Imaging of sacral tumors

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Sacral tumors are somewhat unique to the skeletal system in that the prevalence of various neoplasms is different from that at other osseous sites. There are also unique imaging-related considerations, related in part to diagnosis, but particularly to the evaluation site for tumor biopsy sampling and resection. In this report, the authors describe imaging features of the most common sacral lesions, provide numerous radiological examples, and give suggestions for optimal imaging of this region of the body.

KEY WORDS • sacrum • tumor • neoplasm

Imaging tumors of the sacrum can be a challenge in three respects. First, the lesion can be extremely difficult to detect radiographically, which is usually the initial choice of imaging. Second, there are a number of lesions that are predisposed to primary sacral involvement. Some have a prevalence by patient age group. Others have distinctive features, but many do not. The correct diagnosis requires knowledge of these features, as well as an understanding of how best to demonstrate them radiologically. Finally, the site of involvement must be accurately assessed. Locating the lesion and describing the tumor characteristics alone are not sufficient. To plan and achieve appropriate treatment, a precise evaluation of osseous and soft-tissue extent, as well as involvement of other pelvic structures, must be attained. Because of the oblique orientation of the sacrum, care must be taken to perform the most appropriate imaging suited to the anatomical site. We describe the most frequently encountered sacral neoplasms in the context of the aforementioned concerns.

RADIOGRAPHIC DEMONSTRATION OF SACRAL LESIONS

Patients with sacral lesions often initially present clinically with low-back or buttock pain, and radiography is often the first imaging modality performed. Although this is entirely appropriate, it may provide the clinician with false reassurance because sacral lesions are often not detected on the initial x-ray film. The sacrum is difficult to evaluate fully on radiographs because it is often obscured by overlying stool or bowel gas. Furthermore, the sacrum does not have a distinctive trabecular pattern that can be assessed for disruption. Thus, sacral lesions may become quite large before they are detected on plain x-ray film, and diagnosis is sometimes delayed until either neurological symptoms or symptoms relating to compression of pelvic organs develop. There are, however, specific sacral structures that should be evaluated thoroughly to avoid a false-negative reading. The sacral foramina are paired, with distinct foraminal “struts” that should be seen. The sacroiliac joint is oblique; both the anterior and posterior portions of the joint must be visualized bilaterally. Additionally, the posterior iliac wing should be seen distinctly through the sacral ala. If any of these structures is absent, a lytic lesion occupying the sacral ala should be considered. In some of our cases in which radiographs were obtained, the sacral lesion was initially not identified. The aforementioned features should be kept in mind to identify the lesion in each case.

DIFFERENTIAL DIAGNOSIS OF SACRAL LESIONS: PREVALENCE AND APPEARANCE

Sacral tumors are rare. As with nearly any osseous structure, the majority of lesions are metastatic; these will not be discussed further. Primary benign and malignant tumors of the sacrum are rare, accounting for fewer than
7% of all spinal primary tumors. Additionally, there are other processes that can mimic sacral neoplasms clinically and occasionally radiographically, including insufficient fractures and radiation osteonecrosis. In this section, prevalence and imaging characteristics of the most common sacral lesions will be presented.

**Benign Sacral Lesions**

**Giant Cell Tumor.** Giant cell tumor is a relatively frequent bone neoplasm, found predominantly in the appendicular skeleton, with only 7% involving the spine; however, the spine is the fourth most common location of this lesion. Within the spine, the vast majority of GCTs occur in the sacrum. This lesion is the second most common primary tumor of the sacrum, comprising 13% of all sacral tumors, second only to chordoma. It is the most common benign sacral neoplasm (71%).

The GCT has a distinct age prevalence, occurring almost exclusively after skeletal maturation. The lesion develops most frequently in the second through fourth decades, but the range extends to individuals 60 years of age. Females are somewhat more frequently affected than males, and it is reported that there can be dramatic increases in size of the lesion during pregnancy.

The majority of GCTs are benign; 5 to 10% have been reported to be malignant. Many of the malignant lesions are thought to be related to previous radiotherapy. It is somewhat confounding that the degree of aggressiveness depicted on imaging is not strongly predictive of grade or even malignancy. Furthermore, GCTs occasionally metastasize to the lung even though the primary lesion is considered histologically benign.

The GCT is a lytic, expansive lesion that never contains matrix. In the sacrum, it usually develops in an eccentric position, but commonly extends to individuals 60 years of age. Females are somewhat more frequently affected than males, and it is reported that there can be dramatic increases in size of the lesion during pregnancy.

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Click here to view Fig. 1. Imaging studies obtained in a 21-year-old woman with GCT of the sacrum. Upper Left: Anteroposterior radiograph of sacrum and symphysis pubis. Upper Right: Lateral radiograph of sacrum and symphysis pubis. Center Left: Axial CT scan confirming the presence of a presacral soft-tissue mass. Center Right: Sagittal T1-weighted MR image revealing the presence of a presacral soft-tissue mass. Lower Left: Axial fast–spin echo T2-weighted MR image demonstrating the inhomogeneous mass that contains several areas of low signal intensity (arrows; contrast this signal to the very high signal intensity on T1-weighted imaging of the chordoma in Fig. 16). Lower Right: Sagittal post-Gd fat-saturated T1-weighted (TR/TE 450/11 msec) MR image revealing only mild enhancement, again with several areas of relatively low signal intensity. These low-signal regions represent a common feature in GCTs that may help differentiate them from other lesions such as chordoma, as in this case.

Click here to view Fig. 2. Imaging studies obtained in a 26-year-old woman with GCT. Upper Left: Anteroposterior radiograph obtained after the patient complained of low-back pain, clearly demonstrating the expanded lytic lesion occupying the sacrum. The lesion was not noted at the time the film was obtained, however. Upper Right and Center Left: Axial CT scans obtained several months later, demonstrating the rather featureless lytic lesion occupying the entire sacrum, with attempted thin cortical rim unable to contain the expansive lesion. Center Right: Sagittal T1-weighted MR image (TR/TE 450/10 msec) demonstrating intensity presacral soft-tissue extension. Lower Left and Right: Sagittal T2-weighted (TR/TE 3200/102 msec) and axial fast–spin echo T2-weighted (TR/TE 5000/100 msec) MR images revealing the inhomogeneous mixed high and low signal intensity mass, typical of GCT.

Computerized tomography scanning demonstrates the thin sclerotic rim of the GCT. Its soft-tissue attenuation may contain foci of lower attenuation, indicating areas of hemorrhage or necrosis. Because the lesion is hypervascular, it enhances on CT scans. Magnetic resonance imaging often provides much more distinctive images, allowing fairly definitive diagnosis of GCT. On T1-weighted MR images sequences, low to intermediate signal intensity, associated with most osseous neoplasms is observed; T2-weighted MR imaging, however, is not as nonspecific, demonstrating low to intermediate signal intensity in a very heterogeneous pattern in 63 to 96% of cases. See Fig. 1 for an example of this appearance. This low signal intensity on T2-weighted sequences is a distinguishing feature of the GCT; most other osseous neoplasms demonstrate high signal intensity on T2-weighted sequences (Fig. 1). It is thought that the lower signal intensity is due to prominent collagenous content as well as hemosiderin deposition (Figs. 1 and 2). Occasionally hemorrhage is detected on both T1- and T2-weighted sequences as high signal intensity. Rarely, fluid–fluid levels may be present.

Although the GCT is usually a benign neoplasm, its ideal treatment is wide excision. The recurrence rate is 40 to 60%, usually related to marginal excision. The size and local aggressiveness of the lesion, however, may preclude wide excision, which underscores the need for careful preoperative imaging to identify the exact extent of the lesion. If the lesion cannot be widely excised, curettage supplemented by radiotherapy may be considered. Occasionally, selective arterial embolization may be performed, either prior to resection or as the primary treatment if the lesion is deemed unresectable.

**Aneurysmal Bone Cyst.** An ABC is a benign lesion that is most likely nonneoplastic, although its radiographic appearance is that of a tumor. Pathologically, the ABC consists of multiloculated blood-filled spaces. Two causes have been described: primary and secondary. Primary ABC is thought to be related to osseous trauma and development of a local circulatory disturbance. Secondary ABC is related to an underlying neoplasm (most frequently GCT, osteoblastoma, chondroblastoma, or osteosarcoma) that causes venous obstruction or an arteriovenous fistula. The majority of ABCs (65–99%) are considered primary lesions, but one should always consider the possibility of an underlying lesion when evaluating them radiologically and histologically.

The spine is involved in 12 to 30% of cases of ABCs but, of these cases, sacral involvement occurs in only 20%. There is a very distinctive age distribution, with 80% of cases found in patients younger than 20 years of age. There is a slight female predominance.
In the spine, an ABC nearly always originates in the posterior elements. It extends to involve the VB, however, in 75 to 90% of cases. The location in the sacrum mirrors this concept, with the lesion originating in the sacral ala but often extending to involve the VB. The lesion is lytic, expansive, and has a thin cortical rim that often seems to contain the lesion. This thin cortical rim may be seen only on CT scans (Fig. 3). On Tc bone scanning, ABC may show peripheral increased uptake, with a photogenic center (the “donut” sign described by Hudson). This appearance has also been described in GCT. Computerized tomography scanning often demonstrates fluid–fluid levels caused by hemorrhage with sedimentation. Although fluid–fluid levels can be seen on CT scans, they are much more easily visualized on MR images. Although T1-weighted MR imaging may be nonspecific with the mass showing intermediate signal intensity due to the methemoglobin in the blood-filled spaces, it occasionally reveals an increase in signal intensity due to the methemoglobin in the blood-filled spaces. Magnetic resonance imaging with T1-weighted sequences more reliably demonstrates the fluid–fluid levels (Fig. 3). Note that the high signal intensity methemoglobin may be either the dependent or the nondependent component. Additionally, the useful planes for observing fluid levels are axial and sagittal; coronal imaging masks the fluid levels because imaging is performed with the patient in a supine position.

Click here to view Fig. 3. Imaging studies obtained in a 14-year-old boy with ABC. Upper Left: The anteroposterior radiograph can be easily misread as normal because of the overlying bowel gas obscuring the sacrum, but in fact the third left foramininal line is absent. Upper Right: A lateral radiograph demonstrates only obscuration of the S-3 posterior elements (arrows). Lower Left: The lesion is more readily seen on the CT scan obtained with the patient in a prone position. This scan demonstrates a lytic lesion occupying the left S-3 ala, with a thin cortical rim surrounding the majority of the lesion. Note that the more lucent regions in the center of the lesion actually represent fluid levels. Lower Right: Fluid levels (short arrow) are more readily observed on a sagittal T1-weighted MR image; remember that the patient is supine in the imager and that the fluid levels on the sagittal exam would then be expected to appear vertical, as in this case. The high signal intensity portion of the fluid is blood. Most, but not all, ABCs contain fluid levels. Conversely, most lesions with substantial fluid levels are ABCs, but such levels may occur in other lesions as well. Note also in this case that there is a substantial component of the lesion located anteriorly to the fluid levels that is solid (long arrows). This portion should undergo careful histological evaluation to determine whether it represents a different underlying tumor that might re-quire different therapy than simple resection. (Reproduced with permission from the ACR Learning File.)

Although an ABC is most frequently characterized by its fluid levels, this is not a pathognomonic sign because other lesions (GCT and teleangiectatic osteosarcoma, among others) may contain fluid levels. Furthermore, an ABC may possess significant solid components. Most solid components are found in the septations interposed between the blood-filled spaces and are best seen after gadolinium enhancement. In 5% of ABCs, however, the solid component predominates; these cases most frequently involve the spine (Fig. 3). Therefore, if there is a significant solid component in a lesion that otherwise looks like an ABC, it must be carefully examined during imaging as well as pathological evaluation to establish an underlying primary tumor because the treatment may be very different than that for a simple primary ABC.

Treatment of an ABC is complete resection if possible. The sacrum is a difficult location for wide resection, however, and the recurrence rate is 20 to 30%, which increases after incomplete excision. Surgery may be supplemented with embolization and radiotherapy.

**Osteoblastoma.** Osteoblastoma is a rare lesion (1–2% of all bone lesions), but one that has its predominant location in the spine. Forty percent of all osteoblastomas occur in the spine; of these, 17% arise in the sacrum. Osteoblastomas are found predominantly in young adults (90% in the second and third decades, but with a wide age range of 3–72 years). The male/female ratio is 2:1.

Osteoblastomas, like ABC, usually originate in the posterior elements of the spine, but 42% extend into the VB. A small percentage (10–15%) may have an ABC component. Three radiographic/CT patterns have been described. The first is a lytic lesion that may not contain central calcification and which is surrounded by sclerosis. The second pattern, the most common, involves an expanded lesion with multiple small calcifications and a peripheral sclerotic rim (Figs. 4 and 5). The third pattern is more aggressive, showing bone destruction and infiltration of surrounding soft tissues, often with a matrix. The matrix in osteoblastoma can usually be identified by radiography or CT scanning as osteoid.

Click here to view Fig. 4. Radiological studies obtained in a 21-year-old man with osteoblastoma. Left: Anteroposterior radiograph revealing a subtly expanded lesion that is near the midline at S4–5 (arrows). Right: Axial CT scan demonstrating bone matrix within the lesion, not aggressive in appearance. Thus, based on its location in the spine, presence of bone matrix, and degree of aggressiveness, the lesion must be an osteoblastoma.

Click here to view Fig. 5. Radiological studies obtained in a 15-year-old boy with osteoblastoma. Radiography (not pictured) demonstrated no abnormalities. Left: A Tc bone scan revealing an eccentrically located area of increased uptake in the sacrum. Right: The CT scan demonstrates a minimally expanded lesion containing dense bone matrix in the right side of the lower sacrum. The lesion is not aggressive in appearance. Given its appearance and location, there is no other reasonable diagnosis in this case.

Osteoblastoma shows marked uptake on bone scanning (Fig. 5). On CT scans, its appearance mimics that seen on radiographs. Its MR imaging appearance is nonspecific, with low to intermediate signal intensity on T1-weighted images and intermediate-to-high intensity on T2-weighted, depending on the amount of matrix present. There may be extensive peritumoral edema.

Osteoblastoma should be excised. The lesion recurs in 10 to 15% of cases, but the rate approaches 50% in the more aggressive variety of osteoblastoma. Therefore, it is important to identify aggressive features by imaging prior to surgery because this may lead to more aggressive surgery as well as more frequent postoperative surveillance. There have been rare reports of malignant transformation of osteoblastoma to osteosarcoma with metastases.

Osteoid osteoma is often considered with osteoblastoma, because 10% occur in the axial skeleton (posterior elements) and because their appearance is similar to the first pattern in the aforementioned description. Only 2% of spinal osteoid osteomas occur in the sacrum.
Nerve Sheath Tumors. Nerve sheath tumors (neurofibroma and schwannoma) may arise from sacral nerve roots. They produce an intradural extramedullary mass and therefore are not true sacral neoplasms. They may be large and dumbbell shaped, however, with extradural components that erode and enlarge the neural foramina. This appearance is not difficult to diagnose as a NST. In severe cases, these NSTs may enlarge to such a degree that they result in sacral destruction and large soft-tissue masses (Fig. 6). In such cases, the lesions cannot be radiographically distinguished from other benign or even malignant sacral tumors. Both neurofibroma and schwannoma have been described as occasionally having a “target” appearance on T2-weighted MR imaging, with a low signal center surrounded by high signal mass. Many cases, however, will be nonspecific in appearance (Fig. 6).

Click here to view Fig. 6. Imaging studies obtained in a 34-year-old man with neurofibroma. Upper Left and Right: Antero-posterior and lateral radiographs demonstrating a lytic, expansive, destructive lesion involving S1–3. This location makes the lesion virtually unrecognizable. Center: Axial CT scan demonstrating involvement of the bulk of the sacrum with a solid mass and extension of the mass well into the presacral space (arrows). Lower Left and Right: Sagittal and axial fast–spin echo T2-weighted (TR/TE 4366/96 msec) MR images revealing the extent of the lesion, including both neurological and pelvic content involvement. The lesion is inhomogeneous, containing both low and high signal regions. There is nothing to guide the surgeon as to a diagnosis of neurofibroma in this case. Neurofibromas may exhibit a “target sign” on T2-weighted images, which is not present here. This appearance could represent a malignant peripheral NST, GCT, or even chordoma. Analysis of a tissue specimen confirmed the diagnosis of neurofibroma.

Hemangioma. Hemangioma is the most common primary tumor of the spine, found incidentally in a large percentage of MR imaging examinations. Hemangiomas, however, rarely involve the sacrum. If they are seen, the stroma has an appearance similar to that elsewhere in the spine, with the signal intensity of fat (high signal intensity on T1- and intermediate on T2-weighted sequences). There is nothing to guide the surgeon as to a diagnosis of neurofibroma in this case. Neurofibromas may exhibit a “target sign” on T2-weighted images, which is not present here. This appearance could represent a malignant peripheral NST, GCT, or even chordoma. Analysis of a tissue specimen confirmed the diagnosis of neurofibroma.

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Osteochondroma (Exostosis). Exostoses, extensions of normal marrow and cortex in an exophytic or cauliflower-like pattern, are uncommon in the spine. Although they are relatively frequently seen in the appendicular skeleton, only 1 to 4% of solitary exostoses occur in the spine. Even in patients with multiple hereditary exostoses, only 7 to 9% harbor spinal lesions (and in those few cases, only one spinal lesion is usually found).1 Solitary exostoses are usually discovered as a protuberance by age 20 to 30 years, but a decade earlier if they are multiple. They are more frequent in males than females. The radiographic and CT scanning–based appearance is similar, showing continuity of normal marrow and cortex extending from normal underlying bone, without destructive change or soft-tissue mass (Fig. 7). Magnetic resonance imaging has a similar appearance, with the signal intensity mimicking that of normal marrow and cortex. Magnetic resonance imaging has the advantage of revealing the thickness of the high signal cartilage cap. A cartilage cap that is thicker than 1 to 2 cm is highly suspicious for degeneration to chondrosarcoma. Exostoses may be painful, related to mechanical limitations or local traumatic injury of to the protruding part, and are treated by excision.

Click here to view Fig. 7. Axial CT scan obtained in a 10-year-old boy with multiple hereditary exostoses. Note that the large sacral lesion has normal cortex as well as marrow arising from the underlying bone. This appearance defines an exostosis. We look for a thick cartilage cap to suggest degeneration of an exostosis to a chondrosarcoma. In this case, there is no space for a thick cap because the edge of the exostosis extends to the subcutaneous tissue. If there is any question, MR imaging can demonstrate the cartilage thickness. In this case, we recognized multiple exostoses because of the presence of sessile lesions at the anterior superior iliac spines.

Insufficiency Fractures. Insufficiency fractures of the sacrum are a relatively common cause of low-back pain, particularly in elderly osteoporotic women. It is the authors’ experience that neuroimaging, usually MR imaging, is performed in these patients and that the abnormalities are often misinterpreted as tumor, either primary or secondary. Thus, it is worth understanding the typical imaging characteristics of insufficiency fractures. Insufficiency fractures frequently occur vertically in the pubic rami, adjacent to the pubic symphysis, and vertically in the sacral ala. Although they usually begin as a unilateral process, it is common to see them bilaterally. On plain radiography, a sacral insufficiency fracture is extremely difficult to identify both because the fracture line is obscured by overlying bowel gas and stool and because the fracture is nondisplaced. The osseous structures are so osteopenic that the trabecular pattern is not distinct, and a disturbance by fracture is not visualized. The only abnormality seen on radiographs may be a “smudginess” of the bone in a generally vertical configuration (Fig. 8); needless to say, initial radiographic identification of sacral insufficiency fractures rarely occurs. Technetium radionuclide scanning may demonstrate a very specific appearance that allows diagnosis. The image in Fig. 8 right shows the “Honda sign,” with the “H” formed by the bilateral sacral alar fractures and the body of the sacrum.

Click here to view Fig. 8. Imaging studies obtained in a 64-year-old woman with bilateral insufficiency fractures. Such lesions can be difficult to diagnose by plain radiography. Left: Radiograph demonstrating the normal sacrum, prior to development of symptoms. Five years later, the patient developed bilateral buttocks pain. Center: Radiograph revealing that the sacral ala is somewhat “smudgy” (arrows). No actual fracture line is visible. Right: A Tc bone scan demonstrating the vertical fracture lines in the typical pattern of insufficiency fractures. (Reproduced with permission from the ACR Learning File.)

Although the diagnosis of bilateral sacral insufficiency fractures is simple if a bone scan is available, its pattern is often “incomplete” because the fracture may be unilateral. The bone scan still demonstrates a mostly vertical pattern, as opposed to a more patchy distribution of abnormality seen with most metastatic lesions (Fig. 9). If there is any doubt about the diagnosis, however, CT scanning involving bone algorithm demonstrates the fracture well. Computerized tomography scanning will also confirm that there is no soft-tissue mass or adjacent bone destruction, although osteoporosis can appear somewhat alarming like a lytic lesion in the sacrum (Fig. 9 right).

Click here to view Fig. 9. Technetium bone scan (left) and CT scan (right) obtained in a 75-year-old woman with insufficiency fracture of the left sacral ala (arrows). (Reproduced with permission from the ACR Learning File.)
In cases of sacral insufficiency fractures, MR imaging is generally diagnostic, assuming care has been taken. If the resolution and orientation of the images are sufficiently good, the vertical fracture lines are observed directly as low signal intensity on $T_1$-weighted and high signal intensity on $T_2$-weighted images (or equivalent, such as short inversion recovery imaging) (Fig. 10). Occasionally, MR images may be more difficult to interpret, particularly if the fracture is unilateral and the signal has a more patchy than vertical configuration (Fig. 11). It can be especially confusing if the fracture is subacute and its line is obscured by attempted healing and edema patterns.

Click here to view Fig. 10. Imaging studies obtained in a 76-year-old woman with bilateral sacral insufficiency fractures. A $T_2$-weighted (TR/TE 500/14 msec) coronal MR image (upper) revealed linear vertical low signal intensity fractures (arrows), which were confirmed on short-$T_1$ inversion recovery imaging (lower) as high signal lines.

Click here to view Fig. 11. Magnetic resonance images acquired in a 66-year-old woman with an insufficiency fracture of the left sacrum. Upper: A $T_1$-weighted (TR/TE 500/14 msec) image revealing a vertical rather linear area of low signal intensity (arrows). Lower: Axial fast–spin echo $T_2$-weighted (TR/TE 4300/105 msec) image confirming this as a high signal intensity line (arrows). In this case, the signal intensity is quite linear and the diagnosis is obvious. In other cases, however, the abnormality may not appear as linear on MR imaging, and CT scanning may be required for confirmation that it is indeed a fracture.

Radiation Osteonecrosis. Radiotherapy can have several affects on skeletal structures, and the sacrum is certainly no exception because irradiation of pelvic tumors is common. The manifestations of radiation must always be kept in mind because they can be misinterpreted as tumor. If the pelvis of a skeletally immature patient undergoes irradiation, the initial effect is on the small blood vessels supplying the osseous growth centers. Growth may cease, leaving that part of the skeleton abnormally small compared with the remainder, which continues to grow normally. Hypoplasia of the skeleton in a rectangular “port” distribution is a pathognomonic appearance for previous irradiation (Fig. 12). Irradiation of the pelvis, however, is mostly performed in adults. The most frequent skeletal complication in these patients is radiation osteonecrosis. Osteonecrosis results in a mixed lytic/sclerotic pattern of the bone that is restricted to the distribution of the port (Fig. 13).

Click here to view Fig. 12. Radiograph obtained in a 20-year-old woman with radiation osteonecrosis, demonstrating that the radiation damage occurred when the patient was skeletally immature. Radiation affects the small arteries supplying the growth centers, arresting growth in a skeletally immature patient. The pattern is usually in a rectangular “port” configuration, as in this case, where radiation was used to treat an ovarian tumor. In addition to the radiological abnormality, the irradiated bone shows a mixed lytic/sclerotic pattern typical of radiation osteonecrosis.

Click here to view Fig. 13. Radiograph acquired in a 71-year-old woman with radiation osteonecrosis. The anteroposterior view shows a rectangular area of mixed lytic/sclerotic density including the sacrum and both iliac bones (but not the tops of the iliac wings). This patient has also required bilateral total hip arthroplasties for avascular necrosis of the femoral heads, which were included in the radiation port as well. This case again demonstrates that the pattern of radiation damage is rectangular and thus the diagnosis is straightforward.

The bone destruction can appear rather aggressive and is at risk of pathological fracture. There can be associated pain, and the imaging findings can be mistaken for neoplasm. Findings of mixed lytic and sclerotic bone that lacks good trabecular structure are similar on CT scans and radiographs. Radionuclide bone scanning reveals abnormal uptake in the region and does not provide additional information unless it demonstrates vertical fracture lines. In cases of radiation osteonecrosis MR imaging features are nonspecific, with intermediate signal intensity on $T_1$- and intermediate-to-high signal intensity on $T_2$-weighted images. Still, MR imaging may demonstrate a fracture line (Fig. 14) and will also reveal that there is no soft-tissue mass. Thus, MR imaging helps to differentiate radiation osteonecrosis from tumor recurrence, metastatic disease, and radiation-induced sarcoma of the sacrum.

Click here to view Fig. 14. Imaging studies obtained in a 50-year-old woman in whom pelvic adenocarcinoma was diagnosed, who underwent radiotherapy, and who returned with a complaint of new pelvic pain. A: Axial CT scan of the pelvis obtained at the time of the initial diagnosis, prior to irradiation, demonstrating the sacrum to be normal. B: Ten months later, following completion of radiotherapy, a routine CT scan demonstrated no change in appearance. C: Eleven months thereafter, the patient returned with new pain; the CT scan demonstrated mixed lytic and sclerotic density, and a vertical fracture (arrows) through the left sacral ala. The density is typical of radiation osteonecrosis; the bone is weakened and subject to pathological fracture, as in this case. Radiation osteonecrosis, however, typically develops several years after irradiation. Because of this, the clinician was concerned that the lesion represented tumor. D: Radionuclide $^{99m}$Tc bone scan revealing prominent uptake in both sacral ala, in a fairly vertical pattern of fracture. No other site of abnormal uptake was found. E: Direct coronal $T_1$-weighted (TR/TE 769/12 msec) MR image revealing vertical low signal abnormalities in both sacral alae (arrows). F: Regions are confirmed on a direct axial $T_1$-weighted fat saturation (TR/TE 4600/26 msec) MR image demonstrating the configuration of vertical fractures, without any suggestion of a soft-tissue mass. G and H: Pregadolinium (G) and post-Gd (H) $T_2$-weighted fat-saturated (TR/TE 769/12 msec) MR images acquired in the axial plane confirming the findings, although this was not necessary for the diagnosis. I: Image demonstrating the localizer for obtaining direct coronal images of the sacrum. J: Image showing the localizer for obtaining direct coronal images of the sacrum. These planes are preferable to routine coronal and axial images.

Malignant Sacral Lesions

Chordoma. Chordoma is a relatively rare tumor, representing only 2 to 4% of all primary malignant bone neoplasms. Within the spine, however, chordoma is the most common primary malignant tumor (20–34%). Furthermore, it is the most common tumor of any type involving the sacrum, representing 40% of all primary sacral neoplasms. Because the lesion arises from notochordal remnants, it is not surprising that its location parallels that of the notochord. Fifty percent of all chordomas arise in the sacrum; within the sacrum, the S-4 and S-5 levels are the most commonly involved. The lesion develops within the VB but extends, often with a very large presacral mass, into the canal 60% of the cases.

The most frequent age range for chordoma is 30 to 60 years, with incidence peaking in the fifth decade. The male/female ratio is 2:3:1. Radiographically, the lesion is lytic, expansive, and may have a very large associated...
mass. Intratumoral calcification is seen in 50 to 70% of cases radiographically but in 90% of cases on CT scanning (Figs. 15 and 16). On MR imaging, chordomas display a low-to-intermediate signal on \( T_1 \) - and very high signal intensity on \( T_2 \)-weighted sequences. If the calcifications are large enough, they may be seen as low signal structures within the lesion, but generally low signal is not a common characteristic on \( T_2 \)-weighted imaging. The lesion enhances after Gd administration.

**Click here to view Fig. 15.** Axial CT scan obtained in a 61-year-old man with S-4 chordoma. An expanded lytic lesion is observed, with some matrix remaining within the soft-tissue mass. The mass at this point has not expanded enough to involve soft tissues of the pelvis (note contrast and air in the rectum, anterior to the lesion) and, because it involves only S-4, can be treated by undertaking a wide resection. It is somewhat unusual to diagnose a chordoma this early in its evolution. (Reproduced with permission from the ACR Learning File.)

**Click here to view Fig. 16.** Imaging studies obtained in a 24-year-old man with chordoma involving S3–5. **Upper Left** and **Right:** Axial CT scans demonstrating a large soft-tissue mass extending anteriorly to involve the rectum and posteriorly to invade the buttocks; calcification is seen within the mass. **Lower Left** and **Right:** Sagittal fast–spin echo \( T_2 \)-weighted (TR/TE 4000/102 msec) and axial \( T_2 \)-weighted (TR/TE 2200/80 msec) MR images demonstrating the lesion infiltrating the presacral region, extending to surround the rectum and the perivesical fat but not invading the bladder. Because S-2 is not involved, the pelvis may remain stable following resection.

Primary treatment of chordoma is wide resection, and the prognosis relates to its completeness. Therefore preoperative cross-sectional imaging and interpretation of findings are key. In cases in which an incomplete resection is achieved, supplemental radiotherapy may be performed, but its efficacy may not be as great as in higher-grade lesions. Local recurrence results in high morbidity rates and is often the eventual cause of death. Metastases eventually develop in 5 to 43% of patients and may be found in the liver, lung, regional lymph nodes, and in unusual sites such as the peritoneum, skin, and heart.

**Multiple Myeloma.** Multiple myeloma is the second most common primary malignant neoplasm of the sacrum. Its incidence peaks in the sixth and seventh decades, and the male/female ratio is 2:1.12 Multiple myeloma is seen in the sacrum and other bones as either multiple round “punched-out” lytic lesions, an MR imaging–documented diffuse osteoporosis with an infiltrative pattern, or very occasionally as multiple sclerotic lesions. The earlier solitary form, plasmacytoma, can be more difficult to diagnose because it has a less distinctive appearance. Plasmacytoma is usually seen as a large, expanded lytic lesion (Fig. 17). There may be an associated small- to moderate-sized soft-tissue mass. Magnetic resonance imaging is nonspecific, with low-to-intermediate signal intensity on \( T_1 \) - and high signal intensity on \( T_2 \)-weighted images. Plasmacytoma eventually progresses to multiple myeloma.

**Click here to view Fig. 17.** Radiological studies obtained in a 61-year-old man with multiple myeloma. **Left:** Anteroposterior radiograph revealing a highly destructive lytic lesion involving both the left iliac wing and left sacrum. **Right:** Axial CT scan confirming involvement of both of these bones, as well as a moderate-sized soft-tissue mass. Plasmacytomas may be very large and elicit no osseous reaction, as in this case. This case also demonstrates the propensity of aggressive lesions to cross the sacroiliac joint. This joint does not seem to pose any significant barrier to tumor encroachment, as others do.

**Primary Lymphoma of Bone.** Primary lymphoma of bone is a rare lesion but is listed as the third most common primary malignant neoplasm of the sacrum. It presents most frequently in the second through fifth decades. It may appear as either an aggressive lesion causing prominent bone destruction, or the osseous structures may remain with an intact appearance but with apparent permeation because there is a large associated soft-tissue mass. Magnetic resonance imaging is nonspecific, as are other imaging techniques.

**Ewing Sarcoma and PNET.** Ewing sarcoma and PNET are pathologically distinct lesions that have similar clinical presentations and radiographic appearances. They represent the fourth most common primary malignant tumor of the spine overall and are the most frequent in children. They involve the spine primarily in 3 to 10% of cases but even more frequently involve the spine with their osseous metastases. Within the spine, the sacrum is the most common site of involvement. The age range for Ewing sarcoma is 5 to 30 years, with 75% occurring in the first two decades. The male/female ratio is 3:1.

Ewing sarcoma/PNET is a highly destructive lesion involving a large soft-tissue mass. The osseous portion may be completely lytic, or portions may be quite sclerotic. The sclerosis has been related to prominent host-reactive bone formation. In one study1 the author related it to osteonecrosis as well, stating that diffuse sclerosis is found in 69% of spinal lesions (Fig. 18). Magnetic resonance imaging in Ewing sarcoma is nonspecific, with intermediate signal on \( T_1 \) - and intermediate to high signal on \( T_2 \) - weighted images. Primary therapy in cases of Ewing sarcoma/PNET is radio- and chemotherapy. Many patients, however, require decompressive surgery and stabilization. Unfortunately, these lesions are associated with the worst prognosis when they occur in the sacrococcygeal region, with local control being accomplished in only 62.5% and long-term survival in only 25%.9

**Click here to view Fig. 18.** Radiological studies acquired in a 5-year-old boy. **Left and Center:** Lateral and anteroposterior radiographs of the sacrum revealing sclerosis of the left side of S-1. There are no permeative or destructive changes seen. **Right:** Axial CT scan, however, demonstrated that there is both an anterior and epidural soft-tissue mass (arrows). In a patient of this age, an aggressive sacral lesion most frequently is a Ewing sarcoma. In this case, the sclerosis is due to reactive bone formation, a common type of host bone reaction to Ewing sarcoma. (Courtesy of The Childrens Hospital of Denver.)

**Chondrosarcoma.** Chondrosarcoma is the most common primary malignant bone neoplasm in adults. The spine is the primary site of involvement in only 3 to 12% of chondrosarcomas, and involvement of the sacrum is unusual.13 Chondrosarcoma occurs most frequently in patients ranging in age from 30 to 60 years and has a male predominance (2–4:1). At its initial presentation, it is usually low grade.9

Chondrosarcoma may show mild bone destruction, with extension into the soft tissues. There is usually (although not invariably) chondroid matrix present, which has been described as punctuate, ring or arclike, or having the appearance of “Cs or Js” (Fig. 19). It should be noted that even in the presence of matrix, the diagnosis of a
Imaging of sacral tumors

Sacral lesion is more likely to be chordoma than chondrosarcoma, simply because of the relative prevalence of chordoma.

Click here to view Fig. 19. Imaging studies acquired in a 29-year-old man with chondrosarcoma. Upper Left and Center: Anteroposterior and lateral radiographs demonstrating a highly destructive lesion involving S4–5, with a large soft-tissue mass, which contains chordoid matrix (arrows). These features lead to diagnosis of a chondrosarcoma. Upper Right: Sagittal T2-weighted (TR/TE 600/9 msec) image revealing a tremendous low signal soft-tissue mass extending well into the buttocks (arrows). Lower Left and Right: Axial T2-weighted fast–spin echo (TR/TE 3550/105 msec) MR images with the patient in a prone position, demonstrating that the mass replaces the lower sacrum and extends out into both buttocks. The very high signal intensity and lobulated nature of chondroid lesions can be depicted particularly well (lower right).

In cases of chondrosarcoma, MR imaging demonstrates low-to-intermediate signal intensity on T1-weighted and very high signal intensity on T2-weighted sequences. The high T2-weighted signal intensity may have a lobular configuration that can be distinctive for chondrosarcoma (Fig. 19). If the matrix is a prominent feature, these regions will show low signal on all sequences.

Treatment of chondrosarcoma is wide excision. Because there are high recurrence and mortality rates if the resection is incomplete, complete cross-sectional imaging should be performed prior to surgery to evaluate the operative site. Radiotherapy and chemotherapy are used if the surgical margin is not clear, but their effectiveness in low-grade lesions is not proven. Metastases generally occur late and involve lung and bone.

Osteosarcoma. Osteosarcoma is the most common primary malignant osseous neoplasm in children and has a bimodal age distribution. It is, however, uncommon in the spine. It is the fifth most common primary malignant neoplasm of the sacrum, accounting for only 4% of primary sacral tumors. Many of the osteosarcomas that do occur in the sacrum are secondary to degeneration of Paget disease.

Paget disease occurs in 10% of the individuals greater than age 80 years. Sarcomatous degeneration occurs in less than 1% of these patients, with the prevalence increasing with patient age and number of Paget disease–affected bones. Osteosarcoma is the most frequent sarcoma arising from Paget disease, but chondrosarcoma, malignant fibrous histiocytoma, and fibrosarcoma can also occur.

Paget disease–associated osteosarcoma in the spine may appear lytic in up to 50% of cases. If the amorphous matrix of aggressive osteoid is present, the diagnosis is obvious (Figs. 20 and 21). In either case, however, other bones demonstrating the enlargement and coarsened trabeculae typical of Paget disease should make the diagnosis straightforward.

Click here to view Fig. 20. Radiographs obtained in a 71-year-old man with pain and osteosarcoma secondary to Paget disease. Left and Center: Anteroposterior and lateral radiographs demonstrating the amorphous bone density replacing the sacrum, with no remnant of normal bone in that region (note the very different density and appearance of the sacrum relative to the normal bone of the lumbar spine and the metallic density of the barium in the colon). This amorphous bone production occurs in osteosarcoma; in a patient of this age, one of the most common associations of osteosarcoma is development secondary to another process such as Paget disease. Right: Radiograph demonstrating that the left proximal femur has a typical mixed lytic and sclerotic pattern, with coarsened trabeculae, diagnostic for Paget disease, confirming the underlying disorder in this patient.

Click here to view Fig. 21. Radiological studies obtained in a 78-year-old man with Paget disease. Left: Anteroposterior radiograph demonstrating involvement with the sacrum, lower lumbar spine, left superior pubic ramus, and both femora. The mixed lytic/sclerotic pattern, in conjunction with coarsening of the trabeculae and enlargement of the involved bone, suggest the diagnosis of Paget disease. Right: Although this diagnosis is not in doubt, a Tc bone scan may be useful to confirm the diagnosis in more equivocal cases, because Paget disease is commonly polyostotic, with a highly predictable osseous distribution.

Angiosarcoma. Malignant vascular tumors of bone are rare. When multiple lytic lesions occur predominantly in the lower extremity, however, the spectrum of vascular tumors, including angiosarcoma, belongs in the differential diagnosis along with metastatic disease and multiple myeloma. This should be an especially strong consideration when the patient is younger than the typical patient with metastatic or myeloma bone lesions (Fig. 22). The vascular tumors are lytic and generally do not develop any characteristics that allow a definitive neuroimaging-based diagnosis.

Click here to view Fig. 22. Imaging studies acquired in a 32-year-old woman with angiosarcoma. Upper Left: Anteroposterior or radiograph revealing how subtle a sacral lesion can be, and there is usually overlying bowel gas. The sacroiliac joint is obscured, however, and the left sacral ala has lost its trabecular pattern, indicating a destructive process (arrows). Upper Right: Sagittal T2-weighted (TR/TE 515/16 msec) coronal MR images revealing low signal intensity lesions at these sites (arrows; compare with the contralateral, normal side). Although polyostotic lesions most frequently indicate metastatic disease or multiple myeloma, when they occur in the lower extremity in a young adult as in this case, polyostotic vascular lesions should be considered.

**IMAGING WORKUP OF SACRAL LESIONS**

Because lesions of the sacrum are often large by the time they are diagnosed and because their primary treatment is usually wide resection, careful imaging is a crucial part of the workup. Following radiographic identification of a sacral lesion, radionuclide bone scanning should be conducted. The bone scan is not obtained to evaluate the extent or aggressiveness of the lesion; rather, it is used to determine whether the lesion is polyostotic. If there are multiple lesions, the differential diagnosis (presuming an aggressive appearance) is usually limited to metastases, multiple myeloma, Paget disease, and vascular tumor. Once the bone scan demonstrates that the lesion is monostotic, cross-sectional imaging should be undertaken. Occasionally there is a specific reason to perform CT scanning; this generally relates to a need to evaluate the character of any matrix that may be present. Computerized tomography scanning may also be performed if MR imaging is contraindicated in a particular patient. If CT scanning is substituted for MR imaging, and there is a presacral soft-tissue mass, both rectal and intravenous contrast should be administered to evaluate involvement of
the pelvic structures. When possible, however, MR imaging is the cross-sectional imaging modality of choice.

Magnetic resonance imaging is performed both to help specify the diagnosis and for site evaluation. As previously described, the combination of T1- and T2-weighted imaging or its equivalent may provide specific enough information based on signal intensity, location, morphology, and prevalence of a disease to make a very strong presumptive diagnosis. At other times, these characteristics will be nonspecific and only yield a differential diagnosis. In either case, MR imaging is conducted for site evaluation, which in turn helps guide biopsy sampling and resection, as well as give substantial information regarding prognosis for postoperative functional status. Magnetic resonance imaging should not be performed as a standard examination. The radiologist must work with the surgeon to determine exactly what information must be gleaned from the examination. Generally, this includes exact localization and extent of both bone and soft-tissue mass, as well as involvement of any adjacent soft tissues and neurovascular bundles. In the sacrum, the multiplanar capabilities of MR imaging can be utilized to obtain “true” coronal and axial images of the sacrum, which in fact are oblique coronal and axial images relative to the tabletop (see Fig. 14 I and J). In this way, involvement of nerve roots and the presacral visceral structures and neurovascular bundles can best be evaluated. Sagittal imaging is best for evaluating fluid levels within a lesion. Please note that axial images are required to evaluate for involvement of muscles, neurovascular bundles, bowel, bladder, or other visceral structures. These structures are not adequately evaluated using coronal or sagittal imaging.

The radiologist should bear in mind, when considering site evaluation, that sacral lesions sparing the majority of S-1 and the sacroiliac joints may be amenable to complete excision9 and remain mechanically stable. Functionality considerations show that if the lesion can be removed with the upper three sacral nerves on one side and two on the other side preserved, the patient will maintain close to normal function. On the other hand, loss of all but the first nerve root bilaterally will result in rectal incontinence and impaired sexual function.10 Invasion of the bowel requires resection and colostomy. Studies have shown that it is difficult to distinguish adhesions from rectal wall invasion by cross-sectional imaging, even with insufflation of air in the rectum during MR imaging examination.10

References


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