Tumors of the rib

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KEYWORDS
Bone tumors; Ribs; Osteogenic matrix; Cartilaginous matrix; Fibrous matrix

Abstract  The authors propose a pictorial review illustrating the imaging features of chest wall
tumors and their specific features that discusses the main differential diagnoses. This review is
based on published information and on our own experience.
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The prevalence of tumors of the rib bones ranges from 3 to 8% depending on the series [1,2]. The most common of the malignant costal tumors are metastases and myeloma and
fibrous dysplasia is by far the commonest of the benign lesions [3,4]. These lesions are
often discovered incidentally.

Various features need to be considered in order to make an accurate diagnosis: epidemiological details (age, sex), context (staging assessment of possible malignancy) and
clinical features (pain, deterioration in general health).

Apart from the classical features of the lesion (size, type of matrix, features of aggressive
disease), the site of the lesion within the rib may help with the diagnosis. Cartilaginous
lesions are usually located at the costo-chondral junction, whereas myeloma, metastases
and fibrous dysplasia are found mostly in the body of the rib.

We shall review the main benign and malignant rib lesions.

Benign rib tumors

The commonest benign rib tumors are fibrous dysplasia, enchondroma and osteochondroma [7].

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http://dx.doi.org/10.1016/j.diii.2013.05.006
The presence of a cartilaginous matrix (fine calcifications) points towards an enchondroma. A clearly delineated fusiform expansion affecting one or more bone sections suggests fibrous dysplasia.

**Fibrous dysplasia**

Fibrous dysplasia is the commonest benign rib lesion [3]. It is a congenital but not inherited disorder and is due to an abnormality of maturation and differentiation of the osteoblasts leading to replacement of the bone marrow cavity and canaliclar bone with fibrous tissue and immature bone. Rib involvement is seen in 6 to 20% of single bone forms of the disorder and more than half of the patients (55%) with multiple bone involvement have the disease in the ribs [4,5].

It is usually asymptomatic and develops between the third and fourth decades of life. Pain, if present, suggests a fracture or compression of the neighboring tissues by the tumor (Fig. 1a).

The disease predominantly involves the posterior and middle costal arches and in monostotic fibrous dysplasia the second rib is often affected [4,6].

Radiography shows a centered, prolonged, osteolytic fanning, expansive medullary lesion in the axis of the rib thinning the adjacent cortex with a rim of osteocondensation (Fig. 1b).

Soft tissues are not involved unless a pathological fracture occurs.

CT shows a purely lytic medullary lesion or peripheral trabeculations. "Ground glass" areas may be seen, which are highly suggestive of the diagnosis. Sometimes even cartilaginous nodules are seen (Fig. 1c). This investigation can confirm that no periostal reaction is present or any damage of the adjacent soft tissues, which might cast doubt on the diagnosis. In addition, cortical erosions or fine cracks may be seen which can be missed with radiography [7].

MRI is of limited benefit and shows a relatively homogeneous hypointensity on a T1 weighted sequence whereas the T2 sequence intensity varies depending on the extent of

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**Figure 1.** Fibrous dysplasia. a: 37-year-old patient, axial CT. Fracture through fibrous dysplasia (arrowhead); b: radiographic appearances of fibrous dysplasia in a 45-year-old man. Fanning lytic medullary lesion in the posterior arch of the 10th left rib, expansive along the axis of the rib with thinning of the cortical bone and an osteosclerotic line (arrowheads); c: sagittal oblique CT reconstruction in a 45-year-old patient. Incidental finding of fibrous dysplasia appearing as a lytic medullary lesion expansive along the axis of the rib. Note the cortical thinning with no swelling of the neighboring soft tissues (arrowhead).
Tumors and enchondromas. A peripheral moderate, clear hypointense rim is seen representing the fibrous tissue and distinguishing it from the adjacent normal bone.

**Enchondroma**

Enchondroma is the most common benign rib lesion after fibrous dysplasia. It is a cartilaginous tumor representing 15 to 20% of benign rib tumors [8]. It is usually found in the second to third decade of life and is typically located in the anterior costal arch close to the costo-chondral junction or in the posterior costal arch close to the costo-vertebral joint.

It is a clearly delineated lesion under 4 cm in size. A more definitive diagnosis can be made by CT, which shows a clearly delineated lobulated slow growing osteolytic lesion with or without cortical fanning (Fig. 2a). Calcifications are common (Fig. 2b). The differential diagnosis from low-grade chondrosarcoma (which is more common in the ribs) is difficult and MRI is therefore often performed.

MRI allows the cartilaginous matrix to be recognized easily. This has a pronounced hypointensity on a T1 weighted sequence contrasted strongly by the intense signal from the neighboring fatty bone marrow. The hypointensity is occasionally heterogeneous because of the presence of calcium deposits (more pronounced hypointensity on a T1 weighted sequence) or residual fatty tissue (hypointense on a T1 sequence). T2 weighted sequences show a clearly delineated, lobulated outline. The cartilaginous matrix is rich in water and is clearly hyperintense on T2 weighted sequences, and the septa are hypointense. Calcifications within the tumor are hypointense on all sequences. No abnormalities around the lesion are seen on T2 weighted sequences with fat suppression. Following gadolinium injection, tumor contrast uptake is rarely only peripheral, except in small enchondromas.

**Osteochondroma**

Osteochondromas represent 8% of rib tumors [1,9] and approximately 50% of benign rib tumors. They are usually found in the anterior region at the costo-chondral junction [10]. This type of lesion usually affects children and young adults, in 60% of cases (diagnosed before the age of 20). Clinically a painless, very slow growing hard outgrowth is found.

Radiography shows a pedunculated or sessile bone mass arising from a rib.

Ultrasound shows a hyperechogenic bulge underneath a hypoehogenic band representing the cartilaginous cuff. The soft tissues are not invaded (Fig. 3a).

CT shows a clearly corticalized outgrowth with continuity of the bone marrow cavity and cortex with the adjacent bone (Fig. 3b). No periosteal reaction or soft tissue infiltration is seen. The cartilaginous cuff is not seen without contrast enhancement, when it appears as a hypodense band between the subchondral bone and raised muscle.

MRI shows the cartilaginous cuff as a pronounced hyperintensity on T2 weighted sequences, which allows its thickness to be measured: a thickness of over 2 cm in adults and 3 cm in children suggests malignant transformation.

**Aneurysmal cyst**

Aneurysmal cysts in the rib are rare: 2 to 3% depending on the series [11]. They are often associated with a giant cell tumor. The lesion generally affects young patients and is located on the posterior rib arch. Typically, an expansive appearance is seen on imaging with a fluid-fluid level.

**Giant cell tumor**

This is usually found around the third and fourth decades of life and occurs slightly more often in women. It generally affects the extremities of long bones and is relatively rare in the ribs [12].

The reason given for seeking a doctor’s opinion is usually pain. Palpation rarely contributes to the diagnosis except in the event of large lesions. It sometimes presents as a pathological fracture.

Radiography shows a purely lytic expansive lesion, which is eccentric from the axis of the rib and does not contain calcifications. It has distinct outlines and no peripheral

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**Figure 2.** Incidental finding of a costal endochondroma in a 65-year-old man. a: axial CT. Clearly delineated, lobulated lytic lesion in the posterior arch of their right rib with endosteal erosions. No soft tissue swelling (arrowhead); b: sagittal oblique CT. Note the cartilaginous matrix with fine calcifications (arrowhead).
sclerotic bone changes. A break in the cortex is often seen. Unless a fracture is present, no periosteal reaction is found.

CT confirms that calcification is not present, and can be used to assess the cortical damage and to examine extension of the lesion into the soft tissues (Fig. 4a, b).

Extension into soft tissues can be better assessed by MRI, which shows a hypointense or isointense signal on T1 and T2 weighted sequences due to the very cellular nature of the tumor and hemosiderin deposition. The lesion is enhanced with gadolinium injection.

The confirmatory diagnosis is always histological and the differential diagnosis from chondroblastoma, clear cell chondrosarcoma and aneurysmal bone cysts is difficult.

**Chondroblastoma**

In contrast to its usual site (long bone epiphyses) when it is found in the second decade of life, costal chondroblastoma is often found later. It is located at an ossification site and is therefore usually found at the costo-chondral or costo-vertebral junction [13].

The lesion may look aggressive on a CT. MRI shows considerable edema in the bone marrow and adjacent soft tissues.

**Osteoblastoma**

Osteoblastomas are found in 5 to 10% of cases depending on the series [14]. It is a lesion to the bone matrix, which is typically located on the posterior costal arch. It is usually large and often extends into the soft tissues.

**Brown tumor**

This is a complication of either primary or secondary (chronic renal failure) hyperparathyroidism and is secondary to repeated microfractures, which trigger an influx of multinucleated macrophages and lead to local reactive bone marrow fibrosis. Therefore, it is not a tumor as such but an accumulation of hypervascularized fibrous tissue.

Radiography shows a clearly delineated, occasionally expansive osteolytic lesion. After the hyperparathyroidism has been treated, the lacuna is replaced by reconstructed bone (occasionally denser than the adjacent bone). CT shows an expansive lesion with well-delineated outlines and no invasion of the soft tissue (Fig. 5a).

Increased uptake is often seen during the bone reconstruction phase on Tc 99m scintigraphy (osteoblastic activity) although no uptake may occur with a purely osteolytic lesion. Investigations into the cause may in this case reveal a parathyroid adenoma (Fig. 5b).

**Paget’s Disease**

Paget’s Disease is uncommon in the ribs (approximately 2%) [15].

The features are the same as those in other sites of the disease with enlargement of the rib, very dense cortical thickening, fewer but thicker bone markings and persistent areas of fat densities between the bone markings. The soft tissues are, of course, not invaded.

**Osteoid osteoma**

This is uncommon in the ribs (under 1%) and is found in the posterior costal arch or posterior part of the body of the rib. Imaging reveals the typical appearance of a small cortical or subperiosteal lacuna under a centimeter in size and classically containing central calcification. The lesion is associated with a pronounced compact periosteal reaction [16].
Tumors of the rib

Figure 4. Giant cell tumor (GCT). a: giant cell tumor in a 31-year-old woman with right anterior chest wall pain. Axial CT showing a lytic lesion in the right anterior rib arch with clearly delineated outlines and a break in the cortical bone (arrowhead). Note the absence of calcifications; b: giant cell tumor in a 27-year-old woman with left lateral chest wall pain. Bone and soft tissue window CT showing the tissue appearance of the lesion, which is diffusely enhanced after injection (arrowhead). Note the eccentric appearance of the lesion against the long axis of the rib (arrow).

Other benign lesions

Post-fracture bone callus

The differential diagnosis with an osteoblastic tumor may arise particularly if it hypertrophic (Fig. 6a).

Research will thus be based on the patient's clinical history, which is essential in identifying trauma.

Its main imaging features are: bone callus perpendicular to the axis of the rib, involvement of several adjacent ribs with findings at the same site in each rib (Fig. 6b) and a deformed appearance of the broken rib after consolidation (vicious callus) (Fig. 6c).

A recent fracture is straightforward to diagnose on standard radiography. Where uncertainty exists, an ultrasound of the painful area shows a break in the cortical bone and a subperiosteal hematoma (Fig. 6d). The fracture is seen easily on a CT. This can also be used to investigate for any other fractures of any age or even pseudarthrosis. No osteolysis or soft tissue swelling is seen (at most, minor hematic infiltration of the soft tissues around the perimeter of a recent fracture).

Post-irradiation complications

Osteonecrosis of the ribs is a classical complication of radiotherapy for breast cancer. Depending on the series, it is found in less than 1% of cases and its incidence has fallen considerably with new conformational radiotherapy techniques. Rib necrosis occurs late, on average 12 to 18 months after radiotherapy and may be complicated by fractures, which are often multiple and painless, located in the first five ribs (radiotherapy territory). The second most common complication is infection.

In the early phase (after exposure to radiotherapy) imaging (radiography and CT) shows bone thinning which is associated with fibrous connective tissue containing fibroblast hyperproliferation and excessive deposition of collagen matrix. Once the lesion has become established, the
radiated bone has a disorganized Paget-like trabecular structure (Fig. 7).

Infection, particularly tuberculosis osteitis
Costal tuberculosis is a very rare form of osteoarticular tuberculosis representing 0.5 to 5% of this form of the disease [17]; Bishara et al., showed that its prevalence is increased in pulmonary infection with contiguous rib involvement [18].

Clinical and radiological features may be misleading. Radiography may be normal because of the delay between radiological and clinical findings. Subsequently, a predominantly osteolytic lesion develops, occasionally with areas of sclerosis. Opacification around the bone may be seen due to soft tissue swelling. CT shows an area of osteolysis with clearly delineated outlines, which may sometimes resemble a tumor. It is sometimes associated with a periosteal reaction or bone sequestration. CT provides a better assessment of extension to soft tissues (Fig. 8a) and can be used to investigate for any collections, which are present. A further assessment may demonstrate associated lymph node involvement as can be seen in this case of lymph node tuberculosis with rib involvement (Fig. 8b).

Acute rib infections are often secondary to pyogenic organisms and they are most frequently found in children. These are associated with cortical osteolysis and a periosteal reaction, frequently with soft tissue infiltration.

Degenerative changes in the ribs may also be seen in chronic pleural effusions [19] (Fig. 9).
Figure 6. Rib fractures. a: axial CT in a 65-year-old patient complaining of painless right chest wall swelling. Past history of old rib injury. Hypertrophic bone callus with persistent breach in continuity suggesting a pseudarthrosis (arrowhead); b: same patient. Sagittal oblique CT. The bone callus bridges between two anterior rib arches (arrowheads); c: axial CT. On the left: recent (arrowhead) and old (short arrow) costal fractures. On the right: vicious callus (long arrow); d: chest wall ultrasound showing a recent unicortical rib fracture demonstrated by a discontinuation of the hyperechogenic cortical line (arrow). Note the subperiosteal hematoma (arrowheads).
Figure 7. Seventy-two-year-old female patient with an old (more than 20 years ago) past history of left breast cancer treated with surgery and radiotherapy. Axial CT in the bone window showing a dense appearance with disorganization of the left anterior rib arch (arrow) as a result of radiation necrosis.

Figure 8. Tuberculosis costal osteitis in a 50-year-old female patient followed up after a liver transplant. a: axial and sagittal oblique CT in the bone and soft tissue window. Pseudo-malignant osteolytic lesion with extension to the soft tissues (arrowheads); b: chest CT in the mediastinal window. Enlarged necrotic mediastinal and hilar lymph nodes (arrowhead).

Figure 9. Sixty-five-year-old female patient with right pneumo-nia and chronic pleural effusion. Axial CT in the bone window. Slightly irregular internal cortex (arrowhead) associated with a band of osteosclerosis (arrow) in contact with the effusion.
Benign bone island or enostosis
This is a common benign lesion, which is seen at all ages and is asymptomatic. It is homogeneous in density and is often oblong along the axis of the bone markings (Fig. 10). The classical spiculated appearance is less apparent on the ribs.

Malignant rib tumors
The commonest malignant lesions in the elderly are metastases and myeloma. Approximately 70% of malignant rib lesions are metastases, which have blurred outlines, breach the cortical bone and invade the soft tissues. The difficulty they pose in diagnosis is that they may look like a benign lesion. In addition, tuberculosis can often look like a tumor, which may cause concern. The other malignant rib tumors are primary and consist of chondrosarcoma, which is the predominant tumor in adults and Ewing’s sarcoma in children.

Metastases
After the spine and femur, the rib is the third most common site for secondary lesions. These may be single or multiple. Patients often have a history of malignancy although these lesions may be found incidentally.

Rib metastases are rarely more than 5 cm in size and are often focal. Imaging appearances vary greatly. The lesion may be:
• osteolytic in breast or lung (Fig. 11a, b, c), thyroid or uterine cancer;
• sclerotic in prostatic (Fig. 12) breast, bronchial, stomach, thyroid or colonic cancer;
• mixed, particularly in breast or lung malignancies (Fig. 13).

Myeloma
After the spine, the rib is the second most common site of myeloma and is present in 50% of patients treated for multiple myeloma. It usually occurs in men over 50 years old. The rib lesions are often multiple as costal plasmocytoma is rare.

The lesions cause bone pain and are sometimes found after a pathological fracture (Fig. 14a). They may be found incidentally.

CT shows multiple osteolytic lesions with round or oval lacunae, which have clearly delineated outlines (Fig. 14b). Occasionally, the lesions are surrounded by an osteosclerotic border. They may occur anywhere in the rib although the middle costal arch is a typical site. Soft tissue swelling is frequently found (Fig. 14c).

Chondrosarcoma
Eleven to 16% of chondrosarcomas are found in the rib [20], making it the commonest primary rib tumor. Age at diagnosis ranges from the third to seventh decade of life. It is rarely
found in patients under the age of 20 years old and mostly affects men.

Swelling is the usual initial symptom followed by pain when the cortical bone ruptures. Clinicians should be alerted by the rapidly increasing size of the swelling, particularly for patients over the age of 40.

In 90% of cases, the tumor is primary although it may also occur as a result of degeneration of a chondroma or osteochondroma [20].

The lesion is typically located in the anterior arches of the first five ribs and is often associated with a soft tissue mass. Radiological appearances depend on the histological grade of the tumor, which may appear as more or less delineated osteolysis with or without attachments to the periosteum.

A chondroid matrix, calcified to a greater or lesser extent, is seen in 2/3 of cases (this is highly suggestive of the diagnosis).

The osteolysis can be seen better on CT which is used, above all, to assess calcifications and soft tissue disease (Fig. 15).

MRI shows hypointense cartilaginous lobules on a T1 sequence and hyperintense T2 signals separated by hypointense septa. Calcifications are of zero intensity on all sequences. Gadolinium injection shows relatively early septal and peripheral uptake on dynamic sequences. Fields or nodules of uptake can also be seen. In addition, a peri-medullary hyperintensity on T2 fat sat weighted sequences is highly suggestive of malignant disease.

Osteosarcoma

Osteosarcoma affects the ribs in 1 to 3% of cases [21]. It is a primary tumor of the young (between 15 and 25 years old) although may be seen in far older people, particularly patients with Paget’s disease or following radiotherapy.

It classically presents as a large lesion with a bone matrix forming a sheath over the rib with areas of hemorrhage, necrosis or ossification. Radiography may show osteolysis with breach of the cortical bone and a pronounced spiculated periosteal reaction (‘sun ray’). Soft tissue invasion can be seen better on CT and MRI.

Ewing’s sarcoma

This represents 5 to 10% of malignant rib tumors [22]. It generally occurs between the ages of 10 and 15 years old as a painful chest wall mass often associated with fever.

Radiography (Fig. 16a) and CT show an extrapleural mass, which is eccentric from the rib with osteolysis and a spiculated or lamellar periosteal reaction. Osteolysis is present in 80% of cases [23]. The periosteal ‘onion bulb’ reaction is less common in the ribs than in long bones. The predominant feature of the rib tumor is a large soft tissue mass over 10 cm in size surrounding the rib [23] (Fig. 16b).
Figure 14. Multiple myeloma in a 65-year-old female patient with left shoulder pain after minor injury. a: postero-anterior radiograph showing a pathological fracture of the middle of the left clavicle and disappearance of the middle arch of the 6th left rib (arrowheads); b: SPECT CT and axial CT. Left anterior rib lacuna with clearly delineated outlines and no osteosclerotic border and increased uptake on scintigraphy (arrowheads); c: axial and coronal CT images in the bone and soft tissue window. Left middle rib osteolytic lesion (arrowhead) with expansion into the soft tissues (arrows).
Figure 15. Chondrosarcoma in a 70-year-old male patient with left anterior chest wall swelling which had increased in volume. Axial CT in the bone window. Large mass with a chondroid matrix, which is partially calcified (arrow) developing in the left anterior rib arch. Note the extension to the soft tissues (arrowheads).
Figure 16. Ewing's sarcoma in a 15-year-old boy with deterioration in general health and left chest wall pain. a: postero-anterior chest radiograph. Large left axillary chest opacification (arrowheads); b: CT in the Bone and soft tissue window. Extrapleural tissue mass (arrows), which is eccentric from the rib with osteolysis and a spiculated periosteal reaction (arrowheads).
Conclusion

With any rib lesion, an investigation for evidence of benign or malignant disease (osteolysis, periosteal reaction, soft tissue invasion) must be undertaken. To do this, the patient’s age and the clinical context must be considered. The site of the lesion in the rib can aid the diagnosis. The first diagnosis to consider, for benign lesions, is fibrous dysplasia. If a lesion is aggressive in appearance, metastases or myeloma should be considered primarily as a diagnosis. It is also important to remember that the diagnosis can only be confirmed with a biopsy and histological examination.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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