Sacral masses: What every radiologists needs to know?

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Learning objectives

Review and illustrate the main radiology imaging findings of the most common sacral masses in adults.
Background

The sacrum is a structure that presents itself to the attention of multiple medical specialists as well as imaging subspecialties and there is a difficulty of the initial image findings due to intestinal gas overlap and pelvic structures. Nonetheless, the clinical findings can be delayed because the sacrum can accommodate large, slow-growing masses without many clinical findings, which show clinical findings only when they compress the neural structures and/or pelvic organs.

Usually the findings are characterized by computed tomography (CT) and, more conspicuously, by magnetic resonance imaging (MRI), but the X-ray is usually the first assessment and can show tenuous imaging findings, although there are some method limitations, but that in the persistence of doubt, the axial methods have to be used as complementation.

The sacrum is a structure that has the embryogenesis associated with the elements of the whole column, passing through the developmental processes (mesenchymal stage, chondrification, primary ossification and secondary ossification). During childhood, they are separated by discs, with fusion of S3-S4 and S4-S5 in late adolescence and the other segments complete their fusion around the third decade of life.

It is a structure with an inverted triangle shape, which articulates with the lumbar spine, coccyx and iliac bones. It has a concave inner or pelvic surface and a convex outer surface.

In relation to the sacral bone tumors, they correspond to about 6% of the primary bone neoplasms, being the chordoma the most common of the primary tumors (about half of the cases) and the giant cell tumor the most common of the benign types. In addition, they can be divided into primary and secondary, and metastasis is the most common tumor to reach the sacrum because it contains hematopoietic marrow in its composition.
Findings and procedure details

1. Benign lesions:

1.1. Giant cell tumor: Most giant cell tumors of the spine occur in the sacrum and they are uncommon on the spine/sacral (3-7% of all giant cell tumors), although is the most common benign sacral neoplasm. Sacral giant cell tumors are frequently eccentric and abut or extend across the sacroiliac joint. Patients are usually affected between the ages of 15 and 40 years old, and most women (2:1). They are purely lytic/destructive lesions and with hemorrhagic and fibrotic areas. Spontaneous malignant transformation was reported in fewer than 2% of patients, and it often occurs after radiation therapy. They can be large by the time of detection because of nonspecific clinical symptoms and difficulty in diagnosis on X-rays (Fig. 1 on page 8 e Fig. 2 on page 8).

1.2. Hemangioma: despite being the most common primary tumor of the spine, cavernous hemangiomas rarely involve the sacrum. Although these lesions are typically small and asymptomatic, aggressive spinal hemangiomas have been recognized. The lesions are usually hypervascular and are associated with an epidural soft-tissue component that encroaches on the adjacent neural structures within the spinal canal or neural foramina. An unusual hemangioma at S2-S3 causing pain has been reported. On plain radiograph, hemangioma appears as an irregular and lytic lesion in long bones, with a honeycomb appearance. On CT, thickened vertical trabeculation on axial images are the common findings and MRI exhibit high signal in T1-weighted (when contains fat) and T2-weighted images (Fig. 3 on page 9 and Fig. 4 on page 9).

1.3. Sacrococcygeal teratomas: they are composed of a variable mixture of solid and cystic components containing elements of all three germ layers. The vast majority of the cases are diagnosed in utero or during the first day of life. Although the majority of teratomas in infancy and childhood are benign, there is a tendency toward malignant transformation as the child gets older. The tumor is usually visibly externally in children, but not in adults. Radiography show a large pelvic mass and sacral osteolysis. CT shows a loculated and calcified polycystic mass and visualises the extent of sacral bone destruction. MRI provides more accurate intra-sacral and extra-sacral staging and demonstrates the cystic content with fluid-fluid levels (Fig. 5 on page 10).

1.4. Osteoblastoma: shows similar histology with osteoid osteoma and generally differ from it by the size (usually osteoblastomas are larger than 2 cm) and tend to affect more often the sacrum. Around 40% are located on the spine and 17% affect the sacrum. It shows a lytic defect surrounded by a sclerotic ring. It shows nonspecific signal intensity pattern on MRI, but peritumoral edema in bone marrow and in the soft tissue parts, related
to the inflammatory response, is a characteristic finding and should raise the possibility of osteoblastoma in differential diagnoses.

1.5. Osteoid osteoma: Only 0.2% osteoid osteomas are found in the sacrum. The peak of incidence is between 10-20 years old, affecting men two to three times more frequently than women. Patients present with pain that is often worse at night and is relieved by nonsteroidal / salicylate drugs. The tumors most typically arise from the articulating process of S1. Osteoid osteoma usually has less than 2 cm in diameter surrounded by marked perifocal sclerosis. CT is particularly useful for detecting and identifying osteoid osteomas. The usefulness of MR imaging in detecting the nidus is unclear; when an osteoma is detected generally has low on T1-weighted images and intermediate to high on T2-weighted images.

1.6. Aneurysmal bone cysts (ABCs): they have a 4% incidence in the sacrum (most commonly in the thoracic spine). More than 80% are detected by the age of 20 years with a slight female predominance. ABCs are not true neoplasms. The presenting symptoms include pain, neurologic deficits, and mass. The most common radiographic appearance of a aneurysmal bone cyst is that of an osteolytic expansile lesion surrounded by a thin shell of bone. CT and MR imaging are useful methods of delineating the extent of sacral aneurysmal bone cysts. Both techniques may reveal multiple fluid-fluid levels reflecting hemorrhage with sedimentation, a characteristic feature of this tumor.

2. Malignant lesions.

2.1. Chordomas: most common primary tumor of the sacrum. Despite being a tumor of low aggressiveness it can cause high morbidity and mortality and local recurrence. Almost always occur in a midline or paramedian location. A chordoma manifests as a destructive, lytic lesion, commonly with internal calcifications, associated with increase of soft tissues in the anterior region. It has characteristically high signal in the sequences sensitive to liquid due to its gelatinous component similar to the nucleus pulposus (Fig. 6 on page 11 and Fig. 7 on page 11).

2.2. Metastasis: most common tumor involving the sacrum, mainly from lung, breast, kidney, prostate, and skin cancers. Most metastasis are lytic, although some are blastic (breast and prostate cancers). They reach the sacrum via the subarachnoid space or, most common, via hematogenously, because it contains hematopoietic marrow in its composition (Fig. 8 on page 12 and Fig. 9 on page 12).

2.3. Chondrosarcoma: The thoracic spine is the most common site and sacral involvement is unusual. The mean age is 45 years old. Most chondrosarcomas are
central in origin and primary. X-rays and computed tomographies reveal large destructive lesions with characteristic chondroid matrix mineralization. Calcifications are typically rounded or curvilinear and are also visible in the soft-tissue component of the lesions. Chondrosarcomas usually show high T2 signal but may show heterogeneous T2 signal because of the presence of a mineralized and unmineralized chondroid matrix.

2.4. Plasmacytoma/Multiple myeloma: it is derived from neoplastic clonal expansion of plasma cells. It is the second most common malignant primary neoplasm of the sacrum. Myeloma peaks in the sixth and seventh decades of life and is more common in men than in women. Plasmacytoma is the unifocal tumoral form of multiple myeloma and usually has a better prognosis than multiple myeloma. Typically, multiple round lytic lesions with nonsclerotic margins are seen, although some patients have diffuse demineralization or areas of bone sclerosis. On MRI images, plasmacytomas and myeloma lesions are hypointense to healthy marrow on T1-weighted images and hyperintense on T2-weighted images. The predominant differential diagnosis (Fig. 10 on page 13).

2.5. Lymphoma: primary lymphoma of bone is a rare round cell tumor, yet it is the third most common malignant primary neoplasm of the sacrum, with a prevalence of 8%. Primary lymphoma of the sacrum has a peak incidence during the second and third decades and is rare in children younger than 10 years old. There is a 2:1 male predominance. Aggressive bone destruction is the usual feature. When visible on radiographs, lymphoma is a permeative lytic lesion. Bone marrow invasion can be massive on MRI despite normal findings on X-ray. The differential diagnosis includes other highly aggressive bone neoplasms and, occasionally, aggressive nonneoplastic diseases, such as, acute osteomyelitis.

2.6. Osteosarcoma: is the fifth most common malignant primary neoplasm of the sacrum, yet it accounts for only 4% of primary sacral tumors. Primary osteosarcoma arising in the axial skeleton differs from appendicular osteosarcoma. The peak occurs at 36 years old and has no significant predilection for men. Many cases can be associated with Paget's disease or with previously irradiated lesions. Radiographs and CT images show a purely lytic, mixed, or predominantly osteoblastic lesion. CT also allow identification of both the matrix mineralization and the extension into the paravertebral and extradural soft tissues, being the extension better characterized by magnetic resonance imaging.

2.7. Ewing sarcoma: Ewing’s tumor of sacrum is rare, but should be suspected in low backache in children. Ewing’s sarcoma is a malignant round cell neoplasm of bone. Spinal column involvement is infrequent; compromising 10% of bone lesions of primary Ewing’s sarcoma. Sacral involvement is even rarer, but is the most common site for primary Ewing sarcoma of the spine. The prognosis is worse for sacrococcygeal Ewing sarcoma than for extraspinal Ewing sarcoma, usually owing to to larger tumour size at presentation because of delayed clinical presentation. In Ewing's Sarcoma of the sacrum the CT scan
and radiographs usually reveal lytic, sclerotic or mixed lesions involving paraspinal soft tissue and extra dural space and is best depicted on MRI (Fig. 11 on page 13 and Fig. 12 on page 14).

3. Extraosseous findings

3.1. Ependymoma: is a malignant tumor that arise from ependymal cells. In the spine, they arise from the central canal of the spinal cord or in the *filum terminale*. There is a variant type (mixopapillary) that occur almost exclusively in the *conus medullaris* and *filum terminale* and is the most common tumor of this structures. They represent around 30% of all ependymomas and has a peak of involvement around the age of 30 years.

Generally on the X-ray it shows some widening of the intervertebral foramina and has a posterior vertebral scalloping. Sometimes can erode the pedicles. On CT it shows some canal expansion. On the MRI it can show some high signal on T1-weighted images because of the mucin and show high signal on T2-weighted images with intense enhancement on the postgadolinium sequences (Fig. 13 on page 15).

3.2. Synovial sarcoma: accounts for 2.5-10.5% of all primary malignant soft-tissue neoplasms. Synovial sarcomas typically affect adolescents and young adults. The extremities, particularly the knee in the popliteal fossa, are most frequently affected. Synovial sarcoma is an intermediate to high grade neoplasm with extensive metastatic potential. Radiographs appear normal in approximately 50% of cases of synovial sarcoma, particularly those with small lesions. Calcification is identified in up to 30% of synovial sarcomas at radiography. Lesions are usually hypervascular and displace the native vessels. On the CT it shows a heterogeneous deep-seated soft-tissue mass with attenuation similar to or slightly lower than that of muscle. Areas of lower attenuation representing necrosis or hemorrhage are also common. CT is also useful for detecting calcification and bone involvement in synovial sarcoma. On T1-weighted MRI, synovial sarcoma typically appears as a prominently heterogeneous multilobulated soft-tissue mass with signal intensity similar to or slightly higher than that of muscle. Prominent heterogeneity with predominant high signal intensity is also a feature of these lesions on T2-weighted MRI (Fig. 14 on page 15).

A flowchart with the main findings of the most frequent sacral tumors was performed to guide the general radiologist. (Fig. 15 on page 16).
Fig. 1: Woman, 20 years old with giant cell tumor. (A) Pelvis x-ray, (B) and (C) axial computed tomography - large expansive process located in the sacrum (arrow), notably in the left lateral region, involving the homolateral sacroiliac joint, with signs of involvement and erosion of the iliac bones. Tumor is characterized by the presence of soft tissue density with cystic / necrotic areas (arrohead). (D) Axial T1 and (E) axial T2 magnetic resonance imaging evidence better the cystic component (awwohead in E) and has some areas of high signal probably due to hemorrhagic component (asterisk in D).
Fig. 2: (continuation). Woman, 20 years old with giant cell tumor. (A) Coronal T1, (B) Axial and (C) Sagittal T1 postgadolinium fat-saturated magnetic resonance imaging and (D) Sagittal T2 SPAIR. The coronal view demonstrate the extension of the lesion, affecting the sacral wings, as well as both sacroiliac joints. The lesion shows heterogeneous enhancement after contrast injection with some areas with low signal denoting necrosis / liquefaction (arrow). Also has some fluid-fluid levels windowing on Sagittal T2 SPAIR (arrowhead).

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Fig. 3: Male, 11 years old with primary intraosseous hemangioma. (A) Pelvis x-ray - Expansive heterogeneous lesion affecting the S4/S5 vertebrae (arrow in A). (B) Axial, (C) sagittal and (D) coronal computed tomography demonstrating that the lesion has both areas of osteolysis and sclerosis with extension into the vertebral canal and right intervertebral foramen. There is the radiating/weblike trabecular thickening pattern representing vascular channels (arrowhead in B, C and D) and also a honeycomb trabecular pattern (curved arrows in B and D).

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Fig. 4: (continuation). Male, 11 years old with primary intraosseous hemangioma. (A) Axial T1, (B) Axial T2, (C) Sagittal T2, (D) Coronal T2 SPAIR, (E) axial T1 SPIR postgadolinium magnetic resonance imaging demonstrating that the lesion has low signal on T1, high signal on T2 and intense enhancement by gadolinium due to vascular channels. Also there is perilesional fat edema (arrow in D and E), probably due to its unusual rapid growth pattern.

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Fig. 5: Female infant with 2 months old with sacrococcygeal teratoma. Magnetic resonance (A) coronal T1, (B) axial T1, (C) axial T2, (D) axial T2 SPIR, (E) axial T1 SPIR, (F) axial T1 SPIR post gadolinium and (G) sagittal T1. Large, heterogeneous, exophytic sacral mass with large portion containing fat (asterisks) and a small part cystic (arrowhead). There are thin septa inside the mass with discrete enhancement. There are some little markedly hypointense areas on all sequences, probably calcifications (arrow).
**Fig. 6**: Woman, 31 years old with chordoma. (A) Pelvis x-ray - lytic lesion in the sacral vertebrae (arrow) and in the medial aspect of the iliac bone, notably on the left (arrowhead). (B) Computed tomography of the pelvis without contrast - bone window - sacral lytic lesion with a soft-tissue component that protrudes into the pelvis as well as into the gluteal musculature with some enhancement on the iodine contrast phase (C). The lesion has low signal in T1 MRI (D - Coronal T1), predominant high signal in T2 (E - Coronal T2 STIR) and has gadolinium enhancement in axial T1 post-gadolinium SPIR magnetic resonance imaging (F).

**Fig. 7**: Male, 40 years old with midline chordoma. (A) Axial T1 (B) Axial T2 SPAIR (C) Axial T1 post gadolinium. Expansive lesion arising from the midline of the sacrum associated with a anterior soft mass (asterisk in A). It has a high signal in the T2-weighted sequences due to it gelatinous content (arrowhead in B). Also there are some areas
with low signal in the T1 and T2-weighted sequences probably related to calcifications (arrows in A and B). Also there is a well defined nodular formation in the right sacral wing, with high signal in T1 and T2 and enhancement by gadolinium, compatible with lesion of vascular origin (hemangioma) (curved arrow in A, B and C).

Fig. 8: Woman, 48 years old with breast cancer and diffuse metastatic disease. (A) Pelvis x-ray - Multiple small lytic lesions located in the right sacrum and left femur (arrows); (B) and (C) MRI Coronal T1 demonstrating the correspondence lytic lesions seen on X-Ray (arrow). MRI Axial T1 (D), axial T2 SPAIR (E) and axial T1 SPIR postgadolinium (F) demonstrating diffuse lesions with enhancement compatible with metastatic lesions.

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Fig. 9: Woman, 53 years old with papillary thyroid cancer. Computed tomography (A) coronal (B) axial (C) axial soft tissue window. Magnetic resonance (D) axial T1, (E) coronal T1, (F) coronal T2 SPAIR, (G) coronal T1 post gadolinium. Intraosseous expansive lesion in the left sacral wing (arrow) affecting the left sacral foramen with another lesion invading the lower sacral parts (asterisk). On the MRI the lesion has low signal on T1 (D and E) and high signal on T2 (F) with gadolinium enhancement (G). Also there are some involvement of the left sacroiliac joint space (curved arrow in B and E). (H) Chest computed tomography lung window demonstrating multiple metastatic nodules (arrowhead) and involvement of the posterior elements/rib of the 10th thoracic vertebrae (blue arrow)

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![Fig. 9: Woman, 53 years old with papillary thyroid cancer. Computed tomography (A) coronal (B) axial (C) axial soft tissue window. Magnetic resonance (D) axial T1, (E) coronal T1, (F) coronal T2 SPAIR, (G) coronal T1 post gadolinium. Intraosseous expansive lesion in the left sacral wing (arrow) affecting the left sacral foramen with another lesion invading the lower sacral parts (asterisk). On the MRI the lesion has low signal on T1 (D and E) and high signal on T2 (F) with gadolinium enhancement (G). Also there are some involvement of the left sacroiliac joint space (curved arrow in B and E). (H) Chest computed tomography lung window demonstrating multiple metastatic nodules (arrowhead) and involvement of the posterior elements/rib of the 10th thoracic vertebrae (blue arrow)](image)

Fig. 10: Male, 65 years old with plasmacytoma. (A) pelvis x-ray - lytic lesion affecting the central portion of sacral vertebrae (arrow in A), more conspicuous on computed tomography (B - arrow). Magnetic resonance (C) axial T1, (D) axial T1 post gadolinium, (E) sagittal STIR and (F) sagittal T1 post gadolinium. The lesion has a soft tissue mass with low signal on T1 and high signal on T2 as well as intense enhancement. This findings are not specific, so a biopsy was performed and was proven a plasmacytoma (G) where fragments of connective tissue with an immature neoplastic process characterized by infiltration of plasma cells with discrete cell pleomorphism.

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**Fig. 11:** Male, 16 years old. Ewing sarcoma. (A) Pelvis x-ray showing lytic lesion affecting the left sacroiliac region, with greater component along the greater wing of the iliac bone (arrow). (B) and (C) coronal T1, (D) axial T2 SPAIR and (E) sagittal T2 demonstrating that such lesion presents with an important extra-cortical extension, especially in the gluteal and ipsilateral paravertebral musculature, with low signal in T1 and low to intermediate signal in T2. Also there is a metastatic lesion in the left femur (arrowhead in C).

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Fig. 12: (continuation). (A) Coronal T2 SPAIR, (B) and (C) coronal T1 post gadolinium, (D) sagittal T2 SPAIR, (E) axial T2 and (F) axial T1 post gadolinium. The lesion has heterogeneous impregnation by gadolinium. The sacral foramina of S1 on the left side is affected (arrow in E).

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Fig. 13: Male, 32 years old with sacral myxopapillary ependymoma. (A) Pelvis x-ray - Expansive lesion affecting the sacral vertebrae and posterior elements of the spine (arrowhead in A, C, E, F, G), as well as medial aspects of the bilateral iliac bones, with remodeling of the intervertebral foramina (arrow in B and D); (C) Axial computed tomography demonstrating lytic lesions and a mass that protrudes into the pelvis (asterisk in C, E, F and G); (D) Axial T1, (E) Axial T1, (F) Axial T2 SPIR; (G) Axial T1 MRI postgadolinium fat-saturated magnetic resonance imaging showing peripheral and heterogeneous enhancement with central area that may correspond to necrosis / liquefaction.

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**Fig. 14:** Woman, 30 years old with synovial sarcoma. (A) Front and (B) lateral pelvis x-ray - Extensive increase of posterior soft tissue (arrow). No osseous abnormalities. Magnetic resonance (C) axial T1, (D) axial T2 SPAIR, (E) axial T1 SPIR post gadolinium, (F) sagittal SPAIR. Expansive formation of soft tissue located in the posterior lumbar region and left hemipelvis, involving ipsilateral posterior paravertebral musculature, with extension to the gluteal region. It has a multiseptated aspect (asterisk in F) with multiple hematic levels within it, observing solitary areas that do not show contrast enhancement, inferring areas of intralesional necrosis (arrowhead in E). Also there is irregularity of the posterior cortical bone of the sacrum and left iliac, with extension of the lesion to the left sacroiliac joint, associated to an area of alteration of bone marrow signal, suggesting edema (curved arrow in D).
**Fig. 15:** Flow chart to guide in the diagnosis of sacral tumors.

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Conclusion

Sacral masses are rare lesions with late diagnosis due to slow growing and anatomic peculiarities.

Therefore, it is essential to recognize some subtle signs, specially on radiographies, so that the patient can have diagnosis and adequate treatment as soon as possible.
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