Learning objectives

- To present and illustrate the typical and particular CT and MR appearances of intracranial meningiomas in common and uncommon locations.
- To discuss the differential diagnosis of meningiomas.

Background

**Definition** Meningiomas are the most common benign intracranial tumor. They originate from arachnoid cap cells, which are cells within the thin, spider web-like membrane that covers the brain and spinal cord. Although the majority of meningiomas are benign, these tumors can grow slowly until they are very large if left undiscovered, and, in some locations, can be severely disabling and life-threatening. Most patients develop a single meningioma; however, some patients may develop several tumors growing simultaneously in other parts of the brain \(^{(1)}\).

**Epidemiology** According to the Brain Science Foundation and the American Society of Clinical Oncology, meningiomas account for about 34 percent of all primary brain tumors, and most often occur in people between the ages of 30 and 70 \(^{(1)}\). Although intracranial tumors as a whole show a higher prevalence in males than in females, meningiomas have a 2:1 female-to-male ratio. Between Caucasians and Africans, African-Americans, and Asians, certain differences also have been noted \(^{(2)}\). Meningiomas in children are rare and differ from those in adults and other childhood tumors; they are even more rare in infants \(^{(2)}\). Malignant meningiomas account for about 2-3 % of all meningiomas \(^{(1)}\).

**Common locations of meningiomas** \(^{(3, 4)}\) (Fig. 1 on page 5, Fig. 2 on page 6)

- Convexity meningioma 20%
- Parasagittal/falcine meningioma 25%
- Sphenoid wing 20%
- Olfactory groove 10%
- Suprasellar/Parasellar 10%
- Posterior fossa/ cerebello-pontine angle meningioma 10%
- Intraventricular 2%
- Intraorbital < 2%
- Tentorial < 2%
- Foramen magnum meningioma < 2%
**Histopathological types of meningiomas** \(^{(3)}\) (Fig. 3 on page 6)

- Type I benign
- Type II atypical
- Type III malignant

**Morphological types of meningiomas:**

- globose = globular, well-demarcated neoplasm, with wide dural attachment
- en plaque = sheet-like extension covering dura without parenchymal invagination \(^{(5)}\)
- intraosseous meningioma = a subtype of primary extradural meningiomas \(^{(6)}\)
- intraventricular
- lipomatous

**Meningioma en plaque** represents a morphological subgroup within the meningiomas defined by a carpet or sheet-like lesion that infiltrates the dura and sometimes invades the bone. The en plaque variants commonly involve fronto-parietal, juxtaorbital, sphenoid wing, diffuse calvarial or rarely spinal region \(^{(7)}\). Due to difficulty in complete resection, the recurrence rate of en plaque meningiomas is higher than the usual counterpart. These tumors are also more prone to develop malignant change (11%) when compared to intracranial meningiomas (2%) \(^{(8)}\).

**Intraosseous meningiomas** are thought to arise from ectopic meningocytes or arachnoid cap cells trapped in the cranial sutures during molding of the head at birth. Misplacement and entrapment of meningothelial cells into suture or fracture lines as a result of trauma has also been speculated as the probable cause of calvarial meningioma. According to the literature, 68% of the primary extradural meningiomas involved the calvaria. Frontoparietal and orbital regions are the most common locations for intraosseous meningiomas and they affect with the same frequency each sex. Calvarial meningiomas are more prone to develop malignant changes (11%) compared with intracranial meningiomas (2%) and the association of osteolysis with a soft-tissue mass, is a strong reason to suspect a malignant meningioma \(^{(9)}\).

**Intraventricular** meningiomas are thought to arise from meningothelial inclusion bodies located in the tela choroidea and/or mesenchymal stroma of the choroid plexus. They are most frequently (80%) seen in the trigone of the lateral ventricles and for reasons that are not clear, slightly more frequently on the left, 15% in the third ventricle, 5% in the fourth ventricle \(^{(10)}\).

**Lipomatous meningiomas** are an uncommon subtype of meningiomas with radiological features of conventional meningioma. The pathogenesis of lipomatous meningioma
remains poorly understood and in 2007 they were included within the metaplastic meningioma group. This implies that arachnoidal cap cells, from which meningiomas arise, may undergo gradual transformation into other cell types such as fat, bone, cartilage and myxoid tissue, but studies of lipomatous meningioma have shown that lipid-laden cells retained meningeothelial characteristics such as those of desmosomes and lacked specific features of adipocytes. So, lipomatous meningioma should no longer be considered as a metaplasia and that lipid accumulation results from a metabolic abnormality of the neoplastic cells \(^{(11)}\).

**CT and MRI semiology of meningiomas**

**CT.** Meningioma is a well defined broad-based extra-axial mass, hyperdense on NECT, with homogeneous enhancement, and frequent calcifications that are seen on CT (25%). Also bone erosion or hyperostosis can be associated with meningiomas and is well appreciated on CT \(^{(12)}\).

**MRI.** On T1 Wi meningiomas are generally isointense to gray matter, iso-/ or hyperintense to gray matter on T2 Wi and demonstrate intense enhancement on T1 Wi. A focal thickened collar of enhancement can often be found adjacent to the tumor’s dural attachment. This is the "dural tail" sign which histologically can be associated with tumor infiltration or merely inflammation.

The typical radiological signs for extra-axial location of the lesion are better seen on MRI and there are:

- broad dural base;
- "cortical buckling" of the underlying brain;
- displace and expand subarachnoid space;
- "cerebrospinal fluid cleft”
- displaced subarachnoid vessels
- bony reaction \(^{(13)}\).

"Dural tail sign" (DTS), "dural thickening", "meningeal sign" are similar terms describing thickening of the dura adjacent to an intracranial neoplasm on contrast-enhanced T1 MR images. In 1990 the triple criteria for DTS were established by Goldsher et al. as:

- presence of at least two consecutive sections through the tumor at the same site in more than one imaging plane;
- greatest thickness adjacent to the tumor and tapering away from it;
- enhancement more intense than that of the tumor itself.

No equivalent sign has been described in post-contrast CT scans. Post-contrast CT can show dural thickening in 8% of MR proven DTS. Takeguchi et al noted that the DTS, which was identified on contrast-enhanced MRI, was also observed in all the cases of
DTS on FLAIR images, and concluded that FLAIR imaging is useful for showing dural abnormalities associated with meningiomas without the need for contrast medium (14).

**Oedema.** The probable etiologies of peritumoral oedema include tumor size, histologic subtypes, vascularity, venous stasis, type of arterial supply, sex hormone receptors, secretory activity, inflammation (lymphocytes and macrophage infiltrates), or brain invasion (15).

Two distinct patterns of edema can be distinguished. One pattern is that of a diffuse white-matter process appearing to represent active transudation of water into white matter, which occurs in 43 % of tumors with edema. The second pattern, occurring in 57% of tumors with edema, is a localized peritumoral process. Several studies have indicated that the hypodense area surrounding meningiomas does not solely represent vasogenic edema but may represent tumor pressure ischemia.

**Differential diagnosis** (5)

- dural metastasis - skull often infiltrated, multifocal (16);
- granuloma (sarcoid, TB) - labs often abnormal;
- hypertrophic pachymeningitis - dural biopsy essential for confirmation;
- extramedullary hematopoiesis;
- on CPA location: vestibular schwannoma, acoustic neurinoma, epidermoid, arachnoid cysts, metastases, lipoma;
- on parasellar location: pituitary adenoma, aneurysm, craniopharyngioma, glioma, hamartoma, germinoma, chordoma, metastases (17).

**Images for this section:**
Fig. 1: Frequent locations of meningiomas: 1 - Convexity; 2 - Parasagittal/falcine; 3 - Sphenoid wing; 4 - Olfactory groove; 5 - Suprasellar/Parasellar; 6 - Posterior fossa/cerebello-pontine angle.

Fig. 2: Rare locations of meningiomas: 1 - intraventricular; 2 - intraorbital; 3 - tentorial; 4 - foramen magnum.
### World Health Organization (WHO) Meningioma Classification

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<th>WHO grade I - benign</th>
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<th>WHO grade III - Malignant</th>
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**Fig. 3:** Histopathological types of meningiomas
Findings and procedure details

We retrospectively reviewed CT and MR images of patients diagnosed with cerebral meningioma in the last 5 years, in our department.

Techniques

CT protocol included unenhanced and enhanced acquisitions: sequential (axial) scan: 120 kV, effective mAs 400, rotation time = 1s, detector acquisition/collimation: 8x1,2, slice thickness 4,8 mm (recon: 2,4 mm), Kernel H31s.

In particular cases, we have used a MDCT acquisitions with MPR and 3D reconstructions.

MRI evaluation included: Axial T2, Ax/Cor Flair, diffusion, Axial T1 SE, 3D T1 FSPGR before and after Gd-BOPTA iv administration, T1 SE +Gd in axial/cor or sagittal plane; depending on localization -MRA 3D TOF or 2D TOF.

Locations

The most frequent localization of meningiomas was supratentorial with parasagittal (Fig. 4 on page 11) or convexity (Fig. 5 on page 12) topography.

The most frequent infratentorial location was the cerebellopontine angle. (to see Fig. 10 on page 16)

Others possible locations were:

• the sphenoid ridge (to see Fig. 6 on page 13, Fig. 17 on page 21)
• the parasellar region (to see Fig. 7 on page 14, Fig. 19 on page 23)
• olfactory groove (to see Fig. 8 on page 15)

The extension of the sphenoid ridge meningioma varies widely. The major of them extend in the orbital floor and associated hyperostosis of the sphenoid ridge (to see Fig. 6 on page 13, Fig. 18 on page 22). Some of them are very invasive and its extension should be specified facing the future treatment.

Rare localizations:

• intraventricular (to see Fig. 11 on page 17)
• crista galli (to see Fig. 9 on page 15)
• tentorium cerebelli (to see Fig. 16 on page 20)
• foramen magnum
• meningiomatosis (to see Fig. 12 on page 17) and
• meningiomas in NF type II.

Meningiomatosis is more frequently seen in women, and NF type II is the most common cause in young patients.

In addition to all these globose meningiomas, we reviewed one case of "en plaque" meningioma (to see Fig. 12 on page 17).

**Tipically imaging characteristics:**

**CT findings included:**

NECT

• well-defined broad-based extra-axial masses (to see Fig. 14 on page 19) which can be hyperdense (to see Fig. 13 on page 18) ~ 70-75%, isodense (to see Fig. 14 on page 19) ~ 25%, hypodense ~ 1-5%
• with frequent calcifications: diffuse (Fig. 7 on page 14), focal (Fig. 9 on page 15), sandlike, rim (Fig. 13 on page 18),
• hyperostosis of the adjacent inner table (to see Fig. 6 on page 13, Fig. 13 on page 18)
• varying degrees of surrounding vasogenic oedema (to see Fig. 6 on page 13)
• necrosis, hemorrhage.

CECT

• showed homogeneous enhancement (to see Fig. 14 on page 19)

On **MRI** meningiomas were:

• iso- or slightly hypointense with cortex on T1wi (to see Fig. 10 on page 16, Fig. 11 on page 17)
• with variable signal intensity on T2 wi (to see Fig. 4 on page 11, Fig. 10 on page 16, Fig. 11 on page 17, Fig. 15 on page 20)
• hyperintense peritumoral oedema (to see Fig. 11 on page 17) or diffuse white-matter oedema (to see Fig. 4 on page 11) and dural "tail" on FLAIR
• variable in appearance on DWI and ADC maps (hyperintense on DWI - Fig. 5 on page 12, Fig. 11 on page 17, restriction of water diffusion on ADC map - Fig. 5 on page 12)
After Gd-BOPTA injection

- homogeneously and intensely enhancement (to see Fig. 5 on page 12, Fig. 10 on page 16, Fig. 11 on page 17, Fig. 13 on page 18)
- dural tail, nonspecific (to see Fig. 5 on page 12, Fig. 15 on page 20)
- en plaque: sessile tickened enhancing dura (to see Fig. 12 on page 17)

**Differential diagnosis**

- **Acoustic neurinoma**
  - focused on internal auditory canal in which extension is frequently seen, and it can induce its widening (to see Fig. 20 on page 24, Fig. 22 on page 26)
  - dural tail sign is uncommon,
  - hypo/isointense on T1 Wi and hyperintense on T2 Wi,
  - inhomogeneous enhancement may be seen in extensive neurinoma, (to see Fig. 20 on page 24)

- **Dural based metastasis** may be difficult to differentiate from a meningioma.
  - oncologic history (to see Fig. 25 on page 28)
  - frozen section in the surgery room is the most effective step for a correct diagnosis.

- **Pituitary adenoma**
  - indent at the diaphragma sellae, giving a "snowman" configuration, (to see Fig. 26 on page 29)
  - enlarge the sella turcica (to see Fig. 26 on page 29)

- **Craniopharyngioma**
  - sellar/suprasellar mass
  - heterogeneous aspect with cystic and solid components and calcifications (rimlike or nodular).

- **Cavernous sinus metastases**
  - oncologic history
  - expansive masses generally heterogeneous before and after intravenous contrast material administration (to see Fig. 21 on page 25)

- **Lymphoma determinations**
  - Iso/hyperdense on NECT
  - Iso/hypointense on T1 Wi and T2 Wi (to see Fig. 24 on page 27)
• Enhancement is seen in 97-99% of cases (to see Fig. 23 on page 27)
• Calcifications or hemorrhage are rarely seen

ICA saccular aneurysm

• hyperdense on NECT, with possible peripheral calcifications; they have the same pattern of enhancement with the arteries of the circle of Willis on CTA; the bulky one can be partially thrombosed;
• on T1, T2 Wi appears as flow void, or shows heterogeneous signal intensity if the aneurysm is large
• the 3D TOF and MIP/MPR reconstructions are very useful for the correct diagnosis (to see Fig. 27 on page 30).

Images for this section:
**Fig. 4:** Falcine meningioma. Parasagittal F-P meningioma: extraparenchymatous dense mass with broad base implantation on falx cerebri in hypersignal on T2 WI and FLAIR (a,b), isosignal on T1 WI (c), homogeneous Gd enhancement (d), with surrounding vasogenic edema hyperintense on T2 WI and FLAIR (a,b).
**Fig. 5:** Convexity meningioma. Left frontal meningioma: hyperintense signal on T2 Wi (a), iso/hypointense on T1 Wi (b), homogeneous Gd enhancement (c), hyperintense on DWI (d), with restriction of water diffusion on ADC map (e), and "dural tail" sign (c).
Fig. 6: Left sphenoid meningioma with lobulated borders, discreetly hyperdense on NECT with a small calcification (a), presenting surrounding vasogenic oedema (a,b), homogeneous enhancement on CECT (b, c, d) and hyperostosis of the sphenoid ridge (e - orange arrow).
**Fig. 7:** Suprasellar psamoma on axial NECT (a) and left frontal meningioma partially calcified on coronal NECT (b).

![Fig. 7](image)

**Fig. 8:** Olfactory groove meningioma isointense signal on T1 Wi (a), isointense on T2 Wi (b), with homogeneous gadolinium enhancement on Axial T1, Sag T1 and Cor FSPGR (c, d, e).

![Fig. 8](image)
**Fig. 9:** Crista galli meningioma. Partially calcified small mass on axial NECT (a, b), with hyperostosis of the crista galli on Cor NECT (c).
**Fig. 10:** Cerebellopontine angle meningioma: isodense on NECT (a), shows homogeneous enhancement on CECT (b), is hyperintense on T2 Wi (c), iso/hypointense on T1 Wi (d), with homogeneous gadolinium enhancement in axial (e) and Cor FSPGR (f).

**Fig. 11:** Intraventricular meningioma in the right occipital horn with its mild dilatation: isointense signal on T1 Wi (b), hyperintense on T2 (axial - c) and FLAIR (Cor - a), with circumscribed peritumoral edema, hyperintense on DWI (d), and homogeneous Gadolinium enhancement (e).
Fig. 12: Meningiomatosis - multiple meningiomas: one in the left fronto-opercular region and two parietal, bilateral (en plaque on the left side) which are isointense on T2 Wi (d, e) and show homogeneous Gadolinium enhancement (Cor - a, b, c, Axial - f).
Fig. 13: Left frontal meningioma that is partially calcified on NECT (a), isointense on T2 Wi (b), hyperintense on FLAIR (c), discreetly hypointense on T1 Wi (d), with homogeneous gadolinium enhancement (e).
**Fig. 14:** Right frontal meningioma isodense on NECT (a), with lobulated borders and homogeneous enhancement on CECT (b) and pressure atrophy of the inner table (c).

**Fig. 15:** Left frontal meningioma hyperintense on T2 Wi (a), isointense on T1, with homogeneous Gadolinium enhancement on Cor (c) and Sag (d), which shows "dural tail" sign (c, d, e).
**Fig. 16:** Tentorium cerebelli meningioma with homogeneous enhancement on CECT (a - Cor, b - axial, c - Sag).
**Fig. 17:** Right temporo-spheno-orbital meningioma: hyperdense mass on NECT, with homogeneous enhancement on CECT.
**Fig. 18:** Left spheno-orbital meningioma: hypointense on T2 Wi (a), isointense on T1 Wi (b), with homogeneous Gadolinium enhancement (Axial - c, Sag - d), and important hyperostosis of the sphenoid ridge (e).
**Fig. 19:** Right parasellar meningioma with homogeneous gadolinium enhancement (Cor - a, Axial - b).
Fig. 20: Left acoustic neurinoma in Neurofibromatosis type 2 and brainstem glioma: hyperintense on T2 WI (a), and FLAIR (b), with inhomogeneous Gadolinium enhancement (c - axial, d - Cor FSPGR).
Fig. 21: Left cavernous sinus metastasis on the parasellar region in a patient with breast cancer: T1 Wi with inhomogeneous Gadolinium enhancement (a- Coronal, b - Axial).
**Fig. 22:** Neurofibroma in the left cerebellopontine angle with inhomogeneous Gadolinium enhancement (a - Axial) versus Left cerebellopontine angle meningioma with broad based implantation and homogeneous Gadolinium enhancement (b - Axial).

**Fig. 23:** Parenchymal NH-lymphoma lesions: bilateral masses located into the fronto-basal region, with relative homogeneous enhancement on CECT, the larger one in contact with the fronto-orbital inner table (a) with total remission after nine months of chemotherapy combined with corticotherapy (b, c).
**Fig. 24:** Calotte NH-lymphoma lesion: isointense on T2 Wi (Cor - a), iso/hyperintense on T1 Wi (Cor - b), with mild homogeneous Gadolinium enhancement (Sag - c) that extend epicranial and extradural with meningeal involvement.
Fig. 25: Left frontal metastasis from neuroblastoma: hyperdense on NECT (a), with inhomogeneous enhancement on CECT (b), exophytic periosteal reaction, epicranial and extradural extension with meningeal involvement (c).
Fig. 26: Sellar macroadenoma: isointense on T2 Wi (a), Flair (b) and T1 Wi(c), with homogeneous Gadolinium enhancement (d - Axial, e - Sag, f - Cor) with mass effect on the optic chiasm.
Fig. 27: Right ICA saccular aneurysm in the parasellar region: isointense on T1 Wi (Axial - a), source of images from 3D TOF on axial plane (b), hypointense on T2 Wi (Cor - c), MIP from 3D TOF (d).
Conclusion

Meningiomas are relatively common intracranial tumors, so a radiologist should be aware of its imaging findings and particularities.

Unusual locations may make diagnosis more difficult.

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