Review

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Ultrasound measurements and normal values of the liver: a comprehensive review and practical guide

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Abstract

Reliable and reproducible sonographic measurements are essential for accurate liver assessment, both in daily clinical practice and in research. Reference values enable clinicians to differentiate between physiological and pathological findings and thus support diagnostic accuracy, follow-up, and therapeutic decision-making. This comprehensive review synthesizes current evidence on normal liver size as assessed by ultrasound, with a particular focus on measurement techniques, standard values, anatomical variants, and the clinical contexts in which these parameters are relevant. Special attention is given to the influence of patient-related factors such as body constitution, sex, age, and ethnicity. The role of right, left, and caudate lobe measurements is discussed in detail, outlining their relevance in conditions such as hepatomegaly, vascular disorders, or post-resection follow-up. Limitations of currently available data are acknowledged, especially regarding interobserver variability and lack of global uniformity. Future priorities include the establishment of consensus-based international reference standards and the integration of emerging technologies, such as artificial intelligence and advanced image analysis tools, to enhance reproducibility, reduce variability, and improve clinical utility. Ultimately, standardized liver measurements should form an integral part of multiparametric ultrasound examinations to optimize patient care.

Keywords: ultrasound; liver size; measurement; reference values; examination standard

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Introduction

Hepatomegaly is a common finding in many diffuse liver and vascular diseases, including steatotic liver disease, congestive heart failure, infectious, hematologic, and storage diseases, and malignancies. Therefore, reliable measurements of liver size are crucial for diagno-

sis, determining the course of the disease, and evaluating response to therapy. However, hepatomegaly is not always easy to assess, since the shape of the liver may vary considerably and an increase in organ size makes it challenging to demonstrate the whole organ in the image section [1]. The shape of the liver depends on the body's constitution and the available space for the liver. People with an asthenic, leptosomic constitution have a narrower lower thoracic aperture. The liver, therefore, protrudes further laterally toward the caudal region. In pyknics with a wider lower thoracic aperture, the liver axis is steeper than in asthenics – about 45–60 degrees to the horizontal in supine position. In pyknics, the right lobe of the liver is therefore usually located within the thorax aperture, unless hepatomegaly is present. Depending on the body type and the steepness of the liver's longitudinal axis, the vertical diameter of the right lobe of the liver can vary [2].

The liver may appear enlarged in cases of thoracic deformities or a low-lying diaphragm due to pulmonary emphysema or pleural effusions. In cases of diaphragmatic elevation due to diaphragmatic dysfunction, an enlarged liver may not protrude below the costal margin, and hepatomegaly may not necessarily be detected by physical examination.

This review is part of a publication series that systematically evaluates standard sonographic measurements in abdominal imaging [3-12] focusing on the clinical applications of knowing the reference values and recommending evidence-based reference values. Focusing on hepatic ultrasound, this paper discusses when and why liver measurements should be performed, and how they can be reliably obtained.

Consistent documentation, including both written reports and representative images, is necessary for quality control and reimbursement. To support this, we propose the use of a standardized image set to document normal liver ultrasound findings.

Elastography and ultrasound-based fat quantification are not addressed in this review; for these techniques, we refer to established guidelines and consensus recommendations [13-19].

Review of literature

The literature on reference values in abdominal ultrasound was reviewed based on three German-published papers of Sienz et al [20-22], which will not be repeated but complemented with a follow-up analysis of published literature until July 2025. The PubMed Database was systematically screened for eligible studies. Terms associated with reference value ultrasound, along with specific

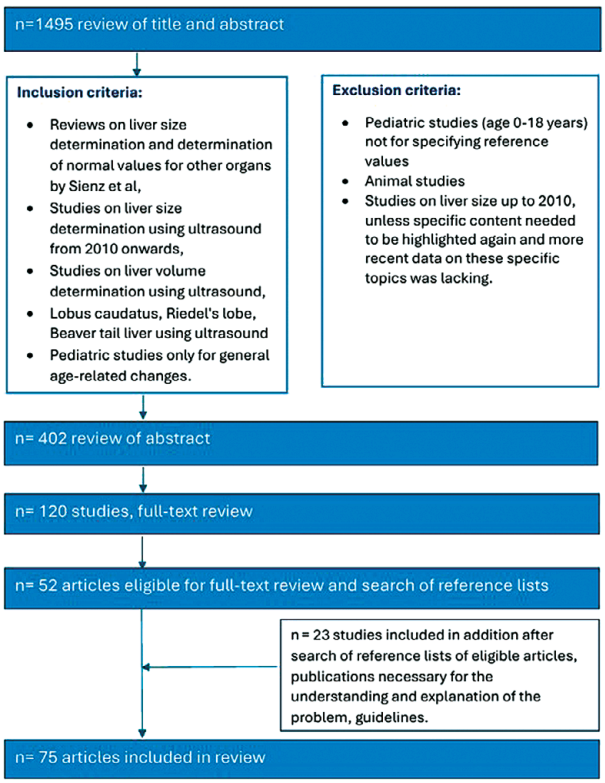

Fig 1. Search strategy.

related terms, were used and analyzed separately. The literature was complemented by extensive cross-checking of the reference list of the retrieved articles. Exclusion criteria were studies involving liver size determination in children and veterinary studies. Figure 1 demonstrates the study process.

Limitations: One limitation of this review is the fact that the patient population was not precisely described in all included studies. Furthermore, some studies did not disclose how many examiners collected the data and what training standards were used. Only a minority of cited studies do provide data on interobserver and/or intraobserver variability [23-27].

Examination technique of the liver

To determine liver size, most authors suggest measuring the right hepatic lobe using two diameters [25,26,28-30]: the longitudinal transducer position in the right midclavicular line (MCL) to measure the craniocaudal (cc) length from the dome to the tip and the maximum anteroposterior (ap) diameter of the right liver lobe. Alternatively, a longitudinal transducer position in the midaxillary line (MAL) or anterior axillary line (AAL) and measurement of the craniocaudal diameter has been suggested [26, 31].

The examination is performed in supine position positioned the right arm to the side or slightly beside their head. Patients do not need to fast before the liver size measurement. The examination is performed using a curved array transducer C1-6 MHz. The measurements of the right liver lobe in the MCL and the significance of the shape are shown in figures 2-6.

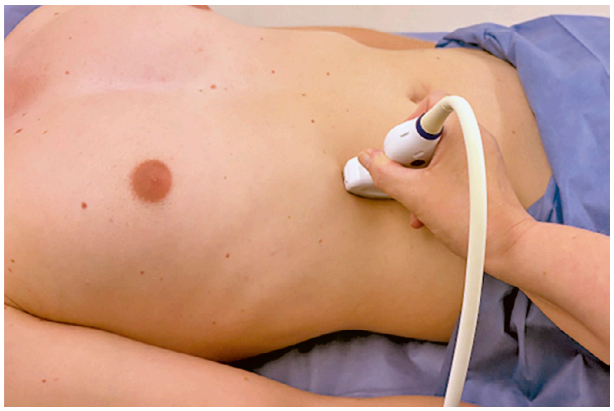

Fig 2. Longitudinal transducer position in the midclavicular line below the right costal margin.

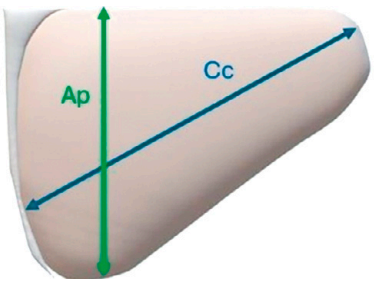

Fig 3. Schematic representation of the measurement of the right lobe of the liver. With the transducer positioned longitudinally in the midclavicular line, the craniocaudal extension of the right hepatic lobe (Cc, blue arrow) is measured from the liver dome, which is not obscured by reverberation artifacts from the lung to the caudal margin of the right liver lobe. The maximum anteroposterior diameter (Ap, green arrow) is also measured in this position. The adjacent lung artifacts are shown in grey in the image.

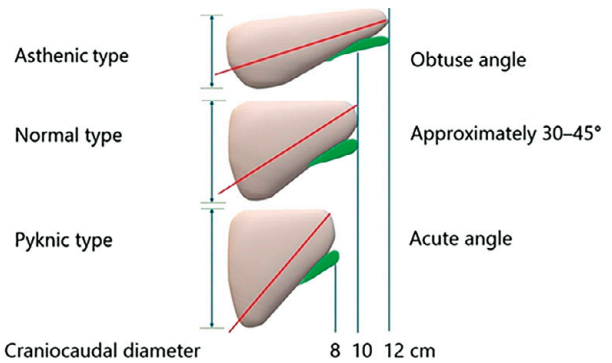

Fig 4. The craniocaudal diameter of the right hepatic lobe depends on the body constitution and width of the thoracic aperture. With different body types, the maximum diameter is presented at various angles (red lines) (according to Rettenmeier and Seitz).

Reproducibility of measured values

In a small study, Childs et al investigated the intra- and inter-rater reliability for 15 different liver size measurements (six each for the right and the left liver lobe, respectively, three to assess the whole liver) and found acceptable inter- class correlation coefficients (ICCs) only for the MCL Dome-to-tip diameter (inter-rater ICC: 0.93 [95%CI: 0.785-0.909], intra-rater ICC: 0.963 [95%CI: 0.883-0.989]), the MCL maximum antero-posterior diameter of the right liver lobe (inter-rater ICC: 0.834 [95%CI: 0.52-0.949], intra-rater ICC: 0.974 [95%CI: 0.912-0.992]), and the Midline maximum antero-posterior diameter of the left liver lobe (inter-rater ICC: 0.865 [95%CI: 0.593-0.959], intra-rater ICC: 0.909 [95%CI: 0.724-0.973]) [32]. Riestra-Candelaria et al reported, that ultrasound measurements of the length of the right liver lobe on the mid-axillary line hat a much better correlation with cadaveric measurements compared to the same measurement in the MCL [25].

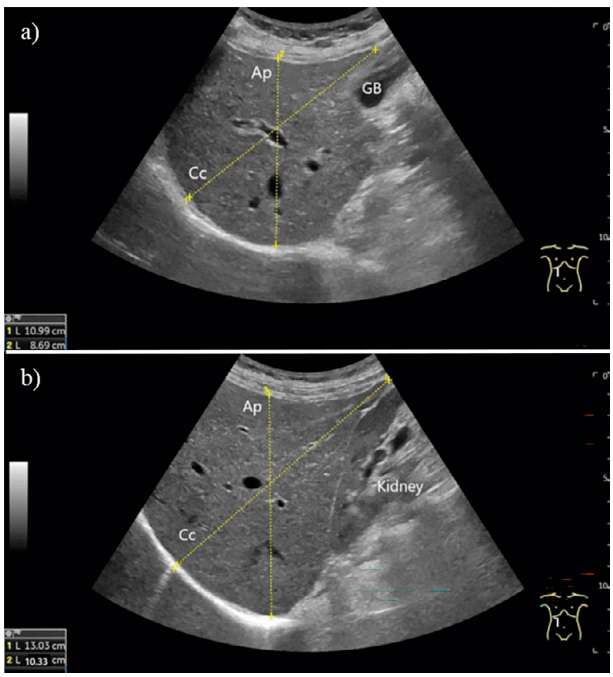

Fig 5. Craniocaudal diameter and anteroposterior diameter of the right lobe of the liver in the area of the midclavicular line, measured in the supine position in deep inspiration, normal findings. In the longitudinal transducer position in the midclavicular line below the right costal margin, the gallbladder (GB) is visualized at the lower edge of the liver in most patients (a). The right kidney is usually visualized in the anterior or midaxillary line, but sometimes also in the midclavicular line (b).

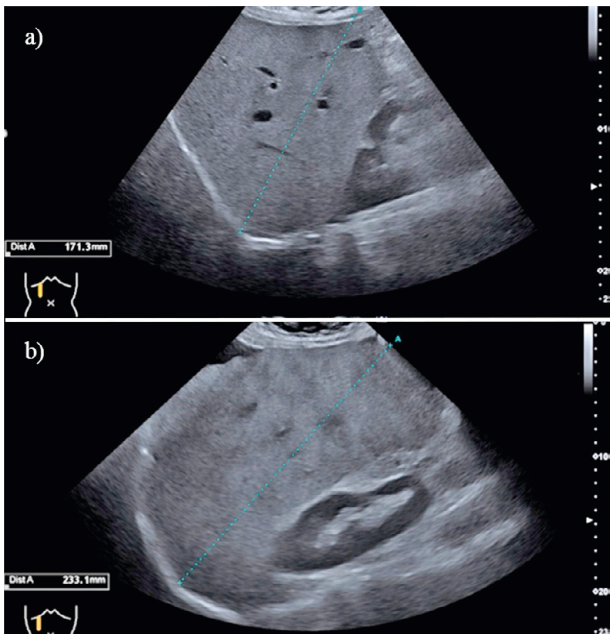

Fig 6. Increased craniocaudal diameter in longitudinal plane in right midclavicular line shows an enlarged right liver lobe in moderate steatosis (a) and severe steatosis (b).

Götzberger et al [31] analyzed correct MCL measurements using ultrasound and CT and compared subcostal and intercostal sonographic measurement approaches. For liver measurements on the right MCL, a good correlation between ultrasound and CT was found. However, intercostal approaches resulted in larger values as compared to subcostal approaches. Therefore, higher upper normal limits for intercostal scanning were defined with good reliability, especially in patients where MCL measurements are impossible (meteorism, inability to perform breathing maneuvers).

Reference values and recommendations

Liver size in several geographical regions and populations

In recent years, there has been increasing interest in determining normative values for liver size in different geographical regions and populations across the world [33-35].

Table I summarizes studies conducted after 2010 to determine liver size. Of particular interest are the values in different regions of the world for different ethnic groups and depending on body measurements such as BMI, body weight, height, and gender. Remarkably, the studies listed here, published since 2010 on the subject of liver size measurements, have hardly recorded any data on measurements of the left liver lobe. Only in two studies, measurements of the left liver lobe were conducted: Gammeradin et al [36] and Childs et al [24] performed various measurements on the left liver lobe in relatively small and heterogeneous patient populations, including the AP and CC diameters in the midline.

Influence of gender, body mass index (BMI), weight, height, and ethnicity on the size of the right liver lobe

Gender: In most studies [34,35,37,38,40-42] except that of Khan et al [33], the right lobe of the liver was larger in males than in females. In further studies, there was no significant difference in liver size between genders [39,43].

BMI: The size of the liver correlated with BMI in most studies including adult patients [34,35,37,39,42] and among University-aged Youth [44]. In two studies with larger samples, the women examined had a significantly higher average BMI than the men examined [33,42]. While in the study by Khan et al [33], the women had larger livers, Tiryaki et al [42] found the opposite, that is, larger livers in men despite a lower BMI. Only the study by Singla et al [38] reported a negative correlation with BMI. Obese individuals were excluded from this study.

In Tiryaki et al study [42], liver size was correlated with different BMI classes. This study included individuals who were underweight, normal weight, overweight, and obese. In terms of liver Cc diameter, all groups showed significant differences from one another. The AP diameter also differed between the groups, except for the underweight and normal weight groups. The smallest liver sizes (Cc and Ap) were observed in the underweight group, while the largest were found in the obese group [42]. One study described also a significant positive correlation with additional features describing obesity: waist circumference, waist-to-hip circumference ratio, and subcutaneous tissue thickness [44].

Steatosis hepatis: Hepatic steatosis affects liver size [34]. In a study involving 2,797 individuals (Cappadocia Cohort Study of Turkey), of whom 36% were overweight, 42% were obese, and 60.1% had hepatic steatosis, a correlation was found between hepatic steatosis and liver size [45].

Height and weight: A positive correlation between liver size and body height and body weight was described [33,40,44]. Concerning body height, the study by Patzak et al showed that individuals with body height <160 cm had a liver span of 14.5±1.6 cm, while individuals with body height of >180 cm had a liver span of 15.4±1.5 cm [34].

Age: Regarding age, the relationship between liver size and age in adult individuals remains controversial. In a study including children and adults, the size increases continuously until the age of 60 years and then decreases

Table I. Size of the right liver lobe in studies conducted after 2010 in various regions of the world

Study / country / number of patients / patients	**Measurement method**	**Average maximum liver span ± SD, median (range) (cm)**	**Comments**
Patzak 2014 [34] Southwest Germany / n = 1789 epidemiologic screening survey of the prevalence of Echinococcus multilocularis in the urban population of the southwestern Germany	Longitudinal axis on MCL, deep inspiration, maximal Cc liver span, liver with simultaneous demonstration of right kidney on the figure.	*Cc diameter:* All: 15.0 ± 1.5 F: 14.9 ± 1.6 M: 15.1 ± 1.5 All: 14.9 (9.0 – 20.4)	Liver size was larger in males. Significant correlation between liver size and body height, waist-to-hip ratio, BMI, hepatic steatosis, metabolic syndrome, age, elevated liver enzymes and GGT
Kheiralla 2016 [37] Saudi Arabia / n = 584 different sonographic examinations not related to the liver	Longitudinal axis in MCL, liver with simultaneous demonstration of right kidney on the figure	*Cc diameter:* F: 11.9 M: 12.5 No further information on standard deviation, mean and range	Larger liver size in male than in female. Female: significant correlation of liver size to height, weight, BMI. Male: significant correlation to height. BMI showed negative correlation with male's liver span, but it was not significant
Singla 2017 [38] India / n = 100 healthy people	At MCL, no further information	*Cc diameter:* F: 12.7 ± 1.4 M: 14.1 ± 1.3 No further information on standard deviation, mean and range	Larger liver size in male than in female. Correlation to age (non-significant), weight, height (both significant). Negative correlation to BMI, obese were excluded
Elkhadir 2017 [39] / Saudi Arabia / n = 90 / abdominal sonography as part of outpatient X-ray diagnostics department, patients with any abnormality of sonographic findings were excluded	Longitudinal axis in MCL	*Cc diameter:* All: 14.6 ± 1.5 (10.5 – 16.0) F: 14.6 ± 1.6 M: 14.6 ± 1.4	No correlation of liver size to gender, height and age. Correlation to body weight and BMI
Riestra-Candelaria 2018 [26] Puerto Rico / n=33	Longitudinal axis on the right AAL	*Cc diameter:* F: 13 ± 1.5 M: 14.1 ± 1.5	
Khan 2018 [33] Pakistan / n = 2212 people with comorbid diseases were excluded	Longitudinal axis in MCL: liver with simultaneous demonstration of right kidney on the figure.	*Cc diameter:* All: 13.7 ±1.6 F: 13.9 ±1.6 M: 13.5 ±1.6 No further information.	Female had significantly larger livers than male. Significant correlation between size and BMI. (Obesity was more common in women.) Significant correlation between size and age in women
Özmen 2018 [35] / northern Anatolian Turkish population / n = 822 community-based study, healthy people	Longitudinal plane in MCL	*Cc diameter:* F: 14.7 ± 1.8 M: 15.0 ± 1.4	Larger liver size in males than in females. Significant correlation to BMI, weight, elevated liver enzymes
Abdalla Eltahir 2020 [40] Sudan / n = 100 people with history of liver diseases, other chronic diseases, surgery, trauma, pregnant women were excluded	Longitudinal axis in MCL; from the right hepatic dome to the inferior hepatic tip, no further description	*Cc- diameter*: All: 13.4 ± 0.8 F: 13.2 ± 0.8 M: 13.7± 0.9 *Ap- diameter*: All: 13.3 ± 0.8 F: 13.0 ± 0.7 M: 13.7 ± 0.8	Males have a significant larger Cc and Ap diameter than females. Positive correlation of both diameters to body height and weight Cc-diameter and Ap-diameter were similar
Khammas 2021 [41] Malaysia / n = 408 72% – without hepatobiliary disease; 28 % – with hepatobiliary disease.	Longitudinal axis in MCL, size extending from the liver top to the bottom	*Cc diameter:* M: 11.7 ± 1.5 F: 12.2 ± 1.5 People without hepatobiliary diseases: 11.9 ± 1.5 With hepatobiliary abnormalities: 12.7 ± 1.2 No further information.	Significant larger size in males than in females. The liver size was larger in patients with hepatobiliary diseases than in those without

Study / country / number of patients / patients	Measurement method	Average maximum liver span ± SD, median (range) (cm)	Comments
Stepanyan 2021 [27] Kaliningrad, Russia / n = 47 healthy volunteers	Longitudinal plane	*Cc diameter (Labeled: oblique craniocaudal diameter)*	The oblique vertical diameter is measured as the cc extension in MCL in transversal transducer position.
	In MCL	*In quiet breathing:* 15.5 ± 2.4 *In deep inspiration:* 15.0 ± 2.5	In deep breathing, the oblique craniocaudal diameter decreases by an average of 5–10 mm regardless of access.
	In AAL	*In quiet breathing:* 15.8 ± 2.9 *In deep inspiration:* 15.3 ± 2.5	With quiet breathing, oblique measurements using any method give an inter-observer error of less than 5%.
	Oblique subcostal transducer position below the costal margin	*Cc diameter (Labeled: Oblique vertical diameter):* *In quiet breathing:* 13.9 ± 3.2 cm *In deep inspiration:* 12.3 ± 2.4 cm	
Tiryaki 2023 [42] Turkey / n = 1918 people with abnormal laboratory values and organ pathologies during US-investigation were excluded	Cc diameter in the longitudinal plane in MCL, the gallbladder and inferior vena cava were visualized in the same plane on the figure.	*Cc diameter*: All: 14.0 ± 1.4 14.2 (13.1 - 15.1) F: 13.9 ± 1.5 M: 14.2 ± 1.4	Cc and Ap diameter were significantly larger in male than in female. However, the BMI in female was significantly higher than in male. Significant correlation between size (Cc and Ap diameter) to BMI in both genders
	Ap diameter of the liver by visualizing the origins of the three hepatic veins in the transverse plane passing through the sternum xiphoid process.	*Ap diameter*: All: 10.6 ± 1.2 10.6 (9.8 - 11.5) F: 10.5 ± 1.9 M: 10.7 ± 1.2	
Medical 2023 [43] Nigeria / n = 500 healthy people	Cc diameter in the longitudinal plane in MCL (denoted as “length 2”)	*Cc diameter*: All: 13.3 ± 1.06 13.4 cm (10.1-15.0 F:13.4 ± 1.1 13.6 (10.1-15.0) M: 13.3 ± 1.0 13.4 (10.1-15.0)	The overall gender difference was not significant. However, there were certain age groups in which the size was larger for male than for female
	Ap diameter in the longitudinal plan in MCL (denoted as “length 1”	*Ap diameter*: All: 11.8 ± 1.2 11.8 (7.9 – 12.1) F: 11.9 ± 1.3 11.9 (9.0 – 12.1) M: 11.7 ± 1.2 11.7 (7.9 – 13.9)	

AAL – anterior axillary line; Ap – antero-posterior; BMI – body mass index; Cc – craniocaudal; MAL – midaxillary line; MCL – midclavicular line; M – male; F – female; Sd – standard deviation

[36]. This is not consistent with other published papers. Other authors found that liver size was not different in the adult group and only decreased slightly in the 51-65 year old group ($p<0.011$) [34]. Another study showed no correlation between liver size and age in an adult study cohort [41].

Diabetes mellitus, alcohol consumption, tobacco smoking: No significant correlation to diabetes mellitus (DM), surprisingly, with alcohol consumption and tobacco smoking could be demonstrated [34]. The influence of currently persistent alcohol abuse has been assessed quite differently in previous studies. While Niederau et al [46] found no impact of alcohol on liver size, the study by Kratzer et al [47] found contrary results.

Ethnic groups: In the studies documented here, smaller craniocaudal diameters were measured in Puerto Rico, Pakistan, Saudi Arabia, India, Sudan, Malaysia and Nigeria [26,33,37,38,40,41,43] than in Russia (Kaliningrad), Germany and Turkey [27,34,35,42]. In two studies from Saudi Arabia, the craniocaudal (Cc) diameters in the MCL differed significantly. In contrast to the study by Kheiralla et al [37], the diameters in Elkhadir's [39] study were significantly larger: the average Cc diameter in MCL was 14.6624±1.5 cm; (10.5–16.0) cm for all subjects; 14.6±1.6 cm in females and 14.6±1.4 cm in males [39]. Liver length exceeded 15 cm in 37.8% of subjects [39]. However, the inclusion criteria were vague. Only patients with sonographically abnormal findings without further specification were excluded. In this study [39], the BMI (27.4 kg/m^2) and weight (73 kg) were significantly higher than in the study by Kheiralla et al [37] (Weight: F – 65 kg, M – 64 kg; BMI: F – 21.6 kg/m^2, M – 23.8 kg/m^2). This shows that liver diameters can vary greatly even within a single geographical region. We would attribute this to significant differences in weight and BMI, especially since in this study [39] and those already mentioned, there was a correlation between size, weight, and BMI.

In routine clinical situations, the key question is whether the liver is of normal size or enlarged. The question of whether it is too small is not usually asked. According to Sienz [20], reference values of 12–16 cm in the craniocaudal extent in the midclavicular line are given. However, looking at the data in Table I, it can be seen that lower normal values of <12 cm were measured in the study from Malaysia [41]. Therefore, regional peculiarities must also be considered here. The diagnosis of liver atrophy, or liver segmental atrophy, is always made in the overall context with a complete sonographic assessment of the liver.

Physical exercise: Physical exercise in different groups with zero hours to more than 10 hours per week did not affect liver size [34]. We were unable to obtain data on ultrasonographical measured liver size in competitive athletes.

Quiet and deep breathing: Stepanyan et al [27] found that the diameter of the right hepatic lobe decreases during deep breathing. Inspiration results in a reduction in the oblique vertical diameter by an average of 15–20 mm. This is due to a change in the configuration of the elastic liver tissue in healthy subjects and a shift in the lower limit, with none of the measurements showing a deviation of more than 5%. The oblique vertical diameter is measured as the craniocaudal extension in the subcostal cross-section.

How does the liver size measured by ultrasound correlate with physical examination data?

Measurements of liver size obtained by clinical examination (percussion, scratch test, palpation) and ultrasound do not match in adult patients. It is challenging to locate the dome of the liver by percussion. Even though it is possible to palpate the caudal edge of an enlarged liver at the MCL below the rib cage, it is not possible to accurately determine the size of the liver by physical examination alone. Compared to ultrasound examination, the liver size determined by percussion is systematically underestimated [48-52]. With a higher BMI, the difference between the clinically determined and ultrasound-determined liver size increases [48,52]. However, several authors described at least moderate correlations between liver size determined using physical examination and ultrasound-determined liver size [48,50-52].

Reference values liver size right liver lobe

- Craniocaudal (longitudinal) diameter in right midclavicular line: 12–16 cm [20].

Liver volume

The most accurate tool for determining liver size is liver volumetry [53]. Due to the time-consuming assessment with calculation based on several diameters in a non-conform volume, ultrasound volumetry is hardly eligible in clinical routine and not routinely used in everyday clinical practice [54]. Furthermore, normal volumetry values derived from other imaging modalities such as CT or magnetic resonance imaging (MRI) scan using cross-sectional techniques, cannot be transferred to ultrasound diagnostics [55].

In conclusion, determining the liver volume is currently only necessary before partial liver resection or transplantation. In terms of surgery, only CT volumetry is accepted, so ultrasound volume measurement of the liver plays no role in everyday clinical practice.

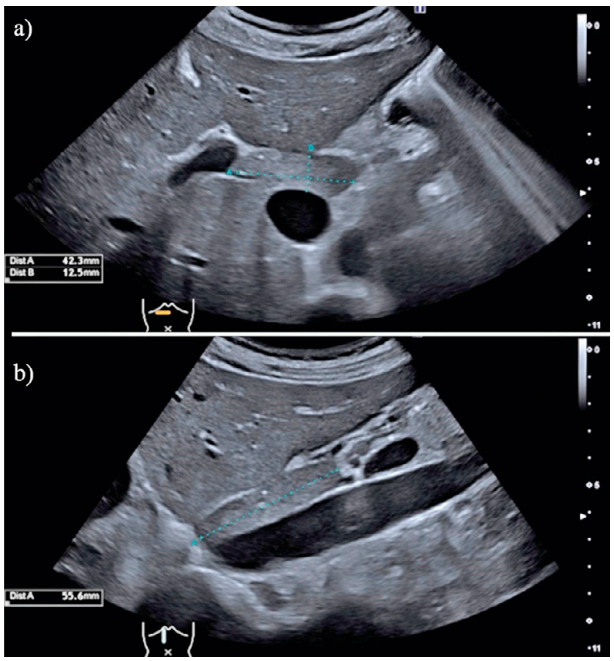

Fig 7. Normal caudate lobe transversely (a) and longitudinally (b) measured in two transducer positions.

Caudate lobe

Measuring maximal Cc and Ap diameter ventral to the inferior vena cava (IVC) in a median or slightly right-sided paramedian line with longitudinal and transversal probe position is recommended [56] (fig 7-8). Due to its specific vascularization with portal venous supply from both portal vein branches and venous outflow via its small hepatic veins into the inferior vena cava, the caudate lobe is affected differently by portal hypertension than other liver lobes. Hypertrophy of the caudate lobe is a typical sign of Budd Chiari Syndrome (BCS), less specific in portal vein thrombosis, and potentially also in liver cirrhosis [12] due to the direct venous drainage into the IVC [57] (fig 9-10). Atrophy of the caudate lobe is extremely rare (fig 11).

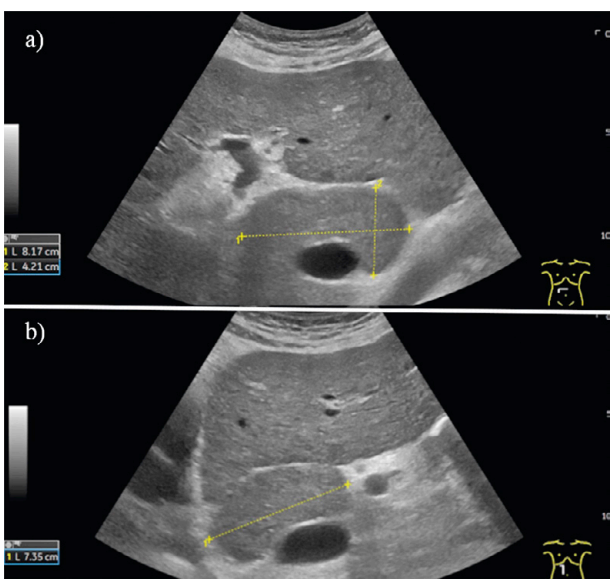

Fig 9. Enlarged, rounded caudate lobe in cardiac cirrhosis, transverse (a), longitudinal (b).

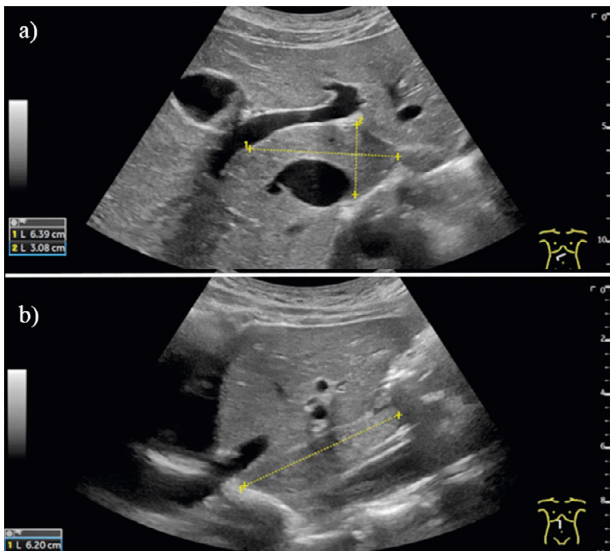

Fig 8. Enlarged longitudinal diameter of the caudate lobe of a healthy young woman with normal liver laboratory parameters – transverse (a), longitudinal (b); measured in two transducer positions.

No recent sonographic study was found analyzing caudate lobe size, nor did any study define the standard measurement points of the caudate lobe.

The cut-off points for caudate lobe measurements were defined as 5.9 cm longitudinal, 4.2 cm transverse, and 3.2 cm antero-posterior [56]. In contrast, newer lit-

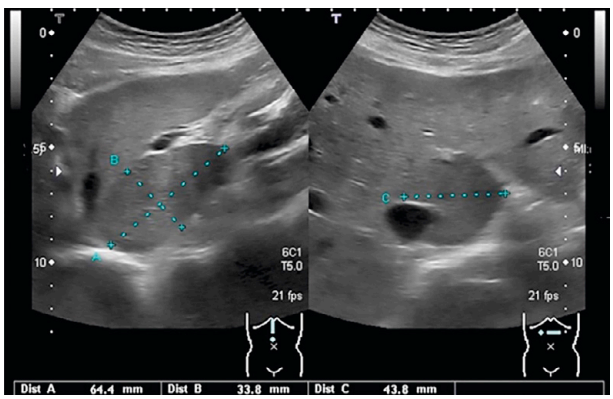

Fig 10. Rounded and enlarged caudate lobe in a female patient with alcoholic hepatic steatosis with acute decompensation. Longitudinal section in the left part of the image, transverse section on the right.

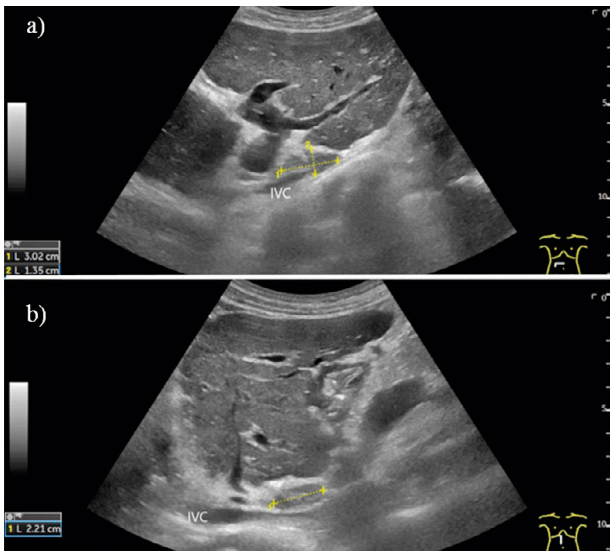

Fig 11. Atrophy of the caudate lobe in a patient with cystic fibrosis-associated liver disease/focal biliary cirrhosis. The atrophied small caudate lobe is located between the markers; transverse transducer position (a), longitudinal (b). IVC – inferior vena cava.

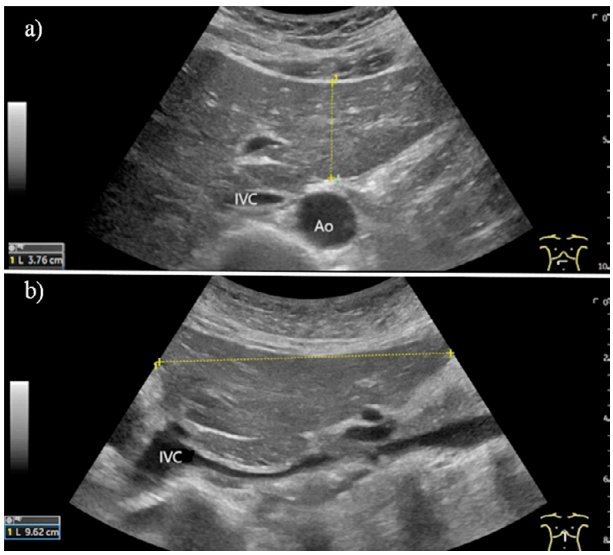

Fig 12. Left liver lobe measured in midline in front of the aorta: transversal (a) and longitudinal transducer position (b). IVC-Inferior vena cava, Ao-aorta.

erature recommends a maximal craniocaudal diameter of ≤5 cm and an antero-posterior diameter of ≤ 2-3 cm [20].

Reference values caudate lobe

- Craniocaudal: 4.6 ± 0.6 cm (<5.9 cm) [56], ≤5 cm [20]
- Anteroposterior: 2.2 ± 0.6 cm (<4.2 cm) [56], ≤2–3 cm [20]

Left liver lobe

Measuring the left liver lobe is infrequent in routine clinical practice but can be useful in specific cases. Examples include measurements due to visual disproportion between the left and right liver lobe or the monitoring of left liver lobe hypertrophy after right hemihepatectomy or portal vein embolization. In women, the left liver lobe is significantly longer and narrower than in men [58]. The measurements are performed in the midline in transverse and longitudinal transducer position in the plane of the aorta in deep inspiration (fig 12). In very slim asthenic individuals, the left lobe of the liver may be visible intercostally above the spleen (fig 13). Since the review by Sienz et al [20] in 2010, we have been unable to find any new studies, with the exception of the measurements by Childs et al [24], in which the diameter of the left hepatic lobe was measured exclusively in an adult population.

Reference values left liver lobe

- Craniocaudal: 10.1 ± 1.7 cm (female); 9.5 ± 1.7 cm (male) [20,58], 9.0 ± 1.1 cm [24].
- Anteroposterior: 5.9 ± 0,8 cm (female); 6.9 ± 0.8 (male) [20,58], 7.0 ± 1.4 cm [24].

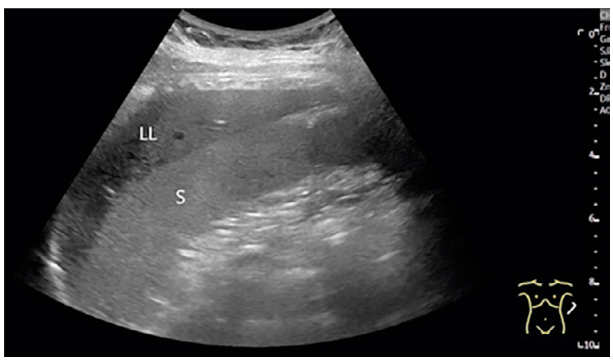

Fig 13. The left lobe (LL) of the liver overlaps the spleen (S) in the intercostal transducer position on the left. The finding was made in a very slim healthy patient with a narrow thoracic aperture. There was no abdominal pathology.

The transducer positions and various measurements in the right and left liver lobes and caudate lobe are summarized in Tables II-IV. However, the authors consider the measurement on the MCL to be the most practical.

Hepatic variations

Riedel's lobe

There are varying data on the prevalence of Riedel's lobe, where the caudal margin of the liver is entirely lateral and inferior to the caudal margin of the ribs (fig 14). The prevalence is 3.3 – 14.5%, depending on the literature [61-63].

Beaver's tail lobe

Rarely, the left lobe of the liver extends across the midline, sometimes touching or encircling the spleen

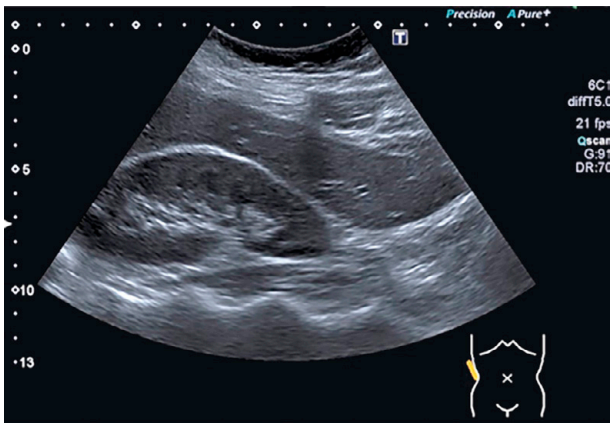

Fig 14. Riedel´s lobe. The lateral inferior border of the liver protrudes beyond the caudal pole of the right kidney and is also palpable below the costal arch.

from above (more often) or below, or stretching between the stomach and the spleen. This anatomic variant is called beaver tail liver [64-66], also known as "sliver tail liver" or "sliver of liver" [67] (fig 15).

Variations of caudate lobe

The main caudate lobe shape for Caucasians is irregular, whereas in India, it is rectangular [68]. Large papillary processes can be found with a prevalence of 1.8–4.3% in cadaver studies [69].

Should the size of the liver always be measured?

In clinical evaluation of the liver, objective size measurement is an essential component of multiparametric ultrasound. Even in examinations for non-hepatic indications, the liver is routinely visualized, and measuring its

Table II. Right liver lobe measurements (RLL)

Transducer position	Measurement technique	Normal values
Longitudinal transducer position on the right MCL – subcostal	Maximal Cc diameter on the right MCL from the uppermost right hemi diaphragm to the inferior tip of the right lobe in deep inspiration [24,30,35,59]	12–16 cm [20] Anatomic norm variations (Riedel configuration) must be considered and excluded for the final interpretation of liver size. Consideration of subject proportion and volume dimensions always has to be made.
Longitudinal transducer position on the right AAL subcostal	Maximal Cc measurement on the AAL from uppermost right hemidiaphragm to inferior tip of right lobe in deep inspiration [31] or in an area between the MALand the AAL [26]	14.0 ± 1.9 cm [31] (comparable with CT measurements; otherwise not further evaluated) upper normal limit: 15.4 cm [31]. 13.0 ± 1.5 (female) 14.1 ± 1.3 (male) [26]
Longitudinal transducer position on the right MAL – intercostal	Maximal Cc measurement on the MAL from uppermost right hemidiaphragm to inferior tip of right lobe in breathing baseline [24,31]	14.9 ± 2.0 cm [31] (comparable with anterior-axillary line measurement and an accurate alternative method to subcostal approaches) Upper normal limit: 15.4 cm [31]

AAL – anterior-axillary line; Cc – craniocaudal; CT – computed tomography; MAL – mid-axillary line; MCL – midclavicular line

Table III. Left liver lobe measurements (LLL)

Transducer position	Measurement technique	Normal values
Longitudinal transducer position on the midline using xiphisternum as an anatomic marker – subcostal	Maximal Cc diameter on the midline measuring from the diaphragm to the lowermost margin of the liver [24,60]	Largest diameter: 9.0 ± 1.1 cm [24]
Longitudinal transducer position on the midline using xiphisternum as an anatomic marker – subcostal	Maximum Ap diameter [24]	Highest reliability: 7.0 ± 1.4 cm [24]

Ap – anteroposterior; Cc – craniocaudal

Table IV. Caudate Lobe Measurements (CL)

Transducer position	Measurement technique	Normal values
Transversal and longitudinal transducer position on the right paramedian line	Maximal Cc and Ap diameter on the right paramedian line ventral to inferior vena cava [56]	Cc diameter: ≤5 cm [20] Cc diameter: 4.6 ± 0.6 cm [56] Ap: ≤2–3 cm [20] Ap: 2.2 ± 0.6 cm [56]

Ap – anteroposterior; Cc – craniocaudal

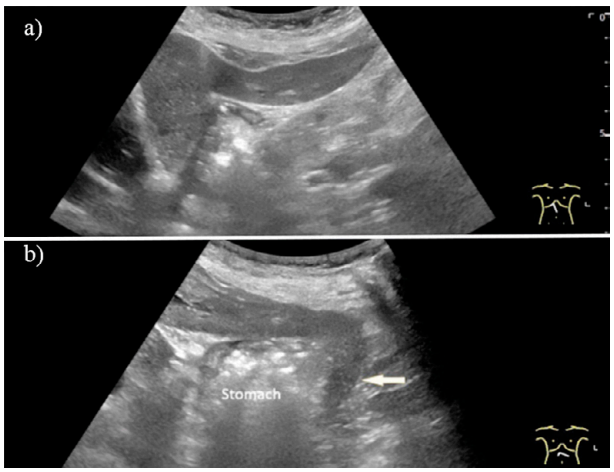

Fig 15. In the longitudinal section, beaver tail liver lobe at the left liver lobe (a). This encases the gastric body (arrow) (b).

size enables an objective statement on normality. Measurement ensures reproducibility and accuracy.

The causes of hepatomegaly and the pitfalls that may lead to apparent or missed enlargement are summarized in Table V.

What is missing, future perspectives, open questions

To ensure the reliable application of standardized ultrasound measurements, it is essential to establish a structured and widely adopted training curriculum [11, 12,70,71].

Future study directions may focus on standardizing measurement techniques across different imaging modalities and populations. Additionally, advancements in quantitative imaging biomarkers and the integration of artificial intelligence could enhance the accuracy and reproducibility of liver ultrasound measurements.

Ultrasound-based artificial intelligence (AI)

Numerous studies have examined the integration of AI into CEUS for liver examination [73-75]. How could AI help in assessing liver size? By recognizing all reference structures, AI could confirm the optimal transducer position and display reference structures for the (inexperienced) examiner. Once the liver contours are recognized, automatic measurements could be taken and evaluated when patient data (height, BMI) is entered. This data can then be used in a complex AI-based liver assessment that includes clinical data and laboratory analyses.

The integration of AI systems into medical processes must be carried out under medical supervision and con-

Table V. Causes of hepatomegaly and clinical pitfalls (apparent hepatomegaly, unrecognized hepatomegaly)

Causes of hepatomegaly and clinical pitfalls
Increased liver size
Diffuse parenchymal liver diseases
• Acute viral hepatitis (Hepatitis A, B, C, D, E), Chronic hepatitis (viral, autoimmune, alcoholic, cholestatic, genetic, etc.)
• Metabolic diseases
– Steatosis hepatis
– Gaucher disease, Niemann-Pick disease, Glycogenosis
• Liver cirrhosis of different causes
– Viral (Hepatitis B, C, D)
– Toxic, metabolic, alcohol related
– Autoimmune and primary biliary cirrhosis
– Hemochromatosis, Wilson' disease
Liver lesions / masses
– Primary malignant liver tumors
– Liver metastases
– Polycystic liver degeneration
– Benign liver lesions
Infectious
– Schistosomiasis
– Malaria
– Infectious mononucleosis
– Liver abscesses (Escherichia coli, Klebsiella, Candia, amoebic, melioidosis and others)
– Echinococcus
Hematological diseases
– Myeloproliferative diseases
– Amyloidosis
Vascular liver diseases
– Hepatic vein congestion in right heart decompensation, cirrhosis cardiac
– Budd Chiari Syndrome
– Portal vein cavernoma (increased caudate lobe)
– FONTAN-associated liver disease
Biliary causes
– Different causes of bile duct obstruction with bile duct dilatation
– Primary sclerosing cholangitis
– Secondary sclerosing cholangitis, e.g. critical illness patient sclerosing cholangitis, IgG4 related sclerosing cholangitis
Apparent liver enlargement
• Low-lying diaphragm – the liver is displaced caudally:
– Chronic obstructive pulmonary disease, pulmonary emphysema
– Pleural effusion, pleural empyema
• Riedel lobe
• Left liver lobe extending far to the left in asthenic body constitution
• Thoracic deformities
Unrecorded liver enlargement
• Diaphragmatic elevation in diaphragmatic dysfunction / paralysis

trol. AI systems must first prove their effectiveness, reliability, and trustworthiness before they can be integrated into clinical processes.

Conclusion

Measurement of liver size should be an integral component of any multiparametric ultrasound examination in hepatological indications, and it is equally valuable in non-hepatological studies to allow an objective assessment. The most reliable and widely accepted parameter is the craniocaudal diameter of the right hepatic lobe, measured in the longitudinal plane along the right midclavicular line during deep inspiration. For Caucasian adults, this value should not exceed 16 cm; in other ethnic populations, normal ranges are often lower and must be interpreted in the context of regional and demographic differences. Additional measurements are indicated in specific scenarios: the left hepatic lobe after right hemihepatectomy or when disproportion is suspected, and the caudate lobe in cases of suspected vascular liver disease or portal hypertension. Size interpretation should always consider constitutional factors, anatomical variants, and correlations with BMI, height, weight, and sex.

Physical examination alone cannot reliably determine liver size in adults and should not replace ultrasound measurement. Future progress will depend on establishing consensus-based, standardized measurement techniques and integrating automated, AI-assisted tools into routine practice under medical supervision. These steps will improve measurement reproducibility, diagnostic accuracy, and the overall quality of hepatic ultrasound assessment.

Take-home message

- Measure liver size routinely in all hepatological ultrasound examinations, and in non-hepatological indications whenever a statement on liver size is made.
- Preferred method: Cc diameter of the right hepatic lobe in the longitudinal plane along the right MCL or anterior axillary line during deep inspiration.
- Reference values: ≤16 cm for Caucasian adults; lower limits apply for some other ethnic groups and for children; interpret measurements in the context of patient constitution and published cut-off values for specific populations.
- Measure the left lobe after right hemihepatectomy or when disproportion is suspected.
- Measure the caudate lobe in suspected vascular liver disease or portal hypertension.
- Consider BMI, height, weight, gender, and anatomical variants when interpreting measurements.
- Physical examination alone is unreliable for determining liver size in adults; ultrasound measurements are more reliable.
- Future improvements depend on standardized measurement protocols and AI-assisted tools integrated under medical supervision to enhance accuracy and reproducibility.

Conflict of interest: none

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