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Rapid MRI protocol for the detection of pathognomonic signs of CSF hypotension syndrome

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KeyWords

CSF hypotension, Magnetic resonance imaging, Differential diagnosis, Qualitative and quantitative sign.

Abstract

CSF hypotension syndrome is caused by a reduction of the CSF within the cerebro-medolar cavities due to trauma or spontaneously and in the latter case it represents a condition that can lead to think, during clinical evaluation, of other pathologies that present similar symptoms. CSF hypotension syndrome can therefore be diagnosed by using magnetic resonance imaging (MRI) of the brain, without and with contrast medium, performed following the purely clinical evaluation of symptoms. The aim of this work is to provide TSRM professionals with the theoretical elements for understanding the causes that induce this syndrome and to describe the qualitative and quantitative signs, which can be obtained with the appropriate MRI sequences, useful to provide the radiologist with all the elements to reach a certain diagnosis.

RESEARCH ARTICLE

INTRODUCTION

CSF hypotension is a pathological condition due to a decrease in the quantity of cerebrospinal fluid in the ventricular cavities of the brain and the ependymal canal.
Under normal conditions, CSF pressure in adults varies from 70 to 200 mm H2O, depending on body mass index, and about 500 ml of CSF is produced daily with a volume of 150 ml, exchanged 3 to 4 times in a day by the choroid plexuses and reabsorbed through arachnoid granulations. When CSF pressure drops below 60 mm H2O, a pathological condition called CSFhypotension syndrome occurs.[3] CSF hypotension can be divided into
Two main categories:
Primary hypotension: spontaneous
Secondary hypotension: iatrogenic (lumbar puncture or surgery) or traumatic hypotension.

Clinical signs

From a clinical point of view, orthostatic headache is the main clinical finding, in particular headache following lumbar puncture (PDPH – Post Dural Puncture Headache) or following surgery on the vertebral spine. [3]
Other symptoms may be nausea and vomiting in half of the patients and more rarely stiffness and pain neck, blurred vision, campimetry defects and diplopia, abnormal blood chemistry of the prolactin, numbness or facial pain, tinniness, taste alterations, limb paresthesia's, transient paralysis of the III and VI n.c. [3] Even rarer forms are represented by loss of consciousness in orthostatism due to diencephalic herniation, cognitive impairment, behavioral changes, parkinsonism. Because primary intracranial hypotension can present with a variety of clinical symptoms, it may lead to misassessment that would put patients at risk of undergoing a treatment not necessary for diseases with similar symptoms such as aseptic menitis or pituitary disorders. It is therefore very importantto have recourse to differential diagnosis considering MRI of the brain a fundamental method for the diagnosis of liqueral hypotension.

MATERIAL AND METHODS

In a time span from January 2021 to the present, they have been sent to our attention in
about 90 patients admitted to the Neurology and Neurosurgery Units of the A.O.R.N. "A.Cardarelli" who presented symptoms of spontaneous CSF hypotension (SIH). All patients were examined with state-of-the-art 1.5 T MRI equipment using a specific study protocol, described below, used at the Neuroradiology Unit of the A.O.R.N. of our hospital ("A. Cardarelli")

MRI STUDY OF THE BRAIN

MRI signs of hypotension syndrome are varied and can be explained by the fact that the cranial theca and vertebral specus create a closed space with constant total volume, so any loss of cerebrospinal fluid would be compensated by the increase in blood volume. This phenomenon would explain venous sinus enlargement, pituitary gland congestion, dural thickening, and extradural collections related to venous engorgement of the dural interstitium. Further findings, related to the decrease in

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volume of the cerebrospinal fluid, are represented by the descent of the brainstem with involvement of the basal cisterns, the lowering of the mammillary bodies, the involvement of the cerebellar tonsils within the foramen magnum as well as the decrease of CSF in the optic nerve sheath. Magnetic resonance imaging is able to demonstrate both morphological alterations and signal alterations at the meningeal level due to vascular engorgement that occurs to compensate for the reduction of CSF. The examination protocol used for the study of the brain in cases of suspected intracranial hypotension syndrome is indicated in Table 1.

N.	Tab 1: Sequence Type
1	Sagittal T1e T2
2	T2-FLAIR Axial
Administration of gadoli-nium-based m.d.c. intravenously (0.1 ml/kg body weight)	
3	SE T1 Axial
4	T1 FS FSPGR on the three planes of space (Axial-Coronal-Sagittal)

The SE sequences (T1=TE100 msec TR > 2000 msec) [1], allow to obtain, thanks also to the relative insensitivity to magnetic field inhomogeneities, a good morphological representation of the structures under examination, useful both for a morphological evaluation as in the case of T1 and for a tissue characterization in T2. Moreover, after injection of gadolinium-based MDC, the SE-T1 sequence shows a significant increase in signal at the points of accumulation of the MDC, favoring a qualitative as well as quantitative evaluation that we will describe later. The FLAIR (Fluid Attenuated Inversion Recoveri) sequence with reversal time (TI) of the order of 2000 – 2500 msec. [1], by suppressing the CSF signal, without the use of m.d.c., it is able to highlight the pachymeningeal thickening characteristic of CSF hypotension, being particularly useful in situations in which the patient presents with an allergic diathesis. In addition, this type of sequence with long TE (100-140 msec)[1] allows to obtain T2-weighted signals capable of highlighting, among other things, the presence of blood inside the CSF. The 3D Fast Gradient-Echo Spoiled Recalled (FSPGR) sequence heavily weighted in T1, despite the low signal-to-noise and contrast-to-noise ratio, not only allows images to be obtained in a short time on the three planes of space, but also effectively highlights the accumulation of contrast at the meningeal level, which represents one of the pathognomonic qualitative signs of CSF hypotension.

Technical Execution

Before any other acquisition, an ultra-fast sequence (15sec) is performed, which simultaneously provides images on the three planes of space. The images obtained in this way are not useful for diagnostic purposes but are only used to correctly set the orientation of the slices for the sequences that will be subsequently acquired. To obtain images in the axial plane, the slices are oriented along the bicommissural line (Fig1) represented by an ideal line passing through the inferior margin of the head and tail of the corpus callosum, which is clearly visible in the median sagittal plane. In this way, any remote controls will allow you to always obtain the same orientation of the slices and therefore images always oriented in the same way and therefore comparable.

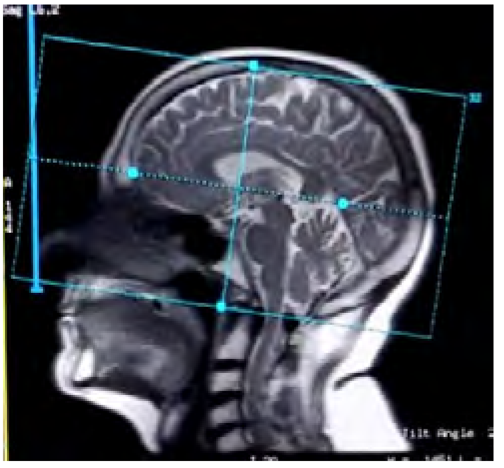

Fig1: *Orientation along the bicommissural line using a sagittal image.*

For the same reason, sagittal images will always be acquired by placing the slices parallel to the hemispheric line detectable on the coronal centering image (Fig.2-A), while coronal images will be acquired by positioning the slices along the major axis of the brainball. (Fig2-B). For 3D sequences, it is sufficient to position the acquisition volume in the same way as described for axial acquisitions.

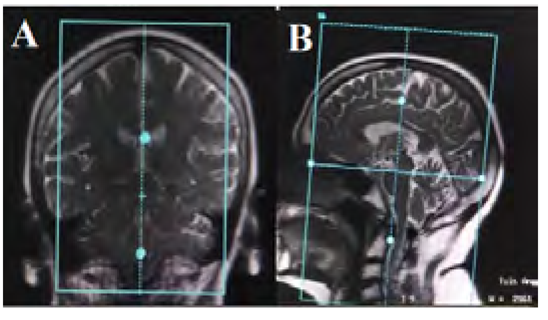

Fig2: *Orientation of the slices along the bihemispheric line (A) and parallel to the bulb (B)*

QUALITATIVE AND QUANTITATIVE FINDINGS

The most common qualitative finding is pachymeningeal thickening followed by dural venous engorgement, tonsillar hernia and subdural collection; however, these features are not always present, which is why quantitative results should also be considered, which are very useful to make a more accurate diagnosis with MRI.

A-QUALITATIVE FINDINGS

1-**Pachymeningeal enhancement**

Associated with the clinic, the most common MRI finding is certainly pachymeningeal thickening, which can already be seen using FLAIR sequences without mdc (3m:20s) (Fig.3). After intravenous administration of gadolinium, the meninges show a diffuse linear impregnation in the Fat Sat FSPGR sequences (3m:58s) (Fig.4-A), at the level of the peri encephalic convexity, along the tentorium and the clivus (Fig.4-B). However, after appropriate therapy, in some (rare) cases there is a complete resolution of the meningeal thickening, in most cases a reduction of the aforementioned thickening is observed, which evolves towards the chronicization of the neuroradiological picture associated with a complete remission of symptoms.

2-**Increased venous blood volume**

As already mentioned above, the cranial theca and vertebral specus create a closed space with constant total volume, so any loss of cerebrospinal fluid would be compensated by the increase in blood volume. This phenomenon would explain the enlargement of the venous sinuses. The main signs of increased venous volume can be:

• sign of venous distention leading to rounding of the cross-section of the dural venous sinuses (Fig.5) Intracranial venous thrombosis is a well-known, although rare, complication and may involve cortical veins and/or dural venous sinuses.

• prominence of the inferior intercavernous sinuses (Fig. 6) is not a sensitive or specific finding, however, it is important to recognize it in cases of intracranial hypotension so as not to confuse it with a pituitary lesion.

• Increased volume of the pituitary gland (Fig.7)

The alteration in the size of the pituitary gland

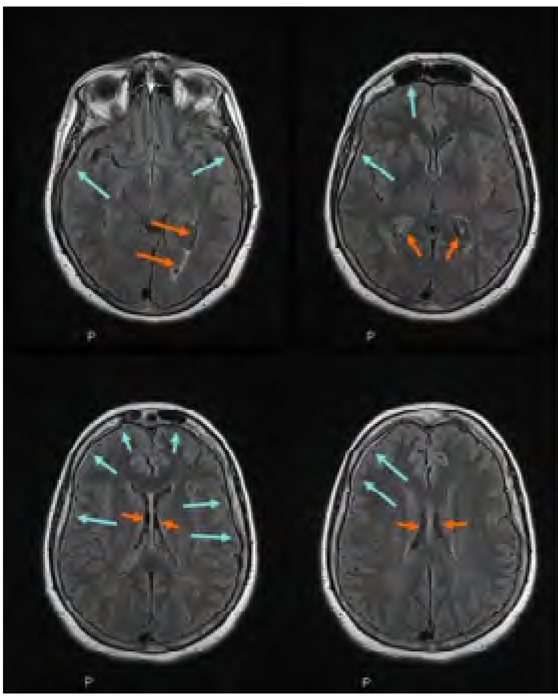

Fig.3-*FLAIR sequence without mdc: 61-year-old patient with clinical suspicion of spontaneous CSF hypotension. There is a thickening of the meninges, which appear slightly hyper-intense (blue arrows) and a reduction in the size of the lateral ventricles (red arrows).*

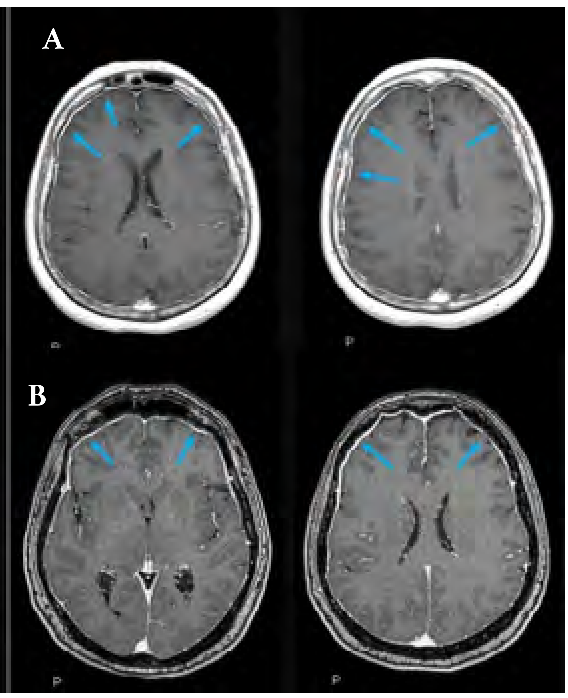

Fig.4-*Same patient; Acquisitions after administration of contrast medium in SE-T1 (**A**) and FS FSPGR (**B**):Pachymeningeal enhancement (light blue arrows)*

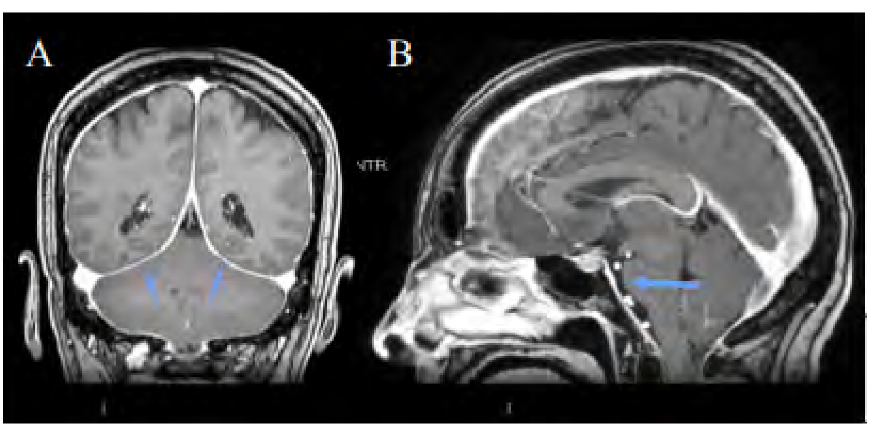

Fig.4-*Meningeal enhancement at the level of the tentorium (A) and a clivus level (B).*

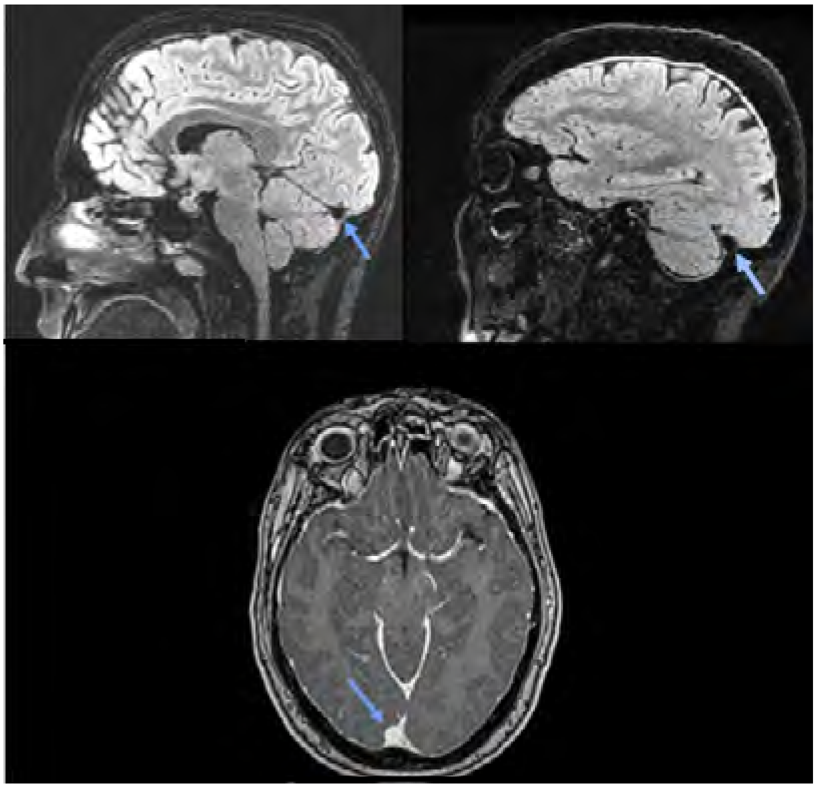

Fig 5-*Images on the sagittal and axial planes showing signs of venous distention that causes rounding of the section of the right lateral venous sinus.*

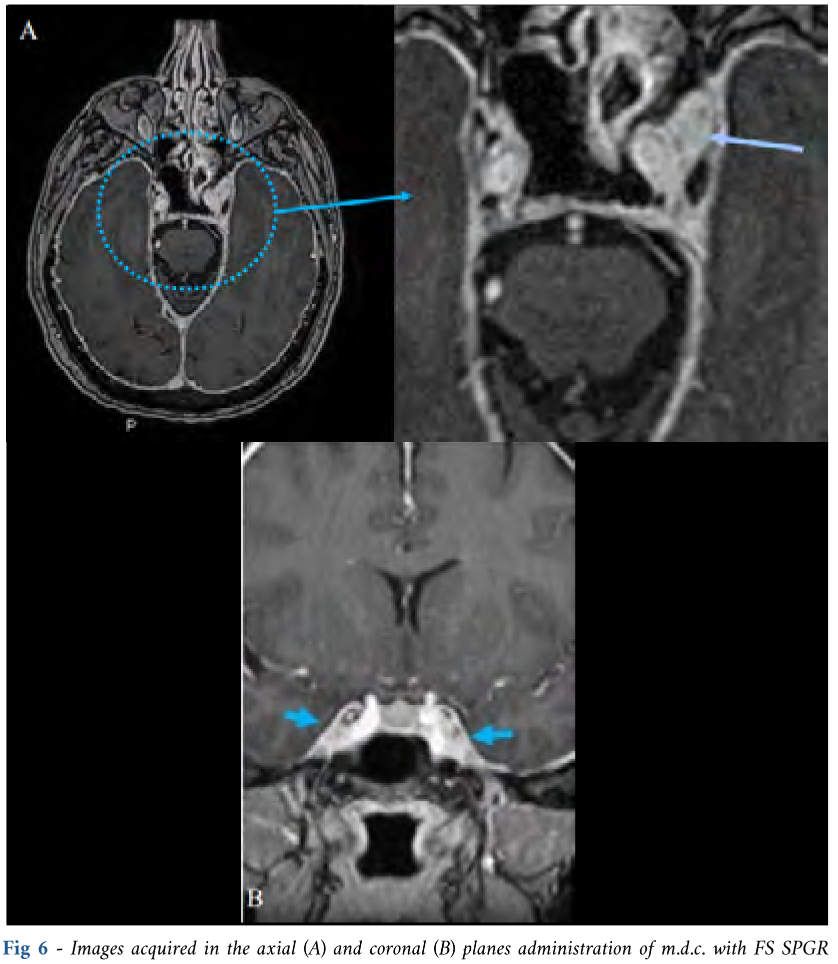

Fig 6 - *Images acquired in the axial (A) and coronal (B) planes administration of m.d.c. with FS SPGR sequence, in which the prominence of the inferior intercavernous sinuses is highlighted (Arrows)*

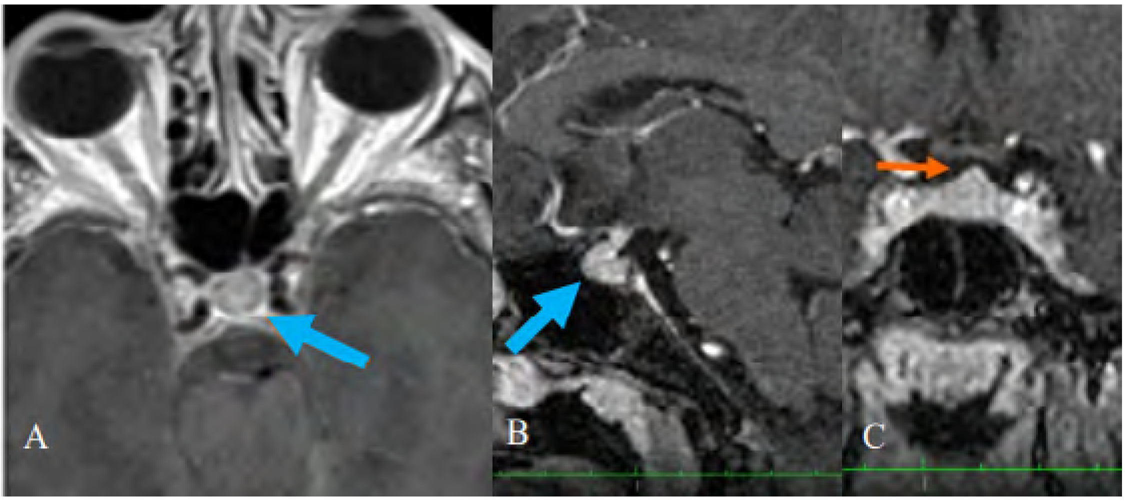

Fig. 7- *Increased size of the pituitary gland (A-B blue arrows) and displacement of the peduncle (red C-arrow) shown in the coronal image*

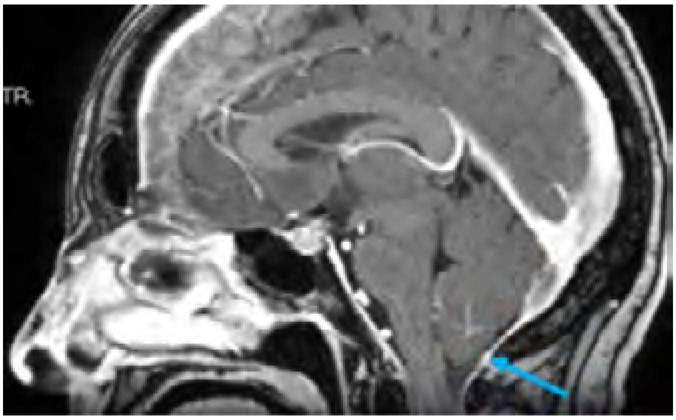

Fig. 8 - *Sagittal plane, tonsillar ectopy*

Fig. 9 - *Flattening of the corpus callosum visible in the sagittal plane (arrow)*

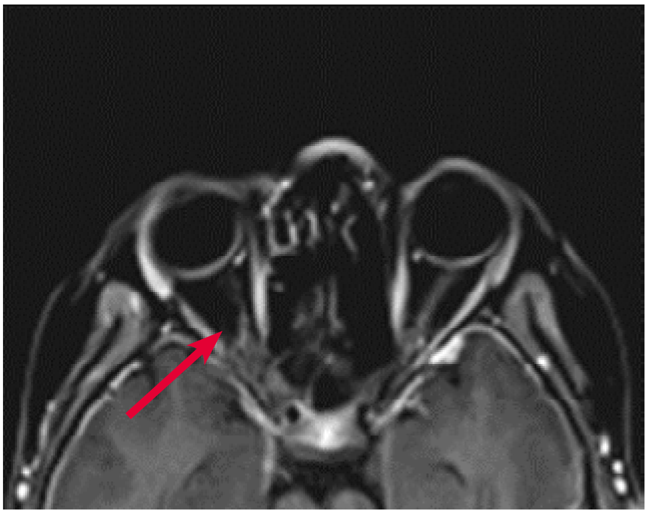

Fig. 10 - *Axial plane - reduction of CSF in the optic nerve sheath (arrow)*

caused by increased blood flow to compensate for intracranial hypotension can lead to alterations in prolactin values and therefore represents one of the conditions that can lead to clinical evaluation errors.

• Reduction in cerebrospinal fluid volume A reduction in cerebrospinal fluid, which is particularly evident in the ventricular area, can cause:
* Brainstem relaxation and acquired tonsillar ectopy (Fig.8)
* Sagging splenium or flattening of the corpus callosum (Fig.9)
* Decrease in fluid within the optic nerve sheath (Fig.10)

QUANTITATIVE FINDINGS

1-**Mammillo-pontine** (Fig.11)
The mammillo-pontine or ponto-mammillar distance is defined as the distance between the mammillary bodies and the top face of the pons. This distance can be measured on mid-sagittal T1 images, the most widely used method is to measure the shortest distance between the lower margin of the mammillary bodies and the upper surface of the pons. In normal situations, ponto-mammillary distance is variously reported as 7 or > 9 mm [2] and decreases in conditions that depress the floor of the third ventricle or change the position of the brain within the intracranial cavity as in the case of intracranial hypotension. It is found to have pathological significance if the mammillo-pontine distance is <5.5 mm [2]

2 - **Ponto-mesencephalic angle** (Fig 12)
It is the angle that is formed between two lines drawn along the anterior margin of the midbrain and the anterosuperior margin of the pons. The ponto-mesencephalic angle is a useful adjunct in the diagnosis of intracranial hypotension. A normal value is 65° +/- 10° and a value below 50° is indicative of intracranial CSF hypotension. [2]

3 - **Interpeduncular angle** (Fig.13)
The interpeduncular angle is defined as the an-

Fig.11
Mammillo-pontine distance indicated from the double arrow on the median sagittal plane.

Fig.12
Ponto-mesencephalic angle (dashed in yellow) identified by the red arrows on the median sagittal plane.

gle formed by the posterior half of the cerebral peduncles on axial images. The interpeduncular angle is indicated as a sensitive and specific measure of intracranial hypotension, especially for iatrogenic hypotension. The angle is defined as the angle formed by the posterior half of the cerebral peduncles obtained on a T2 axial image weighted at the level of the mammillary bodies or the slice immediately below them, whichever gives the lower value. For cases with a U-shaped apex instead of a V-apex such as the one shown in figure 13, the linear portion of the cerebral peduncles is measured. The interpeduncular angle is narrower in patients with intracranial hypotension (< 45.5°). In adults, an optimal threshold is 40.5°. [2]

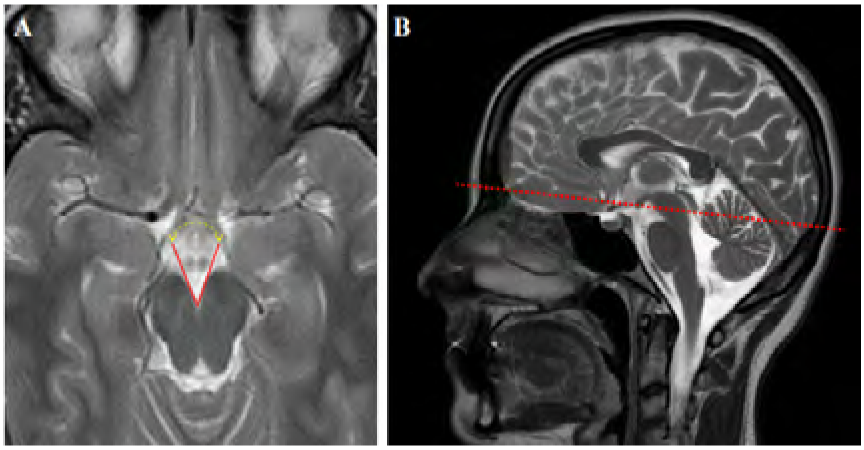

Fig.13

(A) Axial plane. Evaluation of the interpeduncular angle .

(B) Acquisition plane (dashed in red on the sagittal image) passing through the mammillary bodies useful for the evaluation of the interpeduncular angle.

DISCUSSION

MRI is the instrumental method that is currently fundamental for the diagnosis, in suspected clinical cases, of intracranial CSF hypotension. Undoubtedly, the knowledge of the causes that determine CSF hypotension syndrome as well as the qualitative and quantitative signs that characterize it, combined with the purely technical knowledge of the various sequences available today and the use of a rapid and adequate study protocol, can lead TSRM professionals to contribute in a conscious way to the formulation of a certain diagnosis by the Neuroradiologist by providing him with all the elements useful for this At the same time, the aim is to ensure greatercomfort for the patient, who is not forced to undergo long examination sessions.

CONCLUSIONS

In the context of a differential diagnosis aimed at confirming the clinical suspicion of CSF hypotension and in the absence of further clinical signs, the examination protocol described in this work allowed us to optimize the acquisition time of the MRI examination by reducing them to about 15 minutes compared to the 35/40 minutes required for the execution of a “standard” examination with m.d.c.. In fact, from our experience, the data that emerged, comparing the two examination protocols, is that the addition of additional sequences of GRE (Gradient Recalled Echo), DWI (Diffusion) as well as the addition of additional scanning planes outside those described, did not add further information but prolonged the dwell time and therefore the patient’s discomfort, increasing among other things the risk of obtaining motion artifacts.

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