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High-Resolution MRI Insights Into Extra-Axial Intra-Calvarial Brain Lesions Without Trauma

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Abstract

The paper aims to assess the usefulness of having a high-resolution Magnetic Resonance Imaging (MRI) in pathologising and characterising extra-axial, intra-calvarial, non-traumatic lesions within the human brain. As a prospective observational study, conducted in a tertiary care centre, 88 patients with a history or suspicion of extra-axial lesions with a known or suspected age above 10 years were scanned using the 1.5T and 3T MRI systems. Imaging sequences included routine T1, T2, FLAIR, DWI, SWI, and contrast-enhanced sequences, with MR spectroscopy applied in a few cases. Arachnoid cysts, Schwannoma and Epidermoid cysts were the most frequent lesions detected. The lesions were mostly in the cerebellopontine angle, clivus and skull base. Clinical symptoms had good matches in MRI findings and enhanced the rate of accuracy in diagnosis. Pattern of signal intensity pattern in different sequences assisted in the distinction between benign and malignant lesions. The conclusion of the study was that high-resolution MRI is very successful in the non-invasive assessment and categorization of the extra-axial cerebral lesions providing crucial details with regard to early diagnosis and the best approach to treatment.

Keywords: *MRI, Extra-axial lesions, Intra-calvarial, Non-traumatic, Brain lesions, High-resolution imaging, Meningioma, Arachnoid cyst, Schwannoma, Signal intensity*

INTRODUCTION

The group of extra-axial, intra-calvarial, non-traumatic brain lesions comprises a diagnostically difficult and clinically heterogeneous group of central nervous system (CNS) defects. They are lesions that occur beyond the brain parenchyma but still inside the skull, and they form a wide range of neoplastic, congenital, inflammatory, vascular, and infectious situations. Although most of them are often harmless, like meningiomas and arachnoid cysts, they could also contain extremely aggressive malignancies, such as dural metastases or hemangiopericytomas. The lack of trauma in their aetiology requires specific diagnostic tools to effectively differentiate the clinical aspect and organise treatment. Their assessment has seen Magnetic Resonance Imaging (MRI), especially high-resolution contrasts and advanced multiparametric schemes, becoming cardinal. It is essential in achieving proper diagnosis due to its capacity to provide great soft tissue contrast, describe the location and type of lesions, and the dural/vascular location. Particular imaging characteristics, including the dural tail vocation in meningiomas, confined spreading in epidermoid cysts, or non-homogeneous propulsion in metastases, can help diminish the possibilities in a diagnosis. These new and improved modalities, such as MR Spectroscopy, Diffusion-Weighted Imaging (DWI), and Perfusion Imaging, continue to enhance lesion characterisation and give non-invasive information on cellularity, vascularity, and metabolic profile. In low-resource environments, the delays in obtaining an MRI may lead to either erroneous diagnosis or failure to treat a malignant condition, especially those imitating some benign illnesses. The meningiomas are the only cause of primary extra-axial tumours in up to 35% of the cases, and other coinciding entities, such as schwannomas, arachnoid cysts, and epidermoids that have identical clinical manifestations, interpretation of MRI in high resolution is indispensable. Further, radiologic-histopathologic correlation with MRI in the WHO CNS tumor classification is still playing a critical role in diagnosis, grading, and prognosis, as the WHO CNS tumour classification is developed through molecular insights. This article

takes on the diagnostic capacity of high-resolution MRI, in its ability to offer early, correct diagnosis and clinical decision-making in non-traumatic, extra-axial, intra-calvarial brain lesions.

Problem Statement

Although neuroimaging has progressed, identification of extra-axial, intra-calvarial, non-trauma related brain lesions is a serious problem, particularly in terms of diagnosis because these lesions are of different sources and there is overlap in their imaging characteristics. The traditional imaging indicators are usually not clear in helping to differentiate between a benign stain or malignant stain, thus slowing down treatment and the possibility of having complications. Reduced access to high-resolution MRI and inappropriate utilization of high-tech techniques such as DWI, MRS and perfusion imaging further negatively impact the accuracy of diagnosis especially in resource-suppressed environments. This necessitates the urgent need to standardise and optimise MRI protocols to identify and characterise these lesions early and accurately in order to help treatment in order to help the patients and direct the effective treatment approaches.

AIM AND OBJECTIVES

Research Aim:

To evaluate the diagnostic effectiveness of high-resolution MRI in identifying and characterizing extra-axial, intra-calvarial, non-traumatic brain lesions.

Research Objectives:

- To assess the MRI imaging features of common non-traumatic extra-axial, intra-calvarial brain lesions.
- To compare clinical presentations with MRI-based diagnoses for diagnostic correlation.
- To evaluate the role of advanced MRI techniques such as DWI, MRS, and contrast enhancement in lesion characterization.
- To identify specific MRI patterns that aid in differentiating benign from malignant lesions.

Literature Review

The assessment of extra-axial, intra-calvarial, non-traumatic brain lesions has been significantly improved with the introduction and innovation of high-resolution Magnetic Resonance Imaging (MRI) (Prasad Desale *et al.*, 2024). Previously, clinical symptoms and pathological procedures such as angiography or pneumoencephalography have been used to diagnose the disease, but they were invasive and had a high risk to the patient, besides having a limited clinical specificity. The development of the MRI has changed the scenario as it has allowed multiplanar non-invasive imaging with better soft tissue contrast. Using high-resolution MRI, especially utilizing the newer procedures (such as diffusion-weighted imaging (DWI), magnetic resonance spectroscopy (MRS), and perfusion imaging), the lesion origin, vascularity, and biological behaviour can be characterised (Fokkinga *et al.*, 2023). Meningiomas, accounting for 30-35 per cent of all extra-axial lesions, are usually well imaged by MRI because their origin lies on the dura, post-contrast enhancement properties, and display the typical dural tail sign. Although epidermoid cysts are less common, they also exhibit high signal intensity on the DWI and hence they are distinguished by arachnoid cysts, expected to follow the cerebrospinal fluid (CSF) signal on all sequences with no limitations, and choline-to-creatine ratio are imaging markers that can be correlated to the grade and aggressiveness of tumors. Besides, MRI has been successful in the diagnosis of cranial nerve sheath tumours such as vestibular schwannomas, which tend to enlarge the internal auditory canal and produce nonhomogeneous enhancement in a post-contrast scan (Casselman, 2024). SWI and T2* Imaging takes a special value in the detection of hemorrhagic or calcified parts in such lesions. The literature also confirms the diagnostic efficacy of perfusion imaging in the differentiation of a benign tumour, such as meningiomas, and malignant lesions,, such as dural metastases that usually present heterogeneous enhancement and bone erosion. The 2021 WHO CNS tumour classification integration no longer uses access to molecular markers as the driving factor, which further establishes the cons of high-resolution MRI since it correlates observed imaging results with pathologies. Even though it has a strong diagnostic potential, the literature mentions that there are differences in the usage of

MRI protocols and that the most powerful sequences are not used regularly (Ringe *et al.,* 2023). This restricts early and correct differentiation, particularly in situations that suffer resource shortages. In this way, the existing evidence justifies the necessity of standardization of protocols and extension of the use of advanced MRI tools. Modern-day high-resolution MRI is essential in the diagnosis of extra-axial, intra-calvarial non-traumatic lesions, which yields a lot more confidence in diagnosis and more advice to the clinician.

Method

This was a hospital-based prospective type of observational research design that was carried out at the Department of Radiodiagnosis, Dr. D. Y. Patil Medical College, Hospital and Research Centre, Pimpri, Pune (Patil, 2024). The research was conducted over more than two years with a sample of 88 patients above the age of 10 years with clinically suspected or previously detected extra-axial, intra-calvarial, non-traumatic brain lesions. MRI assessment was done on Siemens Magnetom Vida 3 Tesla and Siemens Magnetom Avanto 1.5 Tesla scanners with patients (Yoshizawa *et al.*, 2025). The standard MRI scans were performed: T1, T2, FLAIR, DWI, SWI and post-contrast, and MR Spectroscopy was performed on a few cases. Ethical consent and approval were obtained before imaging with informed consent. Patients who had traumatic lesions or had undergone surgeries were not recommended for MRI, or were allergic to contrast, were excluded. The MRI findings were also compared to clinical features and, in combination, histopathology or MR Spectroscopy, when possible, to determine the characteristics of the lesions, as well as the confirmation of diagnoses (Nguyen *et al.*, 2024).

RESULT AND DISCUSSION

Demographic Profile and Age-Gender Distribution of Study Participants

The experiment involved 88 participants of varying ages, ranging from 12 to 75 years. The age mean was 39.51 years, and the standard deviation was equal to 18.97, which is an indication that both lower age categories and higher age categories were involved. Its median age was 35.5 years, with 13 years as the most commonly identified age (mode). Gender ratio showed male inclination, where 54.5 per cent of the respondents were male and 45.5 per cent (n=40) were female. This almost even split makes the results of the study stronger in terms of its applicability between both sexes.

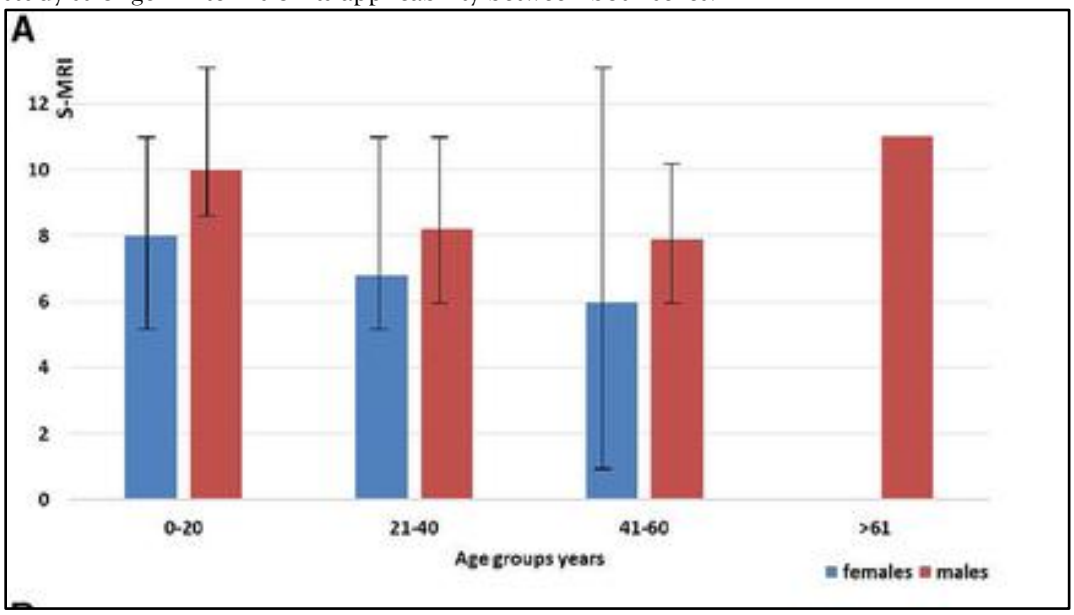

Figure 1: S-MRI distribution according to age group and gender
Source: (Valero-Tena *et al.*, 2023)

The incorporation of the young and old demonstrates the far-reaching demographic effect of extra-axial, intra-calvarial, and non-traumatic brain lesions. The balanced representation also favors the comparison of the age- and gender-based lesion presentation and imaging (Magaloni *et al.,* 2025). It is an important population insight into the predisposition to disease in susceptible individuals and the relation between effective diagnosis involving the MRI to diagnose the lesion correctly in accordance with different age groups.

Clinical Presentations and Symptom Patterns of Extra-Axial Lesions

The participants showed a broad range of clinical symptoms, which corresponds to the diversity of the location and kind of extra-axial, intra-calvarial pathologies. Seizures (21.6) and the most prevalent presenting complaint, followed by headache with seizures (19.3), were closely followed by fever and tremor (18.7), awareness during seizure (16.7), and loss of consciousness (16.0) (Giulia Moltoni *et al.,* 2023). These were focal neurological deficits (17.0%), isolated headaches (12.5%), cognitive disturbances (11.4%), visual disturbances (10.2%), decreased hearing with headache (8.0%).

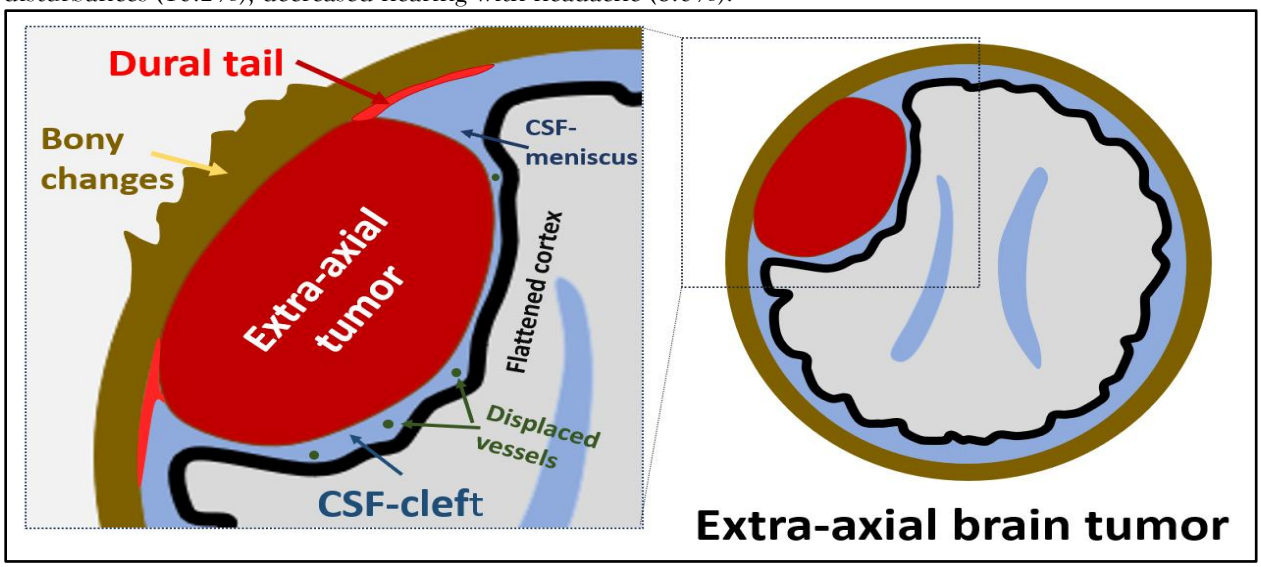

Figure 2: Brain tumours: intra- or extra-axial
Source: (sven, 2023)

The results imply that most of the patients had several neurological and sensory signs and required advanced imaging to determine the extent of their conditions. The differences in the clinical designs indicate that extra-axial lesions are often challenging to diagnose, and can resemble a variety of intracranial diseases. Notably, other symptoms, including seizures and cognitive alterations, are not very specific, and this aspect sustains the significance of MRI in fixing the cause of the problem (Shi *et al.*, 2025). The findings depict the importance of a high clinical suspicion and an extensive imaging process to ensure early or accurate identification of the lesions particularly in unclear or overlapping neurological manifestations in the patients.

MRI-Based Localisation and Frequency of Lesion Sites

According to the MRI analysis, the most common occurrence of lesions was at the cerebellopontine angle (CPA) in 23.9 per cent of the cases (Shi *et al.,* 2023). After this, the clivus, convexity, as well as the skull base, with equal measures of 17.0%, showed a similar occurrence of lesions.

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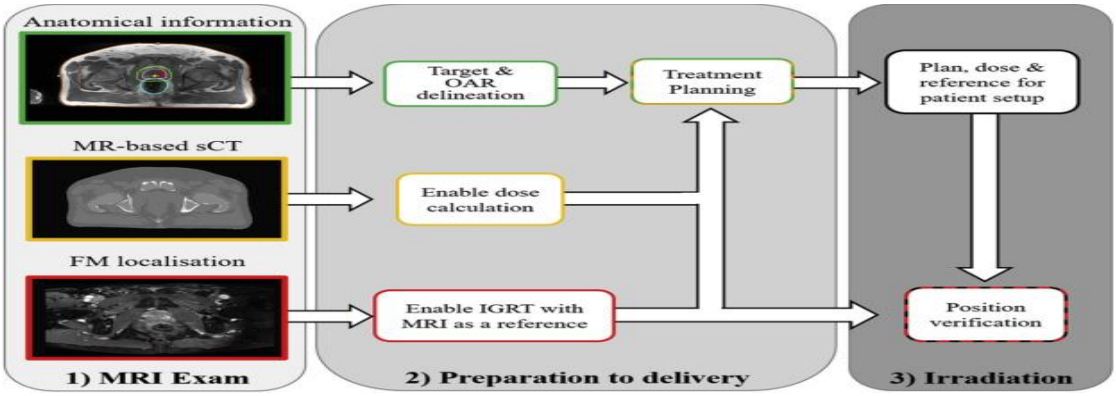

Figure 3: Magnetic Resonance Imaging only Workflow for Radiotherapy Simulation and Planning

Source: (Kerkmeijer *et al.*, 2018)

Parasagittal and parasellar parts took 12.5 per cent of the cases each. The prevalence of involvement with CPA is high and corresponds with the typical lesion type, i.e. schwannomas and meningiomas that have been reported to develop in this anatomical region. Chordomas, metastases, and other intricate dural-based tumors were found to correlate with clivus and the skull base lesions. The parasagittal showed high chances to be meningiomas, whereas the the parasellar showed the pituitary and craniopharyngiomas type of masses. The site-based distribution maintains the anatomical preferences of one type of lesion and assists in simplifying the diagnosis process. Noting common modes of lesion distribution helps the radiologist and clinicians focus on important areas of anatomy when constructively critiquing, leading to more accurate diagnoses and effective treatment scheduling (Joseph *et al.,* 2025).

Prevalence and Distribution of Lesion Types Identified on MRI

A wide range of lesion types was detected in MRI assessment, with arachnoid cysts (28.4%), and schwannomas (26.1%) being the most common ones. They followed with epidermoid cysts (19.3%), meningiomas (14.8%), dural metastases (6.8%), hemangiopericytomas (3.4%) and chordomas (1.1%). This distribution brings out the range of extra-axial, intra-calvarial lesions and its relevance in the use of MRI to distinguish the two conditions. Epidermoids and arachnoid cysts usually show no symptoms but may produce mass effect and resemble craniophagous lesions (Aydin *et al.*, 2024).

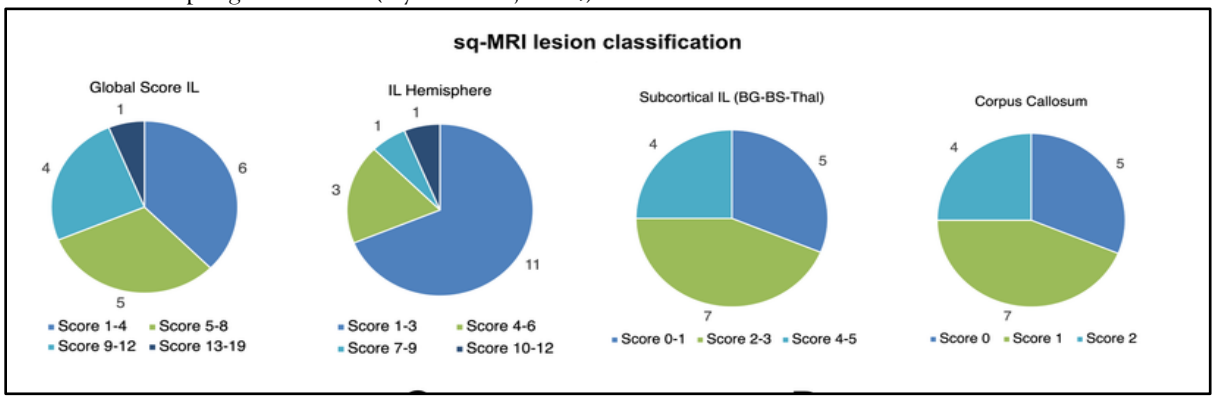

Figure 4: Lesion severity is reported both as global score and specific score for the ipsilesional (IL) hemisphere, IL subcortical structures, and corpus callosum

Source: (Errante *et al.*, 2024)

Schwannomas were prevalent in the CPA area, whereas meningiomas were widespread. Less common but more potentially malignant lesions included dural metastases and hemangiopericytomas. The benign lesions are very common and focus on specific imaging protocols to prevent overtreatment (Nicosia *et al.*, 2024). The results provide credence to the fact that high-resolution MRI on multiparametric assessment can be used to differentiate between cystic, neoplastic, and metastatic lesions, to assist clinicians in defining relevant stratifying procedures.

Signal Characteristics Across T1, T2, and FLAIR Sequences

Most of the lesions on T1-weighted images were hypointense (70.5 per cent), 15.9 per cent on T1-weighted images were isointense, and 11.4 per cent were hyperintense. A small minority (2.3%) demonstrated ambiguous indications. The T2-weighted sequences showed hyperintensity in 75.0 percent, mixed in 13.6 percent, and hypointensity in 11.4 per cent of the lesions. Such attributes of signals were further enhanced by the FLAIR sequence, with 48.8% of the lesions being heterogeneously hyperintense, 18.1% with marked hypointense, and hyperintense lesions were heterogeneously hyperintense (Benson *et al.,* 2025). These contrasts were very useful as they offered useful diagnostic indications. As an example, epidermoid cysts exhibited diffusion restriction with upper T2 and lower T1 signals, whereas meningiomas, as a rule, post-gadolinium enhanced and had isointensity on T1. Characteristics of the signal played a major role in distinguishing the cystic lesions, such as arachnoid cysts (CSF-like signal), and solid tumors or hemorrhagic masses. This proves the value of multiparametric MRI examination, as an isolated sequence is unlikely to provide conclusive diagnostic value in complicated cases.

Correlation Between MRI Findings, Clinical Diagnosis, and Lesion Size

In the study, the results were highly correlated between the MRI results and primary clinical assessment. Out of 88 cases, 40.9 per cent of the clinical suspicions were presented by meningioma, hemangiopericytoma, and dural metastases, whereas the mixture of schwannoma, meningioma, and epidermoid made up 19.3 percent. MRI allowed a system of refinement of these classifications based on the morphology of lesions, enhancement patterns, and the location in an anatomical site (Szekely-Kohn *et al.*, 2025). The size of the lesion varied between 10.4 mm and 44.9 mm, and the mean was found to be 27.70 mm; therefore, moderate and large lesions were frequent. Lesions of smaller size were frequently found as a side effect or without any symptoms, whereas larger lesions were associated with neurologic signs, viz., seizure and focal deficits. MRI, in addition to showing the presence of a lesion, also provided a method of precise definition of size and extent, which facilitated surgery planning and follow-up (Yilmaz *et al.*, 2024). This association not only confirms the use of MRI as a first-line resource to determine the type of lesion, but also to measure the burden of lesion burden, which has a direct impact on the determination of treatment options and prognosis.

CONCLUSION

High-resolution MRI has proved to be a very important investigation tool in the diagnosis of Extra-axial, upper skin, non-traumatic lesions of the brain. This study proved itself as effective in determining the type of lesion, size of lesion, location and features of the signal so that it could accurately distinguish between a benign and malignant pathology. The relationship between clinical manifestations and the MRI results, also helps in understanding its use in early diagnosis and treatment planning. More superior MRI sequences like DWI, FLAIR, post-contrast gave insight to the character and behavior of lesions. In general, MRI causes an improved level of confidence in diagnosis, decreased dependence on invasive assessments and plays a significant role in achieving improved patient outcomes in the setting of neuroimaging practice.

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