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MENINGIOMA DETECTION AND CHARACTERIZATION USING BRAIN MR IMAGING: A CASE STUDY

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Abstract

Meningiomas commonly manifest as granulations, dense clusters exhibiting hyperintense signals on the meningeal layers and close to cranial nerves. Detailed and isotropic imaging are key in the diagnostic evaluation. Nevertheless, standard MRI sequences have been inadequate in capturing these granulations, incorporating the T2 3D CISS axial sequence for improved visualization. Our case study aims to meticulously evaluate the diagnostic imaging strategies used for meningioma cases, explicitly focusing on cranial nerve imaging. The MRI protocol encompassed axial, coronal, and sagittal T2_TSE and DWI sequences and post-contrast T1-weighted imaging. A detailed calibration of the 3D CISS sequence parameters was performed to enhance the imaging of cranial nerves affected by the suspected meningioma. Our findings highlight the necessity of a meticulous MRI protocol, which includes precise imaging sequences, to evaluate meningiomas effectively, particularly for assessing the potential involvement of the cranial nerves.

Keywords: *Cranial Nerve; Meningioma; MRI Brain; T2 3D CISS Axial*

1. Introduction

The brain, the central nervous system, comprises the cerebrum, cerebellum, and brainstem, including the mesencephalon, pons, and medulla oblongata. It is segmented into three main sections: the forebrain, midbrain, and hindbrain. The forebrain is divided into several parts, including the cerebral hemispheres (cerebrum), thalamus, and hypothalamus. The midbrain, diencephalon, and hindbrain form parts of the brainstem, consisting of the pons Varolii, medulla oblongata, and cerebellum (Thau et al., 2022).

Meningiomas are typically slow-growing tumors that can vary in size and complexity. While they often remain asymptomatic for an extended period, their presence can eventually lead to a range of neurological symptoms as they compress adjacent brain tissue, blood vessels, or nerves. Symptoms may include headaches, seizures, vision problems, or other neurological deficits depending on the tumor's location and size (Ogasawara et al., 2021). The Central Brain Tumor Registry of the United States (CBTRUS) Statistical Report highlights that between 2012 and 2016, meningiomas constituted the single most common histological type of all primary tumors within the central nervous system, representing 37.6% of cases, with an estimated 33,560 instances expected in 2019. Meningiomas also had the highest average yearly age-adjusted occurrence rate among primary brain and spinal cord tumors, at 8.6 cases per 100,000 individuals. The likelihood of developing a meningioma escalates with age, peaking at a median diagnosis age of 66. Among the meningiomas that underwent histological verification, the overwhelming majority were benign, with only 1.7% being malignant and classed as WHO grade III (Ostrom et al., 2019).

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MRI brain scans have emerged as the modality of choice in advancing radiological sciences for

optimal meningioma diagnosis. MRI is the primary investigative tool for patients presenting with signs and symptoms indicative of brain abnormalities. The standard sequences in MRI brain examinations include Spin Echo/Fast Spin Echo (SE/FSE) T1-weighted images, SE/FSE proton density/T2-weighted images, Fluid-Attenuated Inversion Recovery (FLAIR), and Diffusion Weighted Imaging (DWI). DWI and Diffusion Tensor Imaging (DTI) are sophisticated functional MRI sequences extensively used to assess tumors (Westbrook, n.d.) . Advanced sequences for meningioma evaluation that include axial, sagittal, and coronal T2-weighted images, axial T2 FLAIR, T1 FLAIR, DWI with a b-value of 1000, axial 3D acquisition in SWAN, high-resolution T2 cube, and Arterial Spin Labeling (ASL). The 3D-ASL is performed before contrast administration, followed by Dynamic Contrast-Enhanced (DCE) MR imaging and a three-dimensional fast spoiled gradient-echo (3D-FSPGR) sequence after contrast injection (Utomo et al., 2022).

MRI brain diagnostic imaging in cases of brain tumors located in the cerebrospinal fluid (CSF) region is an additional sequence known as 3D SPACE (Sampling Perfection with Application Optimized Contrasts using different flip angle Evolution). This sequence's advantage is its ability to visualize the Contrast to Noise Ratio (CNR) between CSF and brain parenchyma with significantly higher definition using 3D SPACE as compared to 3D CISS (Ucar et al., 2015) . The T2 3D CISS Axial sequence is a specialized imaging technique highlighting the T2 values differentiating cerebrospinal fluid (CSF) and pathological entities. Its operational principle relies on fine tissue slicing and high-resolution imaging, enabling the detailed visualization of minute structures. Therefore, this sequence is deemed valuable for depicting the features of intraventricular and extra-axial lesion tissues (Hingwala et al., 2011).

The MRI examination to assess meningioma involves a series of sequences. The standard sequences include T2-weighted Turbo Spin Echo (T2_TSE) in axial, coronal, and sagittal planes, Diffusion Weighted Imaging (DWI) in the axial plane, and Fluid Attenuated Inversion Recovery (T2_TSE_Flair) in the axial plane. These are complemented by T1-weighted Spin Echo (T1_SE) sequences in axial and coronal planes and an axial T2-weighted FLAIR sequence (T2_FL2D_axial). For enhanced detail of the cranial nerves, a specialized axial sequence, the T2 3D Constructive Interference in Steady State (CISS), is utilized. Post-contrast imaging involves T1-weighted sequences with contrast enhancement (CE) in sagittal (T1_SE_Sag+CE), coronal (T1_SE_Cor+CE), and axial (T1_SE_Tra+CE) planes. These post-contrast sequences aim to delineate the tumor's vascularity, anteroposterior dimensions and margins, and superoinferior extent and borders, respectively.

2. Method

The prepared equipment includes a 1.5 T Siemens Magnetom Aera MRI machine, a printer for image outputs, a 20-channel head coil for patient scanning, and a workstation with the necessary computing power. A contrast media set and patient comfort and safety items such as a blanket, sponge, emergency buzzer, and headphones are also prepared. A metal detector prevents metallic objects from entering the MRI suite to ensure patient safety. A Picture Archiving and Communication System (PACS) facilitates image acquisition and analysis, with data management centralized at the MRI Computer Center. The protocol used for scanning is a head routine with stages, which can be seen in Table 1.

Table 1. MRI brain protocols to examine brain meningioma

Sequence	Time Repetition	Time Echo	Slice Thickness	Slice number	NEX	Scan Time
Axial T2 TSE	5000	83	5	19	1	01:27
Axial DWI	4800	109	5	19	1	01:47
Axial T2 Flair	9560	82	5	19	1	02:44
Coronal T2 TSE	4480	83	5	19	1	02:02
Sagittal T2 TSE	4480	83	5	19	1	02:02
Axial T1 SE	550	8.9	5	19	1	02:24
Coronal T1 SE	550	8.9	5	19	1	02:24
Axial FL2D T2	830	25	5	19	1	02:52
Axial 3D CISS	6.72	2.92	0.72	80	1	06:28
Axial T1 + C	550	8.9	5	19	1	02:24
Sagittal T1 + C	550	8.9	5	19	1	02:24
Coronal T1 + C	550	8.9	5	19	1	02:24

3. Result and Discussion

Case 1

A 38-year-old female outpatient from the General Surgery Clinic presented with laboratory results showing a urea level of 28 mg/dL and a creatinine level of 0.9 mg/dL. She reported experiencing persistent headaches for the past year. The headache was described as throbbing, affecting the entire head, and worsening with coughing, sneezing, or straining. Pain relief medications did not alleviate the discomfort. The intensity of the headache increased in the three months before hospital admission, accompanied by a progressive right-sided body weakness. The patient had a history of projectile vomiting twice in the last month before hospitalization. There was no history of seizures, head trauma, or fever. The patient was referred for an MRI Brain with contrast and was admitted to the hospital for one day before the examination.

Case 2

A 48-year-old female patient admitted to the hospital with laboratory results indicating a urea level of 36.5 mg/dL and a creatinine level of 1.2 mg/dL reported severe headaches accompanied by an enlargement of the left frontal area. The patient frequently experienced vomiting and was unable to carry out her usual activities, also noting some visual disturbances. The attending physician referred the patient for a contrast MRI Brain examination.

Case 3

A 64-year-old patient, who was not admitted to the hospital, visited the neurology specialist clinic. The patient reported a chronic headache that occurred on and off for a lengthy period. The frequency of the headaches increased over time and was accompanied by an enlargement of the left parietal area of the head. The referring physician recommended a contrast MRI Brain examination to investigate the presence of a mass. Following hospital procedures, the patient was admitted for one day before the examination to prepare for the radiology procedure. The patient arrived at the Radiology Department in a wheelchair, accompanied by a nurse, and brought laboratory results showing a urea level of 23.7 mg/dL and a creatinine level of 1.5 mg/dL.

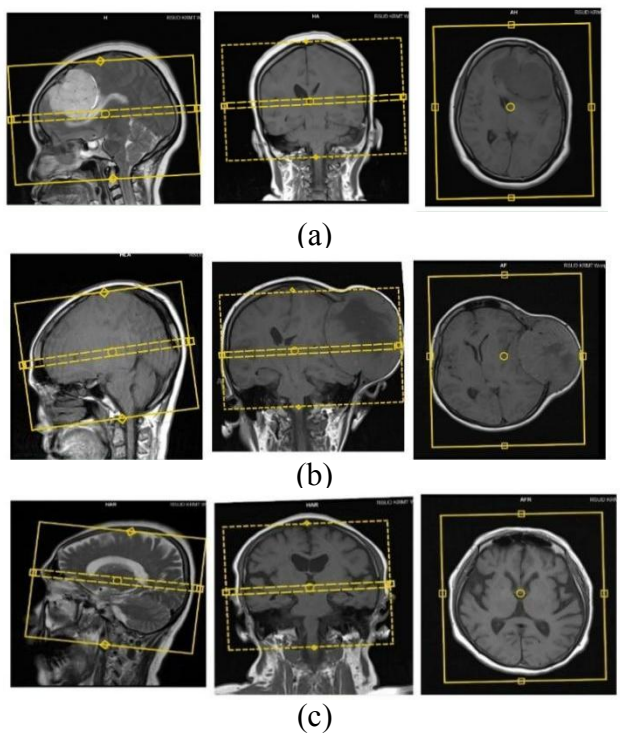
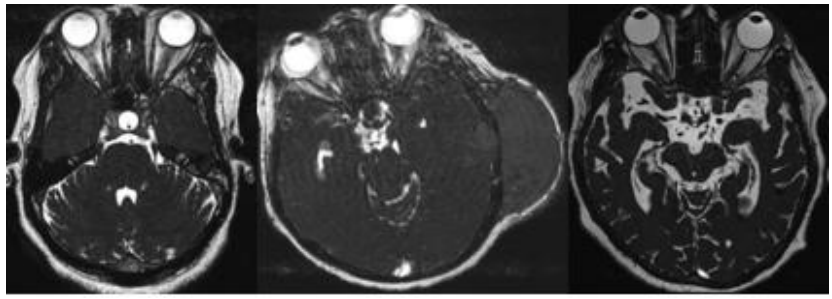


Fig 1. *Localizer (a) patient 1 (b) patient 2 (c) patient 3*

The localizer sequence is a crucial preliminary step in MRI brain examinations, ensuring accurate positioning and orientation for comprehensive brain coverage and precise identification of areas of interest, such as meningiomas. Various MRI sequences serve distinct purposes: Axial T2 FSE highlights pathology with clear boundaries between hyperintense cerebrospinal fluid (CSF) and hypointense fat tissue, while T2 DWI Axial detects molecular movement, identifying infarctions or restricted diffusion areas as dark gray regions. T2 TSE FLAIR Axial suppresses CSF signals to enhance visibility of adjacent pathological conditions, and T2 TSE Coronal and T1 SE Coronal sequences provide views of pathology and anatomical structure, respectively, dividing the brain into anterior and posterior sections. T1 SE Axial reveals anatomical structures with hypointense CSF and dark gray fat tissue. T2* (T2 Fl2d Hemo Axial) identifies hypointense bleeding within hyperintense CSF, and T2 TSE Sagittal highlights pathology with clear boundaries, dividing the brain into right and left halves. T2 3D CISS Axial offers detailed images of cranial nerves, crucial for meningioma cases. T1 SE Axial, Coronal, and Sagittal sequences with contrast media enhance the differentiation between normal tissue and meningioma, with the contrast appearing hyperintense. Each sequence provides complementary views essential for accurate diagnosis and assessment of brain pathology.



(a) (b) (c)

***Fig. 10**. T2 3D CISS axial (a) patient 1 (b) patient 2 (c) patient 3*

The T2-weighted 3D Constructive Interference in Steady State (CISS) axial sequence is recognized for its ability to enhance T2 signal contrast between cerebrospinal fluid (CSF) and pathological tissues. Therefore, this sequence is precious in delineating the characteristics of intraventricular and extra-axial lesions. However, in some instances, additional slices may be required. Due to the lengthy acquisition time of the T2 3D CISS sequence, the inclusion of additional slices in the sagittal and coronal planes is typically performed in consultation with a radiology specialist to ensure clinical relevance and manage scanning efficiency (Hingwala et al., 2011).

The T2-weighted 3D Constructive Interference in Steady State (CISS) Axial sequence provides superior imaging results compared to the 3D Sampling Perfection with Application Contrasts using different flip angles Evolution (SPACE) when it comes to certain aspects of brain imaging. Specifically, the T2 3D CISS sequence offers enhanced resolution in differentiating solid tissue structures, such as the distinction between gray and white matter. Additionally, it provides an increased signal and exceptional visualization of fluid spaces, such as cerebrospinal fluid (CSF), which presents with clear demarcation of mass boundaries. It facilitates a more precise evaluation by radiologists of meningiomas and cranial nerves.

The application of the 3D Constructive Interference in Steady State (CISS) axial sequence utilizes parameters of a TR (Repetition Time) of 6.72 milliseconds, a TE (Echo Time) of 2.92 milliseconds, with a slice thickness of 0.70 mm, covering a total of 80 slices, and a single NEX (Number of Excitations) with a total scan duration of approximately 6 minutes and 28 seconds. The selection of a shorter TR and TE is designed to augment signal intensity in fluids such as water and fat, enhancing the contrast in the resultant images. This sequence produces images with great detail and sharpness due to the thin and closely spaced slicing within the defined localizer area, offering superior image quality compared to other sequences where slices are thicker or more widely spaced.

The imaging orientation matrix (IOM) is aligned parallel to the corpus callosum and the genu for the examination using the localizer settings. The superior border is aligned with the top of the corpus callosum, and the lower border is set at the base of the skull. The anterior border is positioned at the front of the orbit, while the posterior border is aligned with the back of the cerebellum.

The parameters selected for the T2 3D Constructive Interference in Steady State (CISS) sequence are consistent with theoretical best practices. Nevertheless, the localizer is exclusively targeted at imaging the cranial nerves. This focus may result in meningiomas that lie beyond this field of view not being adequately captured, rendering the 3D CISS axial sequences less informative for evaluating such meningiomas. Combining the T2 3D CISS axial sequences with Dynamic Contrast-Enhanced (DCE) Magnetic Resonance Imaging is recommended for a more comprehensive assessment and advanced grading of meningiomas. This combination enables a more detailed examination of the meningioma and its potential interaction with the cranial nerves.

It is crucial to provide comprehensive instructions to the patient to mitigate the limitations of the 3D CISS axial sequence, particularly those associated with patient movement during the extended acquisition time. Explaining the importance of remaining still and the movement's potential impact on image quality can be helpful. Furthermore, ensuring the patient's comfort is paramount; positioning aids such as cushions or supports may be used to minimize discomfort that could lead to movement. The aim is to prevent the blurring of images that can compromise the diagnostic utility of the sequence. Comfortable positioning and clear communication can significantly enhance the chances of obtaining high-quality, motion-artifact-free images.

Indeed, as Westbrook emphasizes, ensuring patient safety and the quality of imaging results requires careful attention to patient immobilization and clear communication regarding the procedure. Using immobilizers such as sponges or straps can help stabilize the patient and reduce the risk of movement during the examination. It is essential for sequences like the 3D CISS axial, where longer acquisition times increase the potential for motion artifacts (Westbrook, n.d.).

The T2 3D CISS axial sequence produces detailed anatomical images, enhancing the evaluation of the optic (II), trochlear (IV), trigeminal (V), and abducens (VI) nerves among the twelve cranial nerves. This sequence is particularly crucial in assessing the possible spread of meningioma to these cranial nerves, especially in patients presenting with visual disturbances. Through this imaging technique, muscles appear in dark gray tones, white matter in a slightly lighter gray, and bone marrow exhibits a darker appearance. The cerebrospinal fluid (CSF) is displayed in a lighter shade, similar to fat, which allows for a clear distinction between normal nervous tissue and potential meningioma metastases within the cranial nerves.

T2 3D CISS (Constructive Interference in Steady State) axial sequence provides exceptionally detailed anatomical images, particularly of the cranial nerves. Its high-resolution capabilities allow for a meticulous evaluation of the optic (II), trochlear (IV), trigeminal (V), and abducens (VI) nerves. This precision is vital for detecting the presence of meningioma metastases. When granulations from a meningioma are present, they can be visualized distinctly using this sequence, thanks to its ability to highlight contrasts in fluid-filled spaces and surrounding structures. The sequence's effectiveness lies in its capacity to delineate the fine details necessary to spot abnormal tissue against the backdrop of the standard anatomical architecture of the brain and its nerves.

4. Conclusion and Suggestion

The MRI brain examination protocol for meningioma begins with a patient screening to exclude any permanent metal objects, followed by an 8-hour fast and urea and creatinine tests. Upon completion of history taking and informed consent, the patient is positioned supine, aligning with the central glabella point. The imaging sequences initiated include localizer, various T2_TSE orientations, DWI axial, T1_SE in multiple planes, and the specialized T2 3D CISS axial for cranial nerve assessment, complemented by post-contrast sequences for enhanced tissue differentiation.

The T2 3D CISS Axial sequence is precious, providing detailed visualization of the cranial nerves and distinguishing meningioma from CSF. Examination results are made available to patients on a CD DISK and medical professionals via PACS, with printed images on dry film for the attending physician's (DPJP) review, aiding in diagnosing and managing nerve-related anomalies such as facial palsy.

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