

CT and MRI findings in calvarial non-infectious lesions

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ABSTRACT

Differential diagnosis of the calvarial lesions is important in order to decide whether biopsy, surgical intervention, or follow-up is required for further management. In this pictorial essay on calvarial lesions, lytic or sclerotic patterns, contours of the lesions, calcifications, soft tissue components, inner and outer table localizations were evaluated with computed tomography (CT). On magnetic resonance imaging (MRI) signal characteristics and contrast enhancement of the lesion, relation to brain parenchyma and soft tissue were evaluated. CT scan is considered to be the best examination to characterize bone alterations whereas MRI depicts bone marrow abnormalities and invasion of adjacent tissues.

Key words: • calvarium • computed tomography
• magnetic resonance imaging

The calvarium encasing the brain parenchyma is formed by the frontal, parietal, and occipital bones, as well as a small portion formed by the temporal bones. It consists of 2 cortical layers, the inner table and the outer table, and in between those 2 layers is the diploe, which contains bone marrow. Focal lesions of the calvarium may originate primarily from bony structures, or they may be secondary to invasion of the skin- or brain-based lesions into bony structures. Well-defined borders and sclerotic margins are characteristic of benign lesions. Slow-growing tumors lead to thinning in the neighboring calvarium, whereas aggressive tumors lead to dramatic destruction. The first step in radiological evaluation of the calvarium is plain radiography, where lesions might be evaluated as lytic or sclerotic. With computed tomography (CT), the nature of the lesion (i.e., lytic or sclerotic), the presence of destruction in the inner or outer table, calcification within the lesion, sclerotic margins, and the density of the lesion can be evaluated (1–3). Magnetic resonance imaging (MRI) is superior to CT in demonstrating early lesions without bone destruction, or those that have an associated soft tissue component and parenchymal involvement. With MRI, the inner and outer tables are seen as signal void. Intensity of the diploe varies with regard to the age of the patient. During the first 2 decades, the diploe is seen diffusely hypointense due to active bone marrow in T1-weighted sequences. After the second decade, it is uniformly hyperintense due to fatty infiltration of the bone marrow. Within the hyperintense diploe, there may be patchy symmetric hypointensities. In MR sequences taken after contrast material has been administered, dura surrounding Pacchionian granulations and diploic channels are enhanced, and in the remaining areas there is no enhancement. Most calvarial focal lesions are hypointense on T1-weighted images and hyperintense on T2-weighted images, and they enhance with contrast. During evaluation of the diploe, T1- and T2-weighted, and contrast-enhanced T1-weighted images should be assessed together (4).

Calvarial lesions may be classified as malignant and benign, based on their biological activity, or they may be classified as congenital, tumoral, inflammatory, or traumatic, according to their histopathological features. In this pictorial essay, calvarial lesions were classified and discussed as lytic, sclerotic, or causing bone defects, according to their CT features (Table).

Lytic lesions

In children and young adults, the differential diagnosis of solitary lytic lesions includes eosinophilic granuloma, epidermoid-dermoid, osteoblastoma, hemangioma, and aneurysmal bone cyst. In older patients with multiple lytic lesions, metastases and multiple myeloma should be considered. Variations, such as parietal foramen, parietal thinning, and Pacchionian granulation, may mimic lytic lesions (3, 5).

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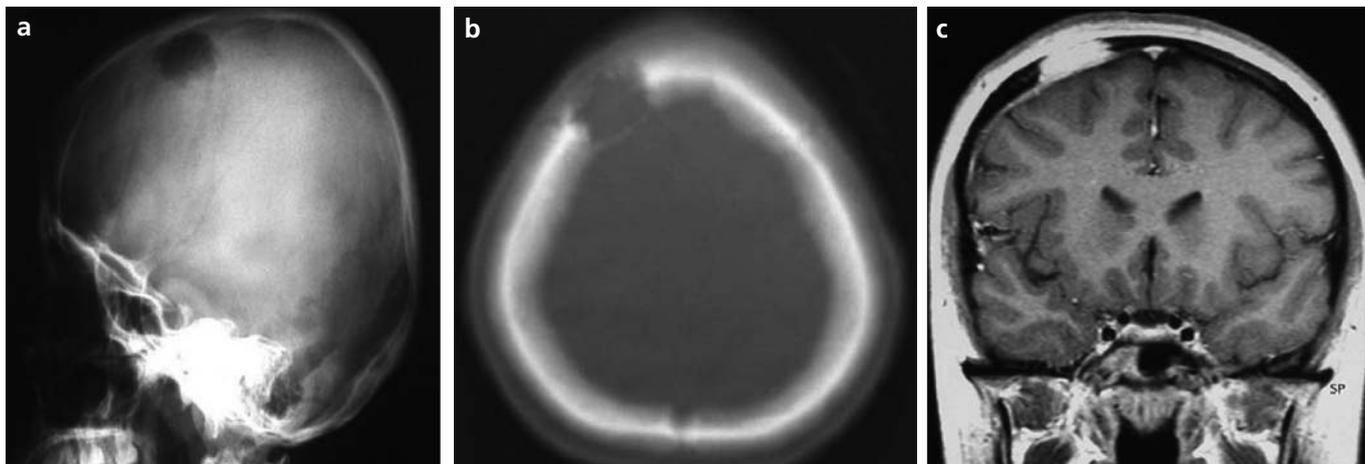


Figure 1. a–c. Eosinophilic granuloma. Lateral skull radiograph (a) of a 19-year-old female shows a lytic lesion in the frontal bone with a narrow transition zone. Axial CT image (b) demonstrates thinning in the inner and outer tables. On coronal SE T1-weighted MR image with contrast (TR/TE, 500/12) (c), the homogeneously enhancing lesion is shown to be arising from the diploe with dural invasion.

Eosinophilic granuloma

Eosinophilic granulomas are most frequently located in the parietal area and are seen in patients 5–15 years old. They are characterized by a lytic lesion invading the inner and outer tables

with well-defined borders. Peripheral sclerosis is not seen unless the lesion is in the healing period. Residual bone tissue, known as button sequestrum, may be detected in the lesion. This may be seen in breast cancer metas-

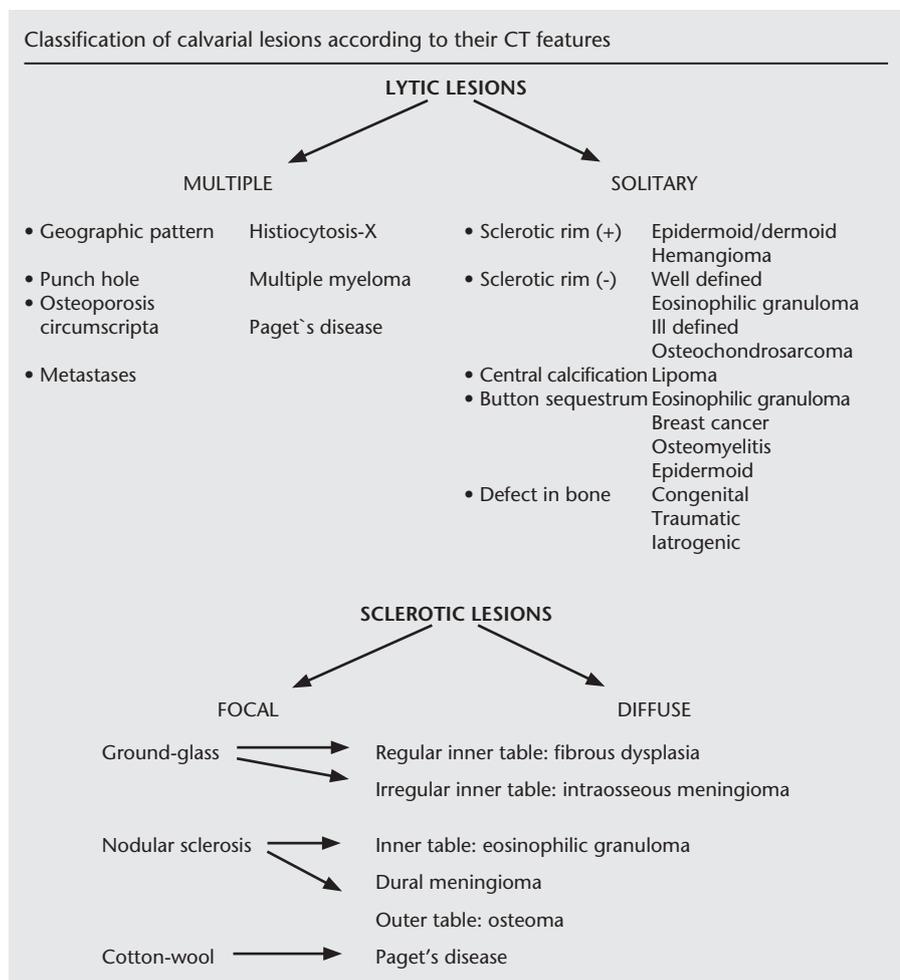
tases, epidermoid cysts, and osteomyelitis as well. On MRI, they appear as a soft tissue mass located in the diploe, appearing hypointense in T1-weighted series, hyperintense in T2-weighted series, and enhancing homogeneously. Dural invasion occurs in cases of bone invasion. Dural enhancement after contrast administration may be seen. Epidermoid-dermoid cyst, hemangioma, meningioma, and osteoblastoma should be considered in the differential diagnosis. (3, 5) (Fig. 1).

Calvarial hemangioma

A calvarial hemangioma is a solitary lesion seen mostly in middle-aged women. The most frequent type is cavernous. This lytic lesion, which affects the outer table, but not the inner table, might have sclerotic borders. The bony striations radiating centrally to the periphery of the lesion form a sunburst or honeycomb pattern, a characteristic feature of the lesion. On the other hand, the same pattern may be seen in meningiomas, osteogenic sarcomas, and osteoblastic metastases. Intensity of the hemangioma on MRI varies; however, hyperintensity on T1-weighted images is a differentiating feature of the lesion (1, 6).

Aneurysmal bone cyst

An aneurysmal bone cyst is a rapidly-growing lesion seen exclusively in childhood and young adulthood. It is a lytic lesion with well-defined borders and is expansile. It may have multiloculations. Low and high signal areas demonstrated in MRI are due to blood



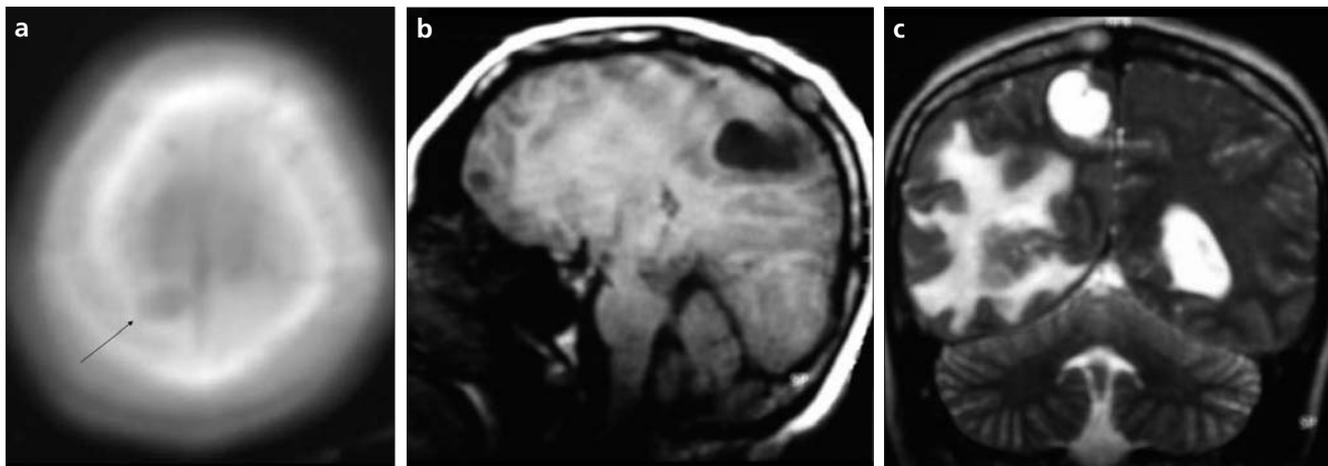


Figure 2. a–c. Metastasis. Axial CT image (a) of a 60-year-old patient with a history of breast cancer shows a parietal lytic lesion. Sagittal SE T1-weighted (b) and coronal TSE T2-weighted (TR/TE, 3500/100) (c) MR images demonstrate a focal lesion in the diploe and associated parenchymal metastasis.

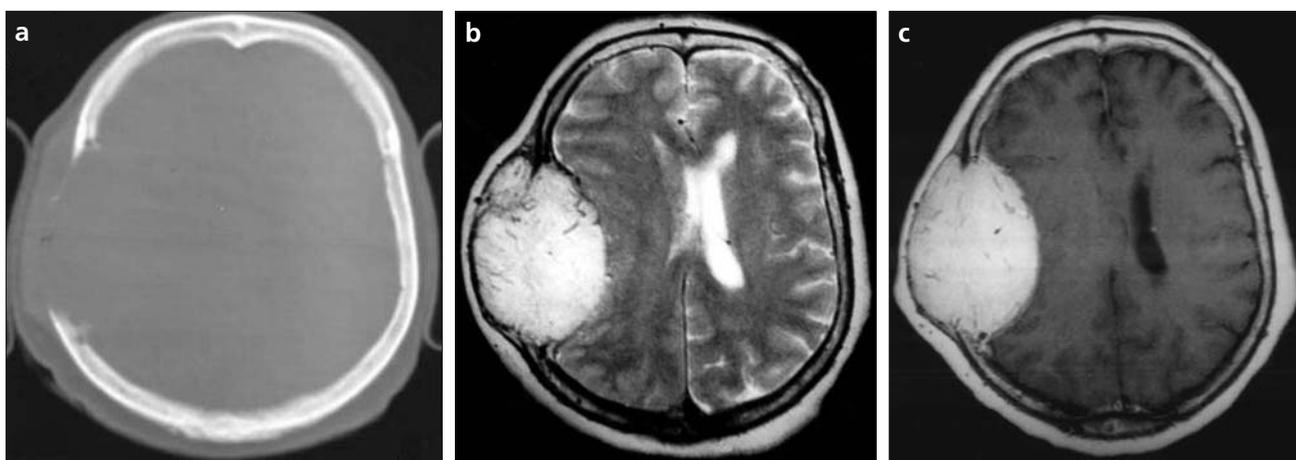


Figure 3. a–c. Metastasis. A patient, who had undergone surgery for thyroid cancer 20 years earlier, presented with the complaint of a slow-growing, painless swelling in the cranium. Axial CT (a), and TSE T2-weighted (b), and SE post-contrast T1-weighted MR images (c) depict a solitary metastatic mass lesion in the right parietal bone. The lesion destroys the inner and outer tables. It is expansile and has a soft tissue component. It extends through the dura mater and subcutaneous tissue, and shows a dense homogenous enhancement pattern.

elements in different stages. Fluid-fluid levels in the cyst and small cysts projected in the larger cyst demonstrate a soap-bubble appearance (7).

Dermoid/Epidermoid

Epidermoid cysts are mostly located in the parietal and temporal bones of patients aged 20–50 years. Lytic lesions with sclerotic borders, they expand to the inner and outer tables. On MRI, they are hypointense on T1-weighted images and hyperintense on T2-weighted images. They occasionally do not enhance after contrast administration. Dermoid cysts are most commonly seen in newborns and infants up to 3 years old. They are mostly located in the anterior fontanel. CT shows fat density and calcification in the lesions, and MRI demonstrates signal heterogeneity (1–3).

Lipoma

Lipomas are expansile lytic lesions with well-defined margins. They may have sclerotic borders and, due to fatty necrosis in the lesions, they may show central calcification. They appear as fat density on CT and show a typical fat signal on MRI (2, 3).

Metastasis

Metastases are mostly secondary to lung, breast, and prostate cancers in adults, and are secondary to neuroblastomas and sarcomas in children. Calvarial metastases are usually multiple and osteolytic. Prostate cancer metastases are usually sclerotic or mixed type. Thyroid and renal cell cancer metastases are generally sclerotic and solitary. On MRI T1-weighted images before and after contrast administration should be evaluated together. Are-

as that are seen as hypointense in fatty bone marrow on T1-weighted images show enhancement following contrast medium administration. In the presence of a known primary tumor, associated parenchymal metastases, and multiple lytic lesions, calvarium metastases should be considered (1, 3) (Figs. 2 and 3).

Multiple myeloma

Multiple myelomas are the most frequently seen primary bone lesions in advanced ages. The solitary form is plasmacytoma. It is a lytic lesion located both in the inner and outer tables with well-defined margins and resembling punch holes. They are hypointense on T1-weighted images, hyperintense on T2-weighted images, and they enhance after contrast administration (1) (Fig. 4).

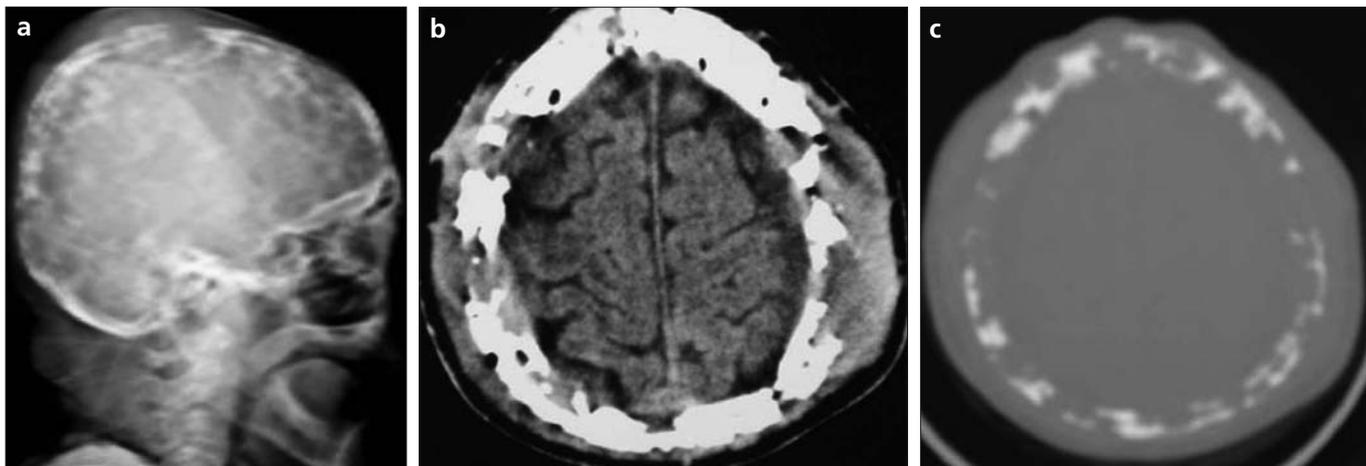


Figure 4. a–c. Multiple myeloma. Lateral CT scanogram (a) of a 64-year-old female demonstrates a lesion near the vertex resembling a punch hole associated with a soft tissue component as well as many other lytic cranial lesions. Parenchymal (b) and bone (c) window axial CT images show punch hole lesions involving the inner and outer tables throughout the cranium with an associated soft tissue component.

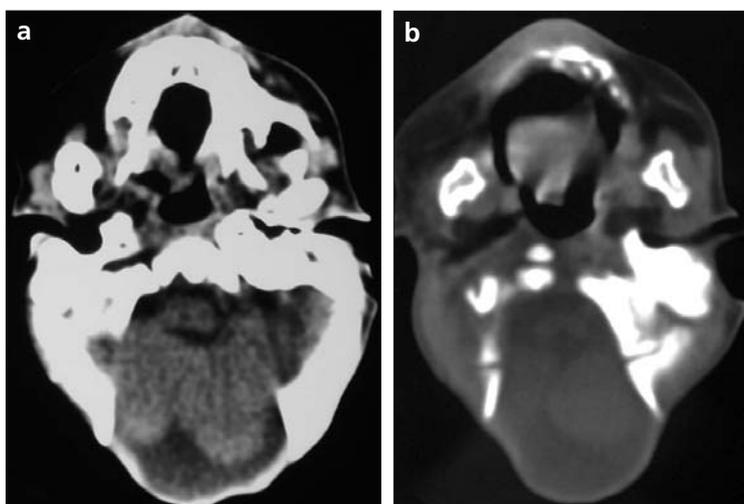


Figure 5. a, b. Cephalocele. Axial CT images of a male newborn in the parenchymal (a) and bone (b) windows show a defect in the occipital region and a sac extending through the subcutaneous tissue.

Defects in bone

Lesions causing bone defects may be congenital (cephalocele, sinus pericranii), traumatic (leptomeningeal cyst), or iatrogenic (pseudomeningocele).

Cephalocele

Cephaloceles are herniations of brain parenchyma due to congenital fusion defects. They are most usually seen in the occipital region in newborns. They are classified as meningoencephalocele, meningocele, atretic cephalocele, and gliocele, based on the neural elements they consist of.

CT is essential in demonstrating the bone defect and MRI is essential in showing the sac contents and associated cerebral anomalies, if there are any (1) (Fig. 5).

Leptomeningeal cyst

Leptomeningeal cysts are a late complication of head traumas that occur before the age of 3 years. There are 2 different forms: growing fractures and intradiploic arachnoid cysts. There is a dural tear in both forms and herniation of cerebrospinal fluid (CSF) or brain parenchyma into the subcutaneous tissue. A growing fracture is a widening of the fracture line >4 mm and involves both the inner and outer tables. Intradiploic arachnoid cysts erode the inner table rather than the outer table. Diagnosis of a leptomeningeal cyst is made in patients with a history of trauma, bone defect, presence of gliosis in neighboring parenchyma, and the presence of cystic lesions having a CSF characteristic (8, 9) (Fig. 6).

Pseudomeningocele

Pseudomeningoceles are the herniation of CSF or brain parenchyma into the subcutaneous tissue due to a post-operative bone defect.

Sinus pericranii

Sinus pericranii presents in newborns. It typically expands with an increase in intracranial pressure and compresses by direct pressure on the lesion. It is an abnormal connection between dural venous sinuses and extracranial vascular structures. It is mostly located in the frontal region, around the midline. It may be spontaneous, traumatic, or congenital in origin. CT demonstrates an enhancing lesion near the defect in the inner or outer table. On MRI, which demonstrates signal void areas within the lesion, the association of the lesion with intracranial dural sinuses can be evaluated. It enhances homogeneously (10).

Sclerotic lesions

Pathologies leading to focal sclerosis in the calvarium include fibrous dysplasia, osteoma, meningioma, Paget's disease, sclerotic metastasis, and osteogenic sarcoma (3).

Fibrous dysplasia

Fibrous dysplasia presents in young adults. On CT it most frequently demonstrates a ground-glass pattern. Rarely, there may be a dense homogenous or cystic pattern. Signal intensity on MRI varies with regard to the amount of fibrous tissue and osseous matrix in the lesion. The most frequent type is hypointense on T1- and T2-weighted

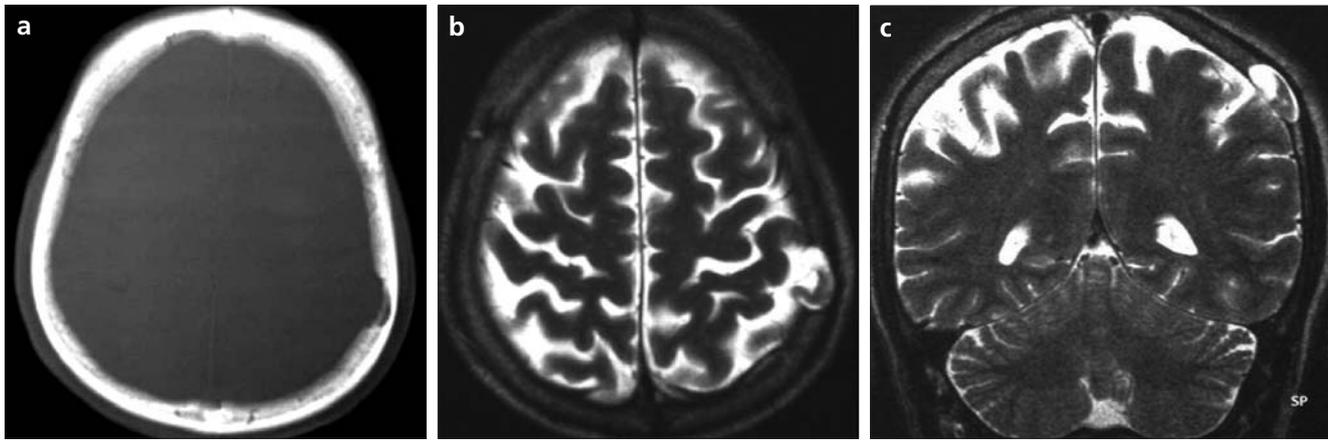


Figure 6. a–c. Leptomeningeal cyst. Axial CT image (a) of a 63-year-old male with a history of trauma in childhood demonstrates erosion of the inner table of left parietal bone. Axial (b) and coronal (c) TSE T2-weighted MR images show a bone defect into which there is herniation of brain parenchyma and cerebrospinal fluid.



Figure 7. a–c. Fibrous dysplasia. Anteroposterior skull radiograph (a) of a 24-year-old female demonstrates a sclerotic lesion in the right temporal bone. Axial CT image in bone window (b) reveals a ground-glass appearance in the right temporal bone. On axial SE T1-weighted MR image (c), a hypointense expansile lesion originating from the diploe is seen.

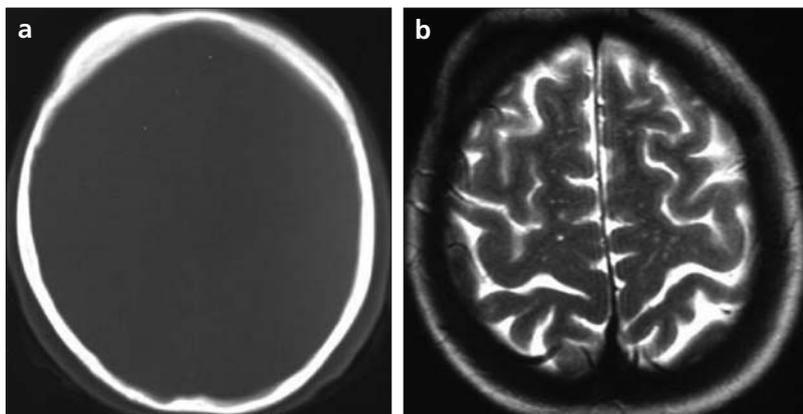


Figure 8. a, b. Osteoma. Axial CT image (a) of a 45-year-old female demonstrates a well-defined focal sclerosis originating from the outer table of the right frontal bone. Axial TSE T2-weighted (b) MR image shows a signal void lesion.

images, and it enhances intensely. Homogenous ground-glass appearance, expansion confined to the outer table, and no affect on the inner table are differentiating features (11) (Fig. 7).

Paget's disease

Paget's disease presents with different radiological features in all 3 of its stages. In the osteolytic stage, there are lytic lesions that erode the outer table

which are known as osteoporosis circumscripta. In the osteosclerotic stage, differentiation between the inner and outer tables is lost and the diploe widens. In mixed stage, irregular areas of sclerosis demonstrate a cotton-wool appearance. MRI demonstrates widening of the diploe and heterogenous signal intensity (1–3).

Osteoma

Osteomas are solid nodular sclerotic lesions usually arising from the outer table and are usually <1 cm. If they originate from the inner table they may be misdiagnosed as osseous meningiomas; however, unlike meningiomas, osteomas do not have a soft tissue component, do not enhance, and demonstrate signal void on all MRI sequences. Rarely, osteomas in the paranasal sinuses may enhance (2, 12) (Fig. 8).

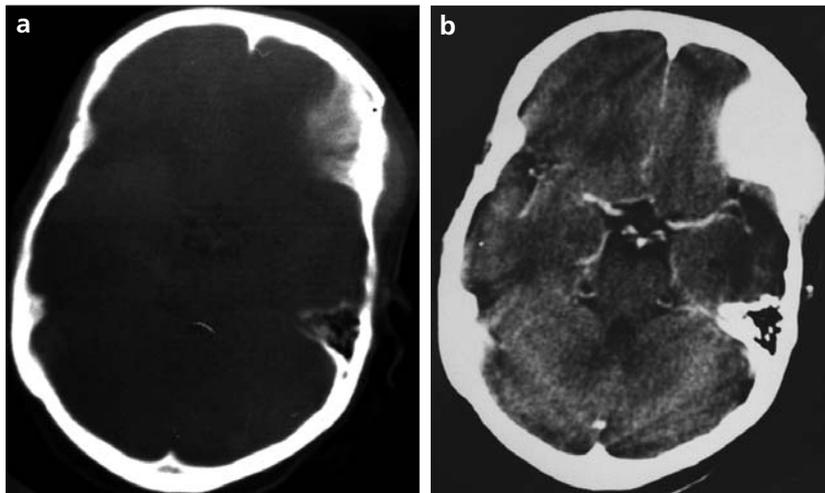


Figure 9. a, b. Sclerotic intraosseous meningioma. Axial CT images in the bone window (a) and contrast enhanced parenchymal window (b) of a 45-year-old female show a homogeneously enhancing lesion in the left side of frontal bone adjacent to the coronal suture and arising from the inner table. A soft tissue component extending through the anterior cranial fossa and subcutaneous tissue is defined.

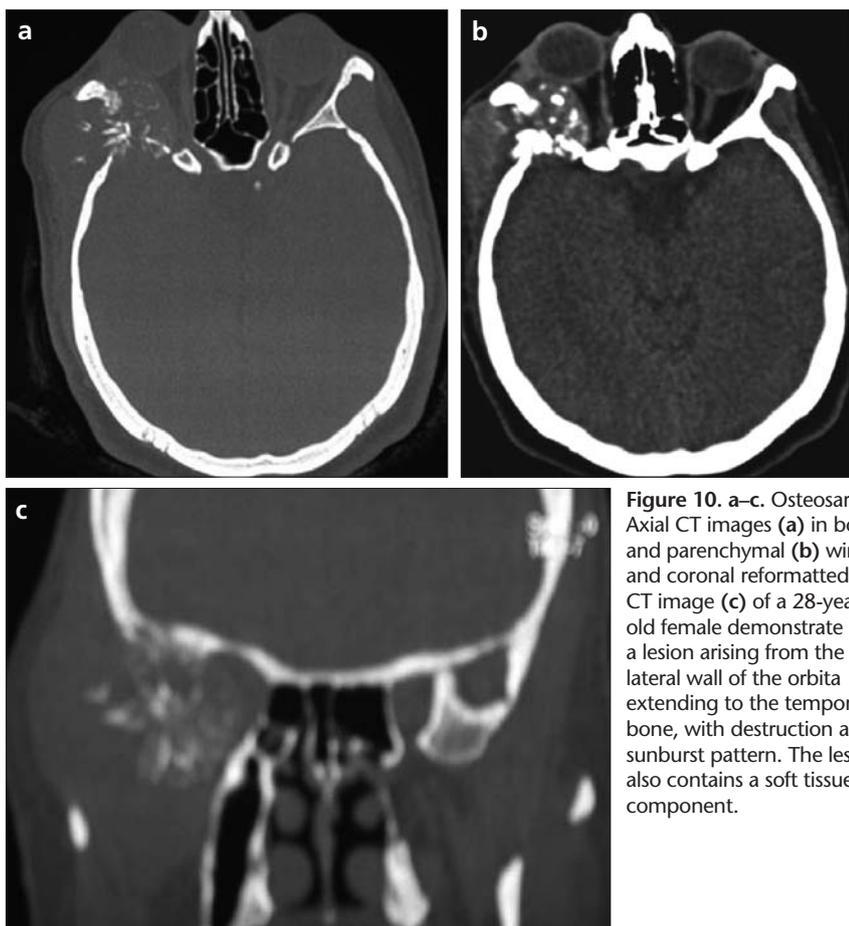


Figure 10. a-c. Osteosarcoma. Axial CT images (a) in bone and parenchymal (b) windows and coronal reformatted CT image (c) of a 28-year-old female demonstrate a lesion arising from the lateral wall of the orbita extending to the temporal bone, with destruction and a sunburst pattern. The lesion also contains a soft tissue component.

Intraosseous meningioma

Intraosseous meningiomas are most often located near the coronal suture. Their expansion in bones and ground-glass appearance may be hard to differentiate from those of fibrous dysplasia.

Nevetheless, meningiomas usually present in middle-aged or advanced aged women, grow after puberty, and lead to irregularity in the inner table, whereas in fibrous dysplasia, the inner table is not affected and growth

of the lesion ceases with puberty (13) (Fig. 9).

Osteosarcoma

An osteosarcoma is mostly a primary tumor in children, whereas it is secondary to Paget's disease, fibrous dysplasia, chronic osteomyelitis, and radiotherapy in adults. Among all 3 types, which are osteoblastic, fibroblastic, and telangiectatic, the osteoblastic type occurs most frequently. CT may reveal focal sclerosis, but it is usually destructive. Mineralization and a soft tissue mass in the tumor matrix may be seen. It may demonstrate a sunburst pattern. In order to differentiate it from hemangioma, which is a benign lesion that also shows a sunburst pattern, it should be considered that osteosarcomas are aggressive, destroying the inner and outer tables, and have irregular contours. Its MRI signal is heterogenous and it enhances heterogeneously (6, 14) (Fig. 10).

Conclusion

CT and MRI are complementary methods in determining the nature of calvarial lesions. In diagnosing lesions, patient age, history of trauma or a primary disease, lytic or sclerotic nature, inner or outer table involvement, enhancement pattern, presence of destruction or expansion, and the lesion being solitary or multiple should be taken into consideration. A relevant radiological approach is essential in the management of the lesion, which includes biopsy, surgery, and follow-up.

References

1. Amaral L, Chiurciu M, Almedia JR, Ferreira NF, Mendonça R, Lima SS. MR imaging for lesions of the cranial vault. *Arq Neuropsiquiatr* 2003; 61:521-532.
2. Burgener FA, Meyers SP, Tan RK, Zaunbauer W. Differential diagnosis in magnetic resonance imaging. 1st ed. New York: Georg Thieme Verlag, 2002; 170-171.
3. Burgener FA, Korman M. Differential diagnosis in conventional radiology. 2nd ed. New York: Georg Thieme Verlag, 1991; 139-146.
4. West MS, Russel EJ, Breit R, Sze G, Kim KS. Calvarial and skull base metastases: comparison of non-enhanced and Gd-DTPA-enhanced MR images. *Radiology* 1990; 174:85-91.
5. Okamoto K, Ito J, Furusawa T, Sakai K, Tokiguchi S. Imaging of calvarial eosinophilic granuloma. *Neuroradiology* 1999; 41:723-728.
6. Khanam H, Lipper MH, Wolff CL, Lopes MBS. Calvarial hemangiomas. *Surg Neurol* 2001; 55:63-67.

7. Senol U, Karaali K, Akyuz M, Tekinalp G, Tuncer R, Luleci E. Aneurysmal bone cyst of orbit. *AJNR Am J Neuroradiol* 2002; 23:319–321.
8. Acikgoz B, Tekkok IH. Posttraumatic intradiploic leptomeningeal fistula and cyst. *J Clin Neurosci* 2002; 9:468–473.
9. Ersahin Y, Gulmen V, Palali I, Mutluer S. Growing skull fractures. *Neurosurg Rev* 2000; 23:139–144.
10. Bigot JL, Iacona C, Lepreux A, Dhellemmes P, Motte J, Gomes H. Sinus pericranii: advantages of MR imaging. *Pediatr Radiol* 2000; 30:710–712.
11. Chong VFH, Khoo JBK, Fan Y. Fibrous dysplasia involving the base of the skull. *AJR Am J Roentgenol* 2002; 178:717–720.
12. Arana E, Marti-Bonmati L. CT and MR imaging of focal calvarial lesions. *AJR Am J Roentgenol* 1999; 172:1683–1688.
13. Daffner RH, Yakulis R, Maroon JC. Intraosseous meningioma. *Skeletal Radiol* 1998; 27:108–111.
14. Bose B. Primary osteogenic sarcoma of the skull. *Surg Neurol* 2002; 58:234–240.