RadioGraphics

Radiographic, CT, and MR Imaging Features of Dedifferentiated Chondrosarcomas: A Retrospective Review of 174 De Novo Cases[1]

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Up to 11% of chondrosarcomas may undergo regional anaplastic change, resulting in a high-grade noncartilaginous sarcoma arising within a typically low-grade chondrosarcoma. Known as dedifferentiated chondrosarcomas, these tumors are highly malignant with a very poor prognosis. The most important factor affecting survival is an accurate preoperative diagnosis. Therefore, the ability to predict the possibility of dedifferentiation in a malignant cartilage tumor on the basis of imaging findings is critical to ensure adequate tumor sampling at the time of biopsy. Imaging findings at radiography, computed tomography (CT), and magnetic resonance (MR) imaging in 174 patients with dedifferentiated chondrosarcoma were reviewed to determine whether there are radiologic features that can help predict dedifferentiation. On approximately one-third of the radiographs, one-third of the MR images, and one-half of the CT scans, the tumors demonstrated bimorphic features (ie, distinctly different tumor features juxtaposed within the lesion), most frequently a dominant lytic area adjacent to a mineralized tumor at radiography and a large, unmineralized soft-tissue mass associated with an intraosseous chondroid-containing tumor at CT and MR imaging. In the initial evaluation of patients with a primary bone tumor, thorough evaluation of the radiologic features of the entire tumor is critical.

Index terms: Bone neoplasms, 40.3211 • Bone neoplasms, CT, 40.1211 • Bone neoplasms, MR, 40.1214 • Bones, radiography, 40.11 • Sarcoma, 40.11, 40.1211, 40.1214

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Introduction

Most chondrosarcomas are well-differentiated low-grade tumors. However, up to 11% of these tumors undergo anaplastic transformation, resulting in a high-grade noncartilaginous sarcoma arising within a preexisting, typically low- to intermediate-grade chondrosarcoma (1,2). This phenomenon, known as dedifferentiation, was first described by Dahlin and Beabout in 1971 (3). These dedifferentiated tumors are highly malignant, with affected patients having median survival times ranging from 5 to 18 months and reported 5-year survival rates of 10.5% and 13% (1,4–6). Mitchell et al (4) suggested that the most important factor affecting survival is an accurate preoperative diagnosis. Because the noncartilaginous component determines the rate of growth and metastasis and, thus, the prognosis of this neoplasm, it is critical that the possibility of dedifferentiation be explored prior to biopsy to facilitate sampling of the dedifferentiated component (2,7).

Although the radiologic features of dedifferentiated chondrosarcomas have been discussed in the literature, the series have generally been small, especially those that examine findings at magnetic resonance (MR) imaging and computed tomography (CT) (7,8). The purpose of our study was to review the radiographic and cross-sectional imaging features of dedifferentiated tumors to determine whether there are radiologic features predictive of two distinct tumor types in juxtaposition. In this article, we present the materials and methods used in our study. We also discuss and illustrate our results in terms of *(a)* histologic subtypes of the dedifferentiated component, *(b)* general tumor imaging features, *(c)* cortical reaction, cortical destruction, and pathologic fracture, *(d)* intraosseous matrix mineralization, *(e)* soft-tissue mass, *(f)* tumor bimorphism, and *(g)* enhancement characteristics at CT and MR imaging.

Materials and Methods

A multi-institutional retrospective review was conducted of 162 radiographs, 63 CT scans, and 51 MR images obtained in 174 patients with histologically proved dedifferentiated chondrosarcoma. Between 1983 and 2001, these patients presented to Mayo Clinic (Rochester, Minn) or had their cases submitted to the pathology consultation file there ($n = 161$), or presented to Saint Louis University in St Louis, Missouri ($n = 7$) or Mount Sinai Hospital in Toronto, Ontario, Canada ($n = 6$). The mean age at diagnosis was

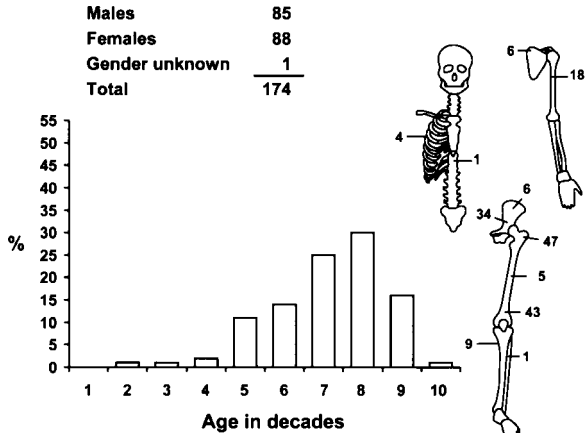


Figure 1. Schematic illustrates the distribution of dedifferentiated chondrosarcoma by patient age, patient gender, and lesion site. Numbers on drawing of skeleton indicate number of patients with disease affecting the corresponding anatomic location.

66 years (range, 15.4–92.9 years); 49% of patients were males and 51% were females (Fig 1). Cases that recurred after previous resection or treatment of a low-grade chondrosarcoma were excluded. The pathologic findings were reviewed by three pathologists to ensure consistency in classification and grading. The high-grade portion of dedifferentiated chondrosarcomas in this series was classified on the basis of histologic and cytologic criteria.

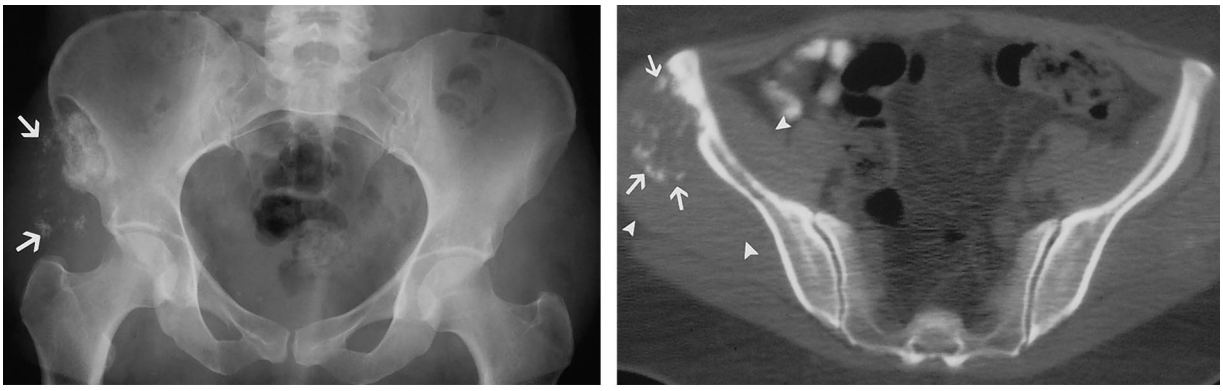
Radiographs were evaluated for patterns of bone destruction, cortical thickening, and cortical endosteal scalloping; the presence and pattern of periosteal reaction; matrix mineralization; the presence and features of soft-tissue masses; pathologic fracture; and the presence of bimorphic features (see Tumor Bimorphism section). The pattern of tumor enhancement at CT and MR imaging and the signal intensity characteristics at MR imaging were also examined.

Results and Discussion

The most common sites of tumor occurrence were the femur (55% of cases), pelvis (23%), and humerus (10%) (Fig 1). Mean tumor size at diagnosis was 10.1 cm (range, 4–23 cm). Among the 174 cases, 169 lesions were centrally located. Of the five peripheral lesions, two developed in an osteochondroma and three on the surface of the bone (Fig 2).

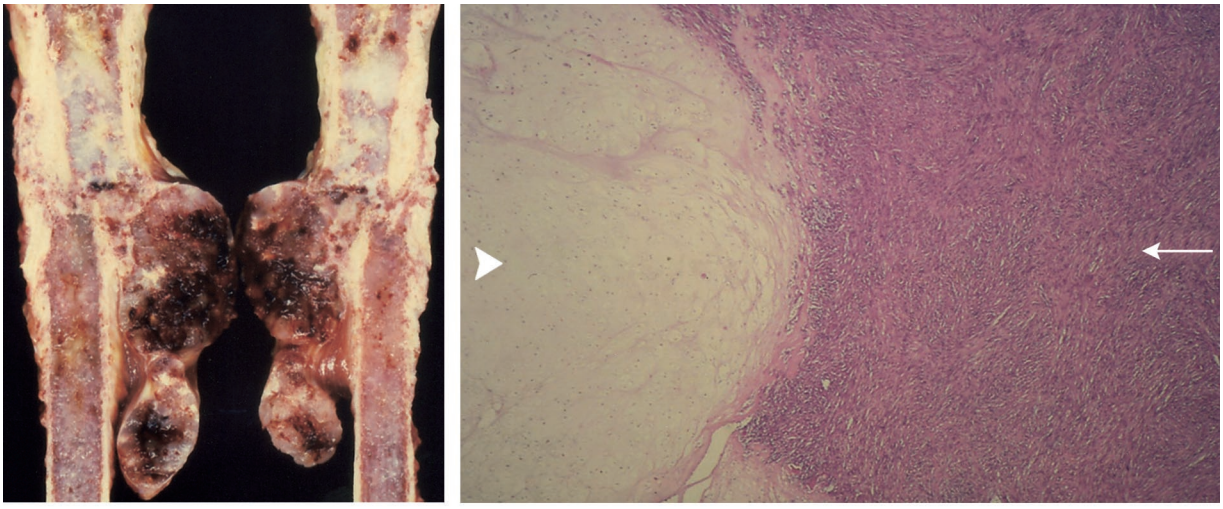
Histologic Subtypes of the Dedifferentiated Component

Almost invariably, the cartilaginous portion of these tumors was consistent with well-differentiated chondrosarcoma (Fig 3). The dedifferentiated component was typically a high-grade



a. b.

Figure 2. Radiograph **(a)** and axial CT scan **(b)** demonstrate a large mass that arises from the surface of the right iliac wing. The mass contains chondroid calcifications (arrows) that suggest chondrosarcoma, as well as unmineralized areas of dedifferentiation (arrowheads in **b**). The dedifferentiated component in this tumor proved to be malignant fibrous histiocytoma.



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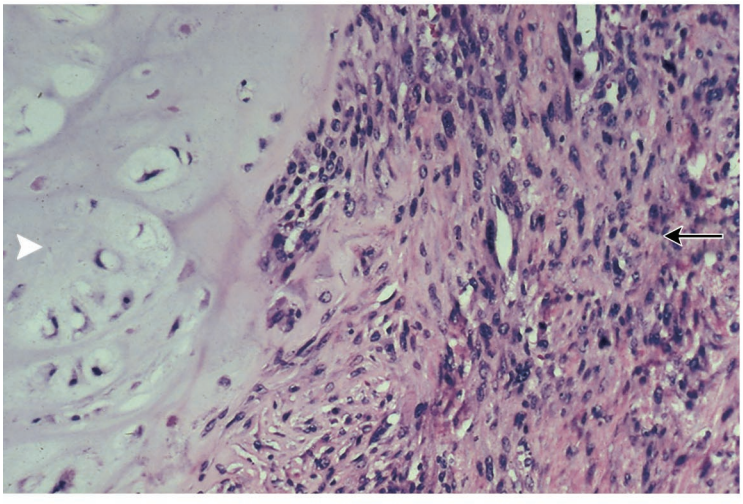
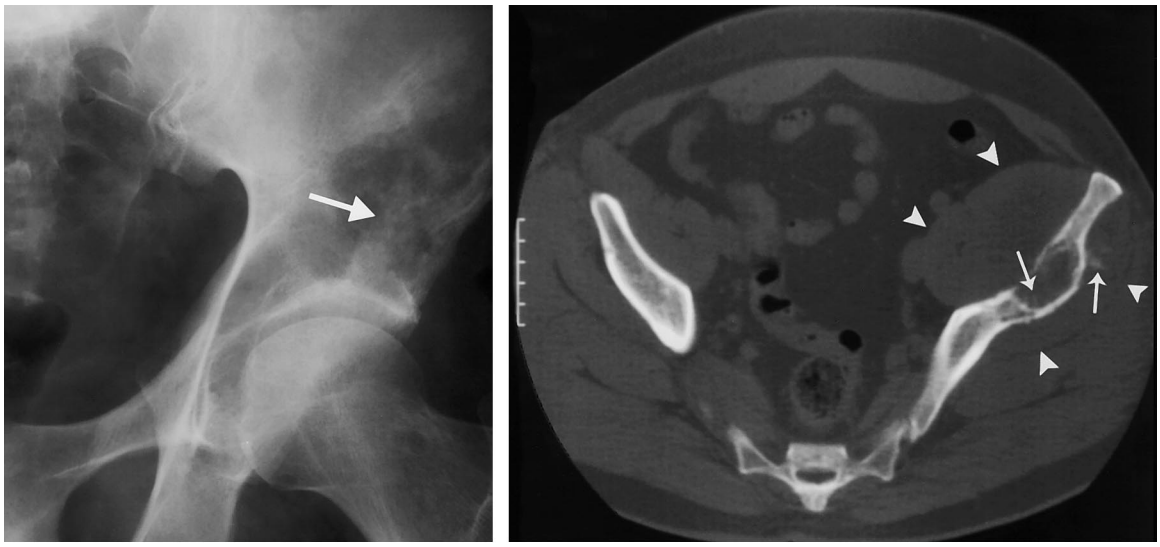


c.

Figure 3. **(a)** Photograph shows a gross specimen with a bimorphic pattern consisting of areas of lobulated gray-white hyaline cartilage adjacent to regions of yellow-brown soft tumor, as well as a soft-tissue mass. **(b, c)** Photomicrographs (hematoxylin-eosin stain) also show the tumor with a bimorphic pattern. The low-grade hyaline cartilage component demonstrates the typical features of ordinary chondrosarcoma, with sheetlike regions of malignant high-grade spindle cells (arrow) immediately adjacent to the well-differentiated chondrosarcoma (arrowhead).



a. **b.**

Figure 4. **(a)** Radiograph of the left hip demonstrates a periacetabular lytic lesion with a suggestion of punctate chondroid calcifications (arrow). **(b)** CT scan of the pelvis shows an expansile soft-tissue mass in the left ilium (arrowheads) and helps confirm the presence of chondroid matrix in the bone and mass (arrows). The cortical destruction and the size of the mass are indicative of a high-grade chondrosarcoma.

Table 1
Histologic Subtypes of the Dedifferentiated Component

Subtype	Percentage of Cases
Osteosarcoma	70
Fibroblastic	39
Osteoblastic	21
Osteosarcoma (not otherwise specified)	7
Chondroblastic	3
Telangiectatic	1
Fibrosarcoma	24
Malignant fibrous histiocytoma	4
Leiomyosarcoma	1
Spindle cell (unable to characterize further)	1

Table 2
Diagnostic Impressions Based on Radiographic and CT Findings

Impression	Percentage of Radiographs	Percentage of CT Scans
Benign enchondroma	1	0
Low-grade chondrosarcoma	4	3
High-grade chondrosarcoma	76	81
Osteosarcoma	6	5
Features of osteosarcoma alone	1	0
Features of osteosarcoma and high-grade chondrosarcoma	5	5
Nonspecific malignant destructive lesion	13	8

sarcoma (usually grade 3 or 4), most commonly osteosarcoma (70% of cases) (Table 1). Of the tumors with an osteoid component, fibroblastic osteosarcoma and osteoblastic osteosarcoma were the most common subtypes. Fibrosarcoma was the second most common dedifferentiated component (24% of cases). In 4% of cases, the dedifferentiated component was malignant fibrous histiocytoma.

General Tumor Imaging Features

In most cases, the overall diagnostic impression based on the imaging findings was consistent with a chondrosarcoma (85% of radiographs and 89% of CT scans), most commonly high-grade chondrosarcoma (Fig 4) (Table 2). The imaging studies demonstrated features consistent with a purely low-grade cartilage tumor on 4% of radiographs and 3% of CT scans. Only one case had features consistent with a purely benign enchondroma at radiography. On 13% of radiographs and 8% of CT scans, the tumors showed a nonspecific malignant destructive pattern with no suggestion of a cartilaginous component (Fig 5). A few cases had characteristics suggestive of an osteosarcoma (6% of radiographs and 5% of CT scans), in all but one case in addition to the presence of a cartilage tumor component.

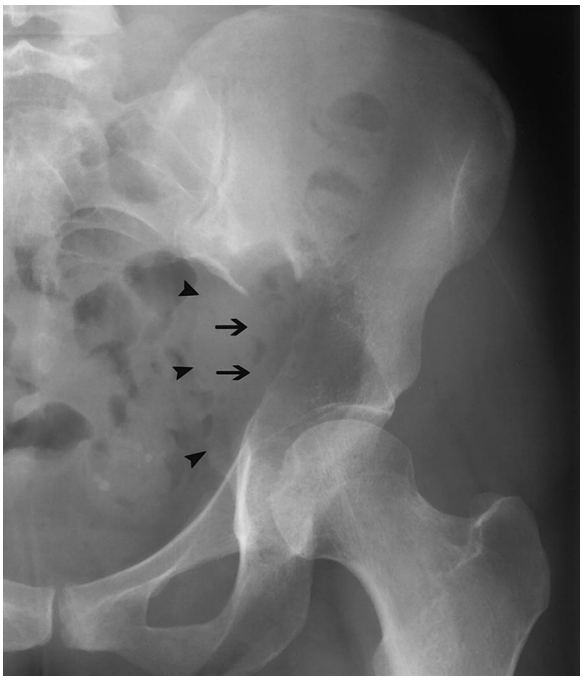


Figure 5. Radiograph of the left hip in a patient with histologically proved dedifferentiated chondrosarcoma demonstrates a nonspecific, malignant, purely osteolytic destructive lesion in the periacetabular region with extensive cortical destruction medially (arrows) and a soft-tissue mass along the pelvic side wall (arrowheads). The differential diagnosis would also include metastasis, lymphoma, and multiple myeloma.

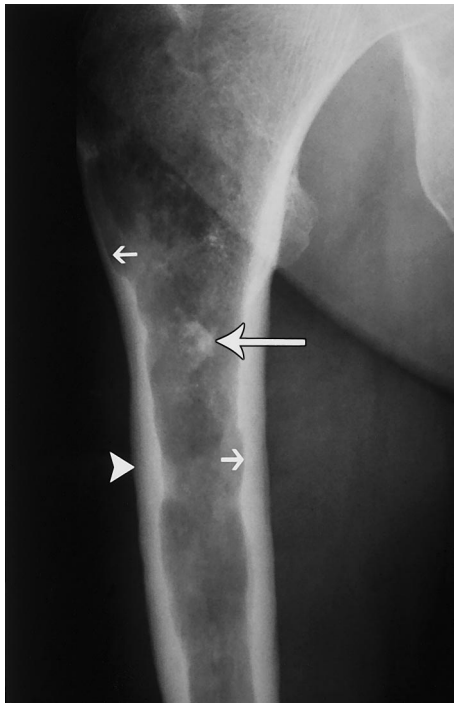
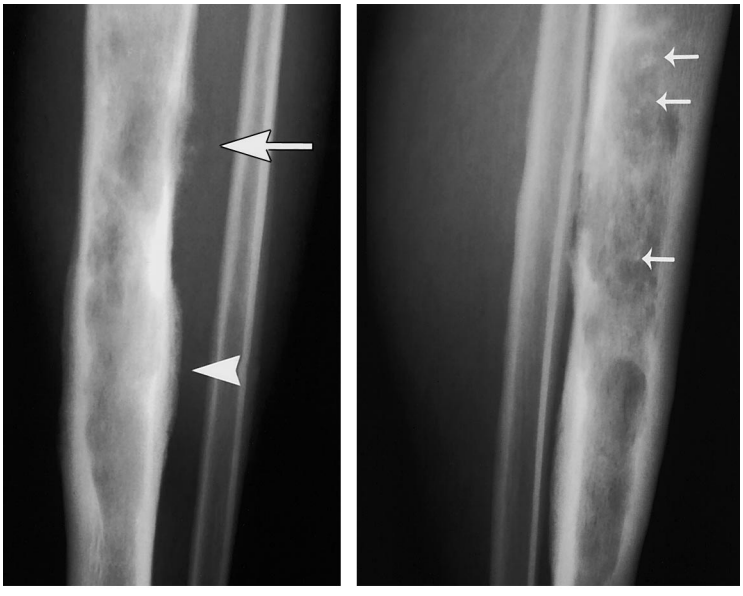


Figure 6. Radiograph demonstrates a cartilage tumor with punctate chondroid calcifications (large arrow), cortical endosteal scalloping (small arrows), mild cortical thickening (arrowhead), and no evidence of periosteal new bone.

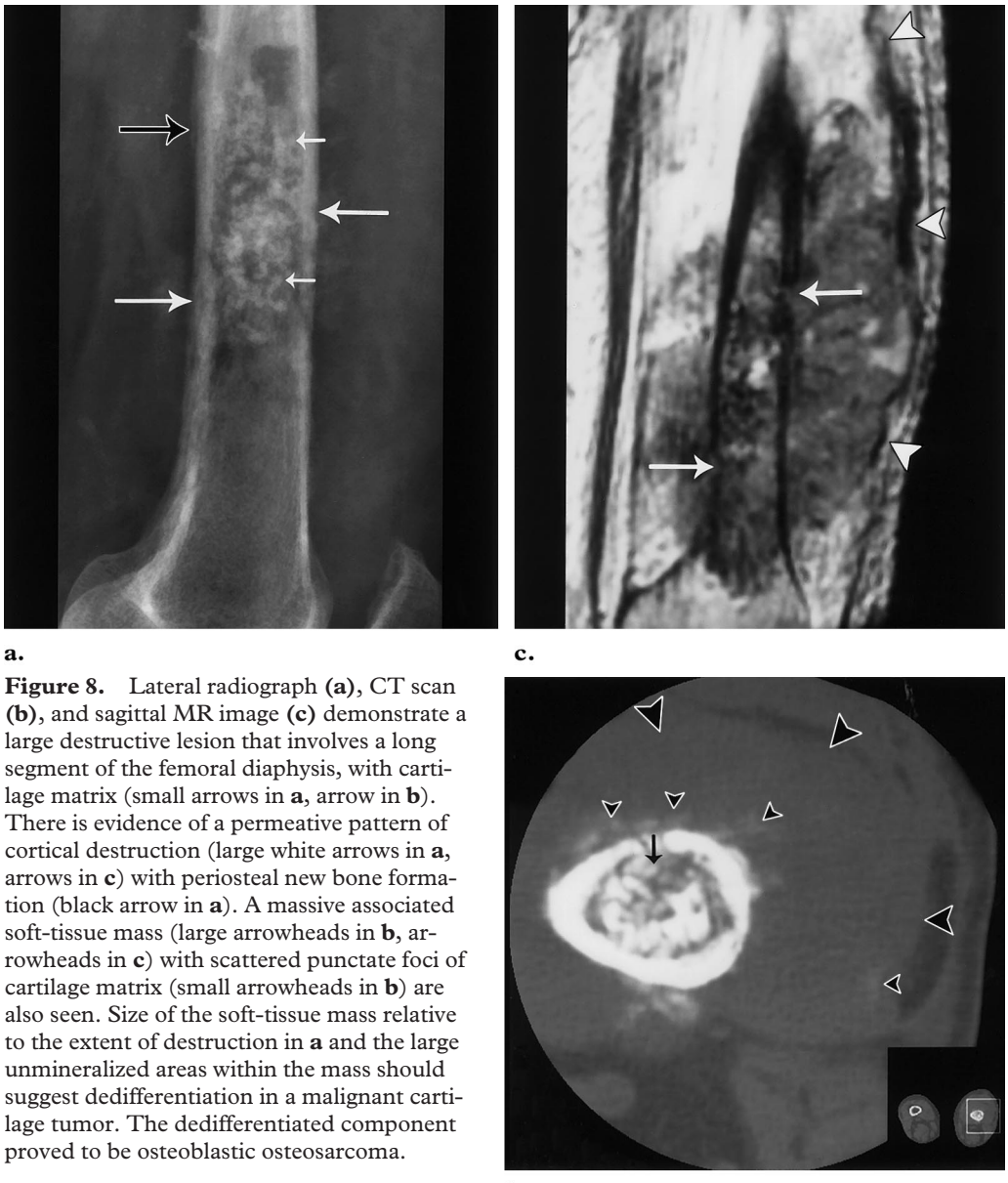


a. **b.**

Figure 7. Anteroposterior **(a)** and lateral **(b)** radiographs of the tibia reveal a lytic and sclerotic lesion in the tibial diaphysis with cartilage matrix (arrows in **b**), a finding that is indicative of a chondrosarcoma. Thick, solid, unilaminar periosteal new bone (arrowhead in **a**), which is characteristic of a low-grade chondrosarcoma, is seen adjacent to a more superior area of spiculated new bone (arrow in **a**), a finding that is suggestive of a more aggressive tumor type.

Cortical Reaction, Cortical Destruction, and Pathologic Fracture

Cortical thickening and endosteal scalloping, findings that are typical of chondrosarcoma, were identified on 32% and 67% of radiographs, respectively (Fig 6). Evidence of periostitis was seen on less than one-half (42%) of radiographs. When present, periosteal reaction was usually benign with a solid or unilaminar pattern of new bone deposition (Fig 7). Malignant-appearing spiculated or multilaminar new bone was apparent in only 6% of cases (Fig 7).



a. **c.** **b.**

Figure 8. Lateral radiograph **(a)**, CT scan **(b)**, and sagittal MR image **(c)** demonstrate a large destructive lesion that involves a long segment of the femoral diaphysis, with cartilage matrix (small arrows in **a**, arrow in **b**). There is evidence of a permeative pattern of cortical destruction (large white arrows in **a**, arrows in **c**) with periosteal new bone formation (black arrow in **a**). A massive associated soft-tissue mass (large arrowheads in **b**, arrowheads in **c**) with scattered punctate foci of cartilage matrix (small arrowheads in **b**) are also seen. Size of the soft-tissue mass relative to the extent of destruction in **a** and the large unmineralized areas within the mass should suggest dedifferentiation in a malignant cartilage tumor. The dedifferentiated component proved to be osteoblastic osteosarcoma.

Overall, these tumors have malignant and aggressive radiologic features. At radiography, the majority of cases (61%) manifested as osteolytic lesions with associated cortical destruction. Of the 96 cases in which MR images, CT scans, or both were available, 90% showed cortical destruction (Fig 8). In 35% of these cases, cortical destruction was not apparent at radiography. Pathologic fracture was apparent on 36% of radiographs, 27% of CT scans, and only 10% of MR images (Fig 9).

Intraosseous Matrix Mineralization

Evidence of punctate intraosseous calcifications suggestive of a cartilage tumor was present on 77% of radiographs and 82% of CT scans (Figs 8, 10). Overall, 66% of MR images showed chondroid matrix mineralization. MR imaging features defined as being consistent with chondroid matrix mineralization included high-signal-intensity medullary calcific lobules on T2-weighted images (20% of cases), punctate low-signal-intensity foci suggestive of medullary calcifications on T1- and T2-weighted images (22%), or both (24%) (Fig 11). When there was no evidence of cartilage at radiography, chondroid matrix was identified at CT in 60% of cases and at MR imaging in 55%.

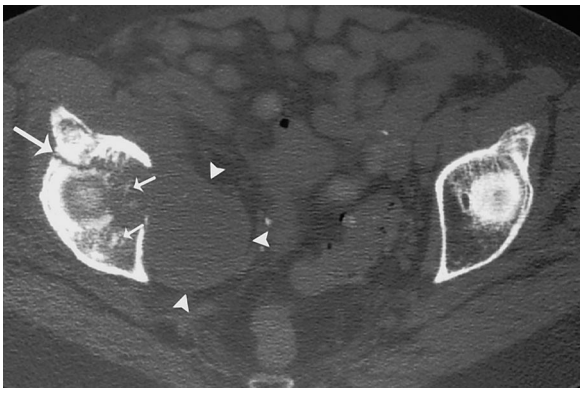
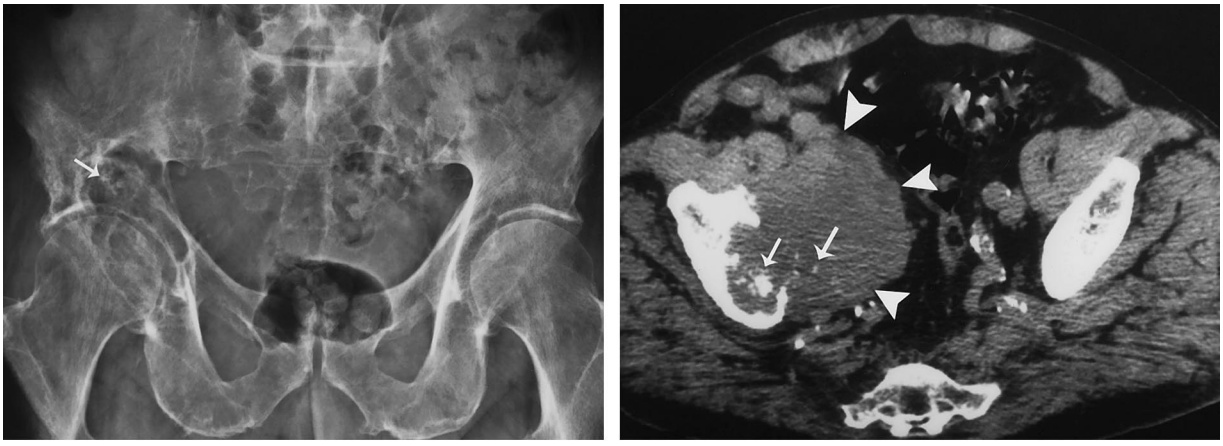
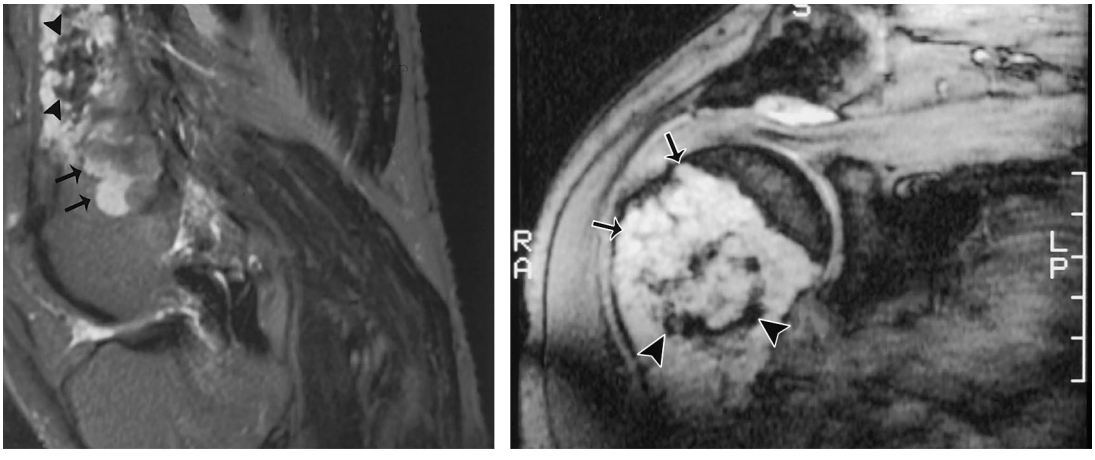


Figure 9. CT scan of the pelvis demonstrates a mixed lytic and sclerotic destructive lesion in the right acetabulum with cartilage matrix (small arrows) and an unmineralized soft-tissue mass (arrowheads), findings that are typical of a dedifferentiated chondrosarcoma. An associated pathologic fracture is also seen (large arrow).



a. **b.**

Figure 10. **(a)** Anteroposterior radiograph of the pelvis shows a large soft-tissue mass in a periacetabular location with a suggestion of chondroid matrix (arrow). The differential diagnosis would include chondrosarcoma. **(b)** CT scan more clearly demonstrates the soft-tissue mass (arrowheads) and chondroid matrix (arrows).



a. **b.**

Figure 11. Sagittal T2-weighted MR image of the distal femur **(a)** and coronal gradient-echo MR image of the right shoulder **(b)** obtained in two different patients with dedifferentiated chondrosarcoma demonstrate high-signal-intensity medullary calcific lobules (arrows) and punctate low-signal-intensity foci representing medullary calcifications (arrowheads). These MR imaging features are typical of chondroid matrix.

Table 3
Radiographic, CT, and MR Imaging Findings in Dedifferentiated Chondrosarcoma

Finding	Percentage of Radiographs (n = 162)	Percentage of CT Scans (n = 63)	Percentage of MR Images (n = 51)
Cortical destruction	61	94	84
Pathologic fracture	36	27	10
Intraosseous matrix mineralization			
None	17	13	35
Chondroid	77	82	66
Osteoid	1	0	0
Chondroid with adjacent osteoid	4	5	0
Soft-tissue mass	25	81	80
Unmineralized mass	13	49	72
Mass containing chondroid alone	9	25	6
Mass containing osteoid alone	2	3	2
Mass containing osteoid and chondroid	1	3	0

Table 4
Evidence of Tumor Bimorphism

Imaging Feature	Percentage of Radiographs*	Percentage of CT Scans†	Percentage of MR Images‡
Dominant lytic area adjacent to mineralized tumor	29	19	14
Large unmineralized or very scantly mineralized soft-tissue mass adjacent to mineralized tumor	4	38	24
Area with osteoid matrix adjacent to chondroid tumor	4	2	0

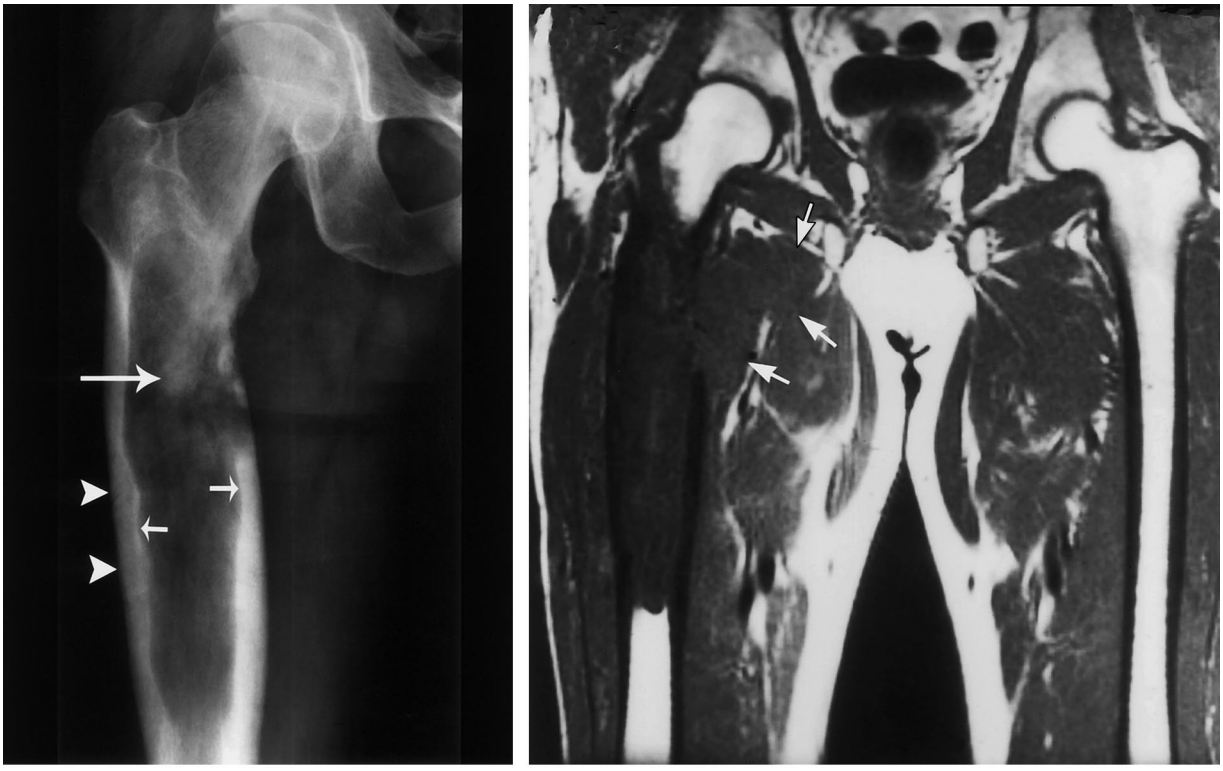
*Percentage of radiographs showing evidence of tumor bimorphism = 35%.
†Percentage of CT scans showing evidence of tumor bimorphism = 48%.
‡Percentage of MR images showing evidence of tumor bimorphism = 33%.

Soft-Tissue Mass

An associated soft-tissue mass was identified on 25% of radiographs, 81% of CT scans, and 80% of MR images (Table 3). In general, the soft-tissue masses were large and did not contain any evidence of mineralization (Figs 5, 12, 13). When present, foci of mineralization within the mass tended to be scant (Figs 8, 10). When no soft-tissue mass was visible at radiography, a mass was nevertheless seen at MR imaging in 74% of cases and at CT in 71%. In 22 cases in which both MR images and CT scans were available, two soft-tissue masses were detected at MR imaging that were not demonstrated at CT.

Tumor Bimorphism

Tumor bimorphism was defined as being present if a lesion had features suggesting a chondroid tumor adjacent to a markedly different area, such as a dominant region of increased opacity within the mineralized tumor, a large unmineralized soft-tissue mass, a different pattern of mineralization, or a combination of these findings. Overall, 35% of radiographs, 48% of CT scans, and 33% of MR images showed evidence of bimorphism (Table 4).



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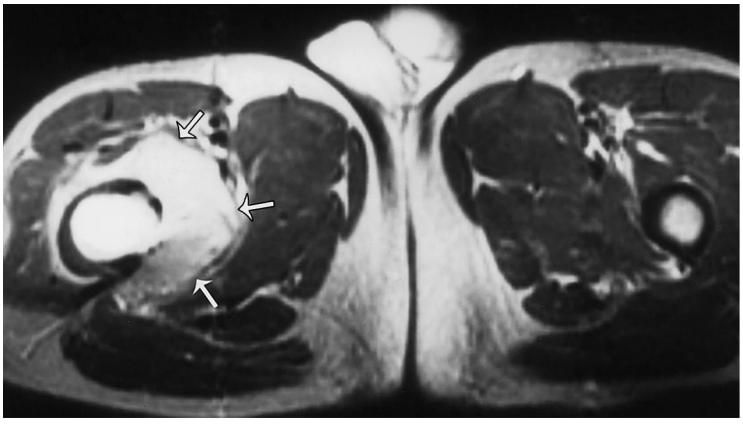


c.

Figure 12. **(a)** Radiograph demonstrates a subtrochanteric lytic lesion in the right femur with cortical thickening (arrowheads), endosteal scalloping (small arrows), and chondroid matrix (large arrow), findings that are typical of chondrosarcoma. **(b, c)** Coronal T1-weighted **(b)** and axial T2-weighted **(c)** MR images help suggest a diagnosis of dedifferentiated chondrosarcoma by depicting a large soft-tissue mass (arrows) that was not detectable on the radiograph.

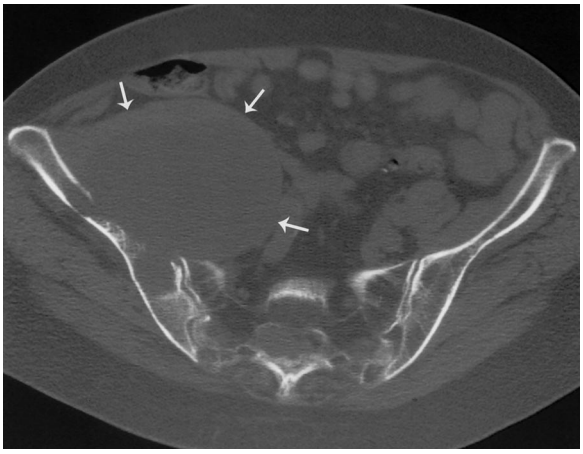
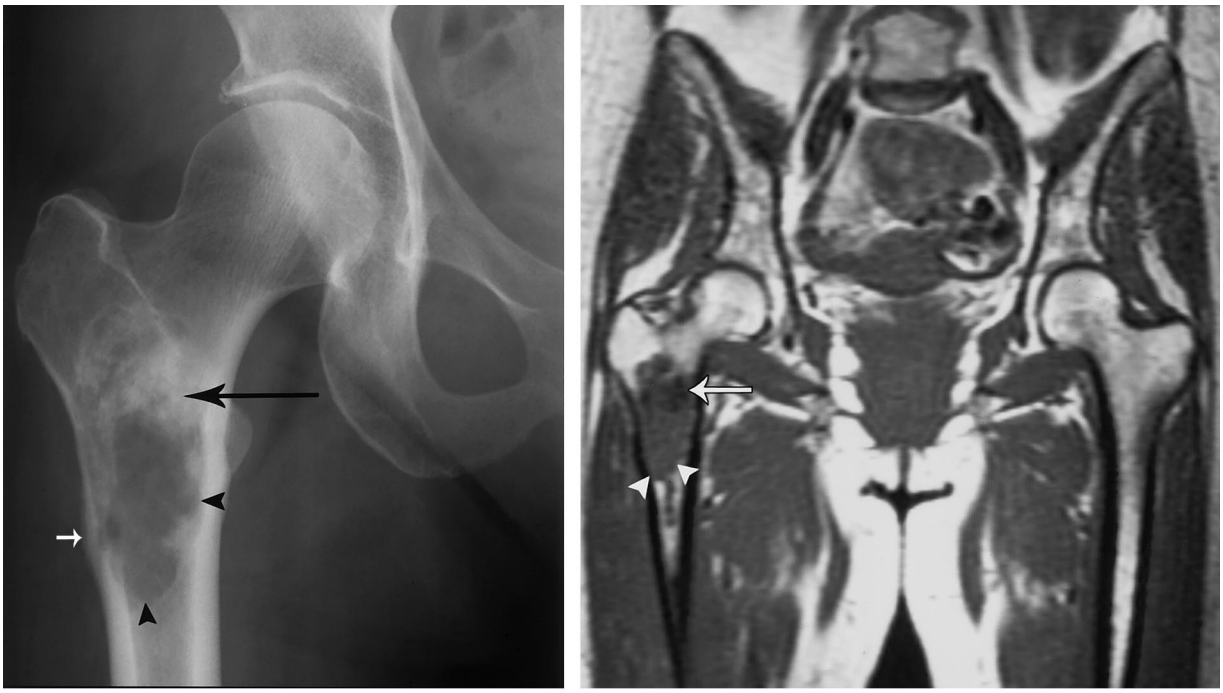


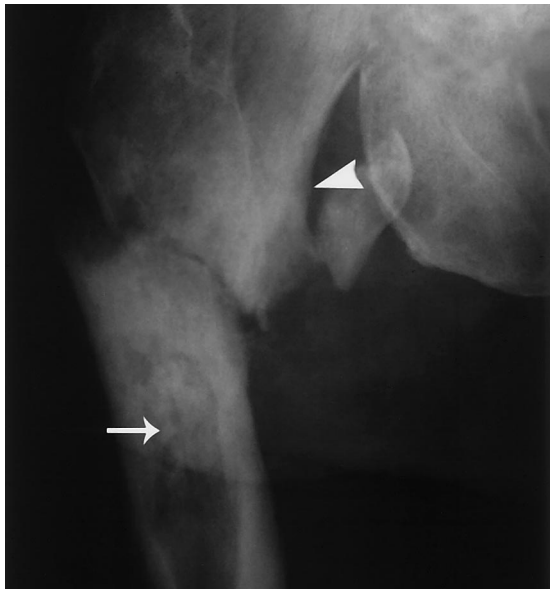
Figure 13. CT scan of the pelvis demonstrates a large mixed lytic and sclerotic destructive lesion in the right ilium without evidence of chondroid matrix. The large unmineralized soft-tissue mass (arrows) is typical of a dedifferentiated chondrosarcoma.



a. b.

Figure 14. Radiograph **(a)** and coronal T1-weighted MR image **(b)** demonstrate a dedifferentiated chondrosarcoma with bimorphic features in the subtrochanteric femur. The radiograph demonstrates cartilage matrix mineralization (black arrow) adjacent to a more aggressive-appearing osteolytic area (arrowheads) with focal cortical destruction (white arrow). The MR image demonstrates an area of low-signal-intensity foci (arrow) that corresponds to the mineralized portion of the tumor, with an unmineralized area inferiorly (arrowheads).

Figure 15. Radiograph shows a mixed lytic and sclerotic lesion with punctate calcifications (arrow) and with evidence of cartilage matrix inferiorly. In addition, there is a denser region of amorphous mineralization superiorly (arrowhead) with features that are more suggestive of osteoid matrix. Pathologic examination revealed a grade 4 osteosarcoma arising within a grade 1 chondrosarcoma.



Of the 57 radiographs that showed bimorphism, the majority (82%) displayed a dominant area of hyperlucency within the chondroid tumor (Fig 14). Less common bimorphic features at radiography included a large unmineralized soft-tissue mass ($n = 7$) (12% of cases) and an area with dense amorphous osteoid matrix ($n = 7$) (12%), the latter being suggestive of an osteosarcoma adjacent to a cartilage tumor (Fig 15).

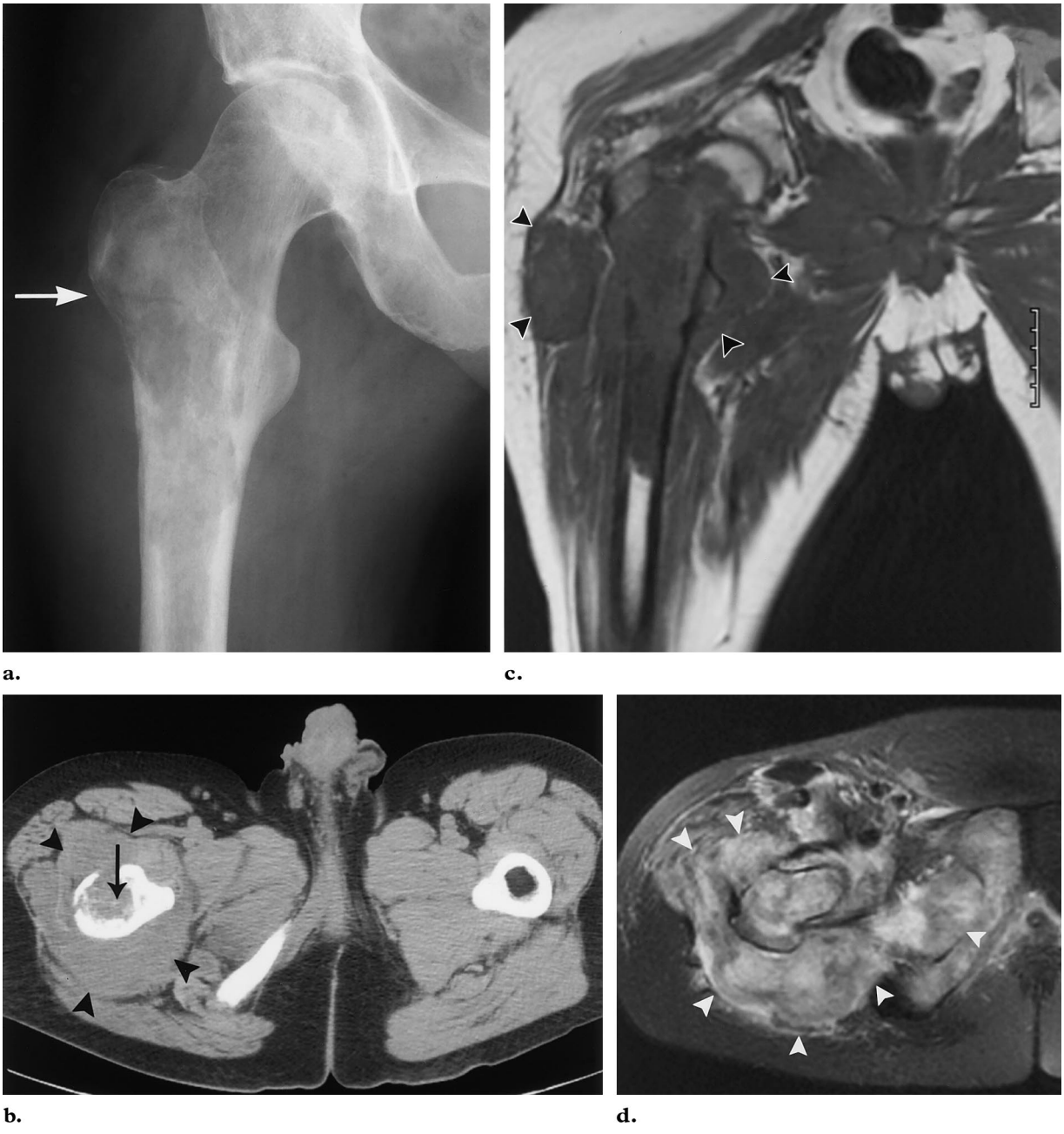


Figure 16. **(a)** Radiograph demonstrates a mixed lytic and sclerotic lesion with a permeative, aggressive, nonspecific pattern. A subtle intertrochanteric and subtrochanteric fracture is also seen (arrow). **(b)** CT scan reveals intraosseous chondroid matrix (arrow) and an unmineralized soft-tissue mass (arrowheads). **(c, d)** Coronal T1-weighted **(c)** and axial T2-weighted **(d)** MR images more clearly show the size and extent of the large unmineralized soft-tissue mass (arrowheads), which represents the dedifferentiated component of a bimorphic cartilage tumor.

Of the 30 CT scans that showed bimorphic features, 80% demonstrated a large unmineralized soft-tissue mass adjacent to the cartilage tumor (Figs 13, 16). In 40% of cases, a distinct area devoid of chondroid calcifications was observed, either alone or in combination with an unmineralized soft-tissue mass. Only one case (3%) had an area with osteoid matrix adjacent to a chondroid tumor with typical punctate cartilaginous calcifications.

Of the 17 MR images that showed bimorphic features, 71% displayed a large unmineralized soft-tissue mass (Fig 16) and 41% showed a dominant area without obvious mineralization, either alone or in combination with a soft-tissue mass. CT or MR imaging demonstrated bimorphic features in 34% of the cases in which radiography did not.

Enhancement Characteristics at CT and MR Imaging

Twenty-five of 63 CT scans and 10 of 51 MR images were obtained after intravenous administration of contrast material. The tumors demonstrated heterogeneous enhancement on 92% of CT scans and 70% of MR images. Of these heterogeneously enhancing lesions, nearly one-half displayed an enhancement pattern characteristic of myxoid change within the tumor at both CT and MR imaging (Fig 17).

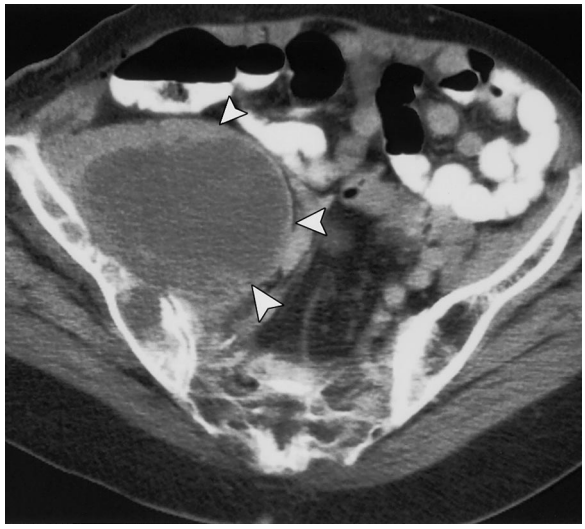


Figure 17. Contrast material–enhanced CT scan of the pelvis demonstrates a mixed lytic and sclerotic dedifferentiated chondrosarcoma of the right ilium with an associated large unmineralized soft-tissue mass (arrowheads). The mass demonstrates heterogeneous enhancement with a large area of low-attenuation myxoid change centrally.

Summary and Conclusions

Patients with dedifferentiated chondrosarcomas, which are aggressive, highly malignant tumors, have very poor 5-year survival rates compared with patients with well-differentiated chondrosarcomas or the noncartilaginous sarcomatous component alone. Increased survival times have recently been linked to a correct pretreatment diagnosis. An inaccurate diagnosis can result from *(a)* relying on biopsy results from the noncartilaginous component alone, without carefully examining radiographs and cross-sectional images for the presence of characteristics suggestive of a chondroid lesion, or *(b)* relying on biopsy results from the cartilaginous component alone, without considering dedifferentiation in a presumed chondroid tumor. For these reasons, thorough evaluation of the radiologic features of the entire tumor is critical in the initial evaluation of a patient with a primary bone tumor.

When a lesion is suspected or discovered, the diagnostic work-up should begin with a complete set of radiographs to determine the pattern of bone destruction and periosteal new bone formation and to assess for the presence of matrix mineralization. In the long bones, where tumor characterization with radiography is frequently sufficient, the work-up should proceed with MR imaging to evaluate the intra- and extraosseous extent of tumor. In the pelvis and other flat bones, where it may be difficult to discern the pattern of bone destruction and the presence of matrix, it is recommended that CT be performed following radiography. If there is a significant soft-tissue component, MR imaging is indicated to accurately evaluate its extent. MR imaging is also helpful in these patients in precisely defining the intraosseous extent of tumor for preoperative planning. At our institutions, the majority of patients undergo CT-guided biopsy for tissue diagnosis.

Most dedifferentiated chondrosarcomas have imaging features indicative of a high-grade cartilage tumor. The most common radiographic findings in our study included lesions with intraosseous chondroid matrix mineralization and cortical destruction. Approximately one-third of the tumors had bimorphic features at radiography, most commonly secondary to a dominant lytic area within or adjacent to a mineralized tumor. CT and MR imaging also commonly demonstrated features suggesting chondrosarcoma with evidence of chondroid matrix and cortical destruction. In addition, a soft-tissue mass was seen at CT and MR imaging in the majority of cases (80%). One-third of MR images and almost one-half of CT scans showed bimorphic features, usually secondary to a large unmineralized soft-tissue mass associated with an intraosseous chondroid-containing tumor. Careful assessment of the radiologic images frequently revealed evidence of dedifferentiation by helping identify contrasting indolent and aggressive imaging features that were juxtaposed within the tumor.

Although radiography is critical in the initial assessment of these tumors, CT and MR imaging are invaluable adjunct tools for optimizing tumor characterization. CT scans and MR images may be useful for identifying chondroid features not apparent on radiographs. In addition, because both MR imaging and CT improve the detection of extraosseous tumor extension, they frequently provide an advantage over radiography by improving identification of associated soft-tissue masses. Evidence of a large unmineralized soft-tissue mass associated with a lesion with radiologic features indicative of a chondrosarcoma is suggestive of a bimorphic tumor pattern and should raise the level of suspicion for dedifferentiation. The ability to accurately predict the possibility of dedifferentiation in a malignant cartilage tumor on the basis of imaging findings improves diagnostic accuracy and may help direct the choice of biopsy site or, perhaps, facilitate multifocal tumor sampling at the time of diagnosis. In addition, when biopsy findings indicate a noncartilaginous spindle cell tumor and imaging findings are suggestive of chondroid matrix within the lesion, the clinician, radiologist, and pathologist should be alert to the possibility of a dedifferentiated chondrosarcoma.

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