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Chest wall – underappreciated structure in sonography. Part I: Examination methodology and ultrasound anatomy

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Keywords
ribs, sternum, scapula, sternoclavicular joints, ultrasound

Abstract

Chest wall ultrasound has been awarded little interest in the literature, with chest wall anatomy described only in limited extent. The objective of this study has been to discuss the methodology of chest wall ultrasound and the sonographic anatomy of the region to facilitate professional evaluation of this complex structure. The primarily used transducer is a 7–12 MHz linear one. A 3–5 MHz convex (curvilinear) transducer may also be helpful, especially in obese and very muscular patients. Doppler and panoramic imaging options are essential. The indications for chest wall ultrasound include localized pain or lesions found or suspected on imaging with other modalities (conventional radiography, CT, MR or scintigraphy). The investigated pathological condition should be scanned in at least two planes. Sometimes, evaluation during deep breathing permits identification of pathological mobility (e.g. in rib or sternum fractures, slipping rib syndrome). Several structures, closely associated with each other, need to be considered in the evaluation of the chest wall. The skin, which forms a hyperechoic covering, requires a high frequency transducer (20–45 MHz). The subcutaneous fat is characterized by clusters of hypoechoic lobules. Chest muscles have a very complex structure, but their appearance on ultrasound does not differ from the images of muscles located in other anatomical regions. As far as cartilaginous and bony structures of the chest are concerned, the differences in the anatomy of the ribs, sternum, scapula and sternoclavicular joints have been discussed. The rich vascular network which is only fragmentarily accessible for ultrasound assessment has been briefly discussed. A comprehensive evaluation of the chest wall should include the axillary, supraclavicular, apical and parasternal lymph nodes. Their examination requires the use of elastography and contrast-enhanced ultrasound.

Chest organs and structures have for years played an important role in diagnostic imaging, yet the chest wall has rarely been discussed in the literature of the subject, particularly in sonography[1–9]. Apart from breast tumors, tumours located in this large structure are estimated to constitute only 5% of all neoplastic lesions of the chest[10]. Rib fractures, on the other hand, are one of the most common bone injuries, and they are easier to diagnose on ultrasound than on conventional radiography[5,6,8,9,11].

This study has been aimed at discussing at length the examination methodology and ultrasound anatomy of the thoracic wall, to facilitate professional evaluation of this complex structure.

A 7–12 linear MHz transducer is primarily used to perform the ultrasound of the chest wall. In some cases, particularly in obese and muscular patients or when lesions are located in the paraspinal area, a 3–6 MHz convex transducer is necessary. The ultrasound machine used for the examination should be equipped with Doppler and panoramic imaging options. Some ambiguous findings may be resolved by comparing both sides of the chest wall. Indications for the ultrasound of the chest wall include localized pain or lesions found or suspected on other imaging modalities (radiography, CT, MR or scintigraphy). The posterior and lateral portions of the chest are scanned in a sitting position, whilst the anterior wall is easier to evaluate in a supine position, with the patient lying on their back. The lateral portions of the chest are accessible when the patient raises the arm over their head. To approach the portion of the chest located between the scapula and the spine, the patient should be instructed to place their hand on the contralateral shoulder. Typically, the transducer should be oriented transversely to the intercostal space compared to the intercostal space and moved from the paraspinal to the parasternal area (including the two adjacent ribs in the picture)[6]. Whenever an abnormality is found, it should be evaluated in at least two orthogonal planes, and its blood vessels should also be examined, avoiding any pressure applied with the transducer. Sometimes, observation during deep breathing permits identification of pathological mobility (in rib and sternum fractures or slipping rib syndrome). In B mode, gradual pressure may be similarly helpful, permitting to assess also the compressibility of the examined lesions. The sternum and the scapula are imaged in two orthogonal planes[5,6]. Sternoclavicular joints should be compared in the longitudinal sections of the sternal (proximal) ends of the clavicles[12]. Real time spatial compound imaging (SonoCT) should be utilized, especially when the lesions are located at the interface of the chest and the parietal pleura and the lung, as this scanning technique helps to reduce the number of artifacts[9]. The evaluation should also cover axillary, supraclavicular, apical and parasternal lymph nodes, utilizing elastography and CEUS[13–19].

Four major components make up the chest wall, i.e. the skin, subcutaneous fat, a complex assortment of muscles (sometimes referred to as the muscle corset), all supported by cartilages and bones (the ribs, sternum, clavicles, and the sternoclavicular joint)[5,6,9,20]. The breasts require separate discussion, and as such have not been included in this study.

Skin

The skin forms a thin outer layer (1–3 mm) of hyperechoic nature[5]. It can be accurately evaluated using a high frequency transducer (20–45 MHz), hence it is not covered in this study.

Subcutaneous fat forms

The subcutaneous fat forms a lipid coat of varying thickness, lining the entire chest. It is hypoechoic compared to the muscles, and is made up of lobules separated by delicate bands of connective tissue[5,6,9] (Fig. 1). The structure is characterized by its high plasticity, clearly visible when the tissues are compressed with the transducer.

Muscle corset

The third layer of the chest includes a complex set of muscles with varying biomechanical characteristics. On ultrasound, the anatomy of these structures does not differ from the appearance of striated muscles in other anatomical regions. Thus, the characteristic feature is the parallel arrangement of hypoechoic fibres separated by delicate echogenic bands[5,6,9,21] (Fig. 2). Some of the muscles, e.g. the pectoralis major and minor, have an insertion in the form of a tendon (Fig. 3). The superficial muscles of the chest wall include the following structures: the pectoralis major, the pectoralis minor, the subclavius and the serratus anterior. The deep layer is composed of external and innermost intercostal muscles (Fig. 4) and the transversus thoracis muscle, inaccessible on ultrasound, situated on the posterior surface of the sternum and the costal cartilages, thin and composed of numerous tendinous fibres. The dorsal muscles line the ribs and the thoracic spine, making up a rigid corset-like structure. The superficial group of well-developed muscles includes: the trapezius, the latissimus dorsi, the levator scapulae, and the serratus posterior muscle (Fig. 5). The deep dorsal muscles are located praspinally, forming a complex intertwining set of various fibres making up the spinal erector (Fig. 6). Beneath the trapezius, on both sides around the scapulae, the muscles that move the upper limbs are suspended, namely the supra- and subspinatus, the teres major and minor muscle, and the subscapularis[20] (Fig. 7).

Cartilages and bones

The ribs

The ribs – bony portions of the ribs are visible on ultrasound only in its anterior aspect, formed by the compact bone, which completely attenuates the propagation of the ultrasound beam[2,5–7,9] (Fig. 8 A, B). In the posterior aspect of the ribs, there is a slight angular bend, known as the costal angle, most pronounced in middle ribs (Fig. 9). The costal cartilages in children and young adults show lower echogenicity than muscles, allowing visualization on ultrasound of the adjacent pleura (Fig. 10 A, B). Figure 10 A shows the point where the bone and the cartilage are joined, sometimes marked with a slight thickening. Fig. 11 shows the sternocostal joint of the third right rib. The seven upper sets of ribs are attached to the sternum, yet the first rib is connected not by a joint (the costochondral joint), but by synchondrosis. It is at this level, that the first osseous formations may appear within the cartilage, which in older people may present as pseudarthrosis (Fig. 12). In costal cartilage at lower levels, random calcification foci show with time (Fig. 13) that should not be considered as a pathology. Cartilages of ribs 6 through 8 are joined together by interchondral articulations, and the

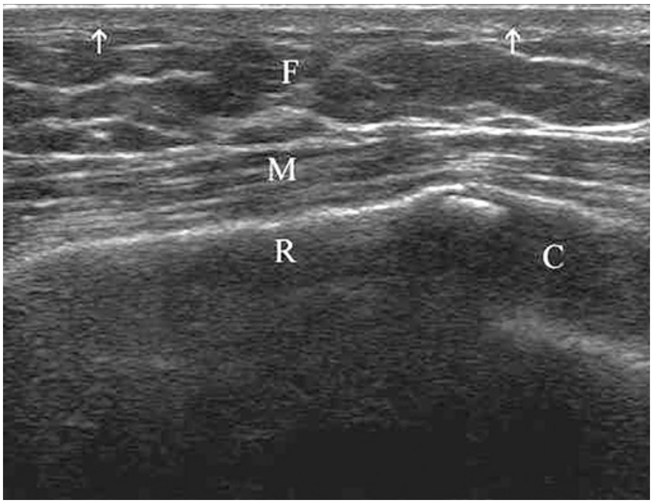

Fig. 1. *Transverse section of the chest wall, showing its anatomy: F – subcutaneous fat, M – muscle, R – rib, C – cartilage, arrows – the skin*

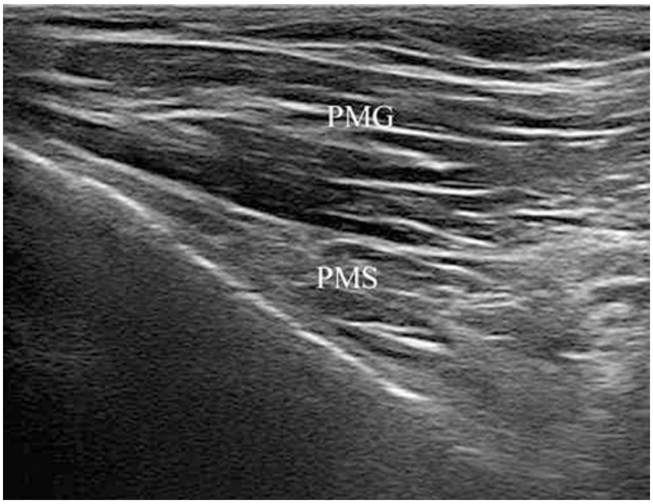

Fig. 2. *Pectoral muscles in transverse section: PM – pectoralis major, PMS – pectoralis minor*

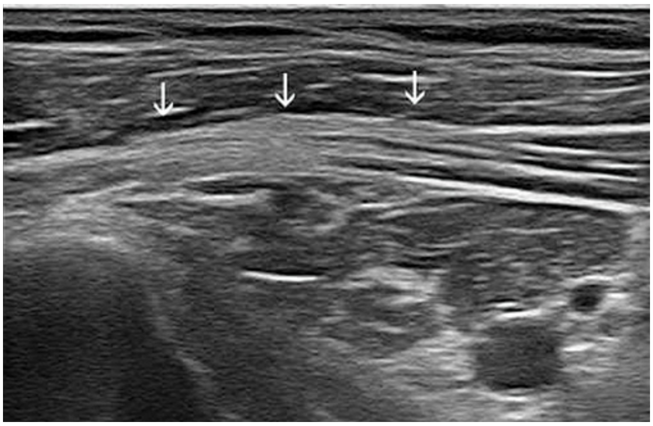

Fig. 3. *Longitudinal section of the pectoralis major tendon – arrows*

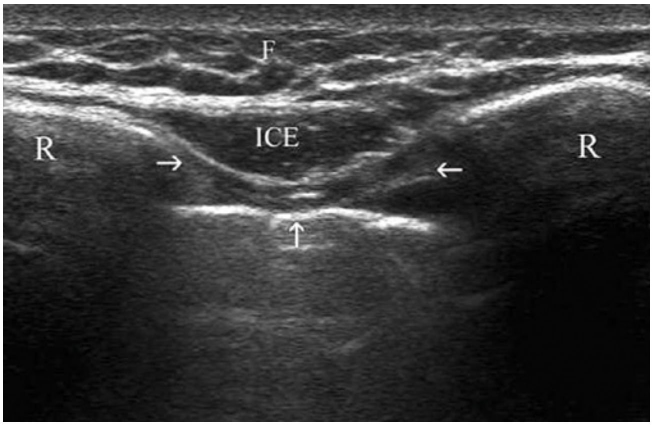

Fig. 4. *Longitudinal section – intercostal space ("bat sign"): F – subcutaneous fat. ICE –external intercostal muscle, R – ribs, horizontal arrows – internal intercostal muscle, upwards arrow – pleura*

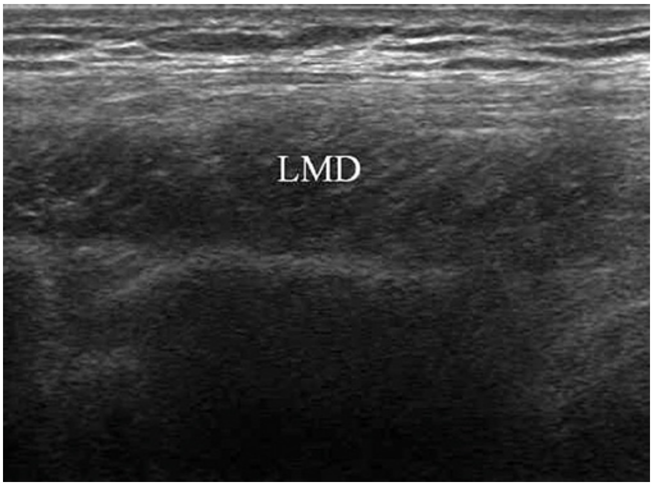

Fig. 5. *In longitudinal section, latissimus dorsi muscle – LDM*

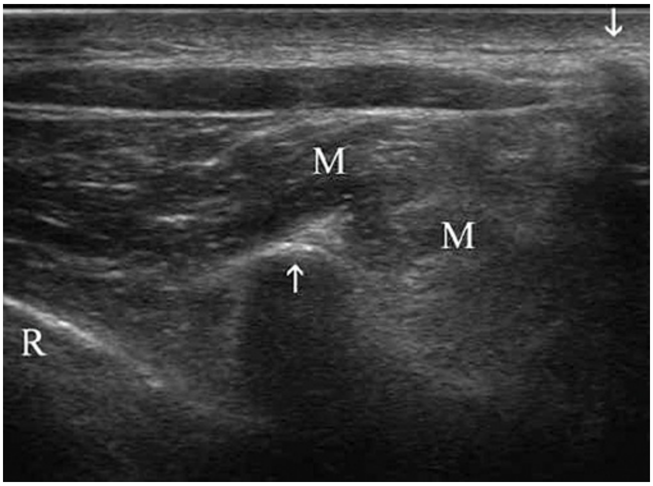

Fig. 6. *Left paraspinal area: M – set of erector spinae muscles, R – posterior portion of the rib, downwards arrow – spinous process, upwards arrow directed – articular processes*

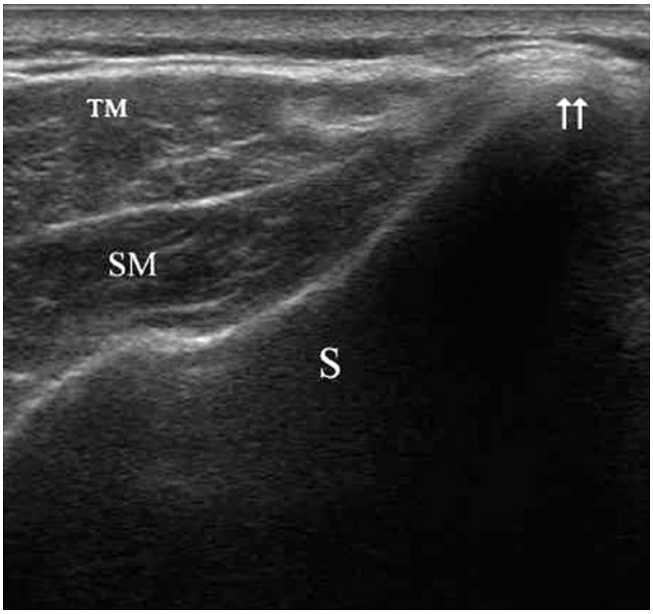

Fig. 7. *Longitudinal section over the upper aspect of the scapula (S): TM – trapezius muscle, SM – supraspinatus muscle; spina of the scapula – arrows*

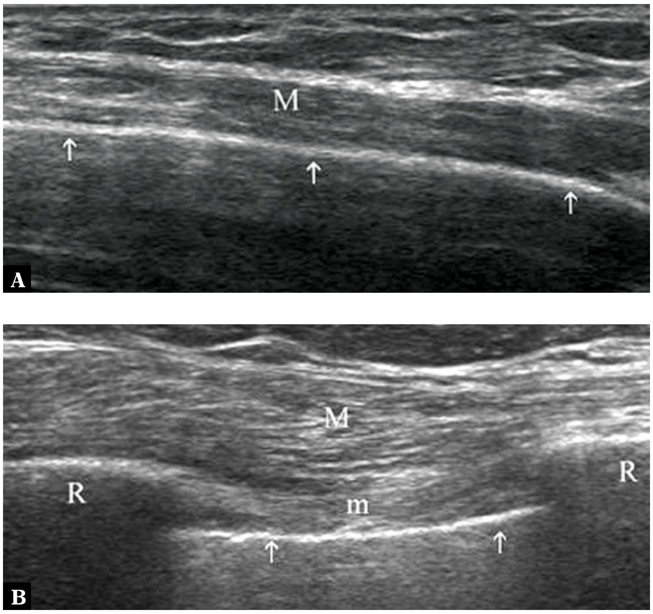

Fig. 8. A. *Anterior surface of the rib in longitudinal section (arrows) M – serratus anterior.* **B.** *Intercostal space in longitudinal section: R – rib, M – pectoral muscle, m – intercostal muscle, arrows – pleura*

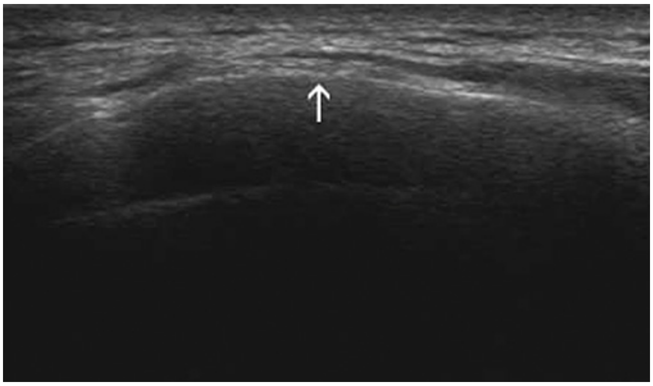

Fig. 9. *Costal angle – arrow*

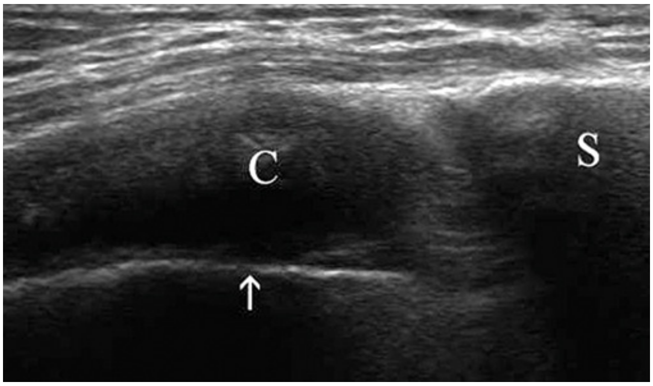

Fig. 11. *Sternocostal joint in transverse section: S – sternum, C – costal cartilage, arrow – pleura*

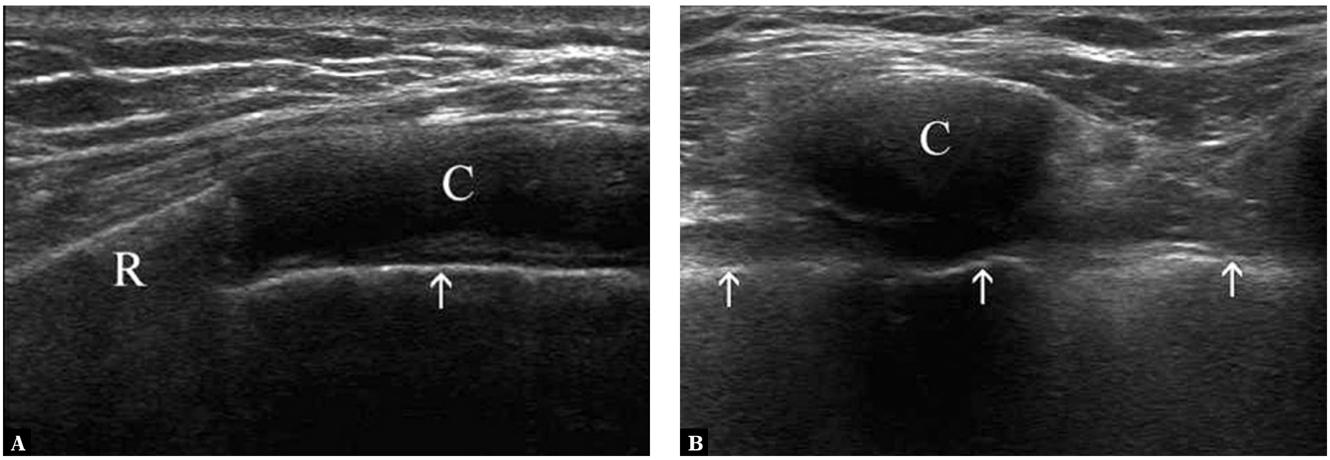

Fig. 10. A. *Junction of rib and its cartilage at rib 3: R – rib, C – cartilage, arrow – pleura.* **B.** *Costal cartilage in transverse section – C. Arrows point to the pleura*

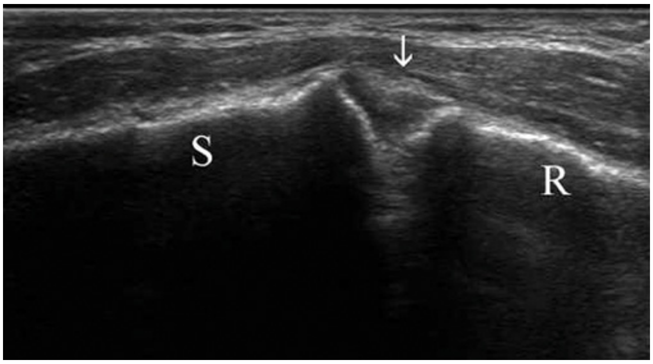

Fig. 12. *Pseudoarthrosis in calcified cartilage I ribs*

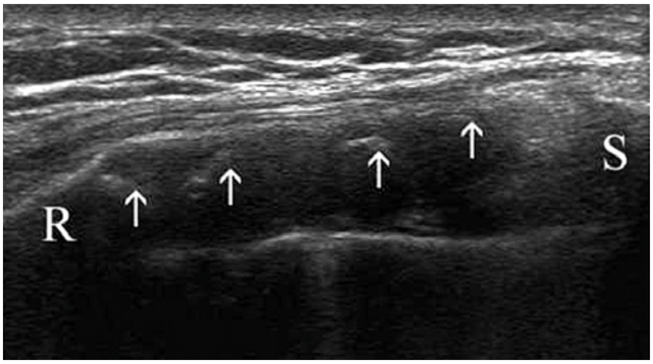

Fig. 13. *Calcifications in costal cartilage – arrows. R – rib, S – sternum*

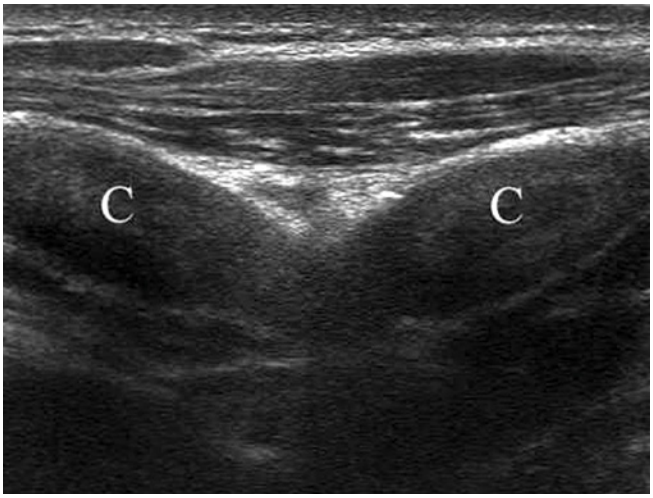

Fig. 14. *Configuration of the costal arch, transverse section*

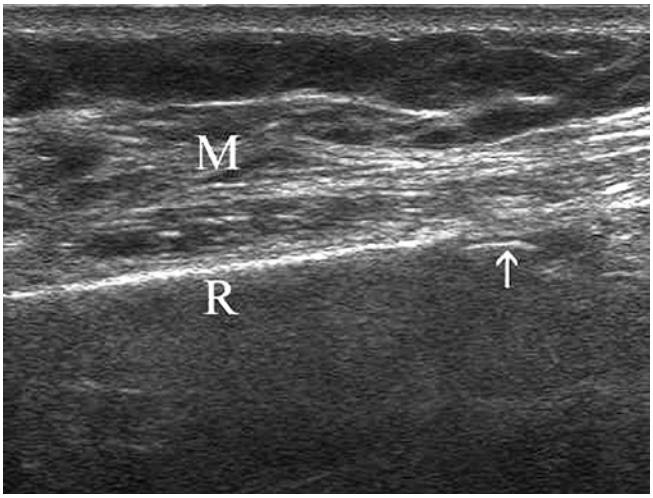

Fig. 15. *Rib 11 in longitudinal section: R – rib, arrow – partially calcified cartilage, M – muscles in anterior axillary line*

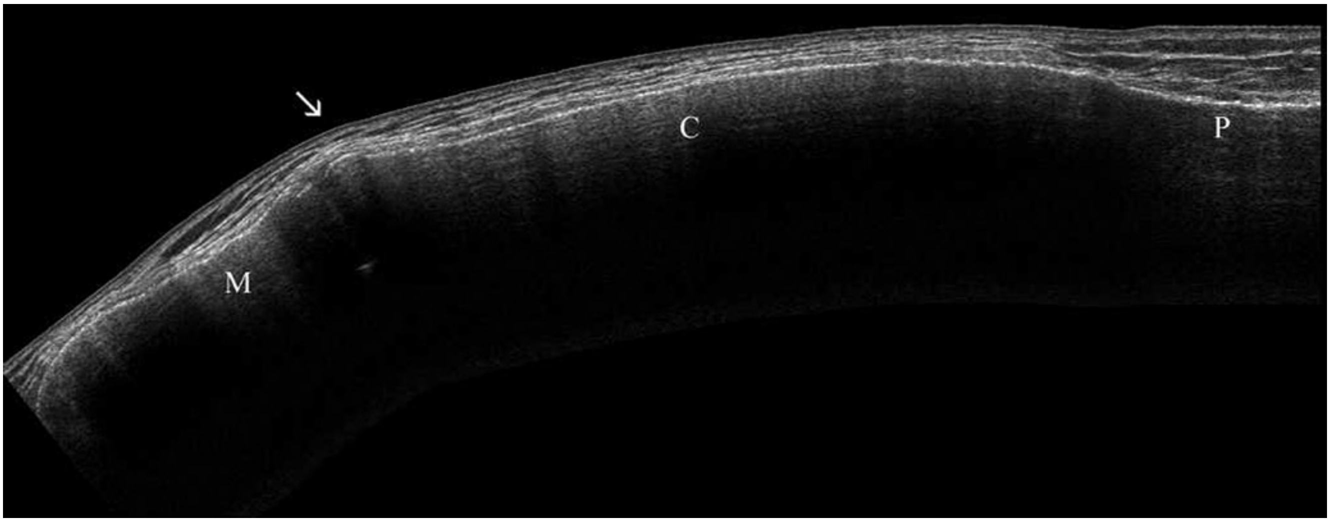

Fig. 16. *Sternum in longitudinal panoramic section: M – manubrium, C – sternal body, P – xiphoid process, arrows point to the sternal angle*

Fig. 17. *The concave surface of the manubrium sterni (arrows), transverse section*

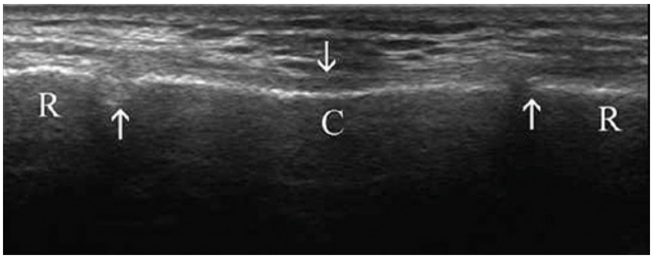

Fig. 18. *Transverse section of the body of the sternum: C – body, R – calcified costal cartilages, upwards arrows – sternocostal joints, downwards arrows – concave surface of the sternum*

Fig. 19. *Longitudinal section of the xiphoid process bent forward – arrows*

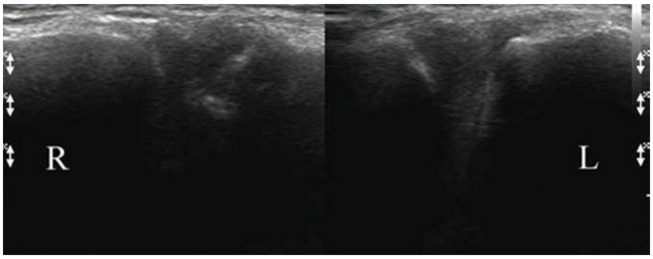

Fig. 20. *Comparison of sternoclavicular joints with well visible articular cartilage*

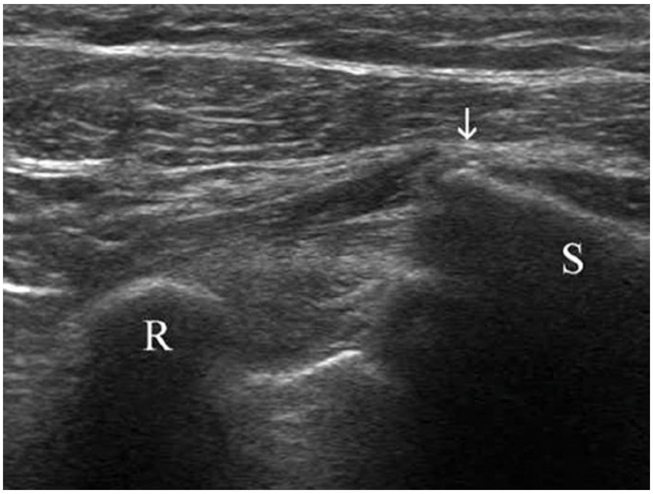

Fig. 21. *Longitudinal section of the uppermost dorsal region: R – posterior portion I ribs, S – scapula, arrow – upper edge of the scapula*

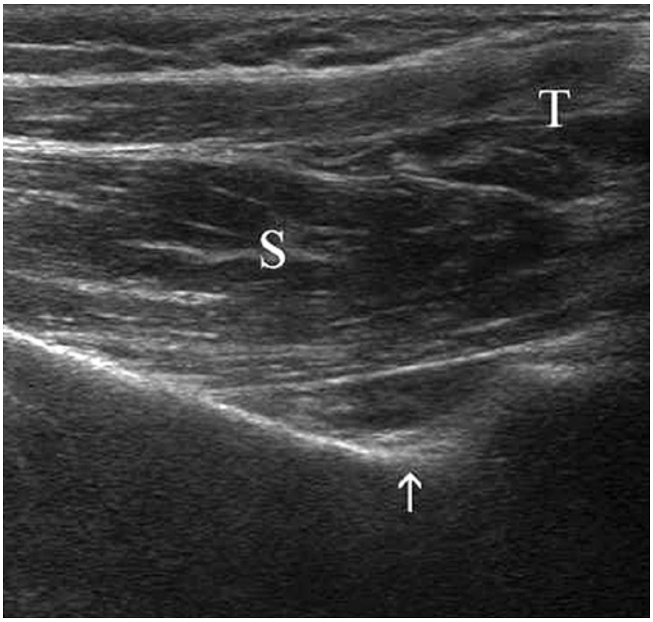

Fig. 22. *Scapular notch marked with an arrow. T – trapezius, S – supraspinatus*

cartilages of ribs 9 and 10 are connected by a loose ligament of a varying shape (Fig. 14). The last two sets of ribs (11 and 12) have free anterior ends with residual cartilage at the top[3,20] (Fig. 15).

Sternum

The sternum is a flat bone composed of the manubrium, the body and the xiphoid process (Fig. 16). The manubrium is the structure's widest element, with a convex anterior surface (Fig. 17) and the jugular notch located on its upper edge. The manubrium is sometimes joined to the sternum's longest component, that the sternal body, by a cartilage (manubriosternal junction). This is where the sternal angle arises, where cartilages of the second set of ribs are attached. The anterior surface of the sternum is slightly concave (Fig. 18), with three horizontal thickenings sometimes visible (the sites where four segments of the sternum are fused). The structural element most

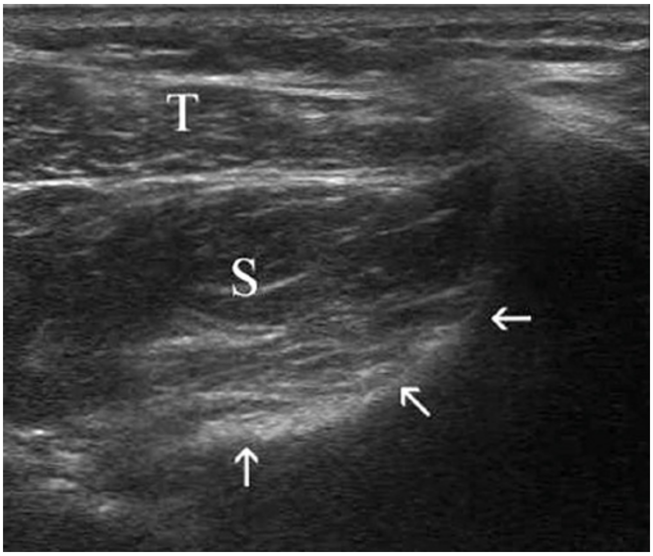

Fig. 23. *Supraspinatous fossa (arrows). T – trapezius, S – supraspinatus*

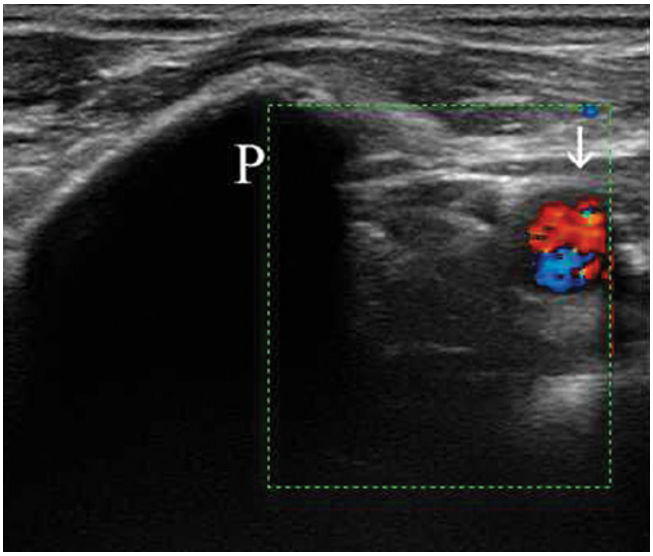

Fig. 24. *Infraspinatous fossa P – coracoid process, T – subclavian artery*

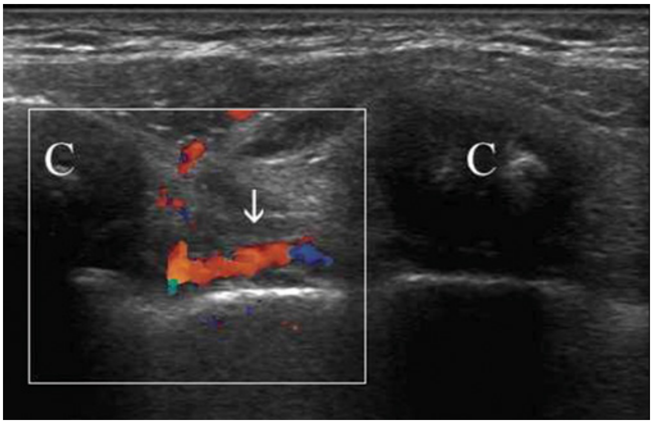

Fig. 25. *Parasternal section. T – internal thoracic artery, C – costal cartilage*

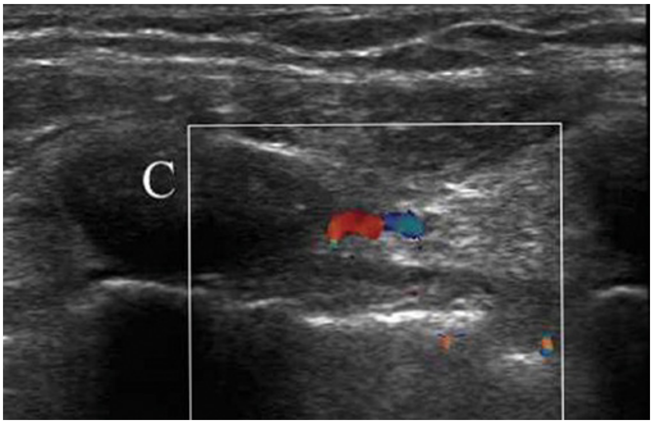

Fig. 26. *Longitudinal section of the area of the costochondral junction intercostal artery and vein. C – costal cartilage*

varying in shape is the xiphoid process. Its agenesis is rare, and it can vary in length, shape, and orientation of its tip (Fig. 19). Its end may be bifurcated, or even perforated[9,20,22].

Sternoclavicular joints

Sternoclavicular joints belong to the joints of the shoulder girdle, but their anatomical and functional relationship with the sternum warrants a brief overview. The joints are characterized by the visible mismatch of their osseous components. The sternal aspect of the clavicle, forming the head of the joint, is much larger than the clavicular notch, its acetabulum. Hence, the sternal ends of the clavicles often extend over the anterior surface of the manubrium reaching its upper edge. Between the articular surfaces there is articular cartilage varying in thickness, and subject to gradual involution with progressing age[20] (Fig. 20).

Scapula

The scapula, even though a part of the shoulder girdle, is almost entirely situated at the dorsal wall of the chest[20]. Its costal surface is inaccessible on ultrasound. On the dorsal surface, on the other hand, its angles, upper edge with the notch, its medial and lateral edge, and spine of scapula with the acromion process at its end may be viewed (Fig. 21, 22, 23). Anteriorly, deep to the scapula and medially from the head of the humerus, the coracoid process may be seen (Fig. 24).

Vascular network of the chest wall

The vascular network of the chest wall is very rich. Its anterior wall is bilaterally supplied by the internal thoracic arteries and veins, fragmentarily visible in the intercostal spaces on both sides in the parasternal area (Fig. 25), and its ramifications in the form of anterior intercostal arteries and veins (Fig. 26).

Bilateral internal thoracic arteries (BITA) are used as important components of bypass grafting, and ultrasound may be performed to evaluate the graft's patency[23,24]. Also, during pericardiocentesis it is important to determine the course of left-side internal thoracic blood vessels[24]. Posterior and medial portions of the intercostal spaces are supplied by posterior intercostal arteries and veins, and at those sites they are usually inaccessible, as they as they run on the underside of the rib, in the costal groove. Due to the rare pathological condition of the thoracoepigastric vein, known as Mondor disease, the superficially located thoracoepigastric vein, which runs bilaterally on the anterolateral chest wall, deserves to be mentioned here[20].

Abdominal ramifications of the spinal nerves of the thoracic wall

The abdominal ramifications of the spinal nerves of the thoracic wall are pairs of intercostal nerves arising from the spinal canal through the intervertebral foramina They run parallel to intercostal vessels seep to the arteries[20,25]. Their largest branches are lateral cutaneous nerves, branching off on the lateral thoracic wall. The autonomic nervous system is represented by nerve trunks that run paraspinally in vertebroscostal grooves[20,26]. Sometimes, a presurgical or postsurgical percutaneous intercostal nerve block (ICNB) is performed, e.g. prior to nephrostomy or after thoracic surgery to treat unresolved pain. A paravertebral nerve block (PVB) is another available method of pain management, performed e.g. prior to tumor ablation for liver cancer or biliary drainage[27].

Thoracic lymph nodes

Thoracic lymph nodes are an important component of diagnostics, not to be overlooked in the evaluation of the chest wall. They are clustered in the axillary, supra- and subclavicular fossae, and trail along the internal thoracic blood vessels. Their normal appearance does not differ from other anatomical locations[8,16].

Endothoracic fascia and the parietal pleura

The interface between the chest wall and the lungs is marked by the endothoracic fascia and the parietal pleura[20]. The latter is in close contact with the visceral pleura and the lung. On ultrasound, it presents as a hyperechoic line with various artifacts visible deep to it both in normal and pathological conditions[28].

Owing to the space limit of this paper, the broad topic of the normal and pathological conditions of the superior and inferior thoracic aperture has not been included in this overview.

Conflict of interest

The authors do not declare any financial or personal links to other persons or organizations that could adversely affect the content of this publication or claim rights thereto.

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