Learning objectives

To illustrate the spectrum of imaging findings of the various types of cartilaginous tumors with emphasis on MR Imaging.

To present typical discriminating MR imaging features that help differentiate chondrosarcoma from other benign cartilaginous entities.

To discuss the role of MR imaging in the evaluation of cartilaginous lesions when malignancy is suspected.

Background

Cartilaginous tumors are typically well recognized on radiographs, but differentiation between benign and malignant cartilaginous lesions can be difficult both for the radiologist and for the pathologist due to overlapping characteristics. Diagnosis is commonly based on a combination of clinical, radiological and histological findings. While benign lesions do not require surgery, the only curative treatment for chondrosarcoma is resection.

This exhibit illustrates the spectrum of imaging findings of the various types of cartilaginous tumors.

Imaging findings OR Procedure details

Clinical features and imaging characteristics of 172 patients with pathologically proven cartilaginous tumors studied at our institution over the last ten-years were retrospectively reviewed. The most frequent cartilaginous lesion found was osteochondroma in 108 patients (62%), followed by chondroma in 47 patients (27%), and by chondrosarcoma in 12 patients (7%). Chondroblastoma was found in 2 patients (1%). The distribution of the different types of cartilaginous tumors found in our review (fig. 1) is similar to that described in literature.

We present 30 illustrative clinical cases with correlative radiographic, CT and MR imaging findings. The major categories include: osteochondroma, enchondroma, soft-tissue chondroma, synovial chondromatosis, chondroblastoma, low-grade and intermediate-grade chondrosarcoma. High-grade chondrosarcoma was not found in our review. Key discriminating MR imaging features that help differentiate malignant from benign lesions are also discussed.
1- ENCHONDROMA

Enchondroma is the second most common cartilaginous tumor of bone and the most common tumor encountered in the phalanx. It is considered to be more like a hamartoma than a true neoplasm. It shows a peak incidence on the third decade and has no sex predilection. Patients are usually asymptomatic in the absence of pathologic fracture or malignant transformation. Enchondromas are usually monostotic, central metaphyseal lesions with predilection for the short tubular bones followed by the long tubular bones.

On plain radiography enchondromas present as ovoid-shaped, well-circumscribed geographic lytic lesions (IA-IB) with varying degree of chondroid matrix. CT allows assessment of cortical integrity as well as matrix calcifications more accurately than radiographs. On MRI enchondromas show the typical appearance of a cartilaginous neoplasm: lobular architecture, high SI on T2-weighted imaging with low SI calcification, low to intermediate SI on T1-weighted imaging, and the characteristic rings-and-arcs pattern of enhancement showing the fibrovascular septae between the cartilage lobules.

The differential diagnoses of enchondromas include epidermoid inclusion cyst, giant cell tumor, aneurismal bone cyst, solitary bone cyst, fibrous dysplasia, bone infarct and chondromyxoid fibroma. The major diagnostic dilemma is the differentiation with low grade chondrosarcoma. In this differentiation, axial or epiphyseal location, larger size, cortical destruction or soft-tissue extension, deeper and more extensive endosteal scalloping and presence of local pain, favor the diagnosis of chondrosarcoma versus enchondroma.

Multiple enchondromatosis (Ollier's Disease) is a rare developmental abnormality characterized by the presence of multiple enchondromas in the metaphyses and diaphyses of multiple bones. It tends to be unilateral and localized in one extremity. Maffucci's syndrome combines enchondromatosis with soft tissue and visceral hemangiomas. The risk of malignancy in these two entities is higher than in solitary enchondroma.

Examples of enchondromas are illustrated in figs. 2 to 7 (Cases 1 to 6).

2- SOFT-TISSUE CHONDROMA

Soft-tissue chondroma is a rare benign cartilaginous tumor that usually arises from tenosynovial sheaths or the soft tissue adjacent to tendons in the hands and feet of adults. It presents as a slowly growing mass, and repeated micro trauma may be an initiating factor.
Plain radiography shows a soft-tissue mass with chondroid mineralization similar to that of enchondromas. MRI is the method of choice in the evaluation of this rare entity.

The major differential diagnoses of soft-tissue chondroma include periosteal chondroma, myositis ossificans, ossifying fibromyxoid tumor, synovial chondromatosis, and soft-tissue chondrosarcoma.

An example of soft-tissue chondroma is illustrated in fig. 8 (Case 7).

3- OSTEOCHONDROMA

Osteochondroma is the most common benign neoplasm of bone. It is considered a developmental lesion rather than true neoplasm. Most cases are diagnosed within the first three decades of life in frequently asymptomatic patients, with no sex predilection. The majority are solitary, most often located on metaphyseal regions of long tubular bones, scapula or ilium.

Osteochondromas consist of two components: a pedunculated or sessile bony protrusion with cortical and medullary continuity to the underlying bone, and a cartilage cap adjacent to it, which may or may not show chondroid matrix. They may increase in size as long as the parent bone grows.

Plain radiography shows a well-circumscribed meta-to-diaphyseal protuberance with cortical and medullary continuity with underlying bone, which is well depict on CT. The exostosis usually points away from the adjacent joint. On MRI the hyaline cartilage cap shows low SI with T1-weighting and high SI with T2-weighting.

Complications of osteochondromas include cosmetic and osseous deformity, fracture, vascular compromise, neurologic sequelea, bursa formation and malignant transformation.

The differential diagnoses of osteochondroma include parosteal ostesarcoma, periosteal chondroma and chondrosarcoma. Only osteochondroma shows a continuous extension of both medullary cavity and cortex to the parent bone.

Osteochondromatosis (Multiple Hereditary Exostoses) is an uncommon autosomal dominant disorder with male predominance. Patients present with multiple exostoses which result in limb shortening and frequent deformities. Malignant transformation occurs earlier in life and with a higher incidence than in patients with solitary osteochondromas.
Examples of osteochondromas are illustrated in figs. 9 to 13 (Cases 8 to 11) and examples of ostochondromatosis are illustrated in figs. 14 to 15 (Cases 12 to 13). Cases 11 to 13 show complications of osteochondromas such as bursa formation and neurologic compromise.

4- SYNOVIAL CHONDROMATOSIS

Synovial chondromatosis is a rare benign neoplasm of the synovial membrane of a joint, bursae or tendon, resulting in the formation of multiple intra-articular cartilaginous bodies. It presents during the third to fifth decade, and is twice as often in men than women. The knee is the most commonly affected site. Patients present with gradual onset of monoarticular pain and stiffness. Secondary synovial chondromatosis may be present after long standing osteoarthritis.

Plain radiography shows multiple round or oval loose bodies within the joint with ring-and-arcs chondroid mineralization and extrinsic erosion of bone on both sides of the joint. Other radiologic signs include effusion, degenerative arthrosis, osteophytes and subchondral sclerosis. CT is the best method to identify and characterize the calcified intra-articular fragments and bone erosion. The non-calcified regions of hyaline cartilage neoplasia demonstrate high SI on T2-weighted MR imaging because of the high water content of this tissue.

Examples of synovial chondromatosis are illustrated in figs. 16 to 18 (Cases 14 to 16).

5- CHONDROBLASTOMA

Chondroblastoma is a rare benign cartilaginous tumor found almost exclusively in the epiphysis in skeletally immature patients. It is the fourth most common cartilaginous tumor of bone. Approximately 70% of chondroblastomas present during the second decade of life with slight male predominance. The most common site of involvement is proximal humerus, followed by proximal femur, distal femur, and proximal tibia. The tumor tends to be eccentrically located within the epiphysis of long tubular bones and may extend into the metaphysis.

Plain radiography shows a round to oval geographic lytic lesion with a thin complete or incomplete sclerotic rim (IA-IB). They may show some amount of subtle chondroid matrix (50% of the time) more of an amorphous pattern instead of the typical rings-and-arcs pattern, which may be seen only on CT. Most chondroblastomas elicit a thick periosteal reaction along the metaphysis, a location remote from the lesion. Due to its
high cellularity, MRI shows low to intermediate SI with T1-weighting and intermediate heterogeneous to high SI with T2-weighting, often in a lobulated pattern. MRI may show the prominent periosteal reaction in the metaphyseal region, and also reaction demonstrated by bone marrow and adjacent soft-tissue edema.

The major differential diagnoses of chondroblastoma include giant cell tumor crossing into the epiphysis, articular lesions with large cysts, and clear cell chondrosarcoma. Though generally a benign tumor, a few cases of malignant behavior have been reported.

Examples of chondroblastomas are illustrated in figs. 19 to 22 (Cases 17 to 18).

6- CHONDROSARCOMA

Chondrosarcoma is a malignant tumor of connective tissue, characterized by formation of cartilage matrix by tumor cells. It is the third most common malignant bone tumor after myeloma and osteosarcoma. Primary chondrosarcomas arise de novo and secondary chondrosarcomas develop on a preexisting benign neoplasm such as enchondroma or osteochondroma. Imaging findings often suggest the diagnosis of chondrosarcoma by demonstrating a lesion with typical chondroid mineralization and aggressive growth features.

Clinical features and key imaging findings of the different histologic subtypes of chondrosarcoma found in our case review are listed in fig. 23.

6.1 CONVENTIONAL CHONDROSARcoma

Conventional intramedullary chondrosarcoma is the most common type of all chondrosarcoma (80%). Most frequently occurs in the fourth to fifth decade of life with male predilection. They are usually central lesions and particularly common on metaphyses of proximal long bones, pelvis and shoulder. Ninety percent of conventional chondrosarcomas, either central or peripheral are low grade lesions. Clinical symptoms are nonspecific with pain (90% of patients), a palpable soft tissue mass or pathologic fracture being common at initial presentation.

Plain radiographs reveal a mixed lytic and sclerotic appearance. The sclerotic areas represent chondroid matrix mineralization. The radiolucent component usually reveals geographic bone lysis and is multilobulated. Continued growth leads to lobulated endosteal scalloping that eventually produces cortical penetration and a soft tissue component. CT allows optimal detection of matrix mineralization, depth of endosteal
A well differentiated chondrosarcoma will show a lobular pattern on MRI with high SI on T2-weighted images reflecting the high water content of these tumors, and rings-and-arcs type of contrast enhancement corresponding to the interlobular fibrovascular septae. Mineralized matrix will have low SI in all sequences. High grade lesions will appear nonspecific and have inhomogeneous high SI on T2-weighted imaging with relatively less extensive areas of matrix mineralization. MRI best depict bone marrow involvement and soft tissue extension.

The major differential diagnosis of central chondrosarcoma is enchondroma. If no chondrogenic calcifications are seen, a larger group of tumors has to be included e.g. metastasis, malignant fibrous histiocytoma, fibrosarcoma or lytic secondary osteosarcoma

Examples of conventional chondrosarcoma are illustrated in figs. 24 to 27 (Cases 19 to 22).

### 6.2 CLEAR CELL CHONDROSARCOMA

Clear cell chondrosarcoma is a rare bone neoplasm that constitutes 1% of all chondrosarcomas. It is most frequent in the third to fifth decade of life and has male predilection. It is a slowly growing tumor, frequently with a clinical history of pain for months or years. The most common location is the epiphyseal region of long bones, especially humerus and femur.

On plain radiography they appear as well-defined lytic lesion that can have a thin sclerotic rim and, in larger lesions the growth can be slightly expansile. Chondroid matrix is usually absent. Periosteal reaction and cortical breakthrough are rare. CT can better demonstrate matrix mineralization, cortical destruction or soft-tissue extension. MR imaging typically shows homogeneous intermediate SI with T1-weightening and heterogeneous high SI with T2-weightening.

The major differential diagnosis of clear cell chondrosarcoma is chondroblastoma due to its epiphyseal location. Patients with clear cell chondrosarcoma are slightly older than those with chondroblastoma. Imaging features that suggest clear cell chondrosarcoma as opposed to chondroblastoma include a large lesion, lack of surrounding edema, and high SI on T2-weighted MR images. In contrast, the vast majority of chondroblastomas have low to intermediate SI with all MR pulse sequences.

An example of clear cell chondrosarcoma is illustrated in figs. 28 to 29 (Case 23).
6.3 MYXOID CHONDROSARCOMA

Myxoid chondrosarcoma has been reported to represent up to 12% of chondrosarcomas of bone. The mean age at presentation is 49 years and the most common location is the femur.

These tumors have a more aggressive clinical behavior which is reflected in the radiologic appearance, with reported radiographic features including a permeative pattern of osseous destruction and an associated soft-tissue mass. Matrix mineralization is frequently apparent on CT scans but not extensive. CT and MR imaging demonstrate the markedly high water content with low attenuation and very high SI with T2-weighted sequences, respectively. Unlike conventional chondrosarcoma, myxoid chondrosarcoma frequently contain hemorrhage, which appears as areas of high SI with all MR pulse sequences, particularly associated with large soft-tissue components. Enhancement after intravenous administration of contrast material is often only mild and septal to peripheral in pattern.

An example of myxoid chondrosarcoma is illustrated in figs. 30 to 31 (Case 24).

6.4 DEDIFFERENTIATED CHONDROSARCOMA

Approximately 10% of chondrosarcomas undergo anaplastic transformation, resulting in a highly aggressive non-cartilaginous sarcoma (malignant fibrous histiocitoma, fibrosarcoma or osteosarcoma) arising within a preexisting, low-to intermediate-grade chondrosarcoma. These tumors are most frequent in the fifth to ninth decade of life and most commonly located in the pelvis, femur and humerus. Prognosis is poor with only 20% five-year survival.

CT and MR imaging may reveal the presence of two different components. The low grade chondrosarcomatous elements have low attenuation on CT scans and very high SI on T2-weighted MR images. The high grade non-cartilaginous component most frequently shows soft-tissue attenuation on CT scans and variable SI on T2-weighted images. After contrast material administration typical mild septal and peripheral enhancement can be seen in the lower grade chondromatous areas as opposed to prominent diffuse enhancement in the high grade non-cartilaginous areas. Penetration of the cortex, ill-defined margins and large soft tissue component can also be seen in the dedifferentiated component.

An example of dedifferentiated chondrosarcoma is illustrated in fig. 32 (Case 25).
6.5 SECONDARY CHONDROSARCOMA

Secondary chondrosarcomas develop out of underlying benign chondrogenic lesions, such as enchondroma or osteochondroma. They represent 20% of all chondrosarcomas and may be central or peripheral.

Peripheral secondary chondrosarcomas are the most common and arise from malignant transformation of an exostosis. Malignant transformation occurs in less than 1% of solitary lesions and in 10-15% of patients with osteochondromatosis. It is due to chondrosarcoma arising in the cartilage cap of the lesion. Lesions that grow or cause pain after skeletal maturity should be suspected of malignant transformation. Radiographic features that suggest malignancy include:

- growth of a previously unchanged osteochondroma in a skeletally mature patient
- irregular or indistinct lesion surface
- cartilage cap more than 1.5 cm thick
- focal regions of radiolucency in the interior of the lesion
- erosion or destruction of the adjacent bone
- a significant soft-tissue mass particularly containing scattered or irregular calcification

Central secondary chondrosarcomas arise from malignant transformation of an underlying enchondroma. They are rare in patients with solitary lesions and much more frequent in patients with multiple enchondromatosis (10-15%). Radiological signs of this malignant transformation include cortical thickening or destruction, periosteal reaction in absence of pathological fracture and soft-tissue extension.Regional pain in absence of pathological fracture is an important sign of malignant transformation.

Examples of secondary chondrosarcoma are illustrated in figs. 33 to 35 (Cases 26 to 28).

6.6 EXTRASKELETAL CHONDROSARCOMA

Extraskeletal chondrosarcomas are rare neoplasms representing approximately 2% of all soft-tissues sarcomas. The most common histologic type is extraskeletal myxoid chondrosarcoma with a mean age at presentation of approximately 50 years and male predominance. It generally occurs in the soft-tissues of the extremities and clinical symptoms are nonspecific, with the most common finding being a slowly enlarging painless soft-tissue mass.
Radiographs often demonstrate a nonspecific soft-tissue mass which may show areas of chondroid matrix. Underlying bone erosion or invasion and periosteal reaction are unusual. On CT and MR images, myxoid chondrosarcomas have features similar to those described for tumors of these histologic types located in bone. Due to their extremely high water content, they show low attenuation on CT scans and very high SI on T2-weighted images, with only mild peripheral to septal enhancement after contrast material administration.

An example of extraskeletal myxoid chondrosarcoma of the knee is illustrated in figs. 36 to 37 (Case 29). An example of extraosseous myxoid chondrosarcoma of the larynx is illustrated in fig. 38 (Case 30).

**Images for this section:**

**Cartilaginous tumors found in our case review**

![Pie chart showing distribution of cartilaginous tumors](image)

- 172 pathologically proven cartilaginous tumors
- 62% Chondrosarcoma
- 27% Osteochondroma
- 7% Enchondroma/chondroma
- 1% Chondroblastoma
- 1% Synovial Chondromatosis

**Fig. 1:** Distribution of the different types of cartilaginous tumors found in our review.
Fig. 2: Case 1. Enchondroma of middle phalanx

**Case 1**: Enchondroma involving the second middle phalanx in a 53-year-old man.

Magnified anteroposterior (AP) and lateral radiographs of right hand show a well-circumscribed ovoid-shaped, geographic lytic lesion with sclerotic margin and punctate matrix calcification in base of second middle phalanx. This is a pathognomonic appearance of an enchondroma.
**Case 2: Enchondroma involving the fifth proximal phalanx in a 56-year-old-woman.**

(a) Magnified AP radiograph shows a well-circumscribed expanded lesion in base of fifth proximal phalanx with typical rings-and-arcs of chondroid mineralization. There is cortical thinning in the proximal part of the lesion and endosteal scalloping extends over more than two-thirds of the lesion (arrow). However the lesion is biologically benign. (b) Axial scan reveals mineralized chondroid matrix extending over the medullary cavity of proximal phalanx. (c) Photomicrograph shows low cellularity of hyaline cartilage lobules.

**Fig. 3:** Case 2. Enchondroma of proximal phalanx
**Case 3:** Enchondroma of the right humerus in a 46-year-old-man. (a) AP radiograph demonstrates a central lesion with mineralized chondroid matrix in the proximal humeral diaphysis. Coronal T1-weighted (b) and sagittal T2-weighted (c) images highlight its multinodular architecture, and lack of endosteal erosion. The lesion shows heterogeneous SI on MR images, primarily low SI with T1-weighting, and intermediate SI with T2-weighting with low SI areas from mineralization. (d) Photomicrograph shows nonvascular chondroid tissue with low cellularity and abundant hyaline cartilaginous matrix.

**Fig. 4:** Case 3. Enchondroma of proximal humerus
Case 4: Enchondroma of the proximal left femur in a 66-year-old woman.

AP radiograph of left hip shows a central lesion involving the proximal femoral metaphysis with rings-and-arcs pattern of mineralized chondroid matrix. There is no sclerotic rim and the cortex is intact. This is a typical appearance of an enchondroma of long tubular bones.

Fig. 5: Case 4. Enchondroma of proximal femur
**Case 5**: Enchondroma of the distal femur in a 51-year-old-woman. (a) AP radiograph shows a central lesion in the distal femoral metaphysis with chondroid mineralized matrix. Coronal (b) and axial (c) fat-saturated proton-density-weighted images show the characteristic lobulation appearance with intermediate to high SI areas reflecting its chondroid matrix and low SI areas reflecting calcification. (d) Photomicrograph shows characteristic lobular architecture with abundant cartilaginous matrix.

**Fig. 6**: Case 5. Enchondroma of distal femur
Case 6: Enchondroma of left fibula in a 48 year-old-woman. (a) AP radiograph shows an eccentric lytic lesion with mineralized chondroid matrix in the fibula head.

The lesion shows heterogeneous SI on axial MR images, with predominantly low SI on T1-weighted image (b), intermediate SI on T2-weighted image (c) and high SI on fat-saturated T2-weighted image (d). Gadolinium enhanced T1-weighted image (e) shows peripheral and septal enhancement. Multiloculated ganglion cyst of the medial gastrocnemius is also depicted on MR images.

Fig. 7: Case 6. Enchondroma of proximal fibula
Case 7: Soft-tissue chondroma in a 64-year old man who presented with a painless growing mass on left foot. (a) AP left foot radiograph shows a well-defined lesion adjacent to second distal phalanx of left foot with typical rings-and-arcs of mineralization. (b) Sagittal scan shows a large posterolateral soft-tissue mass, separated from bone, with polilobulated borders and extensive chondroid matrix. Coronal T1-weighted (c) and T2-weighted (d) images show low SI reflecting extensive calcification, and some high SI foci reflecting its chondroid matrix. Adjacent bone and joint are uninvolved. (e) Photomicrograph shows well-defined lobulated borders, extensive ossification and focal areas of chondroid matrix.

Fig. 8: Case 7. Soft-tissue Chondroma of foot
Case 8: Osteochondroma of the left humerus in a 13-year-old-woman. (a) AP radiograph of left arm shows a broad based sessile osteochondroma extending from the lateral aspect of the humeral diaphysis. (b) Sagittal T1-weighted image shows cortical and bone marrow continuity from underlying bone. (c) A regular and thin cartilage cap with high SI is well demonstrated on sagittal fat-saturated T2-weighted image (arrow). (d) Photomicrograph shows the cartilage cap above the trabecular bone of the osteochondroma.

Fig. 9: Case 8. Osteochondroma of humerus
Case 9: Osteochondroma of right femur in a 20-year-old man. (a) AP radiograph of the knee shows a narrow-based pedunculated lesion arising from the femoral distal metaphysis and pointing away from the joint. Bone marrow and cortical continuity extending from the underlying bone into the exostosis is well demonstrated on coronal (b), axial (c) and sagittal (d) fat-saturated proton-density-weighted images. The lesion is isointense to bone with a uniform and thin high SI cartilage cap (arrow in c).

Fig. 10: Case 9. Osteochondroma of distal femur
**Case 10:** Osteochondroma of the left tibia in a 27-year-old-man. (a) Lateral radiograph of the knee shows a highly calcified pedunculated lesion extending posteriorly from the proximal tibial metaphysis. (b) Sagittal T1-weighted SPIR image demonstrates cortical and bone marrow continuity and heterogeneous SI of the lesion. (c) Axial T1-weighted SPIR image shows high SI irregular thick cartilage cap without osseous destruction. Pathology study of surgical specimen excluded malignant transformation. (d) Photomicrograph shows the interface between the trabecular bone and the cartilage cap.

**Fig. 11:** Case 10. Osteochondroma of proximal tibia
Case 11: Bursa formation overlying a femoral osteochondroma in a 33-year-old man who presented with a painful mass in the right thigh and sciatic nerve block after trauma. (a) AP radiograph of the right hip shows a large cauliflower-like exostosis of the proximal femur. (b) Oblique radiograph shows a large soft-tissue mass overlying the osteochondroma (arrow). (c) Sagittal reconstructed scan illustrates cortical and medullary continuity from the posterior aspect of the femoral metaphysis. (d) Axial scan reveals a large circumferential soft-tissue mass (asterisks) while no clear cartilage cap can be seen. (e) Photomicrograph shows the cartilage cap covering cancellous bone of the stalk of the osteochondroma.

Fig. 12: Case 11. Osteochondroma of proximal femur
Case 11 (Cont.): Coronal T1-weighted (f) and sagittal T2-weighted (g) images show heterogeneous SI of the exostic lesion with no clear cartilage cap. The large overlying bursa shows well-defined borders and heterogeneous low SI on both sequences due to blood content in different stages of evolution. Muscle atrophy due to sciatic nerve compression (arrow in g) can be seen. (h) Gadolinium-enhanced T1-weighted image shows only minimal enhancement of the bursa wall. MRI at 3-month follow-up confirms hematoma resorption: mass size reduction and fluid-filled appearance with homogeneous low SI on coronal gadolinium-enhanced T1-weighted image (i), and high SI on axial T2-weighted image (j).

Fig. 13: Case 11 (Cont.). Osteochondroma of proximal femur
Fig. 14: Case 12. Osteochondromatosis

Case 12: Bursa formation in a 27-year-old-woman with osteochondromatosis. Radiographs (a,b) show multiple osteochondromas arising from left ischium, right femoral epiphysis and left femoral metaphysis. (c) Pedunculated osteochondromas arising from tibial metaphyses point away from the joints. (d,e) Coronal MR images show a large fluid-filled mass with internal septae overlying the left femoral osteochondroma. The bursa shows high SI on T2-weighted image and low SI with septal and peripheral enhancement on T1-weighted image obtained with gadolinium. Chondral filling defects can be depicted (arrow).
**Case 13:** Osteochondromatosis in a 27-year-old-man who presented with low back pain. Radiographs (a,b,c) show multiple osteochondromas in the proximal humeral epiphyses, femoral metaphyses and right ilium. (d,e) Axial scans reveal pedunculated osteochondromas arising from the right ilium with cortical and medullary continuity to the underlying bone. (f) Magnified axial scan of the spine at L4 shows nerve root compression by a broad based exostosis arising from the right posterolateral aspect of the vertebral body.

**Fig. 15:** Case 13. Osteochondromatosis
Case 14: Synovial chondromatosis of the left shoulder in a 39-year-old man. AP radiograph (a) of the shoulder demonstrates an oval-shaped osteochondral body in the biceps sheath, with punctate to linear calcifications. On coronal (b) and axial (c) fat-saturated proton-density-weighted images the osteochondral fragment shows low SI and is surrounded by bright fluid (long arrows). An additional smaller osteochondral body not seen on the radiograph, can be depicted inferiorly on the coronal MR image (short arrow).

Fig. 16: Case 14. Synovial Chondromatosis
Case 15: Synovial chondromatosis of the right hip in a 41-year-old man. (a) AP radiograph of right hip shows extensive areas of intraarticular ring-like calcification. Axial (b,c) and coronal (d) scan images demonstrate multiple intraarticular loose bodies, uniform in size, with the typical ring-and-arc pattern of chondroid mineralization. Joint effusion and extrinsic erosion of the acetabulum can also be seen.

Fig. 17: Case 15. Synovial Chondromatosis
**Synovial chondromatosis**

**KNEE**

**CASE 16**

**Case 16:** Synovial chondromatosis of the right knee in a 66-year-old woman.

Lateral radiograph of the knee demonstrates multiple mineralized intra-articular loose bodies, uniform in size, showing the characteristic ring-and-arc pattern of chondroid calcification.

**Fig. 18:** Case 16. Synovial Chondromatosis
Case 17: Chondroblastoma of left humerus in a 16-year-old man who presented with shoulder pain. (a) AP radiograph of left shoulder shows an eccentrically located epimetaepiphysial lytic lesion with sclerotic borders, and associated thick periosteal reaction along the metaphysis. (b) Sagittal reconstructed scan demonstrates chondroid mineralized matrix, expansile bone remodeling with cortical thinning, and caudal extension into the metadiaphysis. (c) Axial scan shows some areas of cortical destruction in the anteromedial aspect of the lesion. (d) Volumetric scan reconstruction. (e) Photomicrograph shows uniform, eosinophilic round cells and same multinucleated large cells. (f) Chicken wire calcification.

Fig. 19: Case 17. Chondroblastoma of humerus
Case 17 (Cont.): MR images show an expansile lobulated mass which exceeds the underlying humeral contours. Associated joint effusion can be seen in the posterior aspect of the shoulder joint (asterisk). Due to high cellular chondroid matrix, the lesion shows low to intermediate SI on axial T1-weighted image (g) and low SI with only scattered foci of high SI on axial T2-weighted image (h). Axial (i) and sagittal (j) T1-weighted images obtained with gadolinium show heterogeneous enhancement. Contrast-enhanced sagittal T1-weighted image also shows SI changes in diaphyseal bone marrow, glenoid cavity, synovium, choracoid, and adjacent muscles due to surrounding edema.

Fig. 20: Case 17 (Cont.). Chondroblastoma of humerus
**Case 18:** Chondroblastoma of left femur in an asymptomatic 26-year-old man. (a) AP radiograph shows a geographic lobulated lytic lesion eccentrically located on the lateral femoral condyle. (b) Axial scan demonstrates the lobulated contours, well-defined medial margins and posterolateral cortical destruction. (c) Reconstructed coronal scan shows subtle chondroid matrix within the lesion.

**Fig. 21:** Case 18. Chondroblastoma of femur
Case 18 (Cont.): MR images depict the lobular architecture of the lesion which shows low SI on axial T1-weighted image (d), heterogeneous intermediate SI with low SI internal septae on axial T2-weighted image (e), and high SI on coronal fat-saturated proton-density-weighted image (f). Cortical destruction is well demonstrated on MR images, although no soft-tissue mass can be seen. (g) Intraoperative photograph of the tumor correlates with the images, revealing the characteristic multinodular appearance.

Fig. 22: Case 18 (Cont.). Chondroblastoma of femur
**Malignant tumors presented in this exhibit**

<table>
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<tr>
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<th>Gender</th>
<th>Location</th>
<th>Presenting Symptoms</th>
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<td>Cortical disruption. Focal radiolucent areas</td>
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<tr>
<td>Secondary</td>
<td>19</td>
<td>Man</td>
<td>Humerus</td>
<td>Regional pain</td>
<td>Cortical disruption. Soft-tissue mass</td>
</tr>
<tr>
<td>Extraskeletal</td>
<td>65</td>
<td>Woman</td>
<td>Knee</td>
<td>Enlarging mass</td>
<td>Extraarticular extension</td>
</tr>
<tr>
<td>Myxoid</td>
<td>69</td>
<td>Woman</td>
<td>Larynx</td>
<td>Progressive dysphonia</td>
<td>Cricoid destruction. Rapidly enlarging mass</td>
</tr>
</tbody>
</table>

**Fig. 23:** Clinical features and key imaging findings of the different histologic subtypes of chondrosarcoma found in our case review.
Conventional Chondrosarcoma

**Fig. 24:** Case 19. Conventional Chondrosarcoma of proximal humerus

*Case 19:* Conventional chondrosarcoma of the right humerus in a 31-year-old-man who presented with shoulder pain. (a) AP radiograph of right shoulder shows a central lesion with chondroid mineralized matrix involving the proximal humeral metaphysis. Coronal (b) and axial (c) scans reveal extensive amounts of punctate to linear calcifications representing infiltration of the entire medullary cavity by the tumor, without thickening or breakthrough of the cortex. (d) Photomicrograph shows the infiltrative border of a grade 1 chondrosarcoma.
Fig. 25: Case 20. Conventional Chondrosarcoma of proximal humerus

**Case 20:** Conventional chondrosarcoma of the right humerus in a 64-year-old-woman who presented with shoulder pain. (a) AP radiograph of right shoulder shows a central metaphyseal area of punctate calcifications extending to the epiphysis. (b) Axial T1-weighted image demonstrates a low SI lobulated mass. The non-mineralized component has intermediate SI on sagittal T2-weighted image (c) and high SI on coronal fat-saturated proton-density-weighted image (d). The typical multinodular pattern of chondroid tumors is well depicted. (e) Photomicrograph shows the infiltrative border of a grade I chondrosarcoma with low cellularity.
**Case 21:** Conventional chondrosarcoma of the right proximal humerus in a 55-year-old woman who presented with shoulder pain. (a) AP radiograph of right shoulder shows a lytic lesion of the proximal humeral metaphysis with punctate and ring-like calcifications. (b) Axial scan demonstrates cortical thinning, endosteal remodeling and central mineralized chondroid matrix. Coronal T1-weighted (c) and proton-density-weighted (d) images show cortical thinning (arrows), and marrow replacement by a lobulated mass. Axial T2-weighted image (e) demonstrates that more than fifty percent of the medullary cavity is replaced by the eccentric mass. The lesion shows low SI with T1-weighting and high SI with low SI septa with proton-density and T2 weighting. Histology confirmed grade 2 chondrosarcoma.

**Fig. 26:** Case 21. Conventional Chondrosarcoma of proximal humerus
Conventional Chondrosarcoma

CASE 22

Fig. 27: Case 22. Conventional Chondrosarcoma of rib

Case 22: Conventional chondrosarcoma of the rib in a 82-year-old woman who presented with a painless anterior chest wall mass. (a) Axial CT scan of thorax demonstrates an expansile lytic lesion involving the anterior aspect of the left fourth rib. There is osseous remodeling with cortical disruption, medial displacement of pleura, and extension into the anterior chest wall where an associated soft-tissue mass can be seen. (b) Axial CT scan with bone window shows the typical chondroid matrix mineralization. (c) Photomicrograph shows a grade 2 chondrosarcoma with cartilage lobules (C), entrapping osseous trabeculae (T) and cellular atypia.
**Fig. 28:** Case 23. Clear Cell Chondrosarcoma of tibia
Case 23 (Cont.): (f) The lobulated lesion shows low SI on coronal T1-weighted image. (g) On a more posterior coronal T1-weighted image multiple low SI intramedullary satellite lesions in adjacent epimetaphysis can be depicted. (h) The tumor shows high SI on axial proton-density-weighted image. (i) Peripheral enhancement with internal low SI foci is shown on T1-weighted image obtained with gadolinium. (j) Sagittal gadolinium-enhanced T1-weighted image demonstrates lesion protrusion beyond normal bone contours into the joint space and extensive edema in surrounding bone. (k) Coronal contrast-enhanced proton-density-weighted image shows peripheral enhancement of the satellite lesions in adjacent epimetaphysis.

Fig. 29: Case 23 (Cont.). Clear Cell Chondrosarcoma of tibia
**Case 24:** Myxoid chondrosarcoma of the left proximal femur in a 66-year-old man who presented with hip pain. (a) AP radiograph of left hip shows a large femoral metaphyseal lytic lesion with extension to the epiphysis. Expansile bone remodeling, focal thinning of cortices, and broad endosteal scalloping (long arrows) can be seen. (b) Bone expansion and cortical erosion are well depicted on axial CT scan. (c) Axial CT scan with soft-tissue window demonstrates an associated soft-tissue mass (short arrow).

**Fig. 30:** Case 24. Myxoid Chondrosarcoma of femur
**Case 24 (Cont.):** (e) Coronal T1-weighted image shows lobulated contours of the metaphyseal lesion with expansile remodeling. The lesion shows low SI on axial T1-weighted image (f) and high SI on axial T2-weighted image (g). The entire medullary cavity is replaced by the lesion. (h) Sagittal fat-saturated T2-weighted image shows cortical disruption in the anterior aspect of the lesion and associated soft-tissue mass. (i) Contrast-enhanced fat-saturated T1-weighted image shows peripheral and septal enhancement of the tumor and peripheral enhancement of the adjacent soft-tissue mass.

**Fig. 31:** Case 24 (Cont.). Myxoid Chondrosarcoma of femur
**Case 25:** Dedifferentiated chondrosarcoma of the rib in a 73-year-old woman with osteochondromatosis who presented with recent painful right chest wall mass. (a) AP rib radiograph shows multiple rib osteochondromas and a calcified soft-tissue mass adjacent to right eighth rib. (b) CT scan demonstrates a large exostosis projecting into the chest wall with marrow and cortical continuity. (c) Contrast-enhanced CT scan performed 5 months later shows bone destruction by a fast-growing soft-tissue mass projecting into the thoracic cavity. Slight matrix calcifications can be seen proximal to the cartilage cap which are lacking in the soft-tissue mass, which may indicate bimorphism of the lesion. (d) Photomicrograph shows sharp transition between low grade chondrosarcoma and noncartilaginous components. Malignant fibrous hystiocitoma (e) and osteosarcoma (f) components.

**Fig. 32:** Case 25. Dedifferentiated Chondrosarcoma of rib
Case 26: Secondary osteochondroma of scapula in a 34-year-old man who presented with a painful enlarging mass in left scapular region. (a) AP radiograph shows an osteochondroma arising from the left scapular body. (b) Axial scan demonstrates cortical and marrow continuity, and posteromedial extension into the soft-tissue planes. Coronal MR images depict the chondroid nature of the soft-tissue mass. The lesion shows low SI with T1-weighting (c) and high SI with foci of low SI with T2-weighting (d). Peripheral and septal enhancement is seen with contrast-enhanced T1-weighting (e). Photomicrographs show grade 2 chondrosarcoma permeating and entrapping the bone trabeculae (f). Highly cellular non infiltrative area (g).

Fig. 33: Case 26. Secondary Chondrosarcoma of scapula
**Case 27:** Secondary osteochondroma of the right ilium in a 32-year-old man with osteochondromatosis who presented with recent right pelvic pain. (a) AP hip radiograph shows multiple bilateral osteochondromas involving iliums, pubic crests, coccyx and femoral metaepiphyses. There is a large size exostosis located inferior to the anterosuperior right iliac crest where the patient refers recent pain. (b) Axial scan demonstrates irregular contours of the right iliac exostosis, with areas of cortical thinning and destruction together with internal areas of low attenuation. However no clear soft-tissue mass could be depicted. (c) Photomicrograph shows low grade chondrosarcoma with high cellularity and irregular margins. (The patient refused to undergo MR examination due to claustrophobia).

**Fig. 34:** Case 27. Secondary Chondrosarcoma of ilium
Case 28: Secondary chondrosarcoma of left proximal humerus in a 19-year-old man who presented with shoulder pain. (a) AP shoulder radiograph shows an eccentric metaphyseal lytic lesion of the left proximal humerus with sclerotic margins and some flocculent calcifications. (b) The lesion shows low SI on sagittal T1-weighted image. Cortical destruction and posteroinferior surrounding soft-tissue mass are well depicted. (c) Sagittal T2-weighted image reveals a lobulated high SI lesion with central foci of low SI calcification. (d) Photomicrograph showed grade 1 chondrosarcoma with moderate atypia, infiltrative borders and adjacent bone destruction. Histological study performed few months before was considered inconclusive. Note that patient age, location and imaging features are typical of a chondroblastoma. Malignant transformation cannot therefore be excluded.

Fig. 35: Case 28. Secondary Chondrosarcoma of humerus
Case 29: Extraskeletal myxoid chondrosarcoma of the knee in a 65-year-old woman who presented with a slowly enlarging painless soft-tissue mass on right knee. Axial MR images reveal an intraarticular well-defined polilobulated soft-tissue mass with internal septa. The lesion shows intermediate SI on T1-weighted image (a), high SI on T2-weighted image (b) and very high SI on fat-saturated proton-density-weighted image (c). Adjacent bone shows no SI changes. Medial retinaculum involvement can be seen (arrow in b) with the mass extending over the retinaculum fibers. (d) Coronal fat-saturated proton-density-weighted image demonstrates obliteration of tissue planes against the adjacent muscles, and extension into the subcutaneous tissue.

Fig. 36: Case 29. Extraskeletal Myxoid Chondrosarcoma of knee
Case 29 (Cont.): (e) Photograph of gross specimen correlates well with the MR images, revealing the characteristic multinodular pattern of chondroid tumors, also depicted on the sagittal fat-saturated proton-density-weighted MR image (f). Photomicrographs show highly cellular low grade chondrosarcoma with well-defined lobulated contours separated by septae. (g) High power photomicrographs (h,i) show strands of small eosinophilic cells over a myxoid background separated by the fibrous septae.

Fig. 37: Case 29 (Cont.). Extraskeletal Myxoid Chondrosarcoma of knee
Case 30: Laryngeal chondrosarcoma in a 69-year-old woman who presented with a 6-month history of progressive dysphonia. (a) Axial scan of glottic area shows a large mass arising from the right cricoid cartilage, destroying its architecture, and involving the arytenoid cartilage. (b) Axial scan of subglottic area shows extension into the hypopharynx and obliteration of tissue planes against prevertebral muscles. (c) Reconstructed sagittal scan demonstrates the large laryngeal mass extending from the cricoid cartilage to the hypopharynx. (d) Reconstructed coronal scan shows enlarged left thyroid lobe due to multinodular goiter. (e) Photograph of the sagittally sectioned specimen shows myxoid areas and well-defined margins. Histology showed grade 2 chondrosarcoma. Surrounding soft tissues were respected.

Fig. 38: Case 30. Extraosseous Myxoid Chondrosarcoma of larynx
Conclusion

Recognition of the typical imaging characteristics and discriminating features of the various types of cartilaginous lesions is essential to develop an appropriate diagnosis and therefore facilitate optimal patient management.

Personal Information

References
