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Review Article

Pictorial Essay on Meningioma and its Mimics

Dr. Banoth Nandini[1], Dr. M. Uma Maheswara Rao[2]

Third Year Postgraduate, Radiology, Andhra Medical College, King George Hospital Visakhapatnam, Andhra Pradesh
Regd.No:20797, Dnb,Dmrd, Professor of Radiodiagnosis, Andhra Medical College King George Hospital, Visakhapatnam, A.P.

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Corresponding Author:

Dr BANOTH.NANDINI
Third Year Postgraduate, Radiology
Andhra Medical College
King George Hospital
Visakhapatnam, Andhra Pradesh

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ABSTRACT

Meningiomas are the most common extra-axial tumors of the central nervous system and typically demonstrate characteristic imaging features on magnetic resonance imaging (MRI) and computed tomography (CT), allowing confident radiologic diagnosis in most cases. Classical findings include a dural-based extra-axial mass with avid homogeneous enhancement, broad dural attachment, cerebrospinal fluid cleft, calcification, adjacent hyperostosis, and variable dural tail sign. However, a wide spectrum of neoplastic and non-neoplastic dural lesions may closely mimic meningiomas, creating important diagnostic challenges because management strategies and prognosis differ substantially among these entities.

This pictorial essay reviews the imaging spectrum of intracranial and spinal meningiomas, including typical appearances, uncommon variants, and characteristic locations. Illustrative cases include en plaque meningioma, cystic meningioma, multiple meningiomas, inflammatory-appearing meningioma, intraventricular meningioma, spinal meningioma, and rare primary intraosseous meningioma. Emphasis is placed on multimodality imaging findings on MRI and CT, including enhancement patterns, diffusion characteristics, susceptibility changes, vascularity, calcification, and osseous involvement.

In addition, this review highlights important meningioma mimics such as solitary fibrous tumor, Langerhans cell histiocytosis, hypertrophic pachymeningitis, melanocytic neoplasms with dural metastases, and dural metastatic disease. Key differentiating radiologic features are discussed, including patterns of bone remodeling or destruction, multiplicity, diffusion restriction, orbital or extracranial extension, and associated inflammatory or metastatic findings.

Recognition of these distinguishing imaging characteristics is essential for narrowing the differential diagnosis, guiding appropriate clinical management, and facilitating accurate histopathological correlation.

Keywords*: Meningioma; Dural-based lesions; Extra-axial tumors; Magnetic resonance imaging; Computed tomography; Dural tail sign.*

INTRODUCTION

Meningiomas are the most common extra-axial tumors of the central nervous system and typically present as dural-based lesions with characteristic imaging features on magnetic resonance imaging (MRI). Computed tomography (CT) further aids evaluation by demonstrating calcification and osseous involvement. However, several neoplastic and non-neoplastic dural lesions may closely mimic meningiomas, posing important diagnostic challenges due to differences in treatment and prognosis. This pictorial essay reviews the imaging spectrum of meningiomas and their common mimics, emphasizing key radiologic features that facilitate accurate differentiation.

KEY TEACHING POINTS

- Meningiomas usually demonstrate characteristic MRI features that allow confident diagnosis, although atypical appearances may create diagnostic uncertainty.
- A broad spectrum of neoplastic and non-neoplastic dural-based lesions can mimic meningiomas on imaging.
- Osseous involvement may aid differentiation: meningiomas commonly show calcification and adjacent hyperostosis, whereas many mimics are associated with bone erosion or destruction
- The dural tail sign, although frequently seen in meningiomas, is not specific and may also occur in other dural pathologies.
- Vascularity patterns can provide additional clues, as meningiomas generally demonstrate relatively increased perfusion compared with many mimicking lesions.
- Recognition of these distinguishing imaging features is essential for accurate diagnosis and appropriate clinical management.

EPIDEMOLOGY

- Meningiomas are among the most common intracranial tumors, with a reported annual incidence of approximately 6 per 100,000 individuals and a marked female predominance.
- They occur most commonly after the fifth decade of life and are frequently detected incidentally, especially in elderly patients.
- Clinical presentation varies according to lesion location, mass effect, and involvement of adjacent neural, vascular, or cerebrospinal fluid pathways.
- Most meningiomas arise sporadically without a clearly identifiable cause.
- Established risk factors include prior cranial irradiation and genetic predisposition, particularly Neurofibromatosis type 2, in which multiple lesions are common.
- Although head trauma has been proposed as a possible association, a definitive causal relationship remains unproven.
- Meningioma mimics comprise a heterogeneous group of neoplastic and non-neoplastic entities with differing epidemiological and pathological characteristics, emphasizing the importance of accurate imaging evaluation.

LESIONS AND LOCATIONS

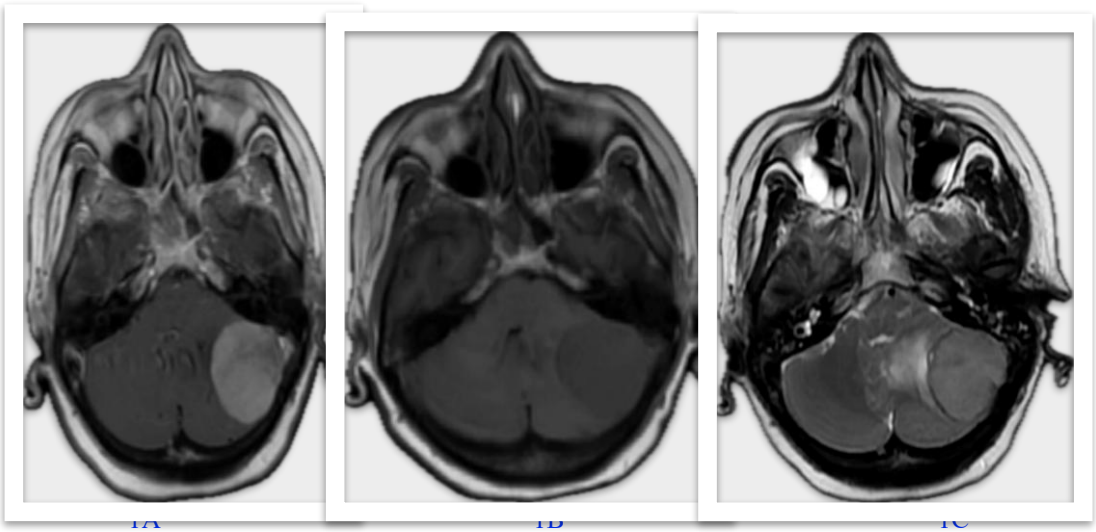
Meningiomas may be found along any of the external surfaces of the brain as well as within the ventricular system where they arise from the stromal arachnoid cells of the choroid plexus. The most common locations include the parasagittal aspect of the cerebral convexity, the lateral hemisphere convexity, the sphenoid wing, middle cranial fossa and the olfactory groove [15]. Meningiomas at the skull base may extend through foramina, for example into the orbit and along the course of the trigeminal nerve. Meningiomas represent the second most common mass lesion of the cerebellopontine angle [8], secondary to the acoustic schwannoma

IMAGING CHARACHTERISTICS OF MENINGIOMA

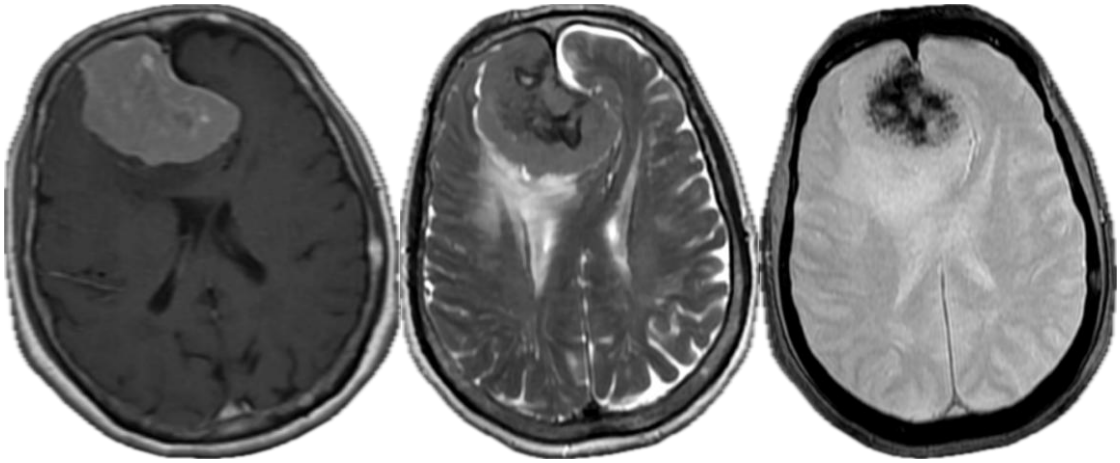
Meningiomas commonly appear as sharply marginated extra-axial lesions with a lobulated contour and broad dural base [3A, 3B] As the lesion enlarges, it may exert mass effect on the adjacent cerebral cortex, producing inward displacement of the gray matter. A subset demonstrates a diffuse sheet-like pattern of dural spread, known as *en plaque* meningioma, most often involving the sphenoid wing or cerebral convexities. Post-contrast imaging is especially useful in these cases, typically revealing focal or asymmetric dural thickening with avid enhancement. [3A, 3B]

MRI typically shows meningiomas as lesions with signal intensity similar to, or slightly lower than, adjacent grey matter on T1-weighted images.[1B] On T2-weighted sequences, they commonly demonstrate iso- to mildly increased signal intensity.[1C] Post-contrast images usually reveal strong, fairly uniform enhancement.[1A] In some cases, small non-enhancing components may be present, corresponding to internal calcification or areas of necrosis.

Calcification is a frequent imaging feature of meningiomas and is most reliably identified on computed tomography, which accurately demonstrates its presence and distribution. It is commonly encountered in psammomatous and transitional subtypes and is often associated with relatively slow tumor growth.[15] On MRI, calcified regions typically appear as areas of signal loss on susceptibility-weighted imaging and may also be seen as hypointense foci on T2-weighted sequences. [2C]

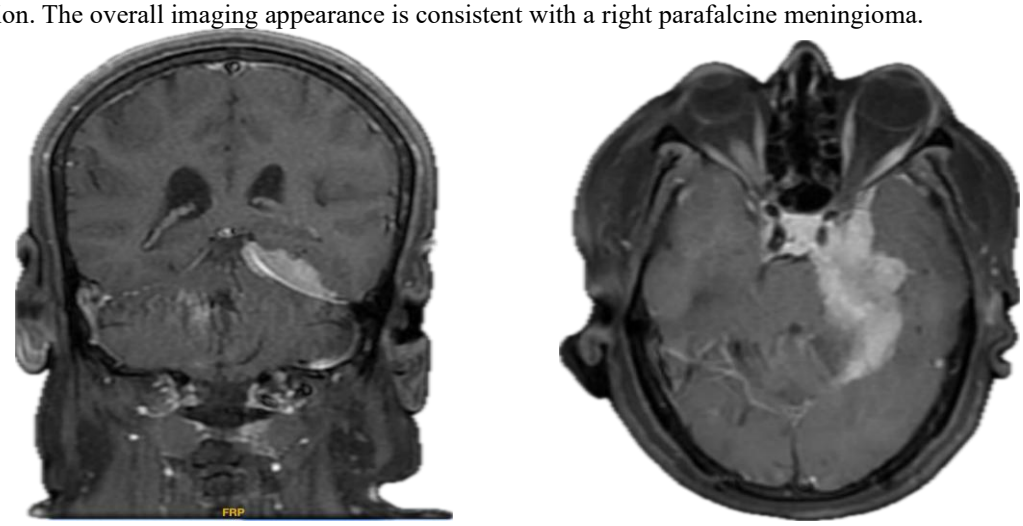


Typical MRI signal intensity characteristics consist of isointensity to slight hypointensity relative to grey matter on the T1-weighted sequence (Fig. 1B) and isointensity to slight hyperintensity relative to grey matter on the T2 sequence (Fig. 1C) After contrast administration, meningiomas typically demonstrate avid, homogenous enhancement (Fig. 1A)



2A 2B 2C

Post-contrast axial T1-weighted images in a 96-year-old woman demonstrate a large, avidly enhancing extra-axial mass along the right parafalcine region, measuring approximately 5.7 × 5.6 × 5.0 cm. The lesion shows a central T2-weighted hypointense area corresponding to non-enhancing components, suggestive of calcification. Associated imaging features include a cerebrospinal fluid cleft, buckling of the adjacent white matter, prominent intratumoral flow voids, and encasement of adjacent cortical vessels. Susceptibility-related signal voids within the lesion further support the presence of calcification. The overall imaging appearance is consistent with a right parafalcine meningioma.



3A 3B

Post-contrast axial T1-weighted images and coronal T1 in a 51-year-old woman with progressive visual blurring demonstrate an avidly enhancing, ill-defined en plaque dural-based lesion along the left tentorium and medial aspect of

the temporal region. The lesion extends into the suprasellar region, prepontine and ambient cisterns, and the left cavernous sinus, closely abutting the optic chiasm and infundibulum and causing compression of the cavernous segment of the left internal carotid artery. HISTOLOGY consistent with an en plaque meningioma

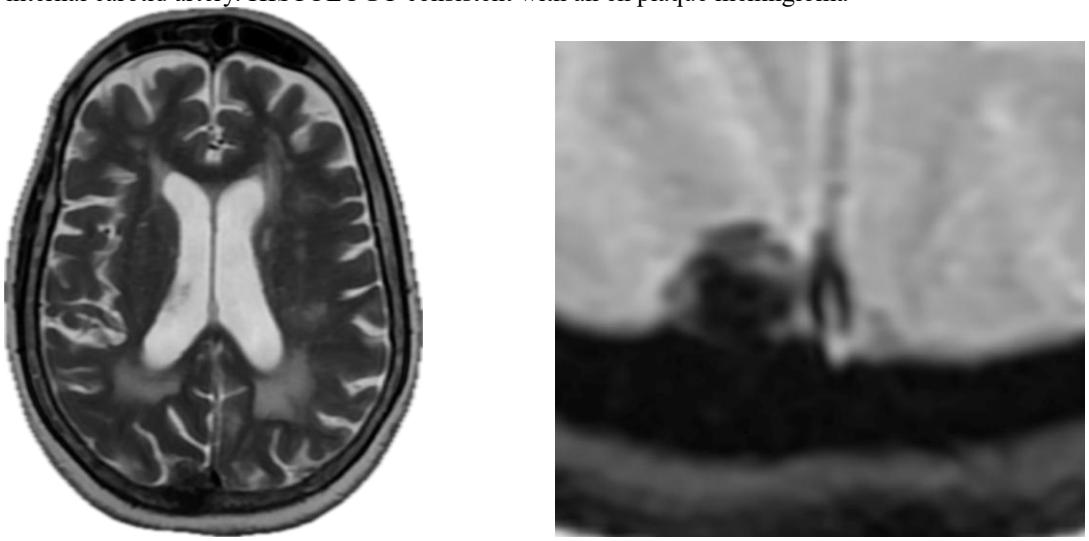
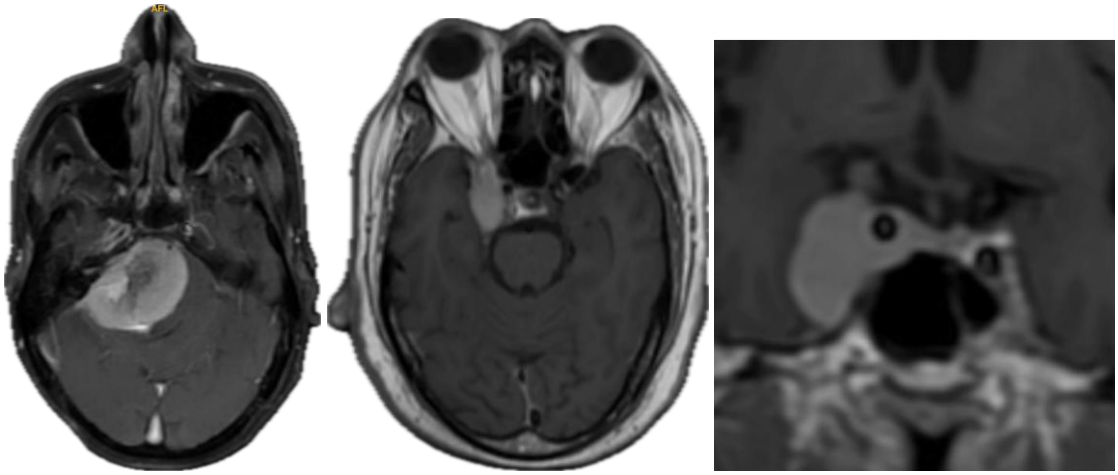
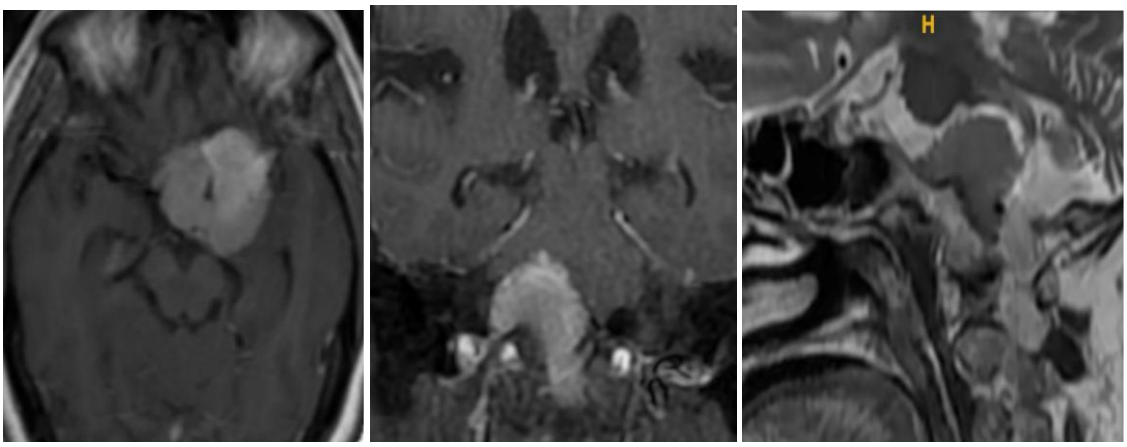


FIG15 MRI brain in a 75-year-old woman performed for acute neurological symptoms shows an incidental, well-defined extra-axial lesion in the right parasagittal parietal region measuring approximately 9.6 mm. The lesion appears hyperintense on T1- and T2-weighted images with marked blooming on susceptibility-weighted imaging, consistent with dense calcification. The imaging features are characteristic of an incidental calcified parasagittal meningioma.

Meningiomas may arise from nearly any meningeal surface and less commonly from the ventricular system via arachnoid cells of the choroid plexus. In this study, lesions are illustrated in diverse locations including the cerebellopontine angle[8], cavernous sinus, suprasellar[9] and parasellar regions[11], craniovertebral junction[12], olfactory groove, intraventricular compartment[14], and spine[13]. Skull base meningiomas may extend through neural foramina and along cranial nerves, particularly the trigeminal nerve. Intraventricular lesions most commonly arise from the atrium of the lateral ventricle, while spinal meningiomas usually appear as intradural extramedullary masses.[13] Rarely, meningiomas may occur as primary intraosseous or extracranial tumors, presenting as calvarial lesions[10] or at ectopic extracranial sites.



CP ANGLE [8] CAVERNOUS SINUS



SUPRASELLAR MENINGIOMA CLIVAL MENINGIOMA

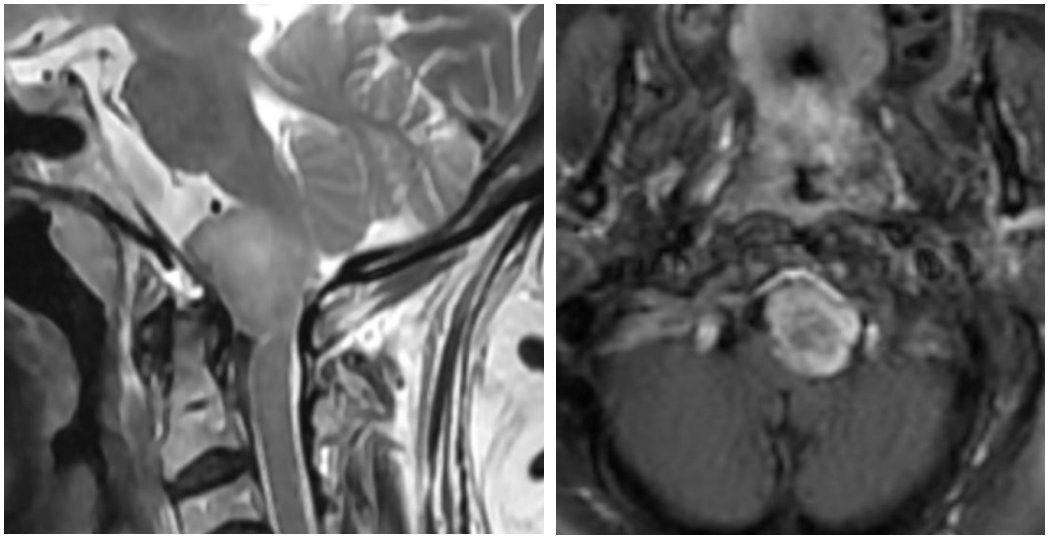


Fig 12, 54-year-old woman presenting with progressive neck pain demonstrates an extra-axial T2-isointense lesion at the cervicomedullary junction measuring approximately 24 × 16 × 26 mm. The lesion shows intense homogeneous contrast enhancement with suspected extension into the left hypoglossal canal and resultant compression of the adjacent brainstem. The imaging features are suggestive of a dural-based lesion at the craniocervical junction, consistent with HPE proven meningioma.

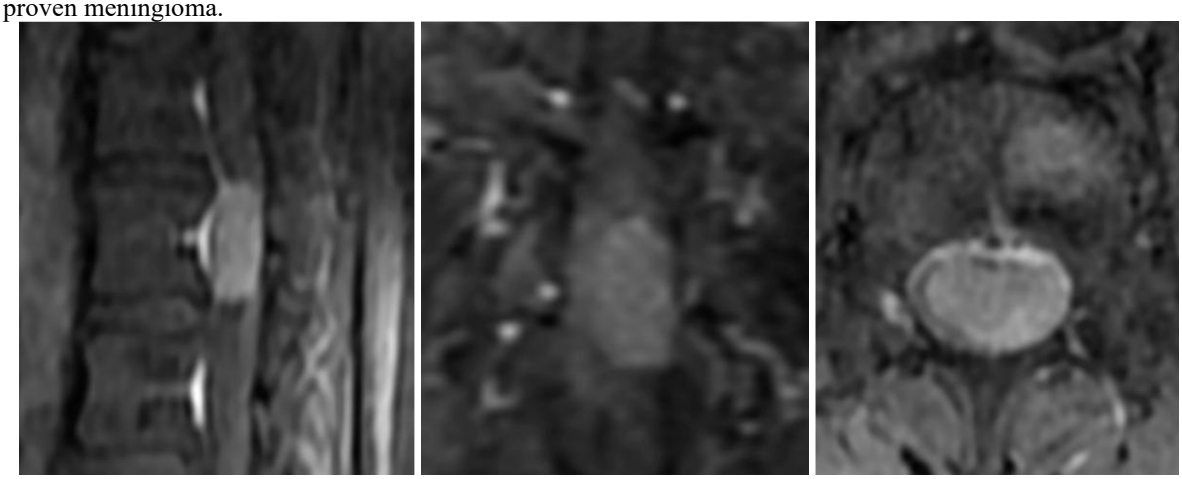
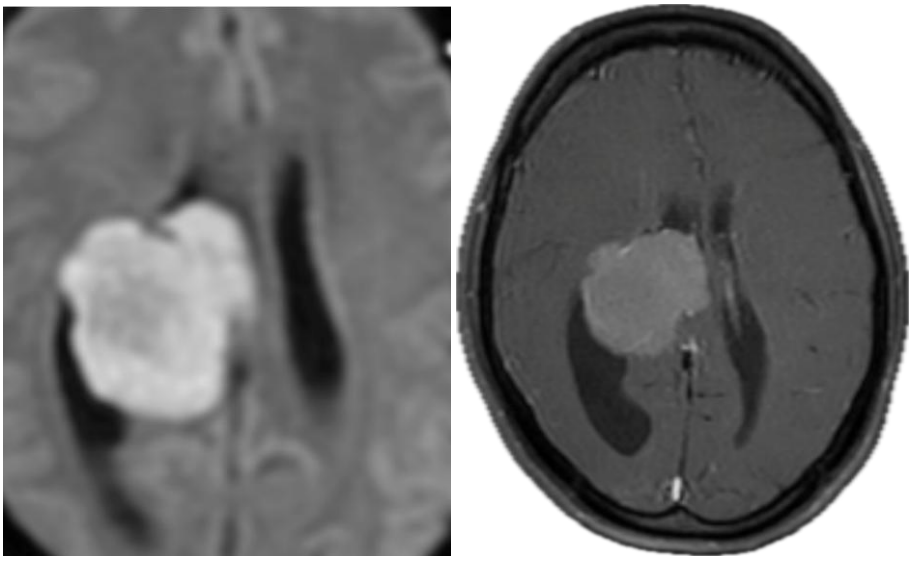
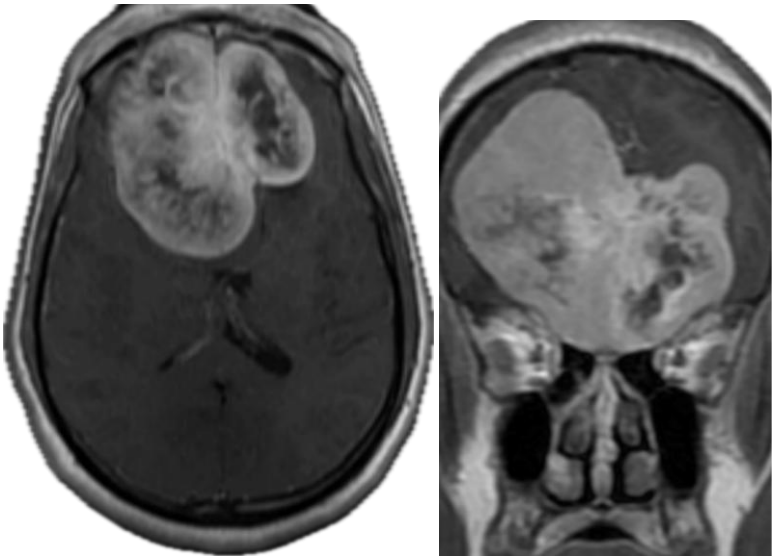


Fig 13 , Contrast-enhanced MRI of the dorsolumbar spine in a 70-year-old man presenting with progressive lower-limb weakness demonstrates a well-defined intradural–extramedullary mass at the D12 level measuring approximately 28 × 14 mm. The lesion shows homogeneous contrast enhancement with a broad dural base and dural tail, causing marked spinal cord compression with flattening and mild associated cord T2 hyperintensity. Histopathological examination confirmed the diagnosis of a psammomatous meningioma[5]



14A 14B

Fig[14B] post-contrast axial T1-weighted sequence in a 44-year-old woman with headaches demonstrates a large, homogeneously enhancing mass within the trigone of the right lateral ventricle associated with ventricular dilatation. Histology was that of a meningioma (grade I)



Olfactory groove meningothelial meningioma [15]

Histological Subtypes of Meningioma (WHO Grade I)

Meningiomas exhibit a wide range of histological patterns based on cellular architecture, collagen content, and calcification. Recognized WHO Grade I subtypes include meningothelial, fibrous, transitional, psammomatous, angiomatous, microcystic, secretory, metaplastic, and lymphoplasmacytic-rich variants.

Histological subtypes demonstrated in this pictorial essay:

Meningothelial (Syncytial) meningioma[4]

Psammomatous meningioma[5]

Transitional (Mixed) meningioma[6]

Histological subtype alone does not determine biological behaviour; WHO grading depends on mitotic activity, brain invasion, and additional histologic criteria.

WHO Grading of Meningioma (WHO CNS 2021)

Meningiomas are graded based on histopathological criteria; imaging alone cannot determine grade.

WHO Grade I (Benign)

<4 mitoses / 10 HPF

No brain invasion

Includes meningothelial, psammomatous, transitional subtypes

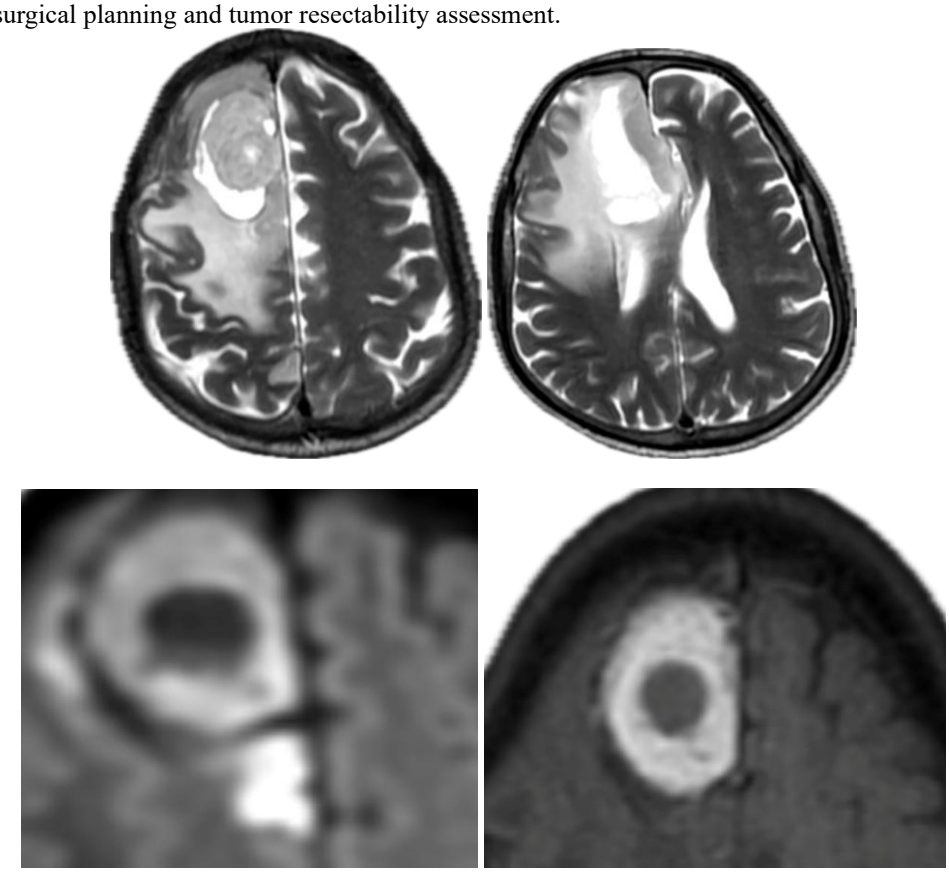
WHO Grade II (Atypical)

≥4 mitoses / 10 HPF or brain invasion

Or ≥3 atypical features (hypercellularity, sheet-like growth, necrosis)
WHO Grade III (Anaplastic)
≥20 mitoses / 10 HPF
Marked anaplasia
Key Point: WHO grade predicts recurrence and prognosis.

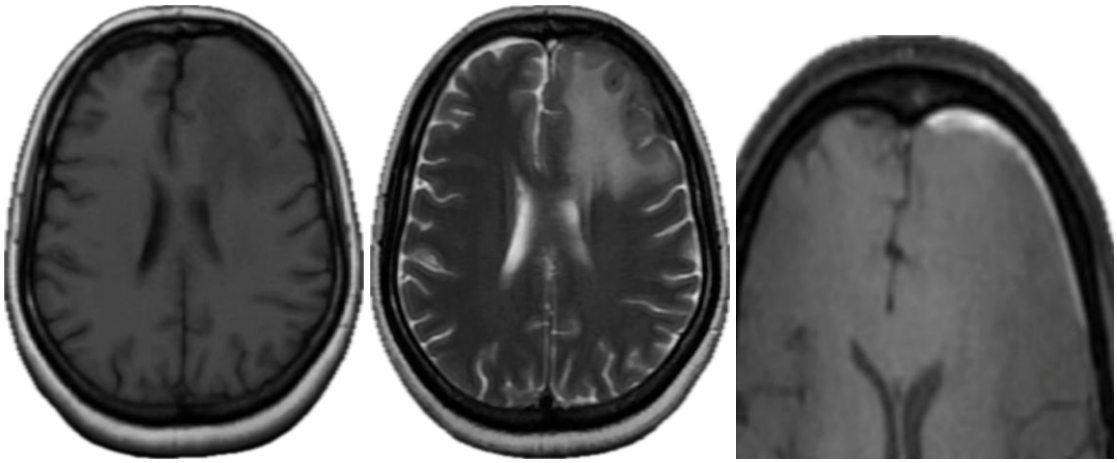
Uncommon / Rare Imaging Features

Cystic meningiomas are an uncommon variant, accounting for approximately 2–4% of intracranial meningiomas. These lesions may contain intratumoral or peritumoral cysts. Intratumoral cysts are usually related to degeneration, necrosis, or haemorrhage within the tumor, whereas peritumoral cysts are thought to result from reactive changes or entrapment of adjacent cerebrospinal fluid spaces. Imaging may demonstrate cyst wall or peripheral enhancement, although definitive classification often requires histopathological correlation. Recognition of these atypical appearances is important, as they may influence surgical planning and tumor resectability assessment.

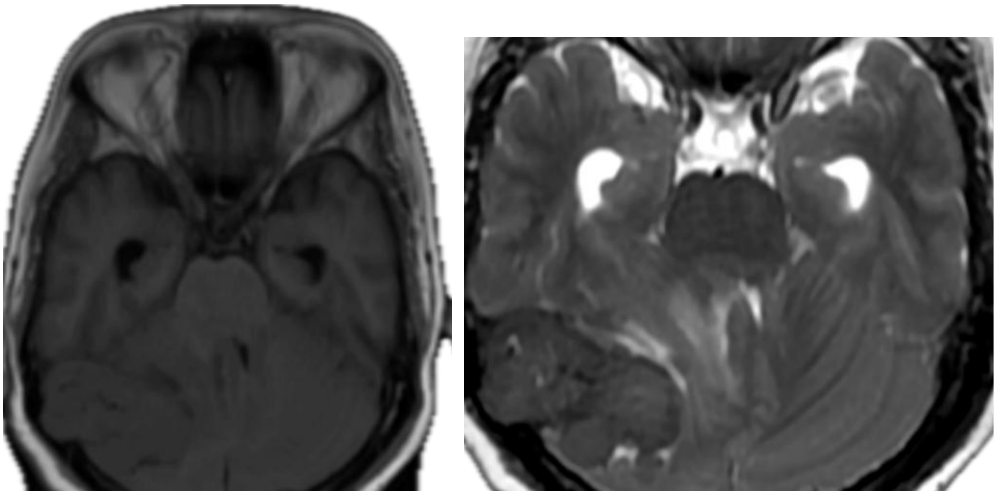


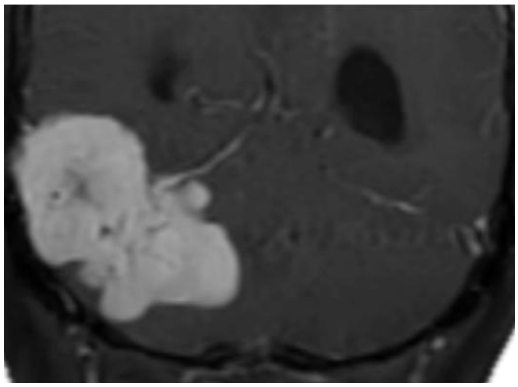
Case [1] contrast-enhanced MRI brain in a 61-year-old man demonstrates an intensely enhancing falcine extra-axial mass measuring approximately 3.8 × 2.8 × 3.3 cm, with central intratumoral T2/FLAIR hyperintensity likely representing necrosis [7] or cystic degeneration, along with additional peripheral cystic components, consistent with combined intratumoral and peritumoral cystic morphology. The lesion is associated with marked vasogenic edema and significant mass effect, including compression of the right anterior cerebral artery with imaging features of ACA territory infarction. Histopathological examination confirmed a WHO Grade II meningioma, supporting the diagnosis of a cystic meningioma with aggressive imaging characteristics

Meningiomas rarely present with a diffuse inflammatory dural pattern that can closely mimic hypertrophic pachymeningitis, accounting for less than 1% of intracranial meningiomas. Instead of a discrete extra-axial mass, imaging may demonstrate diffuse pachymeningeal thickening and enhancement with disproportionate adjacent parenchymal edema. These appearances can resemble inflammatory or infectious dural disorders, creating significant diagnostic difficulty. Lack of systemic inflammatory findings or poor response to medical therapy should raise suspicion for an underlying neoplastic process. Definitive diagnosis usually requires histopathological confirmation, as imaging findings alone may be non-specific.



CASE[2] Contrast-enhanced MRI brain in a 25-year-old woman presenting with new-onset focal seizures demonstrates extensive cortical and subcortical edema involving the left frontal lobe with loss of normal gyriform gray–white matter differentiation. Post-contrast images reveal significant pachymeningeal thickening and enhancement along the left frontal convexity, leading to an initial radiological impression of hypertrophic pachymeningitis. Histopathological examination, however, confirmed a WHO Grade I meningioma, illustrating an atypical inflammatory-appearing presentation mimicking dural disease.

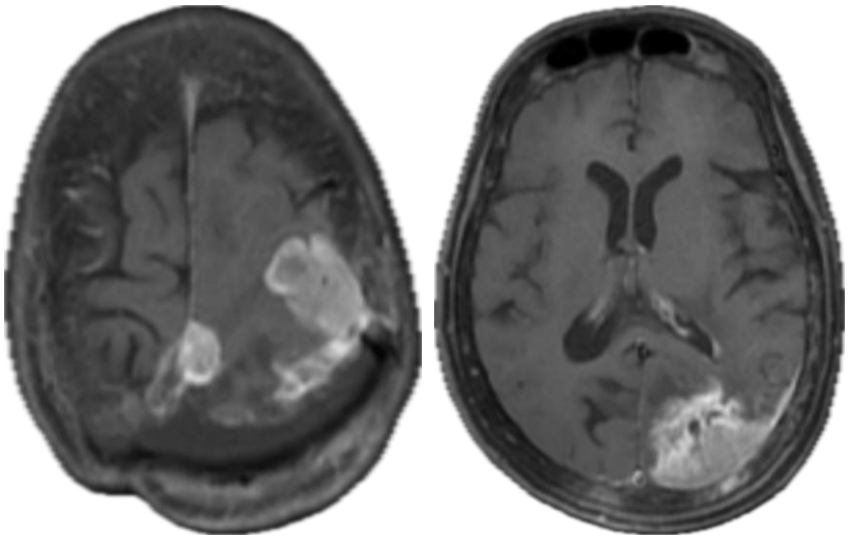




CASE[3] 65-year-old woman presenting with features of raised intracranial pressure demonstrates a large, well-defined lobulated extra-axial mass centred along the right tentorium cerebelli.The lesion appears T1 iso- to hypointense and T2 hypointense, with intense homogeneous contrast enhancement and an enhancing dural tail. Few internal flow voids are noted, without diffusion restriction. The mass extends both superiorly and inferiorly from the tentorium, causing significant brainstem and fourth ventricular compression with resultant obstructive hydrocephalus and mild perilesional edema. Histopathological examination confirmed a transitional meningioma[6], accounting for the imaging features that closely mimicked a solitary fibrous tumor/hemangiopericytoma.

Uncommon / Rare Imaging Features – Multiple Meningiomas

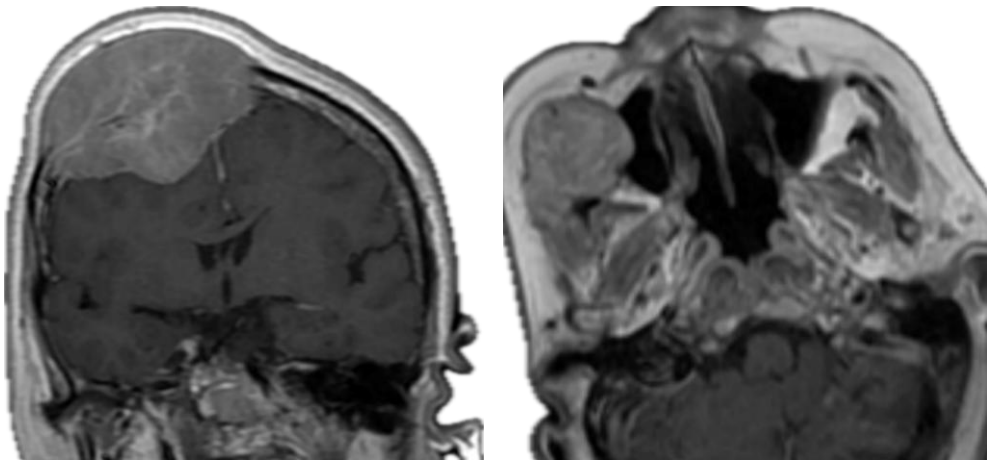
Multiple meningiomas are an uncommon entity, seen in approximately 1–10% of cases, and are characterized by the presence of two or more separate meningiomas occurring synchronously or metachronously. Although commonly associated with Neurofibromatosis type 2, they may also occur sporadically. Imaging typically demonstrates multiple extra-axial dural-based lesions with similar signal intensity and homogeneous enhancement patterns. Differentiation from dural metastases or multifocal inflammatory dural disease may be challenging, particularly in postoperative patients. Recognition of characteristic imaging features is important for appropriate diagnosis, treatment planning, and follow-up.

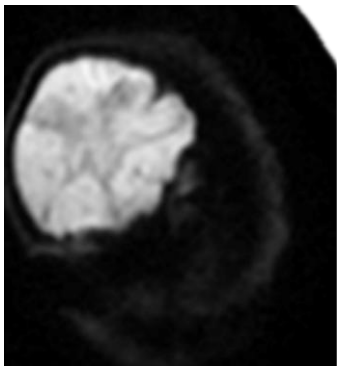


CASE[4] Contrast-enhanced MRI brain in a patient with a known history of meningioma resection presenting with progressive neurological symptoms demonstrates multiple extra-axial, intensely enhancing lesions involving the left frontal, parietal, and parasagittal parietal regions. The largest lesion measures approximately 33 × 26 × 26 mm and is associated with marked surrounding vasogenic edema. Additional lesions of similar enhancement characteristics are noted in the left parietal region, with surrounding dural enhancement. The lesions show diffusion restriction and focal susceptibility changes, consistent with hypercellular recurrent disease. The imaging findings are in keeping with residual and recurrent multiple meningiomas, with dural metastases considered less likely in view of the prior clinical history.

Uncommon / Rare Imaging Features – Primary Intraosseous Meningioma

Primary intraosseous meningiomas are rare lesions, comprising less than 1–2% of all meningiomas, and arise within the calvarial diploë rather than from the dura. Imaging typically demonstrates calvarial expansion with hyperostotic or, less commonly, lytic bone changes. The lytic variant may mimic aggressive calvarial tumors or metastatic disease due to cortical destruction, soft-tissue extension, and heterogeneous enhancement. CT is particularly useful for evaluating osseous involvement, while MRI better depicts associated soft-tissue and intracranial extension. Recognition of this uncommon entity is important for accurate diagnosis and surgical planning.



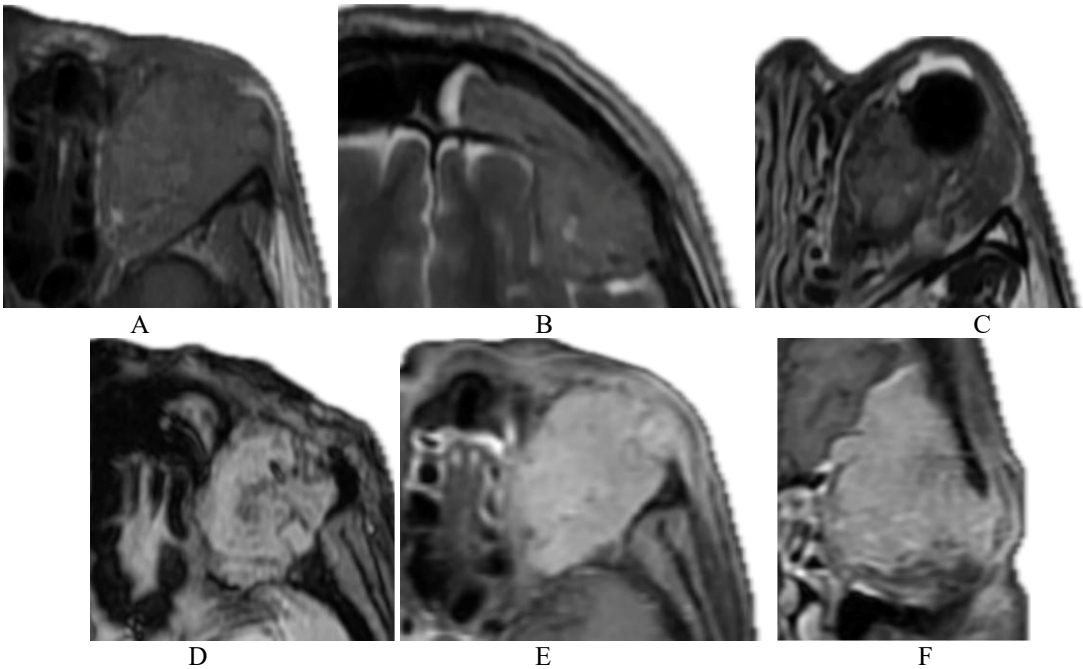


CASE [5] Contrast-enhanced MRI brain with diffusion-weighted imaging in a 52-year-old woman presenting with a slowly progressive frontal swelling and headache demonstrates two lobulated extra-axial enhancing lesions involving the right frontal convexity and right zygomaticomaxillary region. The lesions show intense homogeneous enhancement with diffusion restriction and multiple punctate susceptibility foci on GRE, suggestive of vascular or hemorrhagic components. CT correlation reveals lytic destruction of the involved calvarial diploë at both sites, without significant intraparenchymal invasion or hydrocephalus. Histopathological examination confirmed a primary intraosseous (diploic) meningioma, representing a rare calvarial meningioma variant with multifocal involvement.

The purpose of this pictorial essay is to highlight the spectrum of dural and dural appearing lesions that may radiologically simulate meningioma and pose diagnostic challenges. Awareness of the characteristic imaging features and pathological findings of these entities can significantly aid in accurate diagnosis and optimal clinical management. This pictorial review focuses on solitary fibrous tumor, Langerhans cell histiocytosis, hypertrophic pachymeningitis in suspected IgG4-related disease, meningeal melanoma with associated metastases, dural metastases from carcinoma breast

Solitary Fibrous Tumor

Solitary fibrous tumors are rare dural-based mesenchymal neoplasms that can arise within the meninges. Histologically, they are composed of spindle cells with collagen-rich stroma and characteristic branching vascular channels, typically demonstrating CD34 positivity. Imaging usually reveals a well-defined extra-axial mass that may appear hyperdense on CT and iso- to hypointense on both T1- and T2-weighted MRI, with strong post-contrast enhancement. Because of their dural attachment and enhancement pattern, these tumors can closely resemble meningiomas, often requiring histopathological confirmation for definitive diagnosis.

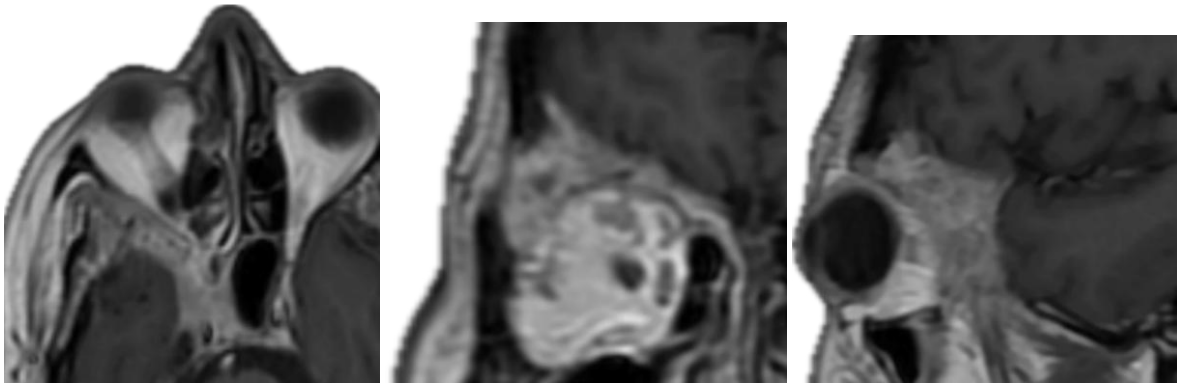


CASE[1] T1 hypo intense (A)T2 (B) and flair(C) intermediate signal with no evidence of diffusion restriction (D)with avid Contrast-enhanced MRI (E&F)demonstrates a left frontal extra-axial, dural-based lesion extending into the frontal sinus and superior extraconal orbit, showing T1 hypointensity, intermediate T2/FLAIR signal, and homogeneous enhancement without diffusion restriction or susceptibility.

Biopsy-proven solitary fibrous tumor, mimicking meningioma due to its dural-based location, well-defined margins, and avid contrast enhancement.

Langerhans Cell Histiocytosis

Langerhans cell histiocytosis is an uncommon proliferative disorder that frequently involves the calvarium. Intracranial disease typically presents as lytic skull lesions with an associated soft-tissue component and adjacent dural involvement, which may mimic a dural-based mass. CT commonly demonstrates well-defined calvarial destruction, while MRI shows an enhancing soft-tissue lesion with variable signal intensity. Although the extra-axial appearance can resemble meningioma, the presence of underlying bone erosion and soft-tissue extension favors LCH.



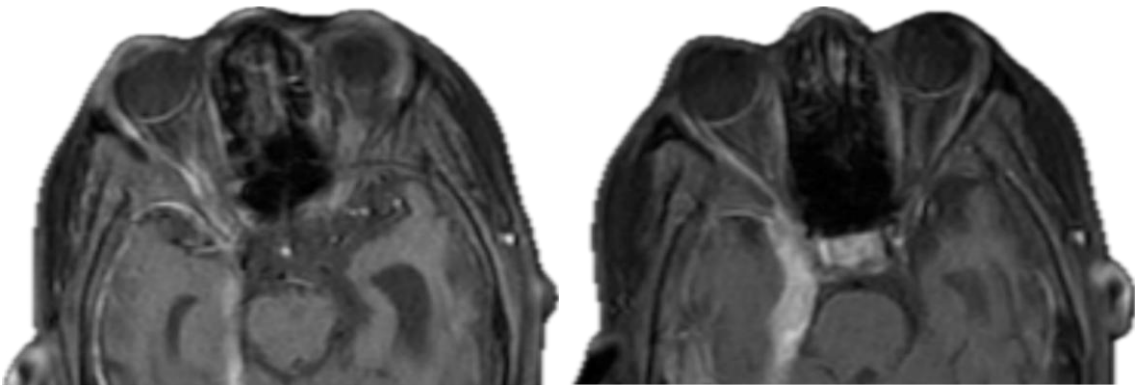
A B C

CASE[2] A patient presented with right-sided proptosis and was evaluated with contrast enhanced MRI of the brain with orbits for suspected skull base pathology

(A, B, C) Contrast-enhanced MRI demonstrated an expansile lesion involving the right greater wing of the sphenoid bone, showing altered signal intensity with associated cortical expansion. The lesion avid enhancement following contrast administration. There was infiltration of the right cavernous sinus, with superior extension up to the roof of the orbit. Associated focal pachymeningeal thickening and enhancement were noted along the right frontal region. Right-sided proptosis was present.

Histopathological examination confirmed the diagnosis of Langerhans cell histiocytosis.

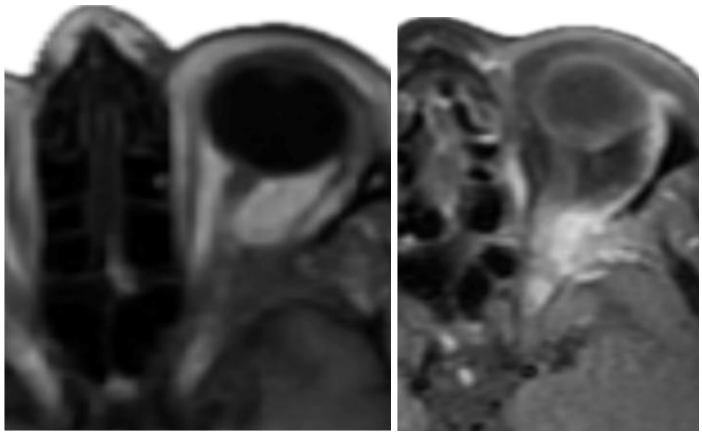
LCH is a rare clonal histiocytic disorder that can involve the skull and meninges, often presenting as lytic or expansile osseous lesions with adjacent dural involvement.



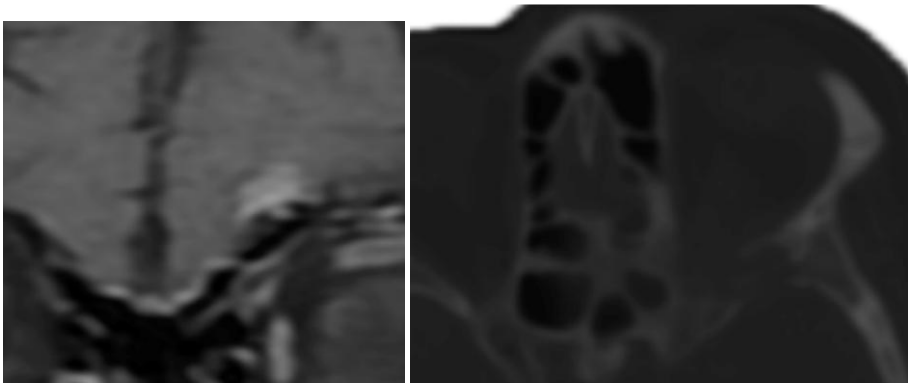
CASE[3] A 14-year-old female presented for evaluation with contrast-enhanced MRI of the brain. The study was performed to assess underlying parenchymal and dural abnormalities in the setting of chronic neurological changes

Contrast-enhanced MRI of the brain demonstrated diffuse pachymeningeal enhancement was noted along the right cerebral convexity.

Hypertrophic pachymeningitis can mimic en plaque meningioma due to focal dural thickening, plaque-like morphology, and intense enhancement.



A B



C D

CASE[4] A 61-year-old female underwent contrast-enhanced MRI of the brain and orbits with CT screening for evaluation of a left orbital mass.

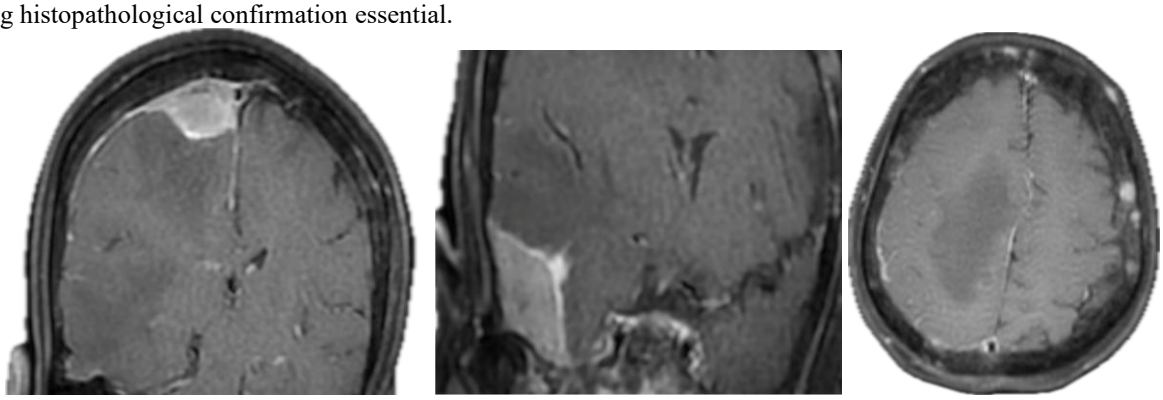
MRI revealed an ill-defined T1 hypointense (A) and contrast enhancing lesion (B)measuring approximately 9 × 13 mm in the left orbital intraconal space, located between the superior and lateral rectus muscles, abutting the optic canal and superior ophthalmic vein. CT screening demonstrated ill-defined lytic destruction with a wide zone of transition involving the adjacent greater wing of the sphenoid bone.(D)

Minimal leptomeningeal enhancement was noted in the left inferior frontal region. An additional ill-defined enhancing dural-based lesion (C)was seen in the left inferior frontal lobe, suggestive of a second dural-based deposit. Relative thinning of the left optic nerve was noted, consistent with optic nerve atrophy.

Amelanocytic neoplasm of the orbit with dural metastases, confirmed on histopathological examination.

Why Melanocytic Neoplasm Mimics Meningioma

Melanocytic neoplasms can closely mimic meningioma due to their extra-axial dural-based location, intense enhancement, and propensity to involve the sphenoid wing and orbit. The presence of dural metastases, bone involvement, and orbital extension closely simulates sphenoid wing meningioma and multiple meningiomas. In the absence of characteristic intrinsic T1 hyperintensity, imaging differentiation from meningioma may be challenging, making histopathological confirmation essential.



A B C

Dural metastases mimicking meningioma.

CASE[5] A 51-year-old female with known carcinoma breast. Post-contrast T1-weighted MRI demonstrates well-defined dural-based lesions in the right parafalcine frontal and right temporal regions showing homogeneous enhancement and broad dural attachment. Imaging features closely simulate meningioma; however, multiplicity of lesions and associated calvarial metastases favor dural metastatic disease.

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