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Cartilaginous compression of the liver – clinical and ultrasonographic aspects

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Keywords

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Abstract

Introduction: The musculocartilaginous complex is a structure composed of cartilaginous, osseous and muscular elements, which is located at the thoracoabdominal junction, at the level of the right costal arch. **Aim:** To determine the ultrasonographic characteristics of this complex under normal conditions as well as to demonstrate its effects on the liver depending on the constitutional body built, respiratory phase and patient's body position. **Materials and methods:** All abdominal ultrasound scans were performed between 2006 and 2015. A total of 1000 patients (566 females and 434 males aged between 35 and 82 years, mean age 52 years), who had no significant upper abdominal pathologies identified based on clinical and imaging data, were enrolled for the analysis. In addition to standard internal organ assessment, we also attempted to identify the symptoms of hepatic compression by the musculocartilaginous complex. We used 3–6 MHz convex and 7–12 MHz linear transducers. The degree of musculocartilaginous compression of the liver was assessed during breathing in supine and sitting position, as well as with trunk inclined forward. **Results:** The study showed that musculocartilaginous compression of the liver mostly affects females (96%) with leptosomatic body build. The complex compressing the liver shows a heterogeneous echostructure. Increased hepatic compression was observed during exhalation, in a sitting position and with trunk inclined forward. **Conclusions:** Cartilaginous compression of the liver depends on body built and patient's body position. The musculocartilaginous complex may cause focal or segmental compression of the hepatic parenchyma, causing pain in the right upper abdomen in some patients.

Introduction

It has been indicated in the literature that constant costal compression on the liver my lead to hepatic deformation in the form of the so-called corset liver. This may it turn result in subcapsular hepatic fibrosis at the site of compression[1,2]. This complication usually does not occur if compression is only temporarily or occurs with varying intensity. However, literature data on this subject is sparse and mostly refers to abdominal CT in an attempt to explain the development of the so-called hepatic pseudolesions resulting from costal compression[3–7]. Our preliminary case report related to the importance of ultrasonography in explaining pain due to rib compression of the liver[8]. The aim of the present paper is to present a morphological and dynamic assessment of the so-called musculocartilaginous complex, i.e. a structure composed of cartilaginous, osseous and muscular elements, which is located at the thoracoabdominal junction, at the level of the right costal arch.

Materials and methods

A total of 1000 patients (566 females and 434 males aged between 35 and 82 years, mean age 52 years) with various clinical symptoms underwent ultrasound examination between 2006 and 2015. No significant upper abdominal pathologies were found in any of the enrol-

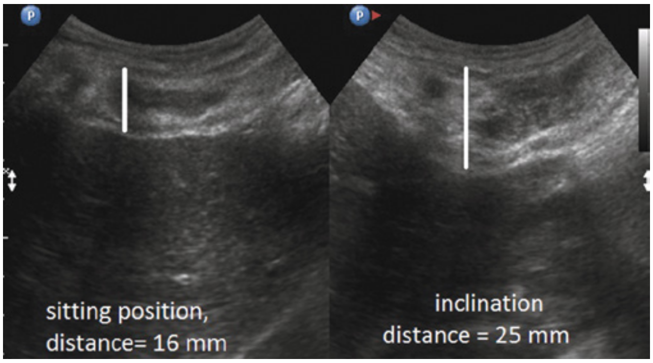

Fig. 1. *A scheme for the measurement of the musculocartilaginous complex in a patient in sitting position and with forward trunk flexion*

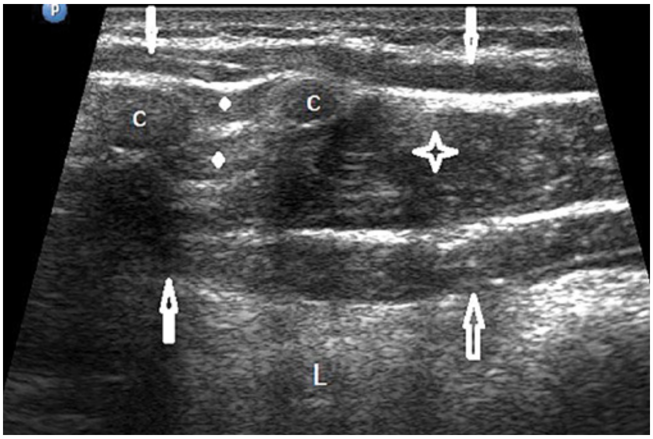

Fig. 2. *A 20-year-old athlete examined in a supine position during free breathing. Right costal arch area.*
Legend: downwards arrows – the external oblique muscle; upwards arrows – the transverse abdominal muscle; asterisk – the internal oblique muscle; a diamond at the top of the figure – the external intercostal muscle; a diamond at the bottom of the figure – the internal intercostal muscle; c – costal cartilages, L – liver

led patients based on clinical and imaging data. A consent from the head of department and an oral consent from the patients were obtained prior to the study. An assessment of the musculocartilaginous complex at the level of the right costal arch was performed as an additional component of ultrasound examination. In the first stage of the study, ultrasound scans were performed to determine normal ultrasonographic structure of the musculocartilaginous complex. We analyzed images in a group of 30 patients aged between 18 and 59 years (mean age 38 years), and then compared these images with textbook anatomical data[(9)]. The musculocartilaginous complex was evaluated using 3–6 MHz convex transducers and 7–12 MHz linear transducers for slim patients. The transducer was first positioned longitudinally, i.e. parallel to the body axis, to visualize costal arch cartilages and the insertions of the lateral abdominal muscles, and then moved from the axillary midline to the midline of the body. Musculocartilaginous compression of the liver was defined as an extrahepatic area more than 10 mm in thickness showing no vascular flow in Color Doppler, associated with the chest throughout the breathing cycle, and showing varying configuration during deep inhalation and exhalation phases as well as during free breathing. The same technique was used in the next stage of the study to assess the behavior of the described cartilaginous/hepatic conflict in patients in a sitting position and with forward trunk inclination of 45°. The obtained imaging data was recorded on sonograms as well as short video sequences in some patients (video recording 1 – available at www.jultrason.pl). The musculocartilaginous complex was measured at its thickest site (Fig. 1) in a supine position during inhalation and exhalation as well as in a sitting position and forward trunk inclination in 178 patients. Furthermore, we attempted to identify the causal relationship between clinical symptoms and musculocartilaginous compression of the liver elicited by a change in the position of the trunk in 54 patients reporting pain in the right upper abdomen. The range of musculocartilaginous complex thickness, mean values and standard deviation at different study stages were analyzed statistically. The analyzed variables had normal distribution.

Results

The analysis of the ultrasonographic structure of the musculocartilaginous complex under normal conditions in a group of 30 patients correlated with textbook anatomical data showed that costal arch cartilages are covered anteriorly by the external oblique muscle and posteriorly by the transverse abdominal muscle. The internal oblique muscle is located between these two muscles and attached to the lower edge of the cartilages of ribs 10–8. Also, intercostal muscles can be visualized at the level of the axillary line (Fig. 2). Although the 10th rib cartilage is often hypoplastic, the thickness of the inserts of the interior oblique and the transverse abdominal muscle bundles, which attach to this site, is impressive and causes an overall thickening of the musculocartilaginous complex (Fig. 2 and Fig. 3A). Dynamic analysis showed particular thickening of the insertion of the transverse abdominal muscle and the internal intercostal muscle, which penetrate the liver, during exhalation and forward trunk inclination (Tab. 1). This was accompanied by costal cartilages being pulled dorsally (Fig. 3B and Fig. 3C). Figure 3B shows variable activity of the intercostal muscles at different respiratory phases. Occasional

Stage	Mean	Stage	Mean
Inhalation	14.5 mm	Exhalation	21.5 mm
Inhalation	14.5 mm	Sitting	17.0 mm
Inhalation	14.5 mm	Flexion	25.4 mm
Exhalation	21.5 mm	Sitting	17.0 mm
Inhalation	21.5 mm	Flexion	25.4 mm
Sitting	17.0 mm	Flexion	25.4 mm

Tab. 1. *Summary of statistical data on the thickness of the musculocartilaginous complex at different testing stages in 178 patients*

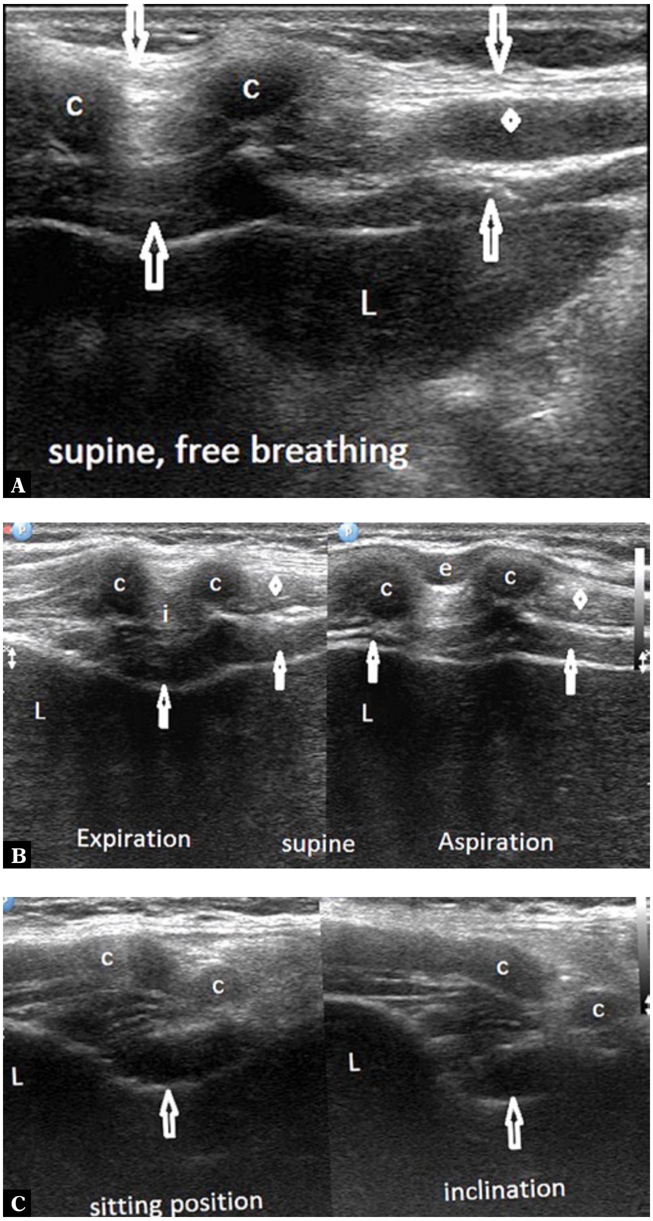

Fig. 3. A *26-year-old female.* **A.** *Examination in supine position during free breathing: right costal arch area imagined with a 7–12 MHz linear transducer; legend: c – costal cartilages, downwards arrows – the external oblique muscle, upwards arrows – the transverse abdominal muscle, a diamond – the internal oblique muscle, L – liver.* **B.** *Examination in supine position: assessment of the musculocartilaginous complex in the dynamic evaluation during deep inhalation and exhalation – on exhalation, a thickening of the transverse abdominal muscle (upwards arrows) and the external oblique muscle (i) occurs, costal cartilages (c) move closer to each another; on inhalation, thinning of the transverse abdominal muscle (upwards arrows) occurs, the tone of the external intercostal muscle with reduced echogenicity increases (e); costal cartilages (c) move away from each other; L – liver.* **C.** *Examination in a sitting position and forward trunk flexion: musculocartilaginous compression of the liver is most pronounced in anterior trunk flexion; which is accompanied by costal cartilages being pulled dorsally*

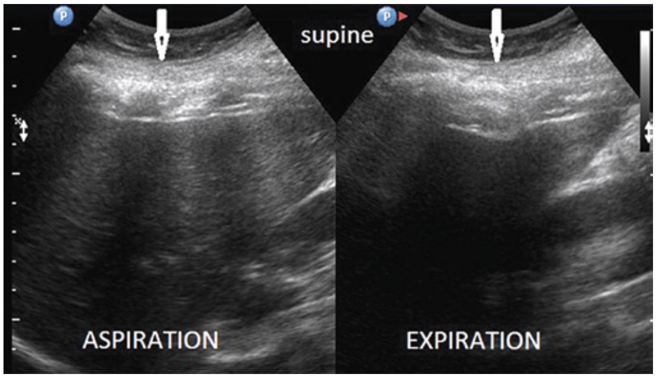

Fig. 4. *A 46-year-old female examined using a 3–6 MHz convex transducer in a supine position during inhalation and exhalation. Minor musculocartilaginous compression of the liver occurs during exhalation; however, precise determination of musculocartilaginous components is not possible*

calcifications in the central portions of cartilages significantly impaired assessment of this area. The use of convex transducer did not allow for the discrimination between the individual components of the musculocartilaginous complex (Fig. 4).

Costal cartilage compression of the liver at the level of the right costal arch was identified based on ultrasound scan in 182 out of 1000 patients. Women (mean age 49 years) clearly predominated in this group (n = 175; 96%). Hyposthenic built (slim body with long and flat chest) was observed in 171 and normosthenic built was observed in 4 patients in this group. Similar findings were reported in the group of males – 4 patients were hyposthenic. In the group of patients reporting pain in the right upper abdomen not associated with food intake, this symptom could be linked with hepatic compression in 19 patients (10.4% out of 182) due to its occurrence at certain trunk positions. In this subgroup, 4 patients were unable to lean forward and tilted their trunk backwards when in a sitting position. Other patients reported pain in this region after longer periods of computer work, when putting on shoes, during housework or work-related activities requiring forward trunk inclination (e.g. two roofers). The pain subsided after straightening of the trunk in all patients. The liver appeared as flattened and elongated in the cranial-caudal axis as well as protruded from under the costal arch with no other significant pathologies in 175 (96%) out of 182 patients diagnosed with musculocartilaginous compression of the liver. Single haemangiomas up to 18 mm and cysts up to 22 mm were detected in only 23 patients based on CT. The musculocartilaginous complex compressing the liver usually showed slightly irregular echostructure in imaging using convex transducer and mimicked a lesion located under the abdominal sac, which was reported for 121 patients (66.5%; Fig. 5A). Hypoechoic musculocartilaginous complex was the predominant acoustic pattern in 35 patients (19.2%; Fig. 5B), while hyperechoic pattern was confirmed in 26 patients (14.3%; Fig. 5C). The indenting musculocartilaginous complex had smooth outlines in all patients, with a broad base lying against the chest wall, and was located near the anterior auxiliary line. Compres-

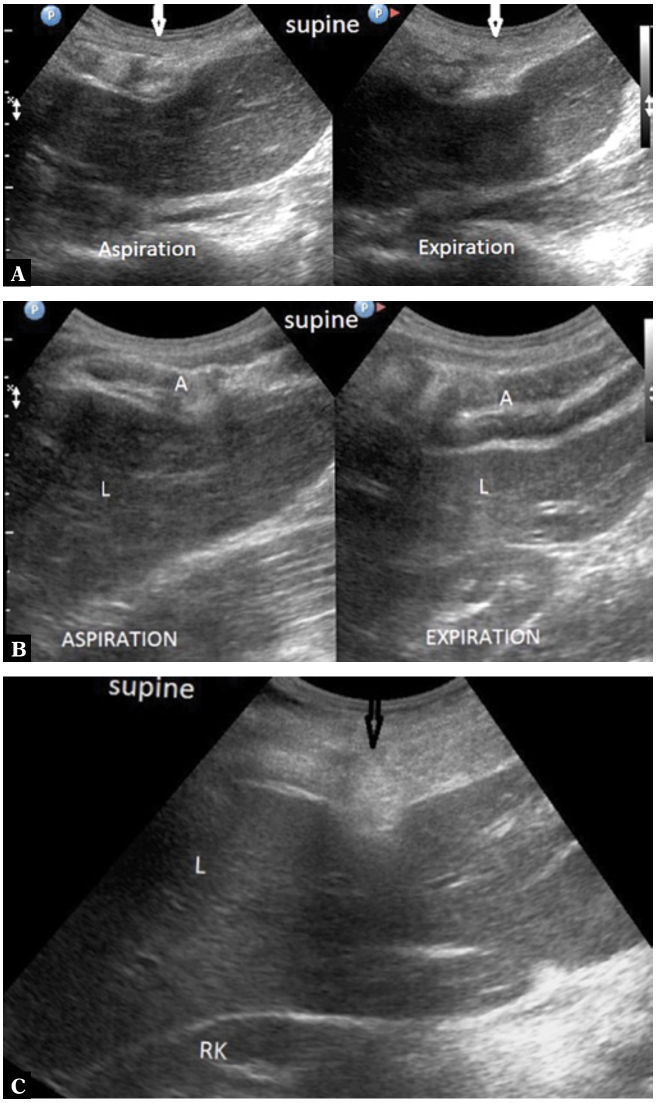

Fig. 5. A. *The musculocartilaginous complex with inhomogeneous echogenicity during inhalation and exhalation with distinct, moderate liver compression (arrows).* **B.** *Hypoechoic musculocartilaginous complex with clear liver compression during exhalation (arrows).* **C.** *Highly echogenic musculocartilaginous complex with clear liver compression (arrow)*

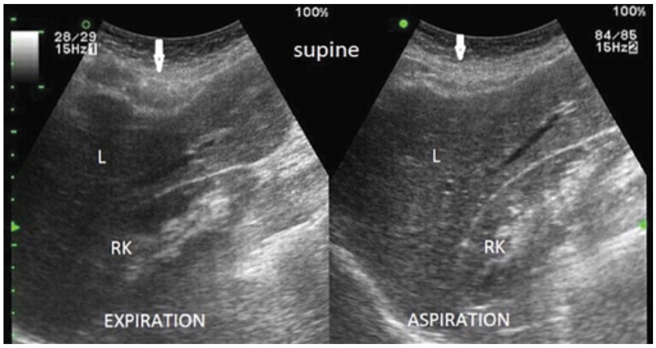

Fig. 6. *Significantly deeper, focal musculocartilaginous compression of the liver (arrows)*

sion was mostly focal (n = 152; 83.5%) during inhalation and became deeper during exhalation (Fig. 6). Compression extending from 4 to 7 cm was less common (n = 30; 16.5%), and its configuration changed depending on breathing and trunk position (Fig. 5B; Tab. 2). The compression decreased at the top of the inhalation, increased on exhalation and was slightly reduced during free breathing. Particularly increased compression occurred during forward trunk flexion due to thickened musculocartilaginous complex, which was observed in 178 patients (Tab. 3). No change in the configuration of the costal arch, which permanently separated two portions of the hepatic lobe as a result of a very deep penetration, was found during respiratory test in 4 females (Fig. 7). These patients did not consent to perform forward trunk flexion due to considerable pain. Figure 8 shows the relationship between the musculocartilaginous complex and the liver in a supine position (inhalation and exhalation), as well as in a sitting position and forward trunk flexion in the same patient. The deepest musculocartilaginous penetration into the liver was observed in the latter position. Apart from a single case of left hepatic lobe compression by an elongated cartilaginous tip of the xiphoid process (Fig. 9), all other cases were related to musculocartilaginous compression of abdominal hepatic segments V and VI. The compression caused no detectable changes in liver appearance in most patients (n = 115). Color Doppler showed no vascularization in the compressed region, similarly as in other peripheral parts of the liver. A subjective finding of reduced sliding surface of the liver relative to the compressing costal arch during free breathing in a sitting position and forward trunk flexion compared to the supine position was another important observation. Minor deformation of the right kidney was observed in some patients with severe compression. Statistical results are summarized in Table 2 and Table 3.

Discussion

Non-contrast-enhanced and contrast-enhanced CT scans demonstrated that costal compression of the liver may appear in the form of pseudolesions in the subcapsular hepatic region, which are seen as an absence of perfusion, usually during the venous phase, less often in the arterial phase[3–7]. Such perfusion defects were found in 2–14% of patients in these studies. The total number of cases of

Feature	Number of patients	Percentage
Heterogeneous	121	66.5
Hypoechoic	35	19.2
Hyperechoic	26	14.3
Smooth outline of indentation	182	100.0
Broad base of the costal arch	182	100.0
Focal costal compression	152	83.5
Segmental costal compression	30	16.5

Tab. 2. *Ultrasonographic characteristics of the musculocartilaginous complex in 182 patients*

Feature	Thickness range	Mean SD	Feature	Thickness range	Mean SD
Inhalation	11–28 mm	14.5 mm +/– 2.4	Exhalation	12–40 mm	21.5 mm +/– 3.3
Sitting	11–31 mm	17.0 mm +/– 2.9	Flexion	20–40 mm	25.4 mm +/– 3.5

Tab. 3. *Comparison of the thickness of the musculocartilaginous complex during inhalation, exhalation, supine position, sitting position and forward trunk flexion in 178 patients*

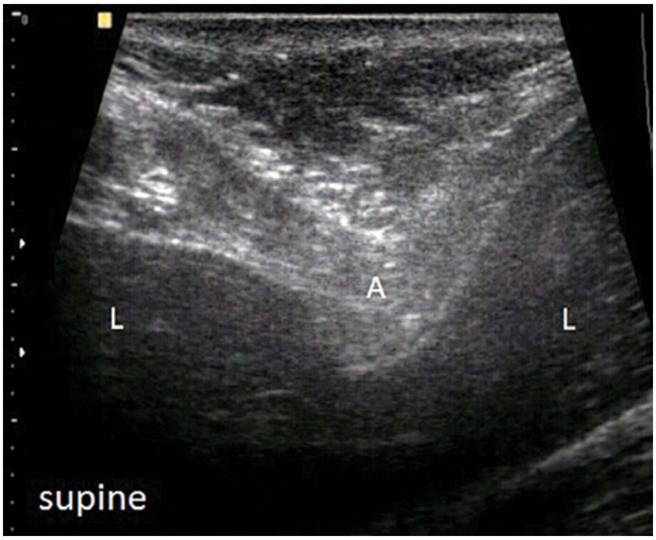

Fig. 7. *Very deep penetration of the costal arch (A) dividing the liver into two parts (L)*

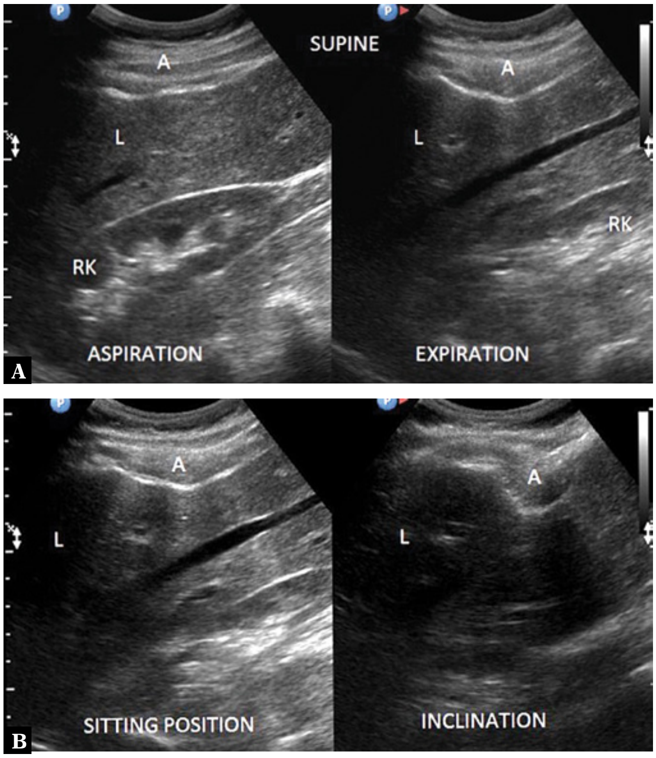

Fig. 8. A. *Patient in supine position – hepatic compression by the musculocartilaginous complex is deeper during exhalation than inhalation.* **B.** *The same patient – in an upright sitting position on the left; in a sitting position with forward trunk flexion on the right – most pronounced hepatic compression*

costal compression was significantly higher, e.g. Nishie *et al*.[7] found this effect caused by 210 ribs among 150 patients. Determination of transient perfusion disorders as clinically insignificant is important for further management, particularly in cancer patients who accounted for the majority of cases in the analyzed studies. Yoshimitsu *et al*.[5,6] found that perfusion defect occurs in the phase of deep inhalation and resolves during exhalation. At this point an apparent discrepancy occurs between CT and ultrasonography. At deep inhalation, the diaphragm pushes the liver caudally while pressing it against the indented rib; the rib is then elevated towards the abdomen, however, as a result of the opposing direction of force vectors (liver vs. rib), the focal compression of the liver increases as an unchanged organ is plastic and thus prone to compression. As a consequence, perfusion abnormality of the liver parenchyma is shown in CT, which cannot be demonstrated with Doppler imaging.

Perhaps such a pathology could be detected by contrast-enhanced ultrasound. On exhalation, the liver retracts cephalically, allowing the rib to return to the baseline position, thus increasing the penetration. The difference between these techniques further depends on the methodology used. In computed tomography based on axial cross-sections, ribs were evaluated for bone parts, whereas ultrasound scans were performed via the costal arch, using longitudinal sections, and therefore involved a different part of the chest and the liver. Our preliminary study on the ultrasonographic anatomy of the thoracic-abdominal junction at the level of right costal arch showed that liver compression is due to the thickening of the musculocartilaginous complex, with the transverse abdominal muscle being the direct compression structure. It was found in the analyzed group of 1000 patients that clear liver/costal arch conflict affects about 18% of adults, with the highest incidence among hyposthenic women (96%). The conflict may cause pain in the region of liver in about 10% of these patients. In this situation and in the absence of lesions, mainly in the liver, bile ducts, stomach and duodenum, the conflict should be included in the differential diagnosis, especially if indicated by medical history. The location of liver compression should be clarified. The costal arch, which is comprised by the cartilages of ribs 8 through 10 does not connect directly to the sternum, but though a syndesmosis with rib 7 and the interchondral articulation. Our study demonstrated that this site shows poor stability, which may often lead to deformation of the chest cartilage and, consequently, liver compression. Furthermore, the

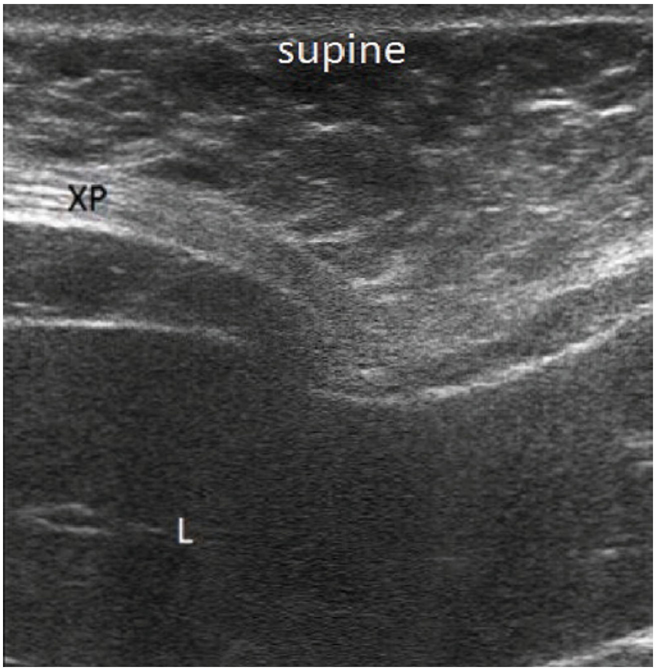

Fig. 9. *The cartilaginous tip of the xiphoid process (XP) compressing the left hepatic lobe (L)*

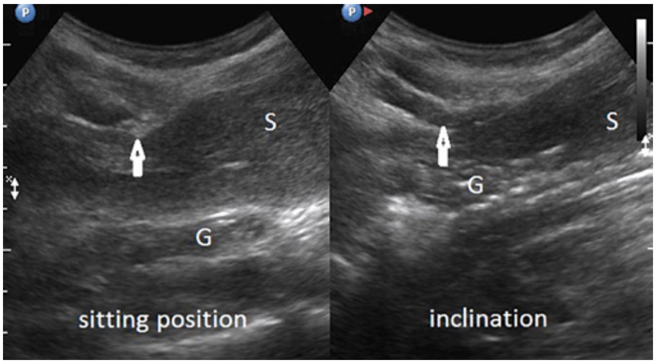

Fig. 10. *Splenic compression (S) by the musculocartilaginous complex on the left (arrows) in a sitting position (left side of the figure) and forward trunk flexion (right side of the figure); G – stomach*

study confirmed the important role of the internal oblique muscle, the transverse abdominal muscle and the internal intercostal muscle in the mechanism of exhalation and trunk flexion(9,10). Examining patients in this position resulted in the thickening of the insertions of these muscles, which consequently led to liver compression. The degree of liver compression is proportional to the degree of anterior trunk inclination and mostly affects hyposthenic women. The relationship between pain in the liver projection and such a configuration of the costal arch may be explained in two ways. Meuwly *et al*.(11,12) believe that subluxated rib cartilages entrap the intercostal nerve, causing pain. Stretching of the innervated liver capsule due to compression by a bent costal arch and abdominal muscles is another explanation. Finally, it is worth mentioning that ultrasound and computed tomography were performed in parallel by Yoshimitsu *et al*.(5) and Nishie *et al*.(7) Yoshimitsu *et al*.(5) found no hepatic lesions in ultrasound, while Nishie *et al*.(7) did not present their ultrasonographic data. In the latter paper, the authors have shown that focal perfusion defects in the liver related to costal compression occur only in patients with normal or slightly impaired liver function. Therefore, it may be concluded that symptoms of variable liver compression indicate its good elasticity. Our preliminary observations indicate a similar behavior of the left-sided musculocartilaginous complex. Figure 10 shows musculocartilaginous compression of the spleen in a patient with splenomegaly, which manifested in pain while sitting. Differential diagnosis should include all primary and secondary disease processes located within the costal arch and cancer metastases on the liver surface. Respiratory test will be useful in precise location of these lesions, while color Doppler will determine the degree of lesion vascularization. However, final preoperative diagnosis can be expected after biopsy. The lack of verification of detected abnormalities using imaging methods other than the presented ultrasound evaluations is a limitation of the study. Although computed tomography and magnetic resonance were performed in some of our patients, they did not allow for an extensive assessment of the dynamics of the described changes.

Conclusions

1. Musculocartilaginous compression of the liver affects about 18% of patients and is more common in hyposthenic women (96%). The disorder may cause pain in the right upper abdomen (depending trunk position) in about 10% of patients.

2. The musculocartilaginous complex compressing the liver usually shows irregular echostructure. It may cause focal or segmental compression, which may penetrate deep into the liver.

3. Musculocartilaginous compression of the liver is most pronounced during exhalation and forward trunk flexion.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organizations, which might negatively affect the content of this publication and/or claim authorship rights to this publication.

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