Abnormal material layering within the CSF spaces within the brain on MRI: Blood, pus or tumour?

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Learning objectives

- To describe the basic anatomy of the cerebral envelope of the brain i.e the meninges.
- To discuss the basics of MR imaging technique for the primary pathologies involving the meninges, namely blood (subarachnoid haemorrhage), pus (leptomeniningitis) and tumour (meningeal carcinomatosis).
- To describe the pathophysiology of the above entities and how it impacts on MR imaging.
- To illustrate the varied findings on multisequence MR imaging in patients with subarachnoid haemorrhage, leptomeningitis and meningeal carcinomatosis.

We outline that abnormal material within the subarachnoid spaces of the brain can be difficult to identify unless the reader has a high index of suspicion. In our experience such an abnormality is frequently missed by the primary reporter and only identified upon subsequent review. This poster clarifies what can and cannot be imaged effectively on the various sequences, and more importantly, the more appropriate sequences to be performed to answer the clinical question posed.
Background

**Background Anatomy:**

The meninges invest the brain and spinal cord. The three main constituent parts are the outer fibrous dura mater, next, the arachnoid mater, and finally, the inner arachnoid mater. A summary of these constituent parts includes;

**Cranial Meninges**

Pachy meninges = dura mater.

Leptomeninges = arachnoid mater and pia mater.

**Pachy meninges - dura mater**

- This is a dense fibrous connective tissue with layered collagen fascicles.
- It is composed of two layers, outer (peri- or endosteal) and inner (meningeal).
- Dural capillaries lack endothelial tight junctions, therefore enhance strongly.
- The normal dura at imaging is smooth and less than 2mm in thickness. It normally should enhance less than the cavernous sinus.
- On coronal T1 contrast enhanced MR it appears most prominent near the vertex.

**Leptomeninges - arachnoid mater**

- This is thin, translucent and loosely attached to the meningeal layer of the dura.
- The arachnoid forms the outer margin of the subarachnoid space.
- Trabelculae extend from the arachnoid across the subarachnoid space to the pia.

**Leptomeninges - pia mater**

- This is a thin delicate membrane closely applied to the brain surface
- It covers the glial limitations of the cortex.
- It covers the vessels and lines the perivascular spaces.

**Background Pathophysiology**
Enhancement which extends into the subarachnoid spaces of the sulci and cisterns is leptomeningeal enhancement. Leptomeningeal enhancement is usually associated with meningitis which may be bacterial, viral, fungal or tumoural.

The primary mechanism of this enhancement is the breakdown of the blood brain barrier. Glycoproteins released cause a breakdown of the blood brain barrier. This allows contrast material to leak from vessels into the cerebrospinal fluid (CSF).

The subarachnoid space is filled with inflammatory cells in the case of infection, blood products in the case of subarachnoid haemorrhage, and seeded with tumour cells and their products in leptomeningeal carcinomatosis.

**Background Imaging concepts**

FLAIR stands for fluid attenuation inversion recovery and it’s concept is simple. This concept is simply to obtain T2 weighted imaging while keeping the CSF dark. The intensity of the CSF is nulled by setting the T1 at 0.69 times the T1 relaxation time of pure water. FLAIR provides a better contrast range with a more obvious delineation of pathology.

Currently, FLAIR sequences in this setting have extended the realm of MR to identification of subarachnoid disease. Blood products and pus in the subarachnoid space change the normally dark signal of CSF, bright. Carcinomatous meningitis also causes the "brightening" of the CSF on FLAIR imaging. The sensitivity to meningeal and subarachnoid pathology is further increased through the use of gadolinium enhanced FLAIR imaging.

There is, however, three documented pitfalls to be aware of.

Firstly, bright CSF can be caused by cisternal flow artefacts and can lead to a false positive description unless the radiologist is aware of their presence.

Secondly, the application of 100% O2 to the patient in some anaesthetic techniques can lead to a reduction in the T1 of CSF and subsequently lead to high signal on the FLAIR imaging. This, however, is a rare occurrence.

Thirdly, there is often incomplete CSF suppression in the posterior fossa.

Overall, however, FLAIR imaging provides a valuable tool in the investigation of possible abnormal layering within the CSF spaces, be that blood, infection or tumour.
Pus - Leptomeningitis

The pathological process of meningitis (leptomeningitis) involves inflammatory infiltration of the pia mater and arachnoid mater. This most often occurs secondary to haematogenous dissemination from a distant infectious focus. Both standard and postgadolinium FLAIR images appear very sensitive for subarachnoid disease in meningitis. Diffusion weighted imaging is frequently helpful as high signal material can also be identified on high B-value images (B1000) in patients with SAH or meningitis. DWI may also display abnormality in the cortex and sulci.
Fig.: T2 weighted FLAIR imaging in a 24 year old woman with meningeal symptoms after a flu like illness, subsequently diagnosed with meningitis. Circled is the abnormal leptomenigeal enhancement of the sulcal gyral pattern of the left centrum semi-ovale.  

References: Radiology, St James Hospital - Dublin/IE
Fig.: T2 FLAIR post contrast imaging in the same patient. The circled area shows the further enhanced conspicuous nature of the abnormality post administration of gadolinium on FLAIR imaging.

References: Radiology, St James Hospital - Dublin/IE

**Blood - Subarachnoid haemorrhage**

The majority of subarachnoid haemorrhage is the result of rupture of intracranial aneurysms. Other causes include trauma, AVM or leakage from an intracerebral source. Routine FLAIR imaging is preformed in the majority of settings. On these sequences the blood can be identified as high signal intensity in the sulci secondary to haemorrhage.
products shortening the T2 of the CSF. On conventional T1 and T2W acute SAH is not visible. Oxyhaemoglobin, in the acute setting, behaves like other nonparamagnetic substances, being isointense to the brain on both T1 and T2 weighted sequences. It is of course of importance to mention that CT should be the primary choice investigation in the investigation of acute subarachnoid haemorrhage.

**Fig.** T2 weighted FLAIR imaging in a 66 year old woman who presented with an acute onset of a severe headache. A CT brain preformed in the ER department was negative. Images show a circled area of abnormally bright CSF with the sulcal gyral pattern of the right occipital lobe. Normal suppressed CSF is identified in the ventricles.

**References:** Radiology, St James Hospital - Dublin/IE
Tumour - Leptomeningeal Carcinomatosis

Other terms for the same entity include meningeal carcinomatosis and carcinomatous meningitis. When tumour has spread to the subarachnoid space this may only be often identified on post contrast imaging. In contrast to blood, MR is much more sensitive than CT. However, both enhanced and unenhanced FLAIR sequences are effective. The malignant cells themselves, or the elevated associated protein products they produce, in the CSF will cause the usually low signal of the CSF to be "bright" on the FLAIR. Common locations of spread within the CNS include the basal cisterns, the interpeduncular cistern, the cerebellopontine cistern and along the course of the cranial nerves.
**Fig.**: T1 post contrast images in a 43 year old breast cancer patient. Images show abnormal dural enhancement with abnormal enhancement of the leptomeninges also in the left parietal region post administration of gadolinium.

**References:** Radiology, St James Hospital - Dublin/IE
Fig.: T1 post contrast images in the same patient. The circled region demonstrates abnormal enhancing leptomeningeal spread of tumour as it deliniates the folia of the cerebellum.

References: Radiology, St James Hospital - Dublin/IE
Conclusion

Abnormalities within the subarachnoid space on MR imaging present a diagnostic challenge both in terms of recognition and accurate diagnosis. Knowledge of the radiological features of the most commonly encountered conditions greatly increases reader’s confidence and accuracy.

The abnormality is identified usually on FLAIR (fluid attenuated inversion recovery images) where the normally suppressed signal of CSF is replaced in some areas by linear high signal which fills the cerebral or cerebellar sulci. Post gadolinium sequences confer extra sensitivity to the exam.

No abnormality is usually evident of T2W images as the high signal material is usually obscured by the high signal from CSF. Diffusion weighted imaging is frequently helpful as high signal material can also be identified on high B-value images (B1000) in patients with SAH or meningitis.

Pre-contrast T1W imaging may be useful in patients with subarachnoid haemorrhage and occasionally in patients with meningitis but is rarely helpful in patients with leptomeningeal tumour.

Post-contrast T1W imaging demonstrates linear focal enhancement in patients with meningeal/subarachnoid spread of tumour and may demonstrate diffuse leptomeningeal enhancement in patients with meningitis. Post-contrast FLAIR imaging has greater sensitivity than T1W imaging for meningeal disease.
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References