Meningeal thickening in MRI: from signs to etiologies

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Learning objectives

- To illustrate the contribution of MRI in meningeal study by reviewing the imaging modalities and the indispensable MRI sequences for positive and differential diagnosis

- To illustrate the imaging of normal meninges

- To illustrate the imaging of meningeal thickening and the process of diagnosis
Background

The meninges are an important connective tissue enveloping the central nervous system. Their functions include providing a protective coating to the brain and participating in the formation of blood brain barrier. Understanding their anatomy is fundamental to understand the location and spread of pathologies in relation to the layers. It also provides an insight into the characteristics of such pathologies when imaging them.

This review aims to describe the anatomy of the meninges, and to demonstrate the imaging findings of normal and pathologic meningeal thickening.
Findings and procedure details

The meninges are composed of three layers. The dura mater or pachymeninx is the outermost layer of the meninges, lying directly underneath the bones of the skull and vertebral column. The arachnoid mater is the middle layer of the meninges, lying directly underneath the dura mater and below which a space known as the sub-arachnoid space containing cerebrospinal fluid and separating it from the pia mater. Both form the leptomeninges.

I- MR Techniques:

MR is the gold standard to study meninges. The MR imaging protocol include in addition to the brain conventional sequences, post contrast T1 Weighted and/or FLAIR sequences (with or not fat suppression).

T1-3D sequences provide better study of meninges by making multiplanar reconstructions and defining meningeal enhancement.

II- Normal MRI appearance of the meninges:

Normal meninges are not seen on unenhanced T1-weighted sequences except dural venous sinuses and falx. On thin slice 3D T2W sequences some subarachnoid trabeculae can be detected.

On postcontrast T1 Weighted sequences, dura mater appears thin (less than 1 to 2 mm), linear or frequently like discontinuous bands while leptomeninge does not enhance.

In fact, many factors may affect these appearances such as magnetic power of the machine, the T1 sequences used (spin echo, gradient echo, inversion recovery, magnetization transfer), the MRI contrast agent dose and the time between injection and the beginning of the sequence.

In practice, a dural enhancement thickening (more than 2 mm), extended and continuous or nodular is to be considered as pathologic.

III- Meningeal thickening:

- iatrogenic conditions:

Many iatrogenic conditions can affect the meninges. The most frequent abnormal intracranial contrast enhancement on MR images are surgery and shunting.

After craniotomy, local or generalized thickening and enhancement of the dura and arachnoid is usually observed until 1-2 years afterward.
Patients with ventricular shunting can develop meningeal fibrosis. MR shows extra-axial collections hypointense relative to gray matter on T1 Weighted images without mass effect or calcification. After administration of contrast material, there was marked enhancement of the convexity collections.

- **Tumoral:**

1- Primary tumor:

Although a large number of primary tumors may arise from the meninges, meningiomas are by far the most common. On short-T1 MR images, meningiomas are generally isointense or hypointense relative to cortex with strong contrast enhancement. Contrast-enhanced MR imaging show also a linear enhanced "tail" extending from the tumor mass along the dural surface. The meningeal tail can be associated to a large number of intra or extra axial tumors, however, is seen more frequently with meningiomas.

2- Meningeal carcinomatosis:

Meningeal carcinomatosis refers to diffuse seeding of the meninges by tumor metastases. It may involve the dura mater, the leptomeninges, or both. It is most commonly found in breast carcinoma, lung carcinoma, and melanoma in adults and hematogenous malignancies and PNET in children.

Dural metastases appear as curvilinear contrast-enhanced segments underneath the inner table of the skull. The pattern of enhancement on MR images does not follow the convolutions of the gyri.

Meningeal carcinomatosis can also manifest as leptomeningeal involvement. On MR images, it appears as thin lines of contrast enhancement following the convolutions of the gyri or as small nodular deposits on the surface of the brain.

- **Infectious and inflammatory diseases:**

The imaging findings of meningitis are nonspecific. Nodular appearances are more typical of tumor but do not preclude inflammatory conditions. Pial enhancement is somewhat more common in patients with meningitis than in patients with leptomeningeal tumor; however in mild cases of meningitis, MR imaging may show no abnormal findings.

Sarcoidosis may also involve the meninges. MR images may show contrast enhancement following the contour of the brain when the leptomeninges are involved, focal plaque formation or as subtle falcine thickening when the dural are involved.
As with other granulomatous diseases, sarcoidosis most often occurs in the basal cisterns, although any area can be affected. Sarcoid involvement can extend to the Virchow-Robin spaces, thus appearing intraparenchymal.

Difuse linear thickening enhancement of meninges is mostly shown in diffuse pachymeningitis. This pattern can be observed with Wegener’s granulomatosis, tuberculosis, sarcoidosis and inflammatory auto-immune.

Idiopathic hypertrophic cranial pachymeningitis is a rare inflammatory disease with diffused involvement of the dura. The reported imaging findings of IHCP include dural thickening, dural mass, sinus thrombosis, and venous congestion with white matter changes.

- **Intracranial hypotension syndrome:**

It can be spontaneously or more frequently following lumbar spinal tap.

On MRI we can observe diffuse enhancing meningeal thickening associated to small lateral ventricules, enlargement of venous sinuses and supratentorial subdural collections.
Fig. 1: Fig1. Sagittal Enhanced T1Weighted image showing frontal lobe brain meningioma: Extra axial mass strongly enhanced with dural tail.

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**Fig. 2:** Axial and sagittal enhanced T1-weighted MR images: left sphenoid wing meningioma invading cavernous sinus  

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**Fig. 3:** Meningeal carcinomatosis: Axial enhanced T1-weighted images: Diffuse linear enhanced meningeal thickening with hydrocephalus  

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**Fig. 4:** Neurosarcoidosis axial FLAIR: bilateral hyperintense periventricular white matter lesions

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**Fig. 5:** Neurosarcoidosis axial unenhanced T1W: linear meningeal thickening

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Fig. 6: Neurosarcoidosis axial and coronal enhanced T1W MR images show diffuse enhanced linear pachymeningeal thickening

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Fig. 7: Neurosarcoidosis MRS of white matter lesions demonstrate elevated choline and decreased NAA
**Fig. 8:** Neurosarcoidosis Axial FLAIR MR images show bilateral hyperintense cortical sulci with hydrocephalus

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**Fig. 9:** Idiopathic hypertrophic pachymeningitis. Axial enhanced T1Weighted MR images: diffuse linear enhanced pachymeningeal thickening

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Conclusion

MRI revealed the frequency of meningeal diseases. Flair and enhanced 3DGE T1--weighted are the most sensitive sequences. Topography, morphology and MRI signal confronted with clinical and biological data often allow an accurate diagnostic orientation.
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