Ultrasonography of the Chest Wall

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Contents

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2.1 Introduction

Due to its rather superficial location, the chest wall is almost ideally suited for ultrasound investigation. The primary indications for performing an ultrasonography of the chest wall include the clarification of swelling or suspicious findings in the chest wall on palpation, and targeted investigation of painful sites in the chest wall (Abstract). Furthermore, ultrasonography of the chest wall plays an important role in performing biopsies and planning surgery for tumors of the chest wall or space-occupying lesions of the lung invading the chest wall . Last but not least, ultrasound plays an important role in the investigation of lymph nodes

Indications for an Ultrasound Investigation of the Chest Wall

- Swelling of the chest wall
- Pain
- Ambiguous findings on palpation
- Ambiguous findings on X-rays
- Chest trauma
- Tumor staging
- Intervention
- Follow-up, monitoring progress

2.2 Accumulation of Fluid

2.2.1 Hematomas

Depending on their red blood cell content and degree of organization, hematomas may cause a variety of echo patterns. Usually they are anechoic or hypoechoic (Fig. 2.1). Occasionally one finds subtle veil-like internal echoes. Intermediate forms may be seen in rare cases, which include more dense echoes in the internal spaces. Organized hematomas may be very inhomogeneous in terms of their echo pattern.

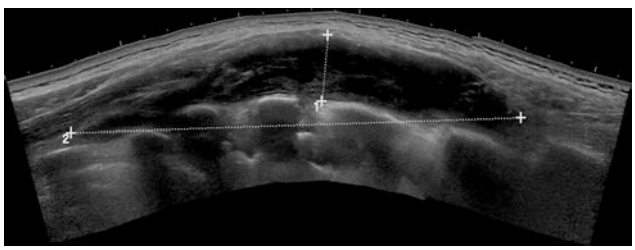

Fig. 2.1 Hematoma. Extensive hematoma of the dorsal portion of the chest wall after a fracture of the scapula and a serial rib fracture. Ultrasound investigation reveals an anechoic septated hematoma measuring 15 cm in length

2.2.2 Abscesses of the Chest Wall

Depending on their cell and protein content, a variety of internal structures may be found in an abscess cavity. Thus, the content of abscesses may be similar to that of hematomas. Quite often they cannot be delineated by ultrasound investigation alone, especially because there may be many intermediate stages such as infected hematomas. A major difference between abscesses and sterile hematomas is that abscesses tend to be accompanied by a capsule of differing shape, with floating internal structures (Fig. 2.2). In the majority of cases, clinical features such as reddening of the overlying skin clearly indicate the presence of an abscess.

2.2.3 Postoperative Seromas

Postoperative seromas are frequently observed after a muscle-sparing lateral thoracotomy. Postoperative seromas are largely anechoic, round or bizarre in shape, and do not have a capsule Lymphatic cysts have a similar structure and are mainly round or -oval. Occasionally the occluded lymphatic vessel can be visualized.

Fig. 2.2 A painful swelling in the right armpit raises suspicion of a sweat gland abscess. Ultrasonography reveals a largely anechoic space-occupying lesion measuring 3 x 1.5 cm in size. The moderately echogenic margin is indicative of an incipient capsule. The ultrasound-guided puncture reveals pus

2.3 Space-Occupying Lesions of the Chest Wall

Tumors of the chest wall are rather rare and usually benign. In most cases, the clinical symptoms alone permit conclusions about the benign or malignant nature of the lesion. Benign tumors are usually asymptomatic, grow slowly, and retain their tissue margins. In some tumors such as lipomas or fibromas, the combination of clinical symptoms and ultrasound features is so typical that a biopsy is not required. In contrast, malignant tumors grow rather rapidly, invasively, and are painful.

2.3.1 Lipoma and Fibroma

Lipomas are the most common tumors of the chest wall and are usually diagnosed by clinical investigation. 'The echogenicity of lipomas and fibromas depends on their cellular fat content, the quantity of connective tissue, and interstitial impedance differences. The texture may range from hypoechoic to relatively echodense (Fig. 2.3). Their demarcation from the environs may be blurred, and a capsule may develop.

2.3.2 Neurogenic Tumors

Neurogenic tumors such as schwannomas or neuromas are seen on ultrasound as oval hypoechoic lesions with sharp demarcations, and therefore do not differ significantly from space-occupying lesions of a different etiology. Evidence of the corresponding nerve is a diagnostic sign of a neurogenic tumor (Fig. 2.4).

2.3.3 Sarcoma and Soft Tissue Metastases

A major criterion of a malignant space-occupying lesion is the presence of invasive growth (Fig. 2.5). In terms of echotexture it is frequently hypoechoic, with inhomogeneous hyperechoic portions. The use of color-Doppler ultrasonography may be helpful in assessing hypoechoic structures suspected of being malignant. The suspicion of a malignant lesion may be confirmed by the type of vascularization and the course of vessels.

Knowledge of the pattern of vascularization is also very helpful in performing ultrasound-guided punctures. In this convenient location, which is usually very close to the transducer, an ultrasound-guided puncture is very useful because it provides material for histological investigation and subsequent confirmation of the diagnosis.

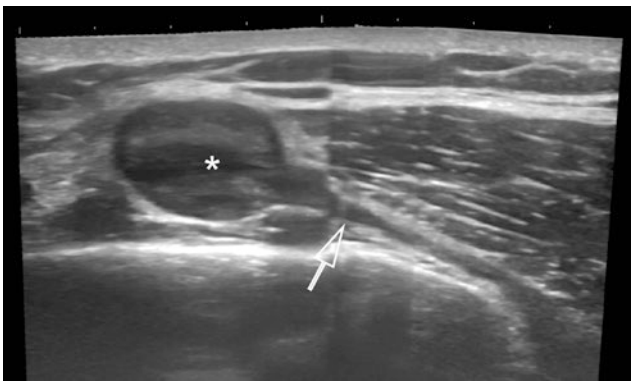

Fig. 2.4 Neurofibroma of the chest wall (*) in a patient with known neurofibromatosis. Evidence of the corresponding nerve is a diagnostic sign of a neurogenic tumor (*arrow*). Courtesy of Gerd Brodner, Medical University of Vienna

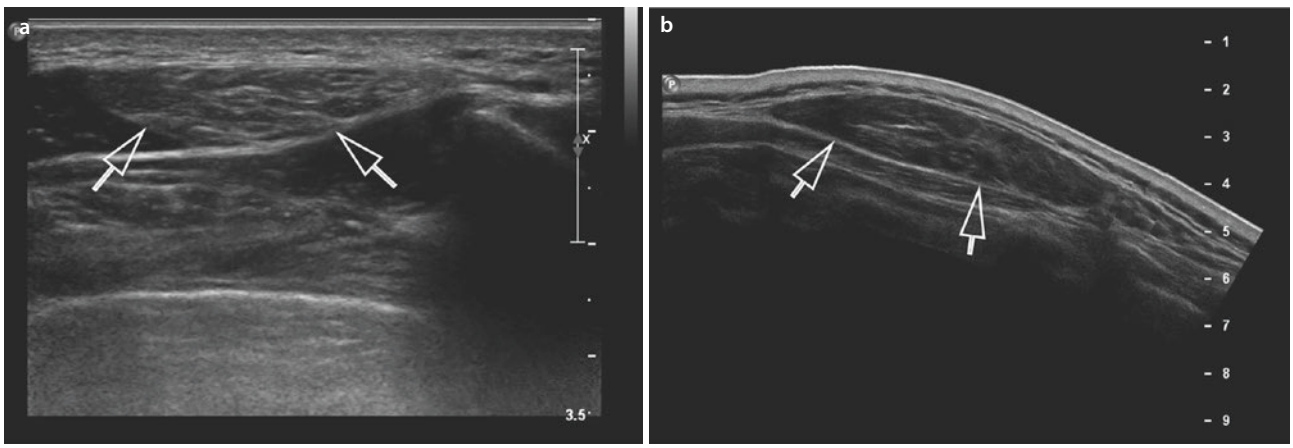

Fig. 2.3 **a**, **b** Lipomas of the chest wall: **a** Lipoma with a hyperechoic texture, **b** Lipoma with a hypoechoic texture

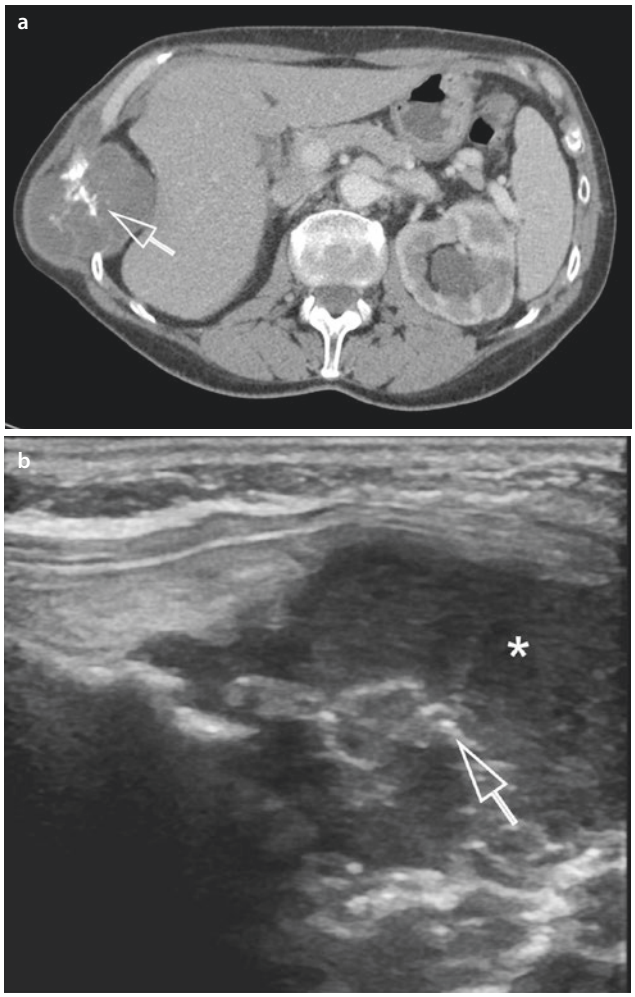

Fig. 2.5 **a**, **b** Chondrosarcoma of the chest wall **a** CT reveals an extensive space-occupying lesion with dense soft tissue and chondroid calcifications (*Arrow*). **b** Ultrasonography shows an inhomogeneous hypoechoic space-occupying lesion (*) with coarse cloddy calcifications (*Arrow*). An ultrasound-guided biopsy was able to confirm the suspected chondrosarcoma

The treatment of choice for a sarcoma is usually radical surgery. The resection margins and microscopic nodules can be determined better by performing a preoperative ultrasound investigation than by CT or MRT (Briccoli et al. 2007a, b). However, a preoperative CT and MRI are necessary to determine the intraosseous spread of the tumors, their depth, and exclude pulmonary metastases.

2.4 Lymph Nodes

Subcutaneous palpable swellings are usually caused by enlarged lymph nodes . The ultrasound morphology of lymph nodes is indicative of their etiology and permits a tentative assessment of the malignant or benign nature of the lesions in accordance with the patient's clinical condition (Table 2.1). High-frequency probes provide a highly differentiated B-mode image. The pattern of vascularization on color Doppler provide information about the type of lymph nodes. The possibility of assessing the malignant or benign nature of a lesion has certainly been improved by the better resolution of the B-mode image as well as the use of various Doppler procedures for the assessment of vascularization patterns (Ying et al. 2004).

However, the benign or malignant nature of a lesion can only be established tentatively by its ultrasound morphology. Confirmation of the diagnosis requires a histological investigation of tissue obtained by performing a puncture. Alternatively, the course of the disease will confirm the diagnosis. In clinical practice, changes in ultrasound morphology are especially significant. Thus, ultrasound follow-up investigations are useful to confirm the diagnosis of inflammatory disease and document the success of treatment in cases of malignant lymph nodes.

2.4.1 Inflammatory Lymph Nodes

Inflammatory lymph nodes are rarely larger than 20 mm in size. They usually have smooth margins, are oval, triangular, or longitudinal (Fig. 2.6). A typical feature of lymphadenitis is the presence of lymph nodes arranged like a pearl necklace along lymph node stations. In accordance with the anatomical structure, one frequently finds a more or less echogenic internal zone which is referred to as the hilar fat sign and corresponds to the fatty and connective tissue in the center of the lymph nodes. This sign is especially seen in healing inflammatory processes. The zone, with sharp edges as opposed to the surroundings, is hypoechoic. One commonly finds regular courses of vessels in this region on Doppler ultrasound. The lymph node hilum with the afferent and efferent vessels are also seen.

2.4.2 Tuberculosis

After the lung, lymph nodes are the second most common site of manifestation of tuberculosis (TB). Lymph node tuberculosis occurs in about 90%of patients without accompanying pulmonary tuberculosis.

On the B-mode ultrasonography image, lymph nodes are seen in various forms in the presence of tuberculosis. Some patients have rather sharply demarcated and sequentially arranged lymph nodes, whereas others have lymph nodes spreading into the environs diffusely or centrally fused hypoechoic lymph nodes with blurred margins, similar to metastases of solid tumors (Figs. 2.7 and 2.8). The pattern of vascularization of

Table 2.1 Ultrasound morphology of lymph nodes

	Inflammatory	Malignant lymphoma	Lymph node metastasis
Shape	Oval, longitudinal	Round, oval	Round
Edge	Smooth	Smooth	Irregular
Demarcation	Sharp	Sharp	Blurred
Growth	Pearl-necklace-like	Expansive, displacing	Invasive
Movability	Good	Good to moderate	Poor
Echogenicity	Hypoechoic margin, "hilar fat sign"	Hypoechoic, pseudocystic	Inhomogeneous, hypoechoic
Vascularization	Regular, central	Irregular	Corkscrew-like

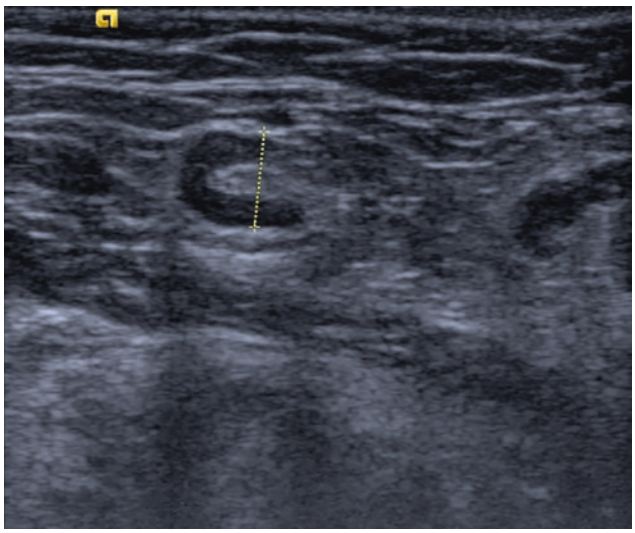

Fig. 2.6 Ultrasound image of a normal lymph node with a bean-shaped appearance, a hyperechoic hilum, and a hypoechoic cortex

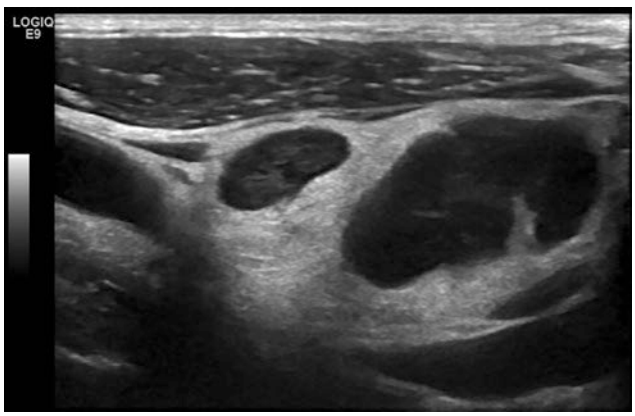

Fig. 2.7 Bean-shaped hypoechoic lymph nodes with sharp margins and a significant surrounding soft tissue edema

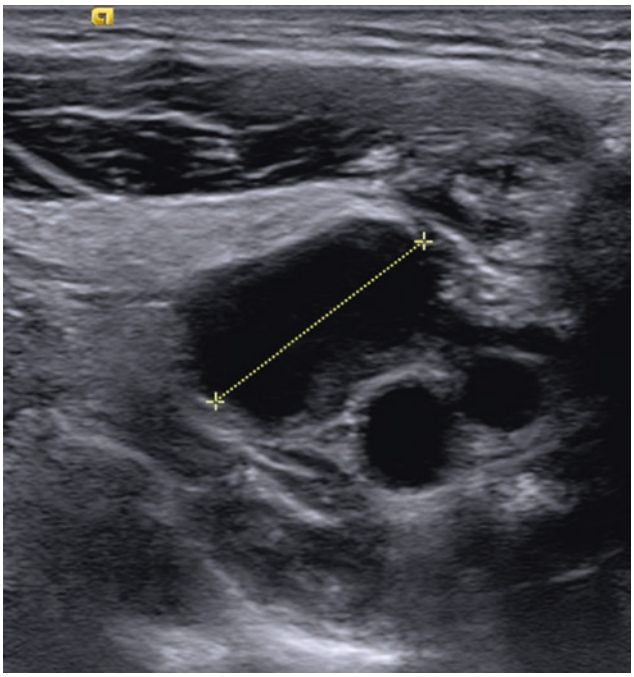

Fig. 2.8 Pseudocystic necrosis of a lymph node in the presence of lymph node tuberculosis

tuberculotic lymph nodes cannot be distinguished from that of lymph node metastases.

2.4.3 Malignant Lymphoma

On the B-mode ultrasound image, lymph nodes in the presence of lymphoma are usually round, hypoechoic, with sharp margins, without a hilum, and thus cannot be distinguished from lymph node metastases of solid tumors (Fig. 2.9). Markedly poor echogenicity of

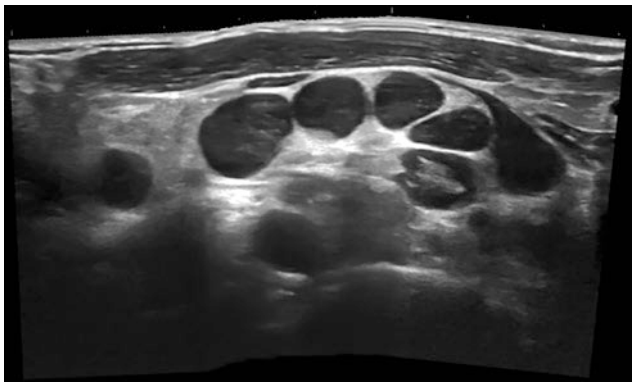

Fig. 2.9 Lymph nodes arranged sequentially in a cobblestone-like pattern, in a patient with a small-cell lymphocytic lymphoma. The lymph nodes are round, with sharp margins, hypoechoic, and without a hilum

Fig. 2.10 Micronodular pattern of a lymph node in a patient with a small-cell lymphocytic lymphoma

the lymph node could be interpreted as sign of lymphoma. On older ultrasound devices the lymph nodes look almost like cysts. On modern ultrasound devices, high-resolution transducers usually show a micronodular reticular internal echo (Fig. 2.10) (Ahuja et al. 2001). Lymph nodes arranged bilaterally around a vessel ("sandwich-like") may be interpreted as a sign of a malignant lymphoma. The vascularization of malignant lymphomas may be regularly enhanced or even irregular at the edges.

2.4.4 Lymph Node Metastases

On the B-mode ultrasonography image, round lymph nodes and the loss of the hyperechoic hilum are signs of lymph node metastases (Fig. 2.11). The demarcation is frequently blurred. Aggressive growth in terms of the invasion of muscles and vessels may be observed. Lymph node metastases are usually irregularly hypoechoic. Lymph node metastases of papillary thyroid carcinomas may be hyperechoic due to thyroglobulin deposits (Esen 2006). Size is an unreliable criterion of malignancy. In supraclavicular lymph nodes, a transverse diameter of 5 mm or more is considered pathological. Occasionally one also finds reactive lymph nodes in the vicinity of metastatic lymph nodes. The pattern of vascularization of lymph node metastases is very characteristic: vessels tend to be located at the edges, are distributed unevenly, follow a chaotic route, flow in various directions, and show changes in color (Tschammler et al. 2002).

Non-palpable lymph node metastases can be seen on ultrasound. Therefore, in the presence of breast cancer an ultrasound investigation of the axilla is recommended in preoperative staging and when monitoring the progress of disease (Ciatto et al. 2007; Krishnamurthy et al. 2002; Johnson et al. 2011).

An ultrasound investigation of the supraclavicular region is especially important in staging bronchial carcinoma because enlarged and usually non-palpable supraclavicular lymph nodes are found in as many as 51% of patients with mediastinal N3 lymph nodes (Prosch et al. 2007a, b; van Overhagen et al. 2004). An inoperable tumor stage (III B) can be demonstrated with minimal

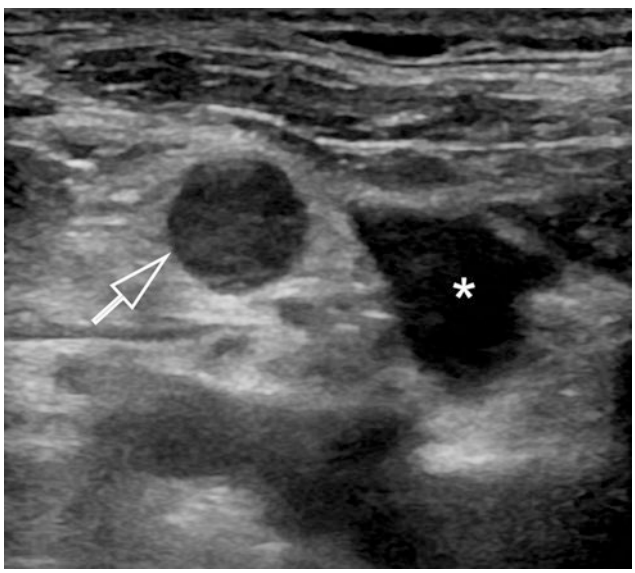

Fig. 2.11 Lymph node metastasis of a supraclavicular lymph node *(arrow)* immediately adjacent to the jugular vein *(*)*. On ultrasound the lymph node has rounded contours and no fatty hilum

risk, at a low cost, by performing an ultrasound-guided biopsy of the lymph nodes (Figs. 2.12, 2.13, and 2.14).

The change in the size of lymph node metastases is a useful parameter of its progress. Despite the fact that the patient responds to chemotherapy or radiotherapy, reactive lymph nodes may persist.

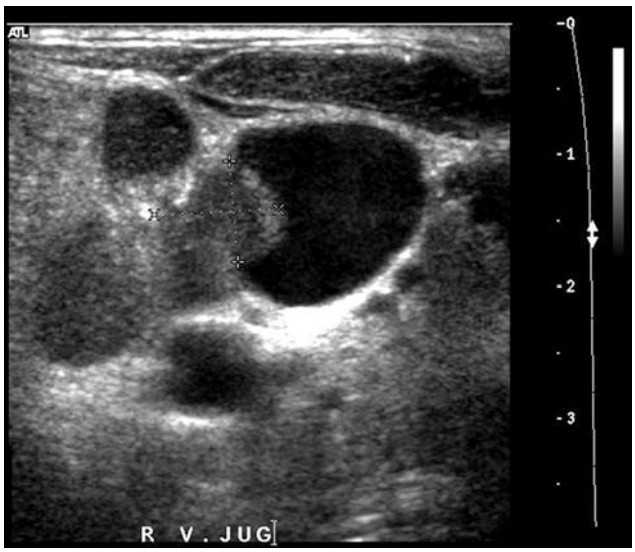

Fig. 2.12 Supraclavicular lymph node metastasis of a squamous cell carcinoma of the lung with disruption of the capsule and invasion into the adjacent jugular vein

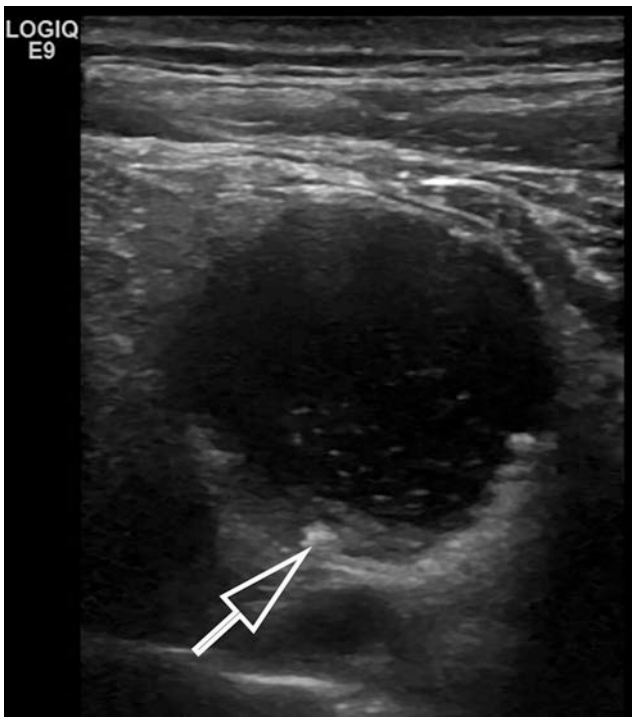

Fig. 2.13 Supraclavicular lymph node metastasis of an ovarian carcinoma. The lymph node is seen on ultrasound as a nearly anechoic (cystic) rounded lesion with sharp margins and calcified edges (*arrow*)

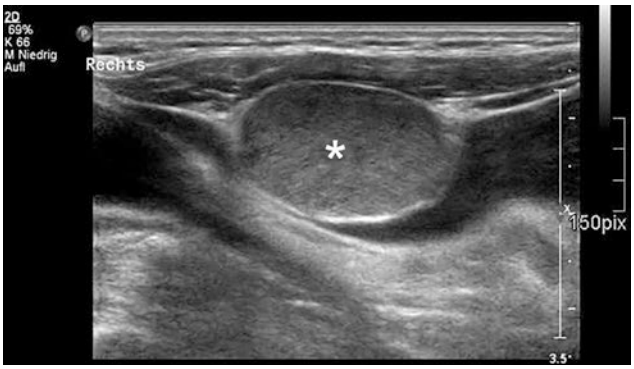

Fig. 2.14 Supraclavicular lymph node metastasis of an adenocarcinoma of the lung. On high-resolution ultrasound it is seen as a largely homogenous hyperechoic oval lymph node with sharp margins and without a hyperechoic hilum (*)

2.5 Bony Thorax

2.5.1 Fractures of the Ribs and the Sternum

Non-displaced rib fractures may be difficult to diagnose in clinical routine because rib fractures frequently escape detection even on targeted X-rays of the ribs. However, timely detection of a rib fracture is important for early initiation of appropriate pain treatment on the one hand, and for differential diagnosis on the other. A number of studies performed in the last few decades have shown that rib fractures are demonstrated with much greater sensitivity by a targeted ultrasound investigation than by an X-ray of the ribs (Bitschnau et al. 1997; Griffith et al. 1999a, b; Turk et al. 2010; Battle et al. 2019). In 19 of 20 patients with no rib fractures on conventional X-rays, Turk et al. found rib fractures in the ultrasound investigation (Turk et al. 2010.

By performing a targeted investigation at the site of pain, a rib fracture can be detected quite rapidly even by an inexperienced investigator. In contrast, the diagnostic reliability of ultrasonography in demonstrating fractures of the sternum is poor.

Criteria of a fracture on ultrasound investigation include direct evidence of a fracture gap or a cortical step (Fig. 2.15). In cases of a very narrow fracture gap (more marrow than the lateral resolution capacity of ultrasound), the fracture may be demonstrated indirectly by the evidence of reverberation echoes or the so-called chimney phenomenon “. These reverberation artefacts arise at the boundaries of fracture fragments and extend vertically into the deeper aspect. In non-displaced fractures, the chimney phenomenon can be triggered by gentle pressure on the point of pain. Some patients have a circumscribed hematoma , which is an indirect sign of a fracture.

Demonstration or exclusion of concomitant injuries like a pneumothorax, a hemothorax , a lung contusion, or injuries to the organs of the upper abdomen are clinically more important than the detection of rib fractures. In clinically stable patients, the rib fracture itself *and* the concomitant injuries can be clarified by performing an ultrasound investigation (Wüstner et al. 2005).

The narrow gap between the osseous cartilaginous portion of the rib and the primary bony rib, a regular phenomenon in elderly patients, may lead to the false-positive diagnosis of a rib fracture (Fig. 2.16).

Anatomical conditions and normal variants should be considered when assessing the sternum as well, in order to rule out the risk of false-positive diagnoses. The normal discrete cortical interruption in the synchondrosis between the corpus and the manubrium should not be mistaken for a fracture. Various forms of missing fusion or bone appositions that may occur in rare cases should also be taken into account (Chan 2009; Hyacinthe et al. 2012).

Fig. 2.15 Rib fracture with a cortical step directly at the site of pain

In clinical monitoring one first finds a local hematoma as a hypoechoic/anechoic edge in the region of the fracture gap. The subsequent formation of callus is marked by incipient organization and consolidation. The beginning calcification causes fine acoustic shadows or even complete ossification. Once this has been concluded, all that remains is a forward hump of the continuous and strong cortical reflex (Fig. 2.17). Disrupted healing can be easily established by the absence of continuous ossification. Consolidation starts from the 3rd to 4th week after an injury; in normal cases complete restitution is achieved after a few months (Friedrich and Volkenstein 1994).

2.5.2 Osteolytic Metastases

An osteolysis is usually a tumor metastasis. A notable aspect of an osteolysis is an interrupted and destroyed cortical reflex with pathological echo transmission. Osteolytic metastases are usually well demarcated, round or oval space-occupying lesions, partly hypoechoic, and of gross echostructure. Color-coded duplex ultrasonography demonstrates corkscrew-like newly formed vessels. In tumor staging, ultrasound is a reliable procedure to differentiate rib fractures from bone metastases (Paik et al. 2005). In cases of doubt, an ultrasound-guided biopsy can be used at minimal risk for histological investigation and confirmation.

During ongoing treatment, osteolysis in the bony portion of the chest serves as a progress parameter in the presence of multiple myeloma, small-cell bronchial carcinoma, prostate or breast carcinoma. An increase or decrease in size on the one hand, and a change in internal structures in terms of ultrasound morphology on the other, can be compared and documented. Recalcification under treatment is seen earlier on ultrasonography than on X-rays.

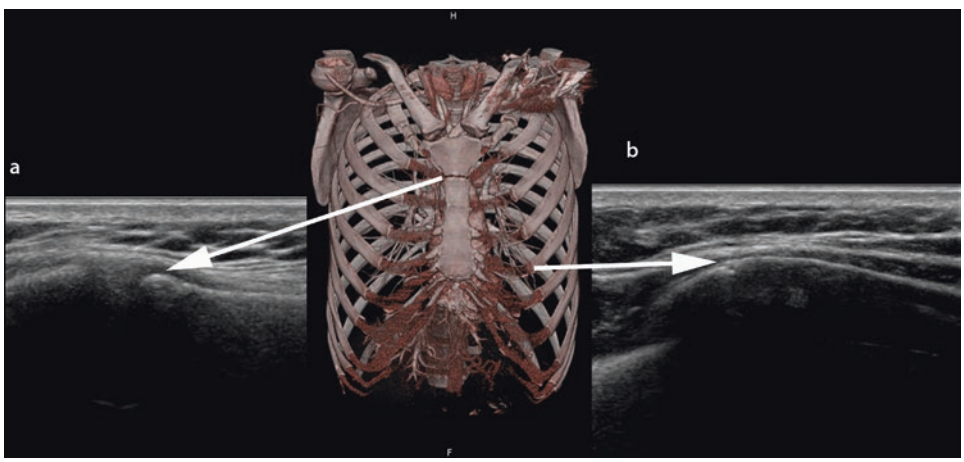

Fig. 2.16 Potential reasons for a false-positive diagnosis of a rib fracture on ultrasound investigation. **a** Cortical interruption in the region of the synchondrosis between the corpus and the manubrium. **b** Gap between the osseous cartilaginous portion of the rib and the primary osseous rib

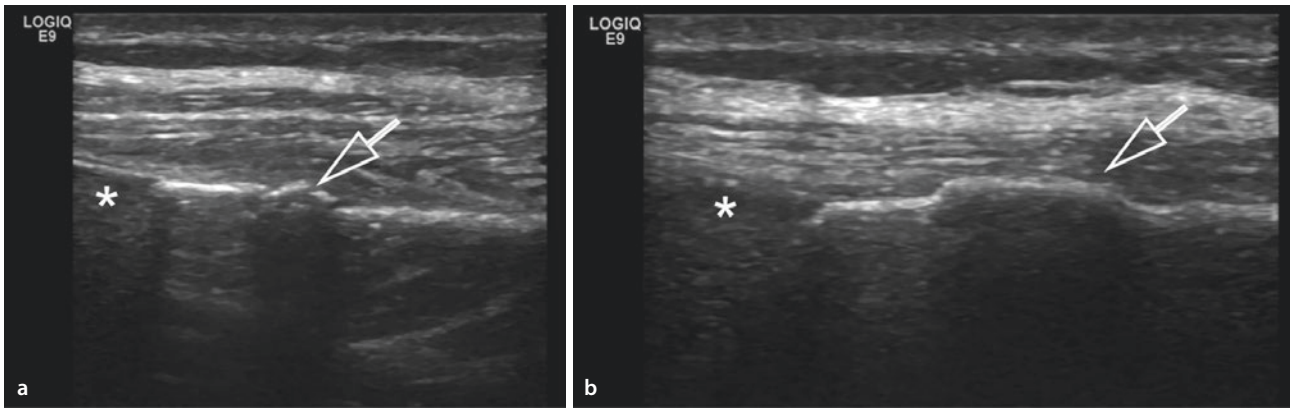

Fig. 2.17 **a**, **b** Fracture **a** A recent fracture (*arrow*) of a rib in the ventral portion of the costal arch, close to the cartilaginous part (*). **b** Complete healing and a minimal hump: a residual finding after 3 months (*arrow*)

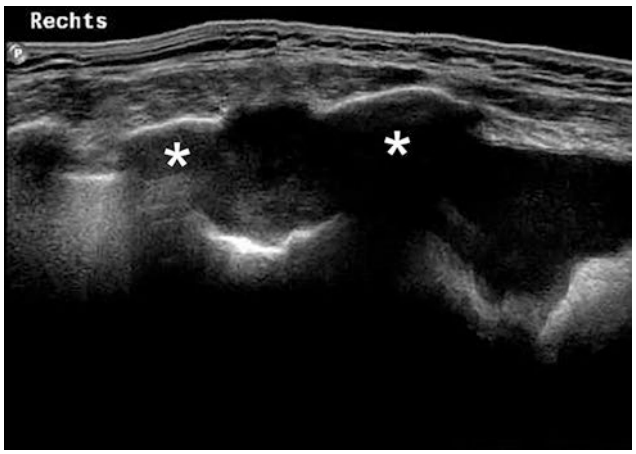

Fig. 2.18 Panoramic view of a lung carcinoma invading the chest wall (arrow) between two ribs (*)

Cave

The staging of bone metastases cannot be performed by ultrasonography. It would be meaningful to examine the sites of positive scintigraphy findings, palpable swellings, and painful sites.

2.5.3 Invasion of the Chest Wall by Bronchial Carcinoma

Percutaneous ultrasonography is especially informative for the assessment of an invasion of the chest wall by a lung carcinoma. According to the TNM staging system, an invasion of the chest wall is defined as a T3 tumor and is found in 6% of patients at the time of diagnosis (Mountain 1997; Facciolo et al. 2001). Invasion of the chest wall as such is no exclusion criterion for curative resection of the tumor but is of crucial importance for the surgical procedure because parts of the chest wall also must be resected in these cases (Fig. 2.18).

Owing to its high spatial resolution, ultrasonography is markedly superior to CT for evaluating an invasion of the chest wall (sensitivity 89–100 % versus 42–68 %) (Bandi et al. 2007; Suzuki et al. 1993). Reliable signs of invasion include direct evidence of tumor spread into the chest wall or rib destruction (cf. Overview, Fig. 2.19) (Bandi et al. 2007). Widening of the pleura and/or limited respiratory motion of the tumor are interpreted as indirect signs because an inflammatory reaction of tissue surrounding a tumor may also cause both of these changes.

Signs of Invasion of the Chest Wall

Reliable signs

- Direct evidence of chest wall invasion
- Rib destruction

Additional signs

- Pleural thickening
- Limited respiratory motion

Preoperative clarification of an invasion of the chest wall is especially significant in tumors that invade the chest wall at the apex of the lung; these are referred to as Pancoast tumors. ‘According to the TNM staging system, Pancoast tumors are T3 tumors as long as they do not invade the mediastinum, a vertebral body, the subclavian artery or vein, the C8 nerve root or higher (Detterbeck et al. 2013a, b). The imaging procedure of choice for the investigation of a Pancoast tumor is an MRI scan. In patients who cannot be investigated by MRI due to contraindications, invasion of the nerve roots or the plexus can be determined by a targeted ultrasound investigation (Fig. 2.20).

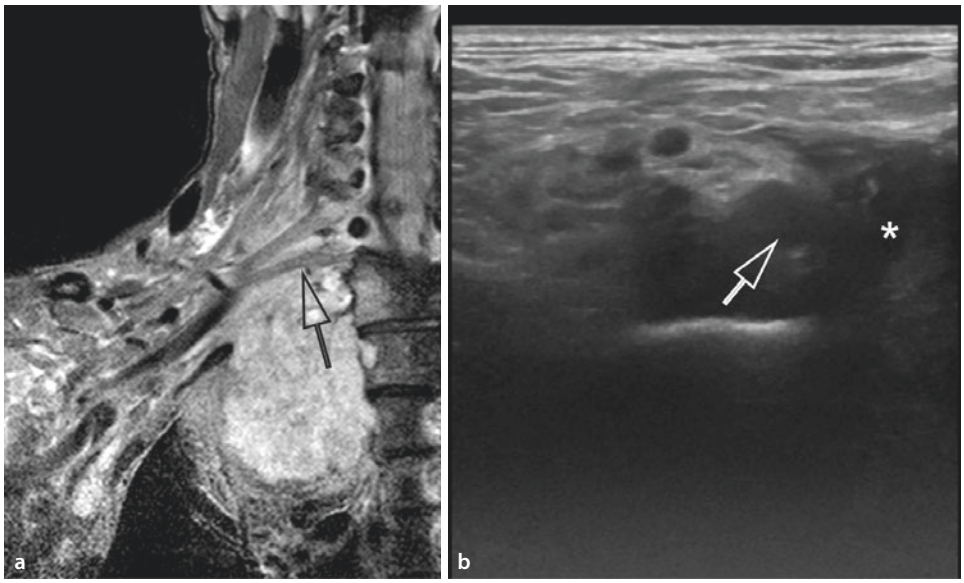

Fig. 2.19 **a**, **b** Pancoast tumor on the right side **a** MRI (coronal T2 STIR) shows an extensive tumor growing around the C8 nerve root and touching the C7 root. **b** High-resolution ultrasound. The C8 nerve root (*arrow*) in the efferent portion is entirely ensheathed by the tumor (*) and swollen

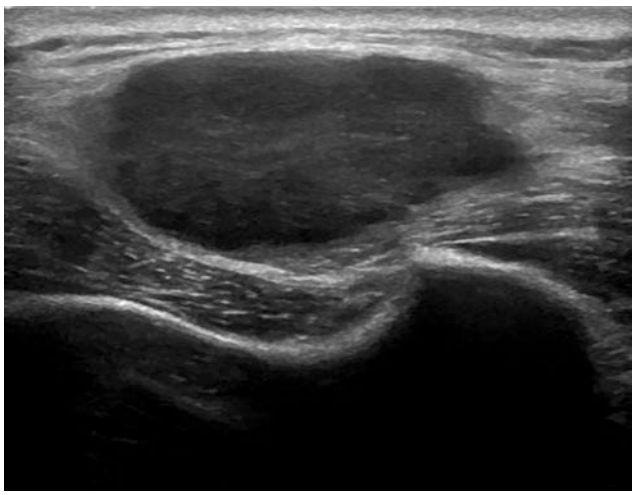

Fig. 2.20 Soft tissue metastasis of a squamous cell carcinoma. On ultrasound the metastasis is seen as a hypoechoic space-occupying lesion with partly sharp and partly blurred margins

Conclusion

Fractures of the ribs as well as the sternum are seen well on ultrasound. Fracture diagnosis based on ultrasound is not only more sensitive than conventional X-rays, but also provides reliable and rapid views of soft tissue lesions, hematomas and pleural effusions.

The visualization of lymph nodes and a tentative assessment of the malignant or benign nature of a lesion are important indications to perform an ultrasound investigation of the chest wall. In case a puncture needs to be performed for the purpose of treatment, all ambiguous lesions of the chest wall can be easily accessed for an ultrasound-guided puncture and subsequent histological confirmation of the diagnosis. The risk associated with puncture are very low because of the convenient location of the lesions. When the malignant nature of a chest wall lesion has been proven, its progress under treatment can be monitored by ultrasonography.

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