Imaging of Calvarial Lesions

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Learning objectives

1. Overview of different types of calvarial lesions encompassing congenital, benign and malignant calvarial lesions.
2. Pictorial review demonstrating characteristic imaging features of lesions to assist with diagnosis.

Background

Introduction

Calvarial lesions may present either as a 'lump on the head' or may be discovered incidentally on imaging performed for other reasons. They encompass a host of possible differential diagnoses. A comprehensive knowledge of possible causes is required to assist in planning subsequent management whether it involve biopsy, definitive surgery or follow up imaging.

This pictorial review provides a framework for the differential diagnosis of calvarial lesions. It has been illustrated by cases found at or referred to our institution over the last 5 years. The case examples used display several disease processes ranging from common neoplastic lesions to more rare congenital abnormalities, as well as benign pathologies that can mimic calvarial bone lesions. Particular focus is placed on imaging features that may help to define the diagnosis.

Approach to Calvarial Lesions

Clinical details

When considering a calvarial lesion, certain clinical details can help to narrow the list of potential differential diagnoses:

- Patient age - an eosinophilic granuloma is a more likely cause of a solitary lucent bone lesion in a child or young adult while a solitary metastasis is more likely in older age.
- Presence of systemic malignancy
- Haematological markers - ESR and white cell count may be raised in infectious or inflammatory causes
The demographics associated with the various pathologies are discussed in the examples provided.

**Radiological features**

Consideration of the following features may assist in determining the diagnosis of a calvarial lesion:

- Solitary or multiple
- Lucent or sclerotic
- Location
- Is it expansile?
- Smooth or ill-defined margin
- Is there a sclerotic margin?
- Bone remnants in the lesion
- Destruction or remodelling of the calvarium
- Associated soft tissue or vascularity
- Attenuation or signal characteristics which indicate the presence of fat, blood or calcification.

The use of CT and MR may be complementary in defining the nature of a calvarial lesion. Typical imaging features which may help to differentiate between lesions are discussed in the case examples.

**Classification of calvarial lesions**

There are various ways of classifying calvarial lesions. They can be divided into aggressive or non aggressive lesions, or benign and malignant lesions. Other classification systems are based on biological activity, for example congenital, neoplastic, inflammatory, traumatic, infective or metabolic lesions. A useful classification is based on the radiological appearances of lucency or sclerosis and numeracy of lesions.

<table>
<thead>
<tr>
<th>Multiple Lucent</th>
<th>Solitary Lucent</th>
<th>Sclerotic</th>
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<tbody>
<tr>
<td>Histiocytosis X</td>
<td>Eosinophilic Granuloma</td>
<td>Fibrous Dysplasia</td>
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<td>Multiple Myeloma</td>
<td>Haemangioma</td>
<td>Intraosseus Meningioma</td>
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<td>Paget's Disease</td>
<td>Epidermoid/Dermoid</td>
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<td>Metastases</td>
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<td></td>
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Findings and procedure details

Case Examples

Below are case examples of the lesions we have encountered and their characteristic imaging features.

Cavernous Haemangioma

Usually a solitary lesion, cavernous haemangiomas may present as a palpable mass or as an incidental finding. A frontal or parietal location is more common and they are more frequently found in middle-aged females. Typically, it is a mildly expansile lucent lesion and a fine sclerotic border is seen on CT. The coarsened internal trabeculae may show a honeycomb appearance or occasionally a sunburst pattern (Fig 1). The signal characteristics on MR will depend on the fat/vessel content and high signal on T1 may be seen with a prominent fat content or secondary to intralesional haemorrhage. They usually enhance avidly due to their vascular nature (Fig 2) and may increase in size.

Epidermoid Cyst

Epidermoid cysts are benign, slow growing lesions thought to arise due to inclusion of ectodermal remnants within the diploic space. Although a parietal location is most frequent, they can occur in any bone of the calvarium and are usually found in the 3rd to 6th decade. Progressive accumulation of desquamating cells from the stratified squamous epithelial lining, cellular debris and keratin causes expansion of the diploic space affecting both the inner and outer tables of the skull (Fig 3). On CT, a sclerotic margin is usually seen (Fig 4). On MR, they usually exhibit low signal on T1 and high signal on T2 (Fig 5) with little enhancement. However, signal characteristics may be altered by a high protein content or haemorrhage into the lesion. Intradiploic epidermoid cysts can rupture into the subarachnoid space causing chemical meningitis.

Eosinophilic Granuloma

Eosinophilic granulomas are the benign variety of Langerhan’s Cell Histiocytosis localised to bone. They usually present in patients between 5-15 years of age, affecting males
more than females, typically with a painful bone lesion or soft tissue swelling. Fifty percent of oesinophilic granulomas involve the diploic space of parietal and temporal bone. Characteristically these lesions are well defined lucent lesions. A 'bevelled edge' may be seen due to unequal involvement of the inner and outer tables (Fig 6). Sometimes remnants of bone can be seen centrally within the lucent lesion ('button sequestrum') or there may be an associated soft tissue mass. Sclerosis is not usually a feature unless the lesion is healing which can occur spontaneously (Fig 9). On MRI they appear as a soft tissue mass located in the diploe, appearing hypointense on T1 weighted images (Fig 7) and hyperintense on T2 weighted images. They enhance homogenously (Fig 8).

Osteomas

Osteomas are common benign calvarial lesions. When symptomatic they often present as a painless swelling. CT shows a dense, smooth well defined lesion arising from the outer table (Fig 10) although they may also be found incidentally on the inner table.

Fibrous Dysplasia

Fibrous dysplasia is a benign fibro-osseous developmental anomaly, manifesting as a defect in osteoblastic differentiation and maturation. It usually presents in childhood or adolescence and there are monostotic and polyostotic forms. On CT, the typical appearances are a ground glass texture of the diploic space and an outward expansion of the outer table with no affect on the inner table, maintaining the convexity (Fig 11). MR imaging varies depending on the extent of fibrous tissue to osseous matrix ratio. Most often it is hypointense on T1 and T2 weighted images (Fig 12). No associated soft tissue abnormality is seen which may aid distinction from other sclerotic lesions.

Intraosseus Meningioma

Intradural meningiomas typically produce hyperostosis in adjacent bone. The presence of this supports the diagnosis of meningioma for a solidly enhancing extra-axial mass. Intraosseous meningiomas are rare and their origin is much debated (see references 6 & 7). Their appearances on CT, of bone expansion and a ground glass texture (Fig 14), make fibrous dysplasia the most likely alternative diagnosis. However, unlike fibrous dysplasia, intraosseous meningiomas tend to affect middle aged women, grow after puberty and involve the inner table of the skull. Associated enhancing soft tissue may be present.

Paget's Disease

Paget's disease is a multifocal chronic skeletal disease characterised by disordered and exaggerated bone remodelling. Characteristic CT appearances are osseous expansion, trabecular coarsening and cortical thickening (Fig 16). Other features which are typical
with skull involvement are well defined lytic lesions known as osteoporosis circumscripta and 'cotton wool' appearance where there is a mixed lytic and sclerotic pattern in a thickened calvarium.

**Metastases**

In adults metastases are most commonly secondary to lung, breast and prostate cancers, in children from neuroblastomas and sarcomas. They are often small and multiple but can be solitary and large. Depending on the primary they can be lytic, sclerotic or mixed. Calvarial metastases are often osteolytic with irregular margins and permeative destruction (Fig 17). An associated soft tissue mass is usually seen (Fig 18 & 19).

**Lymphoma**

Lymphoma involving the calvarium is rare but can mimic other pathologies such as metastasis or intraosseus meningioma. Often there is an associated soft tissue mass which can extend intra or extracranially. Although there can be associated bone destruction, there are a few reported cases where there is no bone involvement. The imaging characteristics are nonspecific, but MR imaging often shows a lesion which is homogeneous and hypotense to grey matter (Figs 20 & 21) with avid enhancement (Fig 22).

**Images for this section:**
Fig. 1: Cavernous haemangioma: Axial CT on bone window settings shows a mildly expansile lucent lesion with a fine sclerotic border and coarse trabeculation within the left parietal bone. Fine spiculations of bone extend from the outer table.
Fig. 2: Cavernous haemangioma: Axial T1 post gadolinium depicting a contrast enhancing lesion centred on the diploic space of the right parietal bone.
**Fig. 3:** Epidermoid cyst: the CT image on soft tissue window settings shows a markedly expansile lesion in the right parietal bone, deeply indenting adjacent brain parenchyma. The slow growth rate of these lesions allows marked mass effect to occur with little clinical effect. The heterogenous attenuation reflects the cellular debris and keratin content of the lesion.
Fig. 4: Epidermoid cyst: Axial CT on bone window settings shows marked thinning and breach of the inner and outer tables of the calvarium. Bony remodelling with a triangular spur of bone at the limit of the lesion within the diploic space attests to the chronicity of the lesion.
**Fig. 5:** Epidermoid cyst. Axial T2 weight MR image. Same lesion as in figures 3 7 4. This shows moderately high T2 signal with low signal corresponding to the calcification seen on CT.
**Fig. 6:** Eosinophilic granuloma: Frontal radiograph shows a well defined lucent lesion involving the right parietal bone. There is unequal involvement of the inner and outer tables producing a 'bevelled edge'.
Fig. 7: Eosinophilic granuloma: Sagittal T1 weighted image of the lesion shown in figure 6 showing an expansile low signal lesion within the diploic space of the right parietal bone.
**Fig. 8:** Eosinophilic granuloma: Sagittal T1 post gadolinium of the same lesion as in figures 6 & 7 showing homogenous contrast enhancement.
Fig. 9: Eosinophilic Granuloma: Axial CT showing a sclerotic lesion of the right parietal and frontal bones. Sclerosis is seen in healing eosinophilic granulomas. This lesion can be mistaken for fibrous dysplasia but there is involvement of the inner as well as the outer table; in fibrous dysplasia the inner table is usually spared.
Fig. 10: Osteoma: Axial CT showing a smooth sclerotic lesion affecting the outer table of the left side of the occipital bone
**Fig. 11:** Fibrous Dysplasia: Coronal CT reconstruction showing ground glass expansion of the lateral wall of the right maxillary antrum.

**Fig. 12:** Fibrous Dysplasia: Axial T2 showing diffuse bone expansion with preservation of the inner table.
Fig. 13: Intraosseous meningioma: Axial CT shows an expansile ground glass lesion involving the right greater wing of sphenoid, causing right proptosis. Involvement of the inner table differentiates this from fibrous dysplasia. Enhancing dural soft tissue was also visible on the intracranial surface.
**Fig. 14:** Intraosseus Meningioma: Axial CT on bone window settings showing expansion and sclerosis of the left parietal bone. (There is a cavernous haemangioma in the occipital bone also)
**Fig. 15:** Intraosseus Meningioma. Axial CT image on soft tissue window settings of the same case as in figure 14, showing an extra axial mass overlying the left parietal lobe. Small foci of high attenuation on its inner surface are most likely calcifications.
**Fig. 16:** Paget’s disease: Axial CT image showing characteristic osseous expansion, trabecular coarsening and cortical thickening.
**Fig. 17:** Metastasis: Axial CT image on bone window settings show an ill-defined lucent lesion involving the right parietal bone. Adjacent soft tissue thickening is evident.
Fig. 18: Metastasis: Axial T2 showing the heterogeneous subcutaneous and intracranial soft tissue masses around the ill-defined bone lesion demonstrated in Fig 17. Note is made of mass effect and oedema within the underlying brain parenchyma.
Fig. 19: Metastasis: Following gadolinium, enhancement of the lesion is heterogenous in comparison to the homogenous enhancement seen in lymphoma (Fig 22).
**Fig. 20:** Lymphoma: Axial T2 shows a homogeneous hypointense soft tissue mass centre over the left parietal bone.
**Fig. 21:** Lymphoma: Coronal T1 image showing a left parietal intra and extra cranial soft tissue mass which is hypotense to grey matter. Although there is no cortical bone destruction, low signal is seen within the interposed bone suggesting disease involvement. Comparison can be made with the normal contralateral parietal bone which is high signal due to normal bone marrow.
Fig. 22: Lymphoma: Coronal T1 post gadolinium shows avid enhancement of the homogeneous lesion in Fig 21.
Conclusion

This educational pictorial review provides an understanding of the various pathologies that present in the calvarium and gives essential information for a relevant radiological approach in the management of calvarial lesions. The example cases shown highlight how a knowledge of the patient's clinical history compliment a radiologists ability to identify cross sectional characteristics and assist in narrowing the list of possible differential diagnoses.

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