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# Cranial intraosseous meningioma: spectrum of neuroimaging findings with respect to histopathological grades in 65 patients

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ABSTRACT

The aim of this study was to determine various imaging features of intraosseous meningiomas (IOMs) and differentiate low-grade from high-grade tumors. The histopathologic evaluation revealed World Health Organization (WHO) grade I tumor in 56 (86%) patients, grade II in 8 (12%), and grade III in 1 (2%) patient. WHO grade I was considered low grade and II and III were designated as high grade. Hyperostosis was observed most commonly in low-grade IOMs. Mixed hyperostotic/lytic pattern with radial bony spiculations and presence of a scalp mass seem to be more frequently associated with higher-grade IOMs.



## 1. Introduction

Primary extradural meningiomas are rare, accounting less than 2% of all meningiomas. Intraosseous meningiomas (IOMs) are a subset of primary extradural meningiomas and represent about two thirds of all extradural meningiomas [1–3]. Osseous involvement by meningiomas may be primary or secondary, but it may be difficult to classify these as either primary or secondary with respect to its origin site, based on the neuroimaging appearance, surgical findings, or histologic features [3]. Based on published data and our experience, we believe such a differentiation cannot be definitively made with imaging or histopathology [3–8].

Although several distinct features of IOMs have been described [9,10], to the best of our knowledge, cross-sectional imaging analyses of IOMs including magnetic resonance imaging (MRI) have not yet been reported. The aim of the present study was to review a series of IOMs to determine various imaging features of IOMs and differentiate low-grade from high-grade tumors.

## 2. Materials and methods

After institutional review board approval, the pathology database was queried for reports with the key words "intraosseous meningioma" and "meningioma within the bone" from December 2000 to February 2012. From this list, a total of 81 patients were identified. Sixteen patients, whose tumor mass within bone was proven to represent secondary osseous invasion according to pathology, were excluded. Sixty-five patients whose mean tumor mass within bone was equal to or greater than 50% of the total mass were included in the study. For all patients, the available clinical records, operative reports, and pathology reports were reviewed. Neuroimaging data, including computed tomography (CT) and/or magnetic resonance (MR), were retrieved from our picture archiving and communication system and were retrospectively analyzed. Although odds ratio associated with meningioma are considerably high for female population, this study aimed to evaluate IOM in general.

CT scans were obtained on multidetector CT scanners, including 4-, 16-, and 64-row detectors from Siemens (Siemens AG, Erlangen, Germany) and Toshiba (Toshiba Medical Systems, Otawara, Japan). Images were obtained with helical technique and 0.75–1 mm thickness and were reconstructed at 3–5-mm-slice thickness and intervals in a soft tissue and bone algorithm. Further CT parameters were as follows: x-ray tube current=400 mAs, 120 kVP, and FOV=24.0 cm×24.0 cm. Nine patients underwent CT with intravenous administration of nonionic iodinated contrast.

The MRI examinations were performed at either 1.5 T or 3 T magnet strength on scanners from different manufacturers: Philips (Philips Medical Systems, Best, the Netherlands), GE (GE Medical Systems, Milwaukee, WI, USA), and Siemens (Siemens AG, Erlangen, Germany). The MRI protocol included diffusion-weighted images, T1-weighted images, fast spin-echo T2-weighted images, fluid attenuated inversion recovery (FLAIR) images, and contrast-enhanced T1-weighted images. All patients underwent postcontrast imaging after intravenous

*Abbreviations:* IOM, Intraosseous meningioma; WHO, World Health Organization; MRI, Magnetic resonance imaging; CT, Computed tomography; MR, Magnetic resonance; FLAIR, Fluid attenuated inversion recovery.

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administration of gadolinium-based contrast media. The sagittal T1W sequence was obtained with parameters as follows: range of TRs, 520–696 ms, and TEs, 4.6–14 ms; matrix size range from 192×192 to 512×196; FOV range from 190×190 mm to 240×240 mm; and range of section thickness/spacing from 1/1 to 5/7 mm. The axial T2W sequence was obtained with the range of TR, 2500–7000 ms, and TE, 83.136–112 ms; matrix size range from 256×184 to 448×335; FOV range from 159×200 mm to 240×240 mm; and the range of section thickness/spacing from 2/2 to 5/5 mm. FLAIR sequence parameters were the following: TR, 6000 ms; TE, 120 ms; TI, 2000 ms; section thickness, 5 mm; FOV, 23 cm; and matrix size, 256×256.

A neuroradiologist with 8 years of experience in this field (II) and a general radiologist with 7 years of experience (ATI) reviewed all the CT and MR exams retrospectively and noted findings in consensus. They were blinded to the pathologic grade of the IOMs. In the event of disagreement between the two reviewers, a third neuroradiologist with 15 years of experience (NA) adjudicated.

## 3. Image analysis

The locations of the meningiomas were divided into three groups: sphenoid ridge (greater sphenoid wing), other skull-base regions, and calvarial convexity. Characteristics evaluated on CT included the location of the tumor, bone density (hyperostotic, lytic, or mixed), presence of bone expansion, contour irregularity or radial bony spiculations, and dural calcification. Expansion was defined when the bone lesion thickness was greater than the thickness of the adjacent normal calvarial bone. Contour irregularity was defined if there were irregular inner or outer calvarial bony surfaces instead of normal smooth borders. Radial oriented bony spiculations along the calvarial surface were also noted if present. Dural calcification is defined as a linear high-density structure above 100 HU along the dural surface subjacent to the IOM on CT. Presence of dural enhancement or an adjacent intracranial dural or extracranial scalp soft tissue mass was noted. The osseous characteristics were evaluated using bone window algorithm (400–600 HU window level; 2400–2600 HU window width).

**Table 1**
Demographics, distribution, and histopathologic grades of IOMs

| Tumor location | Sphenoid ridge | Calvarial convexity | Other skull-base regions |
|---|---|---|---|
| Number of patients (*n*, %) | 35 (53) | 22 (33) | 8 (14) |
| Age (mean/min/max) | 56/32/81 | 58/26/91 | 56/35/69 |
| Sex (F/M) | 27/8 | 16/6 | 8/0 |
| Grade I | 35 | 16 | 5 |
| Grade II | 0 | 5 | 3 |

On MR, the presence of dural enhancement or an adjacent intracranial dural or extracranial soft tissue mass and adjacent parenchymal edema were evaluated. Dural enhancement was defined as a linear enhancement not thicker than 3 mm. Nodular or linear dural-based soft tissue enhancement greater than 3 mm was defined as mass. Cerebral edema was defined as present if there is increased T2/FLAIR signal on MR in the adjacent parenchyma. To quantify the extent of edema, the distance from the maximum inner edge of region of maximum edema to the nearest point of meningioma border was measured in millimeters. If there was no white matter FLAIR hyperintensity, it was accepted as “no edema”. If the white matter FLAIR hyperintensity is less than tumor, it was accepted as “minimal edema”. If the extension of edema was equal or greater than tumor, it was accepted as “extensive edema”.

## 4. Results

Of the 65 patients included in the study, 42 had both MR and CT scans, and 23 had either MR ($n=12$) or CT scan ($n=11$). The distribution, demographics, and World Health Organization (WHO) grades of the cases are summarized in Table 1. The two reviewers disagreed on only 3 cases and those were evaluated by a third neuroradiologist independently and a final consensus was achieved.

Sphenoid ridge and calvarial convexity predominated over the other locations (Figs. 1–3). Most of the calvarial convexity IOMs originated in the frontal or parietal region, except 2 occipital lesions.

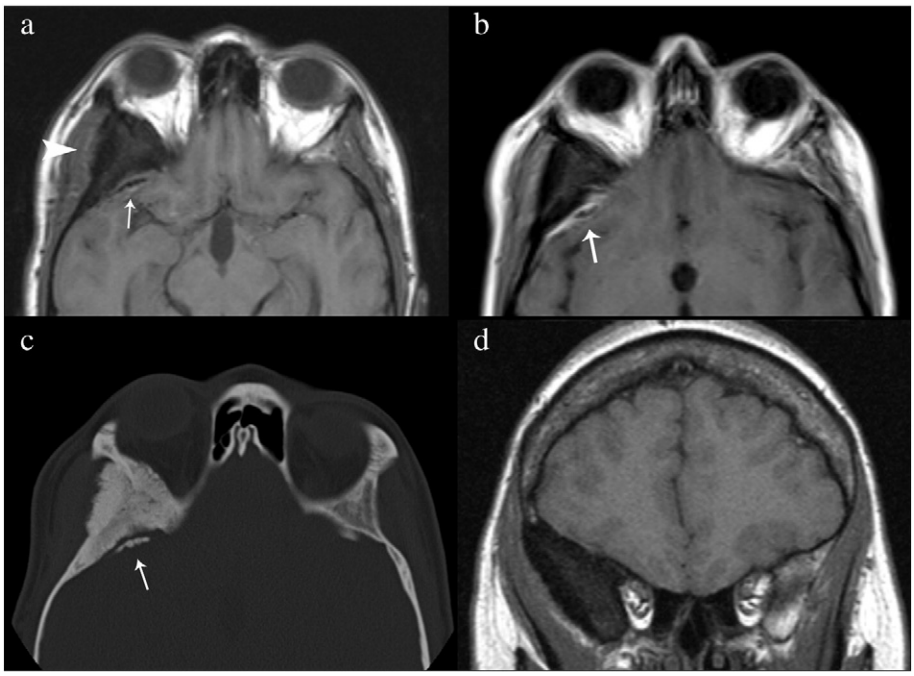


**Fig. 1.** Low-grade sphenoidal IOM with homogenous hyperostotic appearance. Axial precontrast T1-weighted (W) (a) and coronal T1W (d) images show an expanded, hypointense, right sphenoid ridge intraosseous mass with superficial irregularity bulging into the right orbit. Postcontrast T1W image (b) shows no prominent enhancement of intraosseous mass but mild thickening of the adjacent dura. Nonenhancing central subdural layer was compatible with calcification which is better confirmed on previous CT with dural lucent interface (c). Superficial irregularity, expansion, and subdural calcification in this location are pathognomonic with the diagnosis of IOM. An expansile intraosseous very similar looking FD has typically no superficial irregularity.