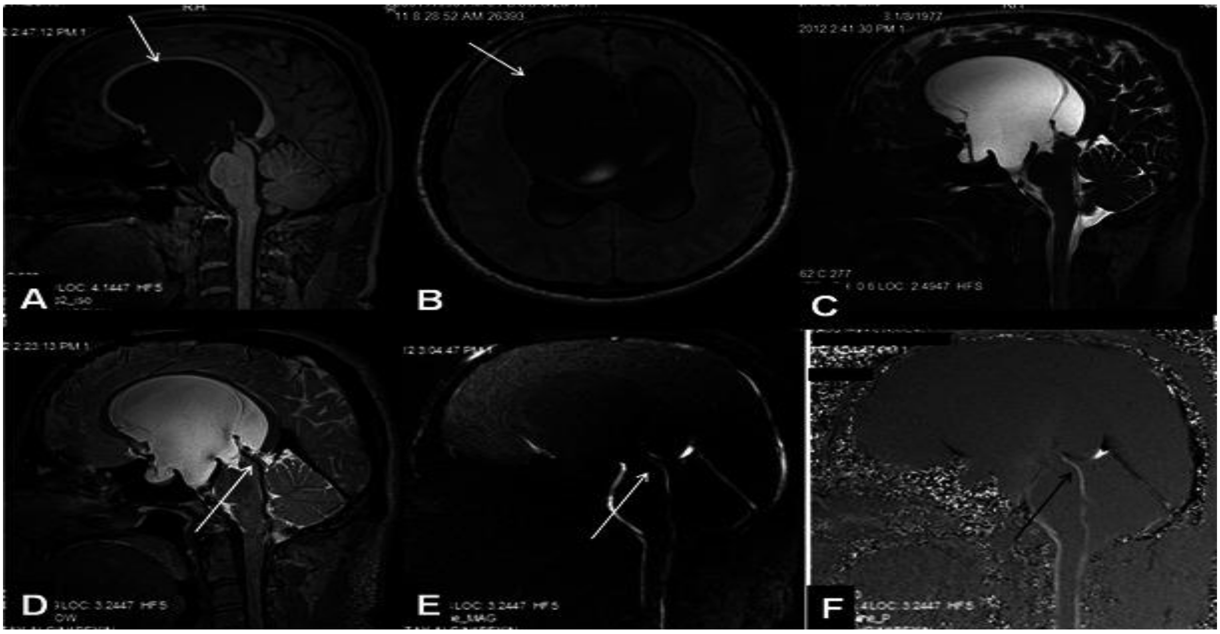

Figure 5: A 34-year-old male patient with intraventicular arachnoid cyst (AC) and hydrocephalus. Sagittal 3D-MPRAGE (A) and axial FLAIR (B) images show AC extending from the right lateral ventricle into the third ventricle (arrows). Sagittal heavily T2W 3D-SPACE image clearly shows the morphology of the AC and third ventricle (C). Sagittal 3D-SPACE with variant FA mode (D) and PC-MRI (E, F) images demonstrate the narrowed aqueduct and decreased aqueductal CSF flow (*arrows*) [35]

4. CONCLUSION

MRI is not just helpful in the medical diagnosis of CSF-flow conditions, however also helps in therapy planning and post-surgery follow-up of the patients. With the advances in MRI systems, freshly established series and techniques enable precise evaluation of numerous CSF-related disorders, the most essential which is hydrocephalus. In order to have the ability to better assess CSF-related disorders, radiologists must follow new technologies that make it possible for much better evaluation of CSF hydrodynamics and must use them in regular use when needed. The PC-MRI approach are relatively simple for assessing real CSF flow and figuring out the obstruction level. These techniques offer additional physiological details.

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