Calvarial Lesions: En-bloc Resection Is a Safe Surgical Procedure

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ABSTRACT

Background: Calvarium could be a target site for either primary or secondary tumors. Calvarial tumors present usually as painless palpable masses, which are asymptomatic neurologically. **Objective:** To perform a retrospective analysis of the calvarial lesions operated in our departments of neurosurgery. **Patients and Methods:** We retrospectively reviewed 41 consecutive patients operated for calvarial masses between 2014 and 2020 at Benha University Hospital and Merciful Brothers Hospital Trier. Clinical data were retrospectively analyzed. The diagnosis was confirmed by the histopathological examination. **Results:** Calvarial lesions included in this series were divided into 3 categories: tumor-like lesions, primary, and secondary tumors. The group of tumor-like lesions involved eosinophilic granuloma (3 patients), epidermoid cyst (3 patients), and fibrous dysplasia (5 patients). The primary tumors included hemangiomas (5 patients), osteomas (5 patients), and meningiomas (11 patients). Nine patients had metastasis. Calvarial lesions mostly presented with local swelling, sometimes local pain and rarely neurologic deficit. En-bloc resection was performed followed by cranioplasty. Pain was improved postoperatively in cases presented with painful swelling. The only postoperative complication was one case of wound infection. **Conclusion:** Although a thorough preoperative radiological evaluation in cases of calvarial lesions could be helpful in narrowing the diagnosis spectrum of differential diagnosis, en-bloc resection followed by cranioplasty could be considered as a valuable treatment option. The next step in treatment of such patients vary widely according to the histopathological findings.

Keywords: Skull metastasis, calvarial tumors, cranioplasty, PMMA.

INTRODUCTION

Calvarial lesions are usually asymptomatic and may be discovered incidentally[(1)]. That's why such lesions carry less clinical importance than intracranial lesions[(2)]. When becoming symptomatic they present themselves as a visible or palpable painless mass, which is sometimes painful[(3)]. It is worthy to note that a wide variety of serious diseases can stand behind such a simple lesion and early diagnosis is crucial for starting the optimum treatment[(2)]. Although CT scan is commonly considered a good tool for the diagnosis of any boney lesion, MRI enables the screening for metastases in both skull and brain[(4)]. Differentiation of the imaging features of both benign and malignant lesions is vital for establishing the radiological diagnosis[(5)].

Histopathological examination is crucial in reaching the definite diagnosis. Additionally, postoperative staging is important not only for metastatic lesions but also for some other lesions like eosinophilic granuloma and fibrous dysplasia. Our strategy in dealing with such lesions is to perform en-bloc resection with immediate reconstruction using polymethyl methacrylate (PMMA). Two-staged surgery is used very rarely in cases with large skull lesions, where reconstruction is performed in the second stage using a 3D-printed cranioplasty.

The aim of our study is to perform a retrospective analysis of the calvarial lesions operated in our departments of neurosurgery.

PATIENTS AND METHODS

A retrospective analysis was performed for all the calvarial lesions operated upon between January 2014 and May 2020 at Benha University Hospital Egypt and Merciful Brothers Hospital Trier- Germany. Preoperative CT and MRI confirmed presence of a calvarial lesion, which was diagnosed through histopathology. No cases were excluded from the study.

The medical records of 41 patients were reviewed for demographic data, the records of each patient were analyzed documenting pre- and postoperative clinical symptoms and radiological as well as intraoperative findings, surgery-related complications, and short-term outcome.

Ethical consent:

An approval of the study was obtained from Benha University Academic and Ethical Committee. Every patient signed an informed written consent for acceptance of participation in the study. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical analysis:

The collected data were coded, processed and analyzed using the SPSS (Statistical Package for Social Sciences) version 22 for Windows® (IBM SPSS Inc, Chicago, IL, USA). P value < 0.05 was considered significant.

RESULTS

This study included 41 patients (18 males, 23 females). The characteristics and presentations of the patients are shown in table 1. Accidental diagnosis was common in metastasis (56% accidentally diagnosed), where the diagnosis was performed during routine staging. An example of the accidental finding was a patient diagnosed for a frontal osteoma in whom a CT-brain was performed due to left-sided weakness, and showed chronic subdural hematoma and the osteoma (Fig. 6). The patient characteristics, pathology and presenting symptoms are presented in Table 1. Table 2 shows the number and location of the lesions in the presented series.

Received: 14/7/2022
Accepted: 12/9/2022

Table (1): Patients' characteristics and presentations

	ALL	Epidermoid	Eosinophilic Granuloma	Hemangioma	Fibrous Dysplasia	Osteoma	Meningioma	Metastases
Number	41	3	3	5	5	5	11	9
Age mean (range)	50.2 (6-86)	48.3 (28-75)	17 (6-24)	42.4 (25-54)	21.8 (13-32)	49 (30-65)	64.5 (39-86)	65.3 (42-84)
Sex Male	18	1	1	1	4	4	3	4
Female	23	2	2	4	1	1	8	5
Presentation Swelling	16 (39%)	1 (33%)	1 (33%)	2 (40%)	3 (60%)	4 (80%)	3 (27%)	2 (22%)
Pain	5 (12%)	1 (33%)	2 (67%)	1 (20%)				1 (11%)
Accidental	13 (32%)	1 (33%)		3 (60%)	2 (40%)	1 (20%)	1 (9%)	5 (56%)
Other	8 (20%)						7 (64%) (tumor-related symptoms)	1 (11%) (tumor-related symptoms)

Table (2): Location and side of different calvarial lesions

		ALL	Epidermoid	Eosinophilic Granuloma	Hemangioma	Fibrous Dysplasia	Osteoma	Meningioma	Metastases
Number		41	3	3	5	5	5	11	9
Location	Frontal	23		2	1	1	5	8	6
	Parietal	7	1	1	2	1			2
	Temporal	6			2	1		3	
	Occipital	5	2			2			1
Side	Right	22	1	3	2	4	4	3	5
	Left	17	2		3		1	7	4
	Midline	2				1		1	

Radiological findings **(Figs. 1-6 and Table 3)**

CT-scan was available in 37 patients and showed that 57% of the lesions were osteolytic. All eosinophilic granuloma lesions (Fig. 1) and epidermoid (Fig. 2) were osteolytic. In addition, most metastatic lesions (75%) were osteolytic. The margins were regular in benign osteolytic lesions (epidermoid, hemangioma, eosinophilic granuloma), however in metastasis the margins were irregular. In cases of fibrous dysplasia, 40% of the cases showed only osteolytic lesion, however in the majority of the cases (60%), the lesion showed mixture of osteolysis and hyperostosis and demonstrate the typical ground-glass appearance (Fig. 3). In hemangioma, the lesions showed a special pattern of osteolysis, where thickened trabeculae (sunburst appearance) were pronounced in CT scan (Fig. 4).

On the other hand, hyperostosis was found in 32% of the cases. The lesions in osteoma cases were hyperostotic in 67% of the cases and osteolytic in 33% of the cases, however all of these lesions involved only the outer table with preservation of the inner table (Fig. 5). Most of osseous involvement in cases of meningioma (82%) were hyperostotic, however osteolysis was very rare (18%). All the osteolytic lesions in meningioma were WHO grade II (Fig. 6). No definite bony involvement was observed in one case of lymphoma, the patient presented with a painful scalp swelling, CT-brain showed subcutaneous swelling with minimal erosion of the inner table, however MRI brain showed leptomeningeal contrast enhancement with underlying intraparenchymal area of restricted diffusion.

Almost all the lesions were hypointense in T1WI-MRI (95%), however in T2WI the intensity of the lesions were variable; 51% were hyperintense, 32% were hypointense and 16% showed heterogenous intensity in T2WI. Although epidermoid and eosinophilic granuloma are osteolytic lesions in CT, both lesions have different intensity in T2WI-MRI, where epidermoid mostly shows heterogenous intensity and eosinophilic granuloma is mostly hyperintense. Fibrous dysplasia shows also heterogenous intensity in T2WI, but it mostly has special pattern in CT with mixed osteolysis and hyperostosis (ground-glass appearance). The same for hemangioma lesions which were hyperintense in T2WI and have special osteolytic pattern in CT (sunburst appearance). MRI usually shows intracranial involvement in cases of metastasis with meningeal and intracerebral enhancement.The primary tumor in the calvarial metastatic cases in our series were; breast carcinoma (4 cases), bronchial carcinoma (2 cases), thyroid carcinoma (1 case), melanoma (1 case) and lymphoma (1 case).

Surgery was performed in all cases. En-bloc resection was performed and immediate cranioplasty was done using polymethyl methacrylate (PMMA) was performed in 40 cases, two-staged surgery was performed in one patient with a large fibrous dysplasia in whom the skull defect was reconstructed using a 3D-printed implant (Fig. 4). Pain was improved postoperatively in cases presented with painful swelling. The only postoperative complication was one case of wound infection, surgical revision was performed and the cranioplasty was removed, 3 months later reconstruction was done using a 3D-printed cranioplasty.

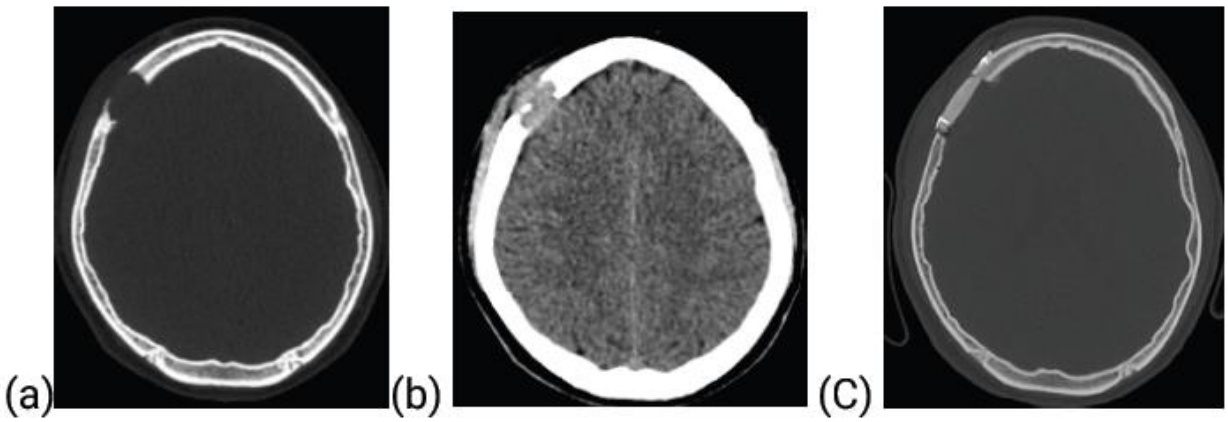

Figure (1): Eosinophilic granuloma: Axial sections cranial multidetector CT scan shows; (a) preoperative bone window with inner and outer table endosteal scalloping. (b) an osteolytic lesion of the right frontal skull with a subcutaneous soft tissue density mass. (c) postoperative bone window after cranioplasty with PMMA.

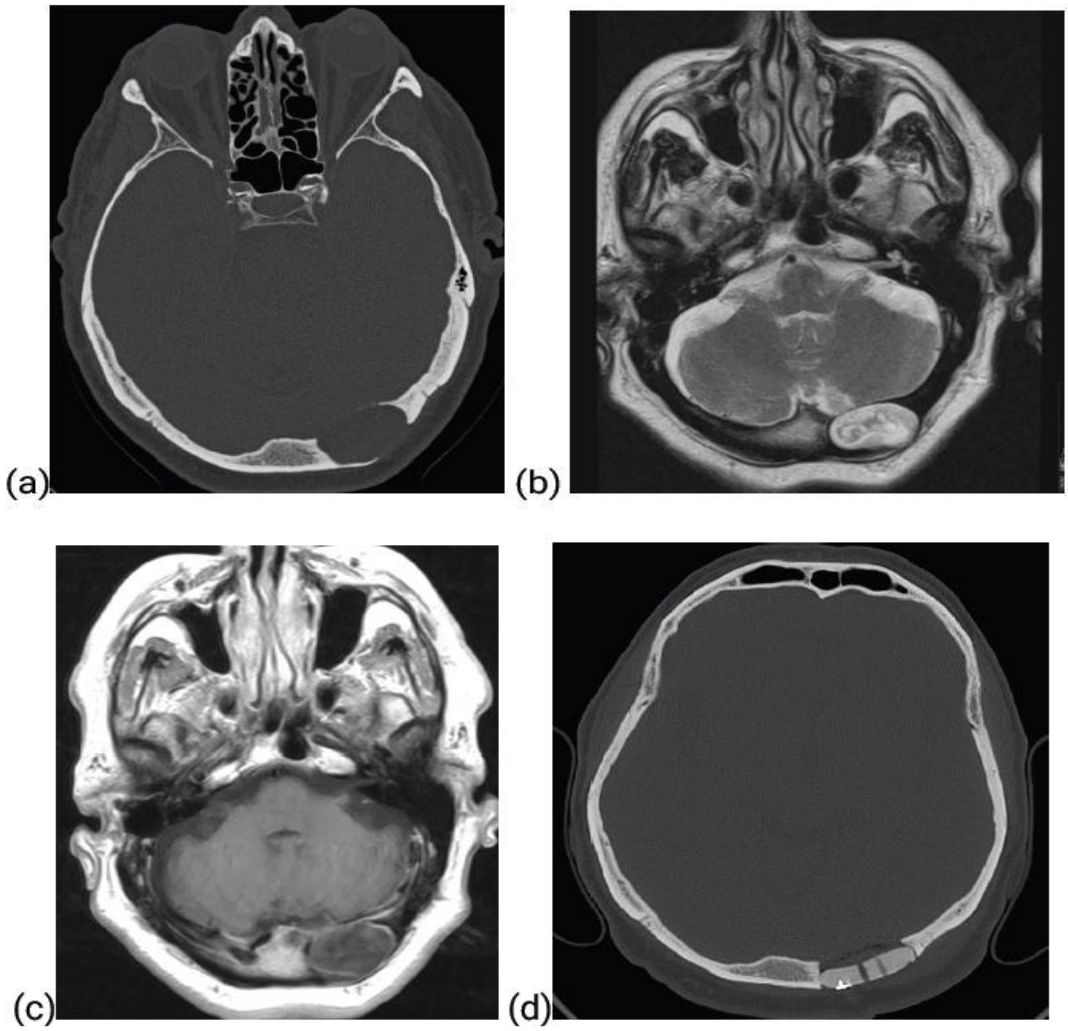

Figure (2): Epidermoid cyst. (a) preoperative CT-bone window with left occipital oval expansile osteolytic lesion. (b) T2WI-MRI shows rounded circumscribed extracranial hyperintense soft-tissue mass. (c) T1WI-MRI post-contrast demonstrates the lesion with its capsule. (d) postoperative bone window after 3D reconstruction of the skull.

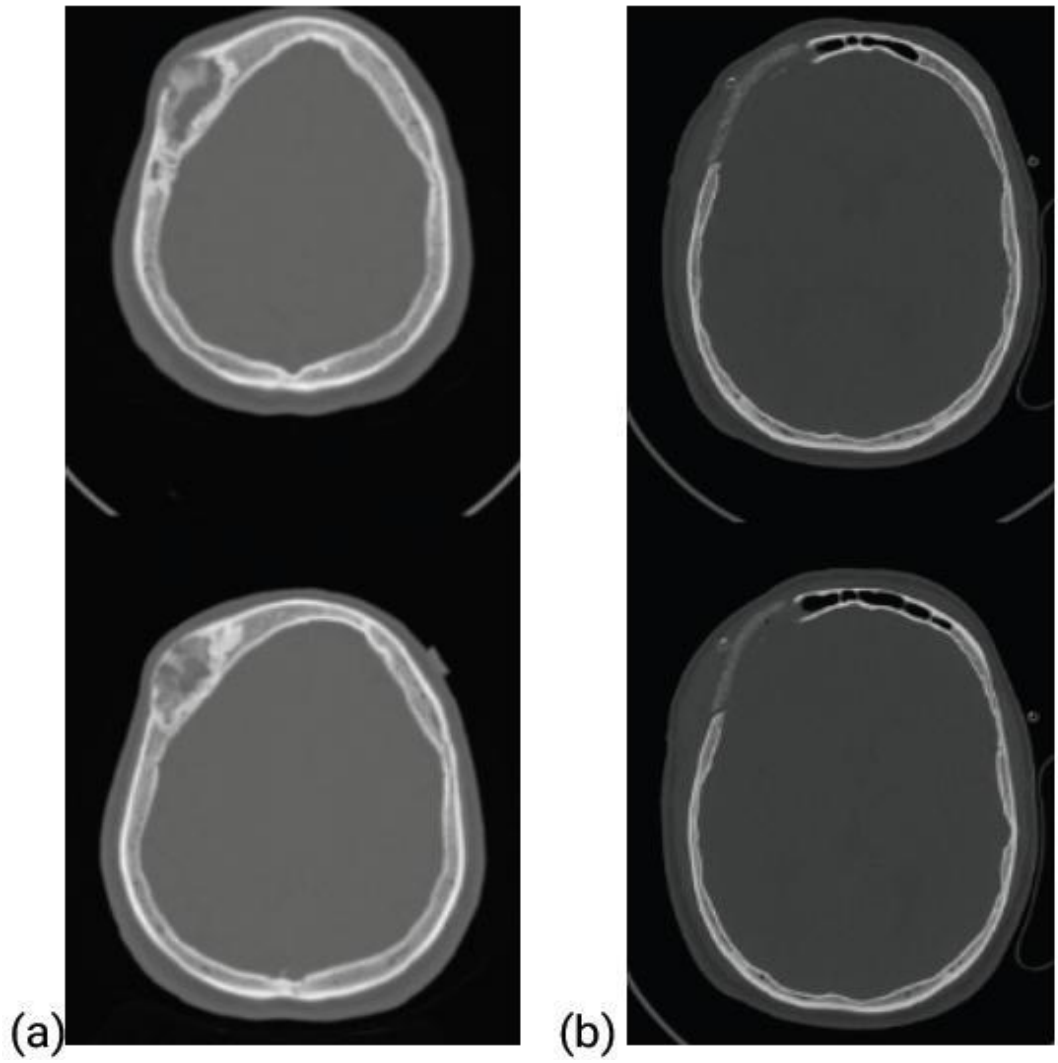

Figure (3): Fibrous Dysplasia. (a) axial head CT images demonstrate an expansile osteolytic lesion with the typical ground-glass matrix in the right frontal bone. (b) postoperative axial head CT images bone window after 3D reconstruction of the skull.

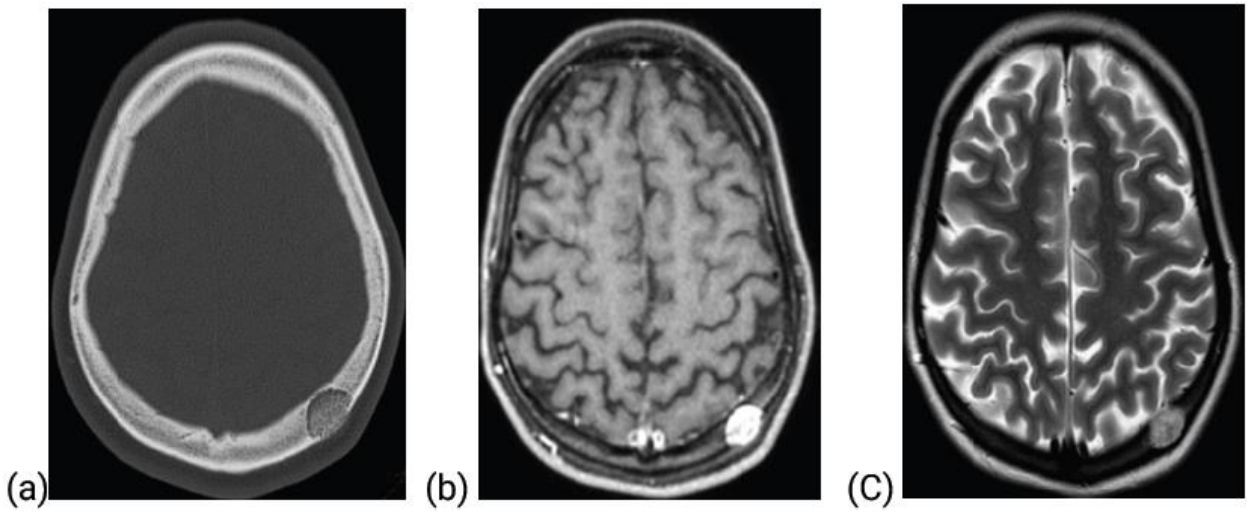

Figure (4) Hemangioma. (a) CT-bone window axial image shows left parietal rounded, diploic, expansile, lytic lesions with sunburst appearance and intact inner table. (b) post contrast T1WI-MRI shows enhanced lesion with intact inner table and eroded outer table with minimal subgaleal soft tissue. (c) T2WI-MRI image shows hyperintense left parietal calvarial lesion.

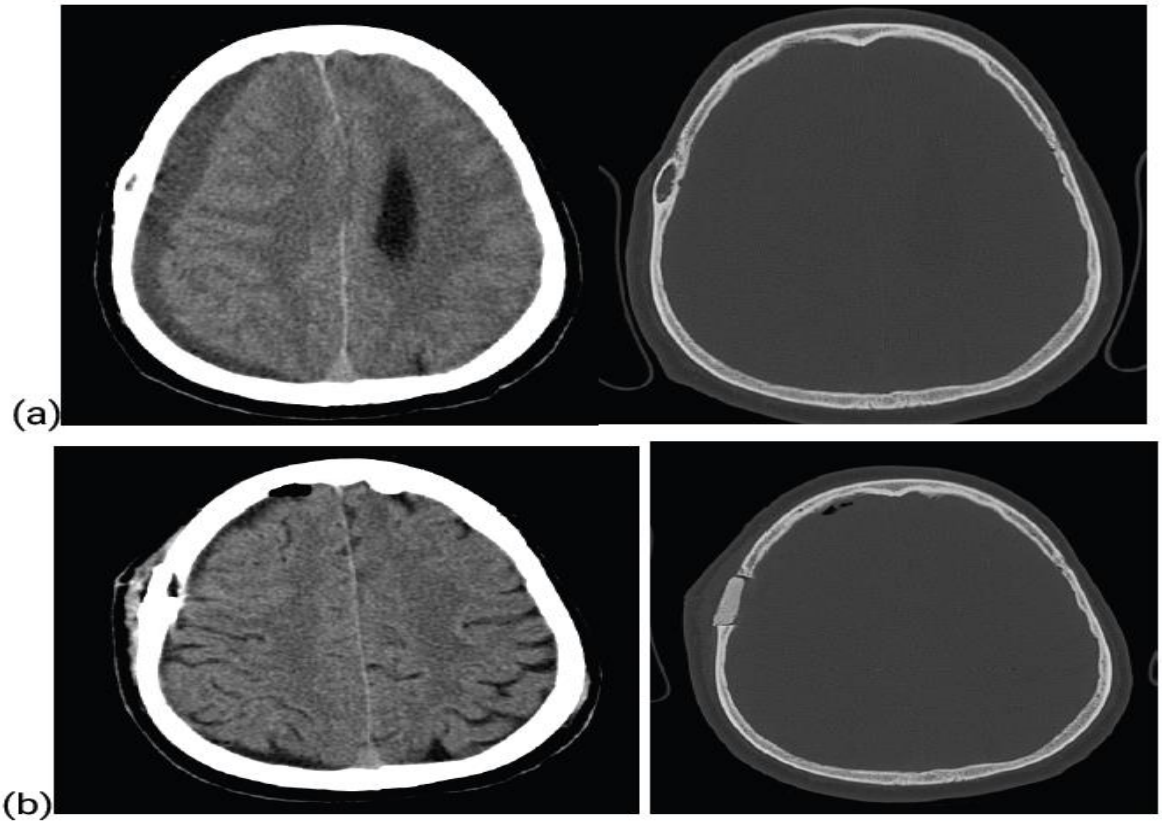

Figure (5): Osteoma. (a) preoperative cranial CT-scan shows right-sided chronic subdural hematoma and osteolytic lesion involving the outer table in the right frontal skull bone. (b) Postoperative CT-scan shows good evacuation of the chronic subdural hematoma and skull reconstruction with PMMA after removal of the osteolytic osteoma.

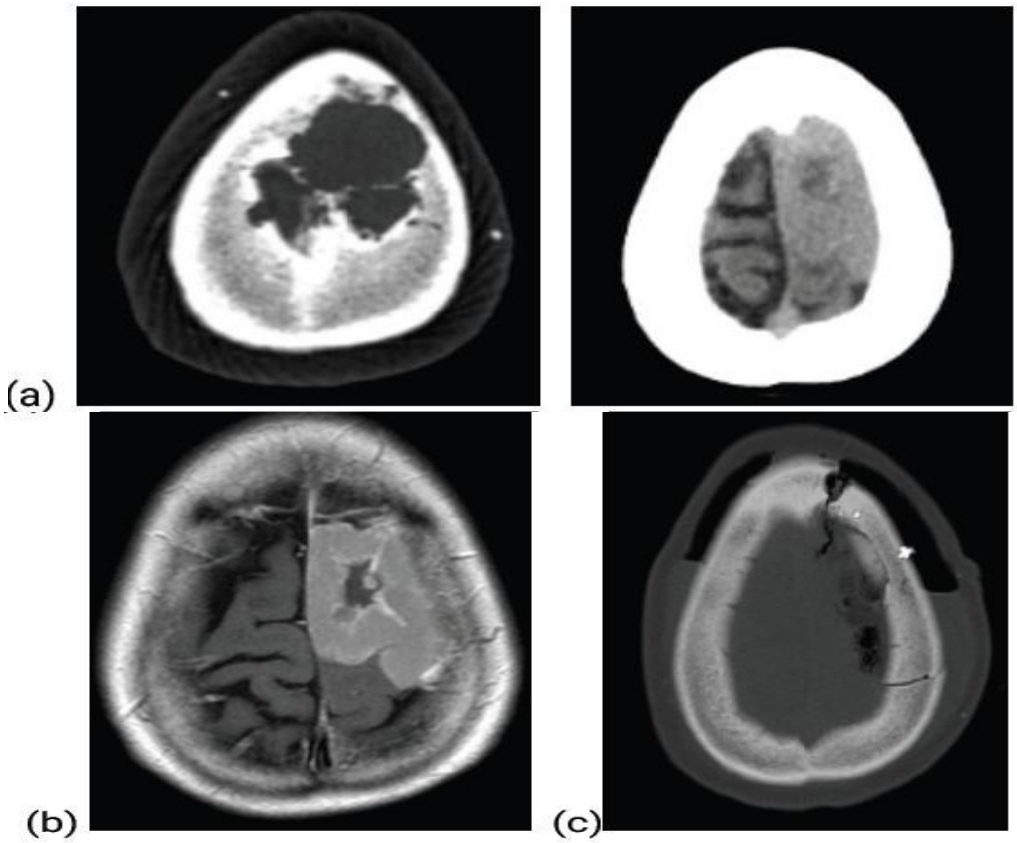

Figure (6): Meningioma (Grade II). (a) preoperative CT-scan bone and brain window axial image shows left frontal high convexity intra diploic, expansile, lytic lesions with great hyperostosis as well as eroded inner table. (b) preoperative post-contrast T1WI-MRI shows enhanced extraaxial mass with dural-based dural tails. (c) postoperative axial head CT images bone window after reconstruction of the skull.

Table (3): Radiological findings (including CT and MRI) for different lesions

		ALL	Epidermoid	Eosinophilic Granuloma	Hemangioma	Fibrous Dysplasia	Osteoma	Meningioma	Metastases
Number		41	3	3	5	5	5	11	9
CT findings	Available in	37	**3**	**3**	**4**	**5**	**3**	**11**	**8**
	Osteolysis	21 (57%)	3 (100%)*	3 (100%)*	4 (100%)**	2 (40%)*	1 (33%)*	2 (18%)***	6 (75%)***
	Hyperostosis	12 (32%)					2 (67%)	9 (82%)	1 (13%)
	Both osteolysis and hyperostosis	3 (8%)				3 (60%)			
	Inner table involvement	1 (3%)			1				
	Outer table involvement	6 (16%)			1	2	3		
	Both tables involvement	11 (30%)	3 (100%)	3 (100%)	2	3			
	No abnormality in CT	1 (3%)							1 (13)
MRI findings	Available in	37	**3**	**3**	**5**	**5**	**1**	**11**	**9**
	T2 Hyperintense	19 (51%)	1 (33%)	2 (67%)	5 (100%)	2 (40%)		4 (36%)	5 (56%)
	T2 Hypointense	12 (32%)					1 (100%)	7 (64%)	4 (44%)
	T2 Heterogenous	6 (16%)	2 (67%)	1 (33%)		3 (60%)			
	T1 Hypointense	35 (95%)	2 (67%)	3 (100%)	5 (100%)	5 (100%)	1 (100%)	11 (100%)	9 (100%)
	T1 Heterogenous	1 (5%)	1 (33%)						
	Contrast enhancement	35	2	3	5	5	1	10	9

* regular margins, ** special feature, *** irregular margins

DISCUSSION

Calvarial lesions could be divided into 3 categories: tumor-like lesions, primary and secondary tumors [(7)]. The group of tumor-like lesions involves eosinophilic granuloma (Figs. 1), epidermoid cyst (Fig. 2) and fibrous dysplasia (Fig. 3).

Calvarial *Eosinophilic granuloma* (EG) is a benign disorder of unknown etiology characterized by the presence of destructive granuloma[(6)]. EG represents the focal bony presentation of Langerhans cell histiocytosis[(7)]. It affects both children as well as young adults, specially males[(8)]. Matching with our finding, skull lesions are typically lytic and well-defined with sclerotic or non-sclerotic margins, with possible periosteal reaction. Endosteal erosions (scalloping) and slight expansion beyond outer and inner tables reflects the characteristic "hole within a hole" and "beveled edges" signs[(9)]. MRI brain shows a homogeneous contrast enhancement limited to the bone[(10)]. We agree with **Samara *et al.***, that staging is an important step after removal of eosinophilic granuloma. If the lesion is limited to skull, no further treatment is recommended after removal of the calvarial lesion, however adjuvant treatment is required in multifocal pathology[(11)].

Epidermoid cysts may be either acquired secondarily due to trauma or primary congenital, as a result of ectodermal inclusion during neural tube closure. Matching with **Morón *et al.*** [(12)], the lesions are well-defined benign slowly growing lesions. Despite their non-neoplastic nature, large growth is common. Epidermoid cysts are osteolytic lesions in CT, mostly heterogeneous intensity in MRI and show heterogeneous contrast enhancement. The most characteristic feature in epidermoid cyst is the restricted fluid diffusion in MRI[(13)].

The third tumor-like lesion is *Fibrous dysplasia* (FD), which accounts for about 5 to 7% of benign tumors of bone[(14)]. It is a benign condition affecting

mainly children and young adults where normal bone tissue is replaced by abnormal fibrous connective tissue[15]. Ground glass appearance is a characteristic finding for FD in CT-scan with alternating dense sclerotic and radiolucent fibrotic areas (pagetoid fibrous dysplasia). Sometimes bone lysis is predominant in the cystic type or sclerosis is more predominant in the sclerotic type[16]. MRI without additional imaging can be misleading as the lytic components correspond to hyperintense areas on T2-weighted images (T2WI) and the "ground-glass" includes T2 hypointense fibrous tissue that enhances avidly after contrast[17]. The lesion can affect either a single bone (monostotic), or multiple bones (polyostotic). Extraosseous manifestations may be present such as café au lait spots and endocrinologic disturbances (McCune–Albright syndrome)[15]. Agreeing with **Nasi-Kordhishti *et al.* [10],** we recommend surgery in the monostotic type, however conservative treatment with analgesics and bisphosphonates is used for the polyostotic type and surgery is indicated only to relieve compression of important structures.

The most common benign calvarial lesions include hemangiomas (Fig. 4), osteomas (Figs.5) meningiomas (Fig.6).

Intraosseous hemangioma is a rare tumor of the bone found mainly in the vertebral column and rarely in the calvarium[18]. Calvarial hemangiomas are slow-growing benign vascular malformations accounts for about 0.2% of all bone tumors, and about 13% of calvarial lesions[19]. It has a female preponderance and may occur at any age, specially the fourth and fifth decades[20]. Multifocal calvarial hemangiomas are extremely rare as the majority of cases have only a single lesion[21]. Documents of **Mitra *et al.* [4]** are matching with our radiological findings that the lesion diagnostic characteristics are; an intradiploic expansile, circumscribed, and lytic lesion, which typically affects the outer table. Pronounced thickened trabeculae ("spoke-wheel" or "sunburst") are the classical appearance on CT imaging. Complete surgical removal down to healthy bone is recommended to avoid recurrence.

Osteoma is considered as the most commonly neoplasm of the frontal bone[22]. Osteomas in the calvarial region are mainly asymptomatic or associated with other problems such as Gardner syndrome, which is manifested by multiple osteomas associated with fibromatosis, familial polyposis, dental and skin lesions[4]. Identifying exophytic, rounded, sclerotic lesions attached to the bones on imaging is diagnostic. They are typically lesions of the outer table[10]. They are structurally composed of mature (normal bone with peripheral cortex and central marrow) or ivory (cortical bone alone), or mixed (heterogeneously distributed) [23].

Meningioma is the most common benign intracranial tumor[24]. Intra-diploic and primary extraosseous meningiomas account for about 2% of all meningiomas[25]. These pathologies are mainly osteoblastic, however some few cases reported osteolytic nature of the lesions. Osteolytic type is considered more malignant than the osteoblastic type[26]. In our series all cases of osteolytic meningioma were WHO grade II meningiomas. Careful evaluation of the preoperative images in cases of meningioma is very important to detect the intraosseous lesion and to plan surgery accordingly to achieve Simpson grade 1 removal. If complete removal is not possible, the need for adjuvant therapy should be evaluated according to the histopathology[27].

Metastases are the most common neoplastic lesions of the bone especially from breast and prostate cancers[28]. Metastatic calvarial tumors are rare and commonly originate from the breast, lung, or prostate[2]. Clinical presentations can range widely from asymptomatic to serious complications[29]. In most cases, they are asymptomatic and detected as random findings in the regular staging. Patients can develop pain when the periosteum is infiltrated. Intracranial extension, can cause neurological deficits. Irregular osteolysis with bone remodeling, a variable contrast enhancement, and signs of a co-reaction of the surrounding tissue are typical radiological findings[4]. In our series 75% of the metastases were associated with calvarial osteolysis, however in a case of lymphoma, there was soft tissue reaction in the form of subcutaneous swelling as well as intracranial enhancement and focal cerebral edema, while the bone appeared almost normal in CT-scan. Expanding lytic (or blowout) metastases are typical of renal-cell or thyroid papillary carcinomas. While breast and prostate tumors are the usual suspects with blastic metastases[30]. After complete removal of calvarial metastasis, an adjuvant therapy such as chemotherapy, immunotherapy, or radiation may be required[31].

Our different radiological findings for variable lesions confirm **Hong *et al.***, recommendations that imaging is very important in the differentiation between various calvarial lesions, therefore careful evaluation of CT and MRI gives some clues in the differential diagnosis (as seen in table 3). Also, careful evaluation of the images is important to detect the extension of the disease before surgical intervention. For example, in meningioma, the infiltrated bone has to be removed to achieve complete removal. Also, in cases of polyostotic fibrous dysplasia, surgery is not recommended unless the lesion is associated with compression of vital structures. Another example is the perifocal edema which gives us a clue of aggressive infiltrating lesion[32].

Agreeing with **Alkhaibary *et al.* [33],** we recommend complete surgical removal for calvarial lesions either for cosmetic reasons, to avoid recurrence, to improve pain or to make the accurate diagnosis in unclear cases. After complete surgical removal, reconstruction of the bony defect should be performed either in the same setting using one of the available synthetic options like polymethyl methacrylate (PMMA) or titanium mesh. Another option in the

setting of large bony defect is to perform reconstruction using 3D-printed synthetic implant in a second setting.

CONCLUSION

Although a thorough preoperative radiological evaluation in cases of calvarial lesions could be helpful in narrowing the spectrum of differential diagnosis, en-bloc resection followed by immediate cranioplasty using PMMA could be considered as a valuable treatment option. The next step in treatment of such patients vary widely according to the histopathological findings.

Financial support and sponsorship: Nil.
Conflict of interest: Nil.

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