Baz et al. Egypt J Radiol Nucl Med (2024) 55:54
https://doi.org/10.1186/s43055-024-01224-z

Egyptian Journal of Radiology and Nuclear Medicine

RESEARCH

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Diagnostic efficacy of abdominal US compared to contrast enhanced CT in the evaluation of the left hepatic lobe volume for morbidly obese patients before bariatric surgery

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Abstract

Background Bariatric surgery has been widely distributed as an effective treatment method for morbid obesity. An increased volume of the left hepatic lobe may affect the ergonomics of bariatric surgery, which could complicate the surgical techniques and require special instruments. CT of the abdomen is considered the gold standard imaging modality in the assessment of the left hepatic lobe volume; nevertheless, it has some drawbacks, such as exposure to ionizing radiation, besides the contrast and gantry limitations. The objective of this study is to investigate the diagnostic accuracy of abdominal US in comparison to CT in measuring the left hepatic lobe volume in morbidly obese patients as part of their preoperative evaluation. Seventy-two morbidly obese patients of different ages (between 22 and 55 years) and genders were included in this study who were scheduled for bariatric surgery.

Results The intraclass coefficient and Cronbach's alpha reliability coefficient with their 95% CI were used. There was a strong positive correlation between left hepatic lobe volumes as measured by US and CT ($r = 0.999$, p value < 0.001), indicating a significant linear relationship between them. The mean of the two variables was very close (474.2 ± 164.9 cm^3) by US and (475.1 ± 164.5 cm^3) by CT.

Conclusions Abdominal US examination for assessment of the left hepatic lobe volume is considered a valid diagnostic method compared to CT (with a clinically accepted slight difference between values) in preoperative assessment of morbidly obese patients. It provides an accurate, simple, and inexpensive diagnostic tool that avoids the drawbacks of CT.

Keywords Ultrasound, Left lobe of liver, Morbidly obese, Bariatric

Background

Obesity is a global illness that is becoming more common. It is associated with an increased risk of developing diabetes mellitus, cardiovascular disease, hypertension, and hyperlipidemia, among other health problems. Since bariatric surgery improves the quality of life, reduces obesity-related comorbidities and mortality, and achieves

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sustained weight loss, it is widely acknowledged as a highly successful therapy for obesity [1, 2].

Body mass index (BMI) was used to classify obesity into three groups: class I, which had a BMI of 30–34.9 kg/m^2; class II, which had a BMI of 35–40 kg/m^2; and class III, which had a BMI of ≥ 40 kg/m^2. Morbid obesity was described as having a BMI of ≥ 40 kg/m^2, or class II, with substantial comorbidities [3, 4].

One crucial stage in bariatric surgical treatment is the retraction of the left hepatic lobe (LHL). A well-executed liver retraction will simplify the procedure and lessen complications. As part of the preoperative assessment, the LHL volume is estimated [5]. Because computed tomography (CT) is noninvasive and has excellent contrast and spatial resolution, it is the ideal diagnostic tool for assessing LHL volume. Ionizing radiation is a risk associated with CT scans; nonetheless, claustrophobia is a problem with MRI and is not recommended when a pacemaker or cochlear implant is present. Therefore, a simple, reliable, uncomplicated, and valid method for assessing LHL volume is still needed [6].

The examination of LHL volume by ultrasound (US) is a readily available, reasonably priced, and quick imaging method that doesn't involve ionizing radiation [7].

The current study aims to investigate the diagnostic accuracy of abdominal US in comparison to CT in the measurement of LHL volume in morbidly obese patients, as part of the preoperative evaluation of patients undergoing bariatric surgery to reduce the operative and post-operative morbidities.

Methods

Subjects

The study was designed as a cross-sectional analytic study carried out on 72 patients of different sex and age groups (range 22–55 years) (mean ± SD = 41.57 ± 10.1) who were scheduled for bariatric surgery and admitted to the general surgery department of our institute from August 2021 to February 2023.

Inclusion criteria Patients with morbid obesity who were scheduled for bariatric surgery were included. Morbid obese subjects were defined as having a BMI of ≥ 40 kg/m^2, or class II (BMI ≥ 35 kg/m^2), with substantial comorbidities.

Exclusion criteria Patients who were contraindicated for bariatric surgeries, pregnant females, patents known to have HCC or hepatic metastasis and patients who weigh over the maximum weight that can be supported by the CT table/gantry (205 kg) were excluded from the study.

The present study was conducted following the ethical guidelines of the Research Ethics Committee of our institute. The reference number: Code is Ms-388-2021, its date of approval is 20-10-2021; and it was approved by the local Research Ethics Committee of our institute. All of the included participants were informed of the details and they gave their informed consent.

All of the study patients were subjected to:

1. Full history taking and clinical-laboratory examination.
2. Ultrasound examination.

A single operator used a LOGIQ P7 US machine (made in South Korea) with a convex probe (2.5–5 MHZ) to perform a preoperative US examination on a supine patient to assess the LHL volume. To determine the LHL volume, the ellipsoid formula (width × height × length × 0.52) was utilized. By measuring the distance between the diaphragm and the lower margin of the left lobe, an epigastric longitudinal scan was used to determine the height of the lobe. On the axial scan, the length of the lobe (lateral–lateral diameter) was determined by drawing a line between the LHL lateral boundary and the round ligament. By measuring the distance between the liver's anterior and posterior margins, thickness (width) was determined [6, 7].

As the exam was targeting the left hepatic lobe, which is relatively superficial, more accessible to US exam than the right one and often not masked by the abdominal gases, thus a careful sweeping of the US probe from the subxiphoid region and sometimes asking the patient to take a deep breath and withholding might help to get a quite better image.

US examination was done under supervision of a senior staff with 10-year experience in the radiology field. The obtained US LHL measured volumes were correlated to those measured by the contrast enhanced CT and to the operative data.

3. Contrast enhanced CT examination.

A MSCT (16) scanner (Optima, GE, USA) with a tube voltage of 130 kV, tube current of 150–280 mA, 1.5 mm slice thickness, and GE workstation was implemented preoperatively to quantify the LHL volume. The retro-hepatic IVC and the gallbladder were carefully excluded from the segmentation volume. The LHL volume was quantified and a volumetric reconstruction of the lobe was produced.

Contrast administration was done in our study after checking the patient serum creatinine level.

Three steps made up the semi-automated volumetric measurement process. Manual delineation, which was done in two dimensions (2D), was the first step. By using user input control points, it was able to capture the left lobe cross-section. The next stage involved reconstructing the 3D surface using a radial basis function that was determined by manual delineation. Using a level-set framework made up of both image and shape data, the reconstructed 3D surface evolved in the final stage, known as surface evolution [8].

4. Statistical analysis.

Data were coded and entered using the statistical package for the Social Sciences (SPSS) version 28 (IBM Corp., Armonk, NY, USA). Data was summarized using mean and standard deviation for quantitative variables and frequencies (number of cases) and relative frequencies (percentages) for categorical variables. Comparisons between groups were done using the unpaired t-test and ANOVA test. Correlations between quantitative variables were done using the Pearson correlation coefficient. Testing for reliability was done using the intraclass coefficient (ICC) and Cronbach's alpha reliability coefficient with their 95% confidence interval (95% CI). *p* values less than 0.05 were considered statistically significant.

Table 1 The demographic characteristics of the patients

Variables	Statistics	Values
Gender		
Male	N (%)	10 (13.9)
Female	N (%)	62 (86.1)
Age		
	Min–Max	22.0–55.0 years
	Mean ± SD	41.57 ± 10.1 years
BMI		
	Min–Max	35–68
	Mean ± SD	49.33 ± 9.86
BMI categories		
Obese type II	N (%)	11(15.3)
Morbid obese	N (%)	61(84.7)

N number, % percentages, *SD* standard deviation

Results

Demographic characteristics of the patients in the study

Female patients constitute most of the study sample (86.1%, n = 62), versus (13.9%, n = 10) males. Their mean age was 41.57 years (mean ± SD = 41.57 ± 10.1). In addition, the mean BMI of the study sample was 49.33. However, most of the patients were morbidly obese (class III) (84.7%, n = 61) (Table 1). The substantial comorbidities in patients with class II obesity was including hypertension in 7 patients (9.7%) and diabetes mellitus was present in 4 patients (5.5%).

US and CT characteristics

The mean LHL volume ± SD measured by US was 474.16 ± 164.90 cm^3, while that measured by CT ± SD was 475.07 ± 164.54 cm^3, by US, the mean LHL width ± SD was 10.30 ± 1.97 cm, mean length ± SD was 13.94 ± 2.60 cm and the mean depth ± SD was 6.28 ± 0.86 cm (Table 2).

Comparison between LHL volume regarding gender

An independent-sample t-test was calculated comparing the LHL volumes measured by the US and CT regarding gender. The mean LHL volume in males (M = 539.6, ± 162.9 cm^3) was higher than in females (M = 463.6, ± 164.1 cm^3) as measured by the US. However, no significant difference was found, *p* value = 0.178. Additionally, the mean LHL volume as measured by CT in males (M = 540.6, ± 161.4 cm^3) was higher than in females (M = 464.5, ± 163.86 cm^3), as well, no significant difference was found, *p* value = 0.176. Thus, gender has no statistically significant effect on the measured LHL volume (Table 3).

Table 3 The differences between LHL volumes according to gender

Hepatic volume	Gender	N	Mean (cm^3)	SD deviation (cm^3)	*p* value
US volume	Male	10	539.6	162.9	0.178
	Female	62	463.6	164.1	
CT Volume	Male	10	540.6	161.4	0.176

Table 2 US and CT measurements of the patients

Statistics	US length (cm)	US width (cm)	US depth height (cm)	US volume (cm^3)	CT volume (cm^3)
Min	10	7.2	4	224.22	230
Max	19.7	13.8	7.9	1040.42	1025
Mean	13.94	10.30	6.28	474.16	475.07
Standard deviation	2.60	1.97	0.86	164.90	164.54

Table 4 The differences between LHL volumes according to BMI

Hepatic volume	BMI categories	N	Mean (cm^3)	SD deviation (cm^3)	Minimum (cm^3)	Maximum (cm^3)	*p* value
US volume	Obese type II	11	274.7	26.3	224.2	319.98	< 0.001
	Morbid obese	61	510.1	153.1	324.3	1040.4	
CT volume	Obese type II	11	272.4	25.7	230	310	< 0.001
	Morbid obese	61	511.6	151.8	325	1025	

Table 5 The correlation between the dimensions of the LHL and BMI

variables		BMI
Length	*p* value	< 0.001
Width	*p* value	< 0.001
Depth	*p* value	0.007

Comparison between LHL volume regarding BMI

One-way ANOVA was conducted to compare the LHL volumes measured by US and CT regarding BMI categories. Concerning the US-measured LHL volume, a significant difference was found (p value < 0.001). It showed a significant difference in the two BMI categories, where class II morbid obese patients had a mean US volume of 274.7 cm^3, while morbidly obese ones (class III) had a mean US volume of 510.1 cm^3.

Second, regarding CT-measured LHL volume, a significant difference was found (p value < 0.001), as well, it showed a significant difference in the two BMI categories, where class II morbid obese patients had a mean CT volume of 272.4 cm^3, while class III morbidly obese subjects had a mean CT volume of 511.6 cm^3. Consequently, there was a statistically significant correlation between BMI and LHL volume (Table 4).

Correlation between BMI, length, width, and depth

An independent-sample t-test was calculated by examining the relationship between length, width, depth, and BMI. There's a significant difference between length, width, and depth in class II morbid obese patients versus class III morbidly obese ones (Table 5).

Correlation between LHL volume and age

A Pearson correlation was calculated by examining the relationship between LHL volume measured by the US and by CT in relation to the patient's age (Table 6). A weak non-significant correlation was found between US-measured volume and patient age (r = 0.015, p value = 0.902) as well as the CT-measured volume and age (r = 0.016, p value = 0.892), therefore, there were no statistically significant correlations between LHL volume and age.

Table 6 Correlation between volume of the LHL and age

variables		US volume	CT volume
Age	Pearson correlation	0.015	0.016
	p value	0.902	0.893

Table 7 The correlation between the LHL US and CT measured volumes

		Volume (US)
volume (CT)	r	0.999
	p value	< 0.001
	N	72

US and CT LHL measured volume correlation

The intraclass coefficient (ICC) and Cronbach's alpha reliability coefficient with their 95% confidence interval (95% CI) were used (Table 7; Fig. 1). There was a strong positive correlation between US and CT measured volumes (r = 0.999, p value < 0.001) thus, indicating a significant linear relationship between them. The mean of the two variables was very close. It was 474.2 (± 164.9 cm^3) by the US and 475.1 (± 164.5 cm^3) by CT (Figs. 2, 3, 4 and 5).

Discussion

Obesity is brought on by several causes. It is possible to classify over one-third of the global population as overweight or obese at this point. It raises the chance of all-cause mortality, with cancer and cardiovascular disease being the two most common causes of death [9].

Currently, bariatric surgery is considered as the most effective way to manage morbid obesity. Retraction of the (LHL) is a crucial step in bariatric surgery operations. A well-executed liver retraction will simplify the procedure and lessen complications. Patients with voluminous LHL had much greater rates of complication associated with

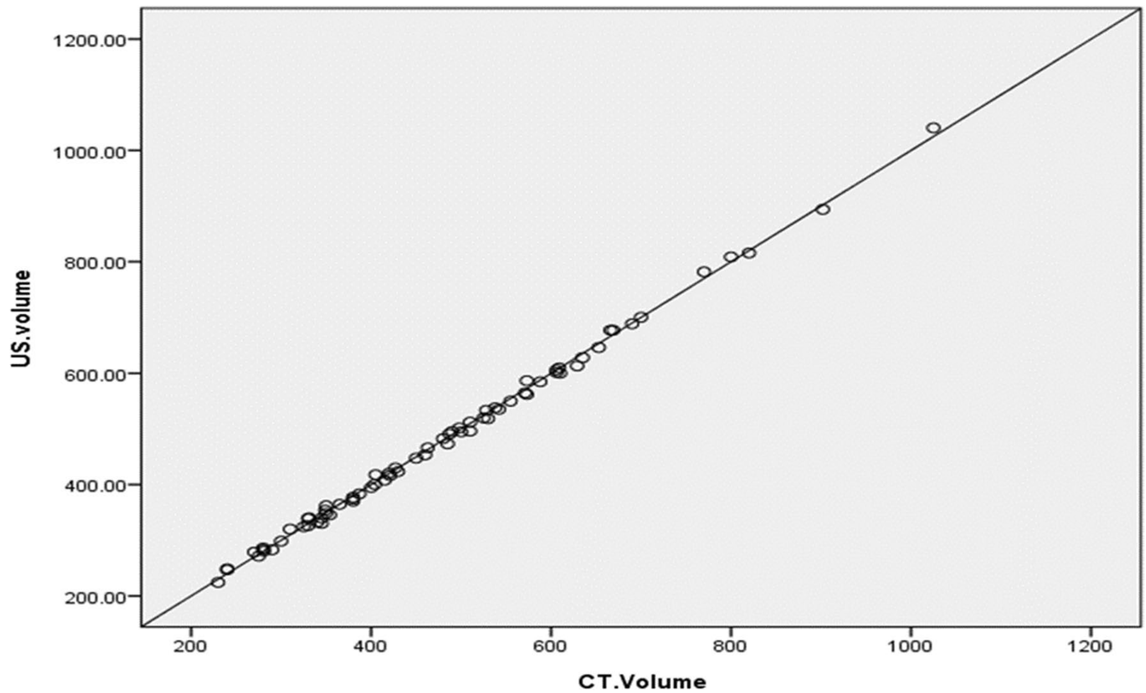

Fig. 1 Scatter-dot curve showing the correlation between US and CT LHL measured volumes ($r = 0.999$, p value < 0.001)

retractors. Preoperative evaluation can assist in reducing complications because a large LHL can be foreseen, thus, preoperative assessment of patients undergoing bariatric surgery includes the estimation of the LHL volume. Measuring liver volume is a better way to determine liver size since it gives an exact portrayal of the entire organ, as opposed to using linear measurements in certain planes [10–13].

The gold standard imaging for determining hepatic volume is CT. It is utilized for preoperative evaluation in bariatric surgery because it provides an accurate measurement of the liver volume. Previously, the process involved manually drawing the hepatic border and figuring out the hepatic total area on each axial slice. But in addition to be time-consuming, this method has lengthier diagnostic wait times, a weight limit, a gantry diameter limit, and a higher risk of radiation exposure. A straightforward, simple, and precise method for determining the hepatic volume is still required, even though automated and semi-automated volumetric measurements have supplanted manual hepatic volumetry for accurate liver volume measurement [6, 8].

To the best of our knowledge, we found relative scarcity in studies evaluating abdominal US examination in assessment of the LHL volume in morbidly obese patients in comparison to CT, therefore, our study aimed to provide a non-invasive technique for determining the LHL volume, which is essential for enhancing laparoscopic bariatric surgery ergonomics and lowering stress levels at work. Our goal was to validate abdominal US as a substitute for CT abdomen in determining the LHL volume during preoperative bariatric surgery preparations.

The present study subjects' mean age and BMI were 41.57 years (mean ± SD = 41.57 ± 10.1) and 49.33 kg/m^2, respectively. Females made up 86.1% (n = 62) of the total number of included subjects, while males made up 13.9% (n = 10) of the participant population. This differs from the results of Oguoma et al. who found that the study sample consisted primarily of males (56%), with the individuals' mean age and BMI being 43 years and 30 kg/m^2, respectively, however, in their study, females were more obese than males while males were more overweight [14]. This may be explained by the fact that our study's inclusion criteria differed from theirs, where we included subjects with BMI more than 35 kg/m^2 (class II with substantial comorbidities) in addition to the morbidly obese (class III) ones with BMI more than 40 kg/m^2.

In the present study, males had a mean LHL volume of 539.6, ± 162.9 cm^3, which was larger than females' mean LHL volume of 463.6, ± 164.1 cm^3, according to US measurements. Furthermore, compared to females (M = 464.5, ± 163.8 cm^3), males had a greater mean CT measured volume (M = 540.6, ± 161.4 cm^3). We didn't obtain statistically significant differences in p values (p value = 0.178, p value = 0.176, respectively), even though males and females had significantly different

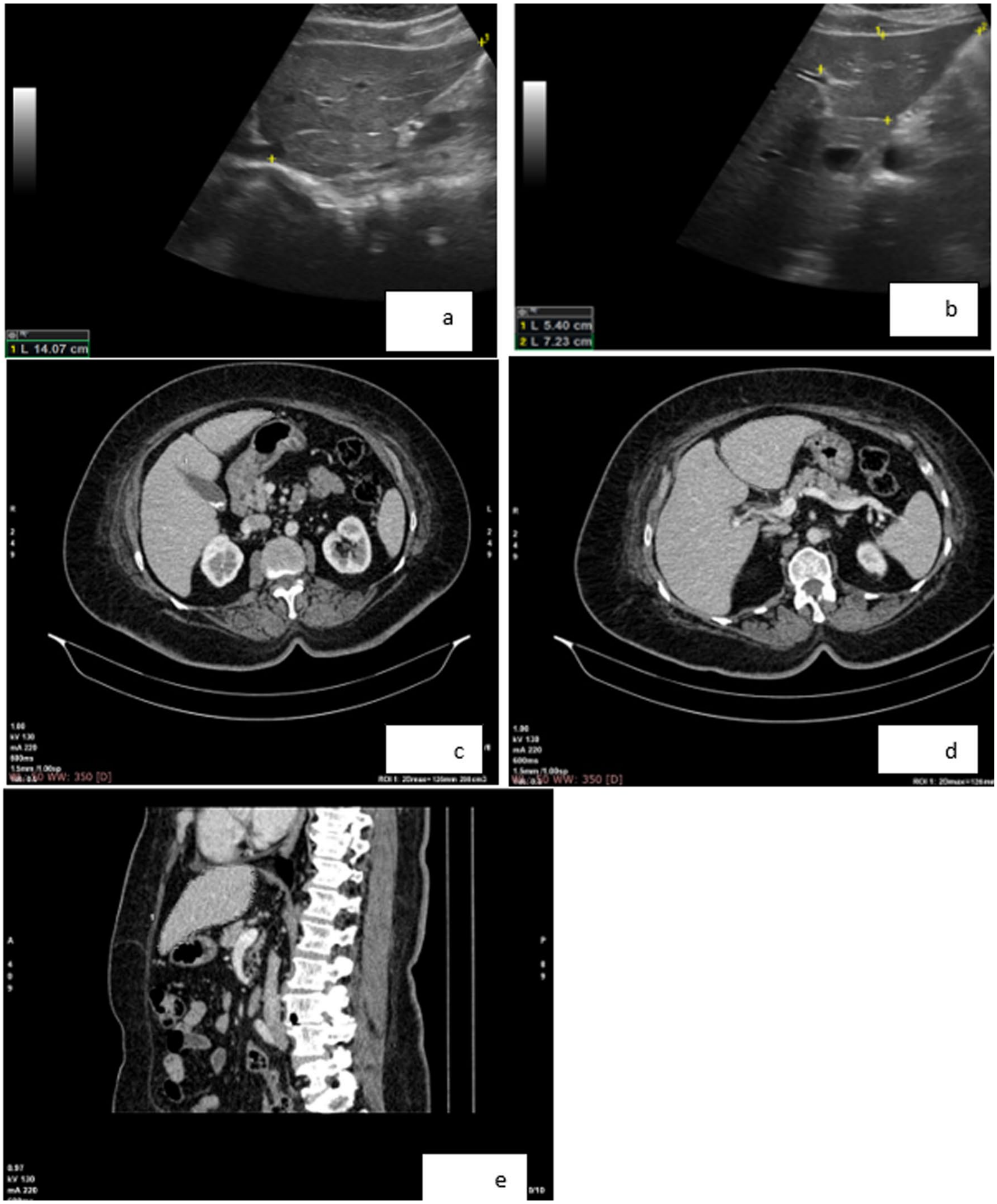

Fig. 2 **a**–**e** US and CT images for 37 years old female with a history of diabetes and BMI = 37.5. **a** and **b** US images measuring the height, length, and width with the estimated LHL volume by ultrasound = 285 cm^3. **c** and **d** axial CECT images and **e** sagittal CECT image estimating the LHL volume = 290 cm^3

LHL volumes on both abdominal US and CT scans. This could be explained by the relatively small number of male participants in our study. Consequently, we anticipate that if a larger sample with a higher proportion of men was used, a substantial association could be found.

This is in keeping with the research results of Mindikoglu et al. which demonstrated that females had considerably lower median estimated liver

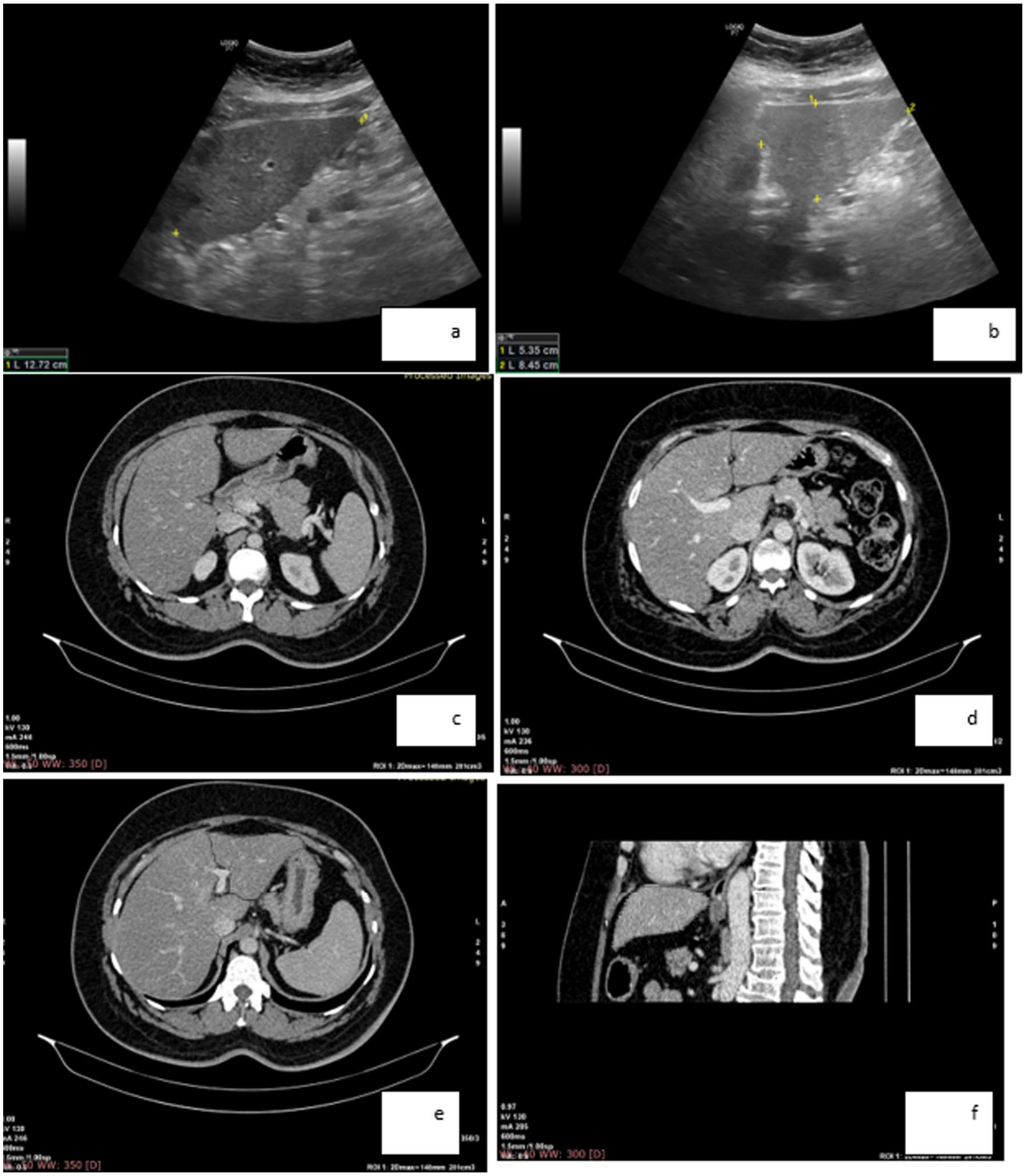

Fig. 3 **a**–**f** US and CT images for a 45 years old female with a history of diabetes and hypertension, his BMI = 39. **a** and **b** US images measuring the height, length, and width with the estimated LHL volume by ultrasound = 303.1 cm^3. **c**–**e** axial CECT images and **f** sagittal CECT image estimating the LHL volume = 280 cm^3

volumes (ELV) and weights (ELW) than males did (p values < 0.0001) [15]. According to Choukèr et al. young males (16–30 years old) had a noticeably larger liver weight than young females. Furthermore, male livers were shown to have a larger mean hepatic size than female livers, according to studies by Patzak et al. and Özmen et al. this can be explained by the well-known fact that the gastrointestinal systems of males are larger than those of females, which had been shown by research employing diagnostic imaging techniques and validated by the outcomes of previous autopsy investigations [16–18], however, Kratzer et al. discovered a weaker association with sex and a positive correlation with height, BMI, and age [19].

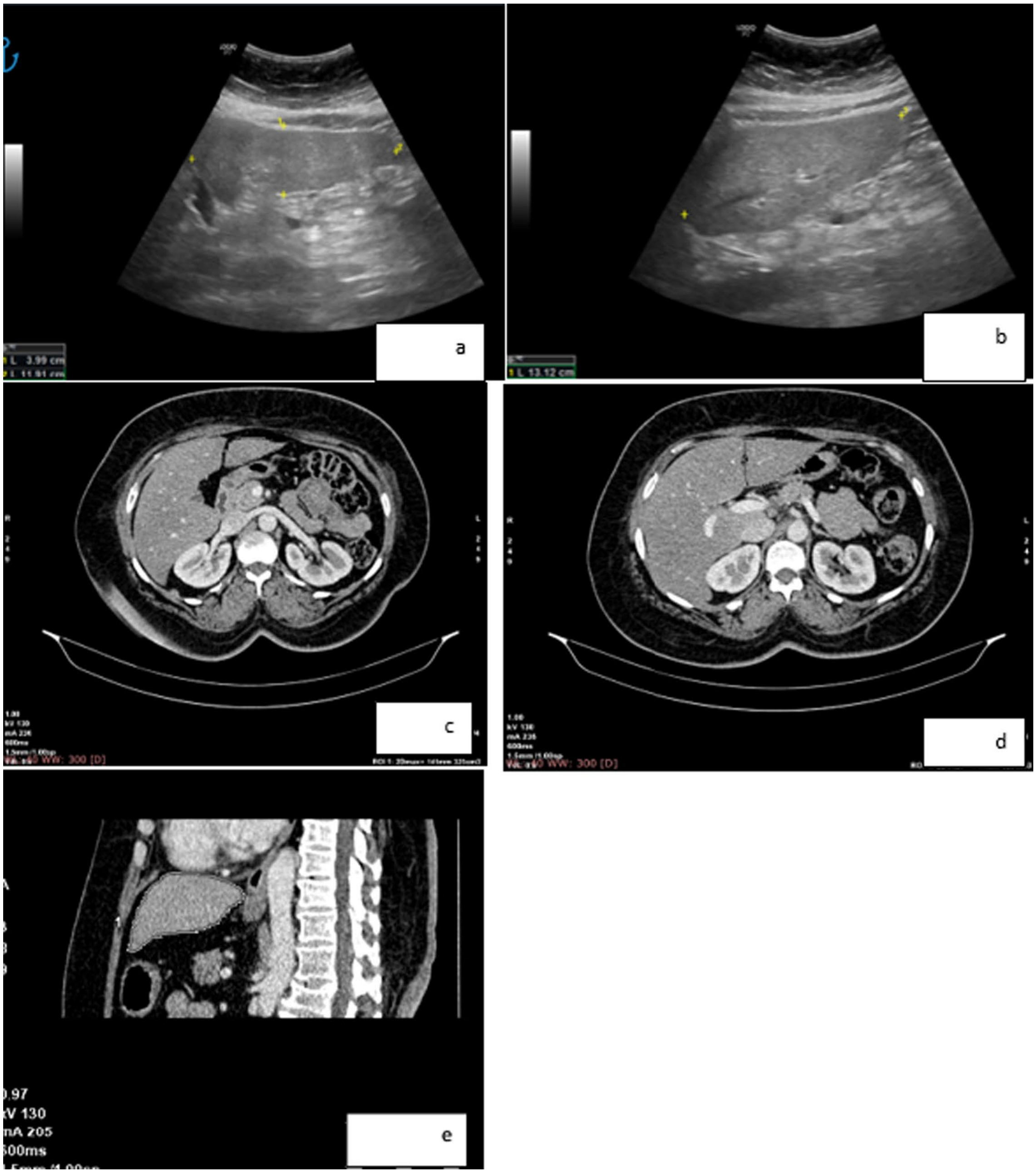

Fig. 4 **a**–**e** US and CT images for 59 years old female with a BMI = 42. **a** and **b** US images measuring the height, length, and width with the estimated LHL volume by ultrasound = 324.3 cm^3. **c** and **d** axial CECT images and **e** sagittal CECT image estimating the LHL volume = 325 cm^3

With a *p* value of less than 0.001, our research showed a significant association between LHL volume as determined by CT and US and BMI. This was consistent with research findings showing a high association between LHL and BMI, additionally, Childs et al. found a substantial positive correlation between liver volume and the anthropometric parameters of weight, BMI, and waist circumference. Furthermore, a study conducted by Fris et al. who monitored obese patients, found that the patients who lost the most weight and had the greatest drop in BMI also had the greatest reduction in hepatic volume (r = 0.43, *p* value = 0.0047). They also reported a highly significant decrease in liver size in just 2 weeks [20–22].

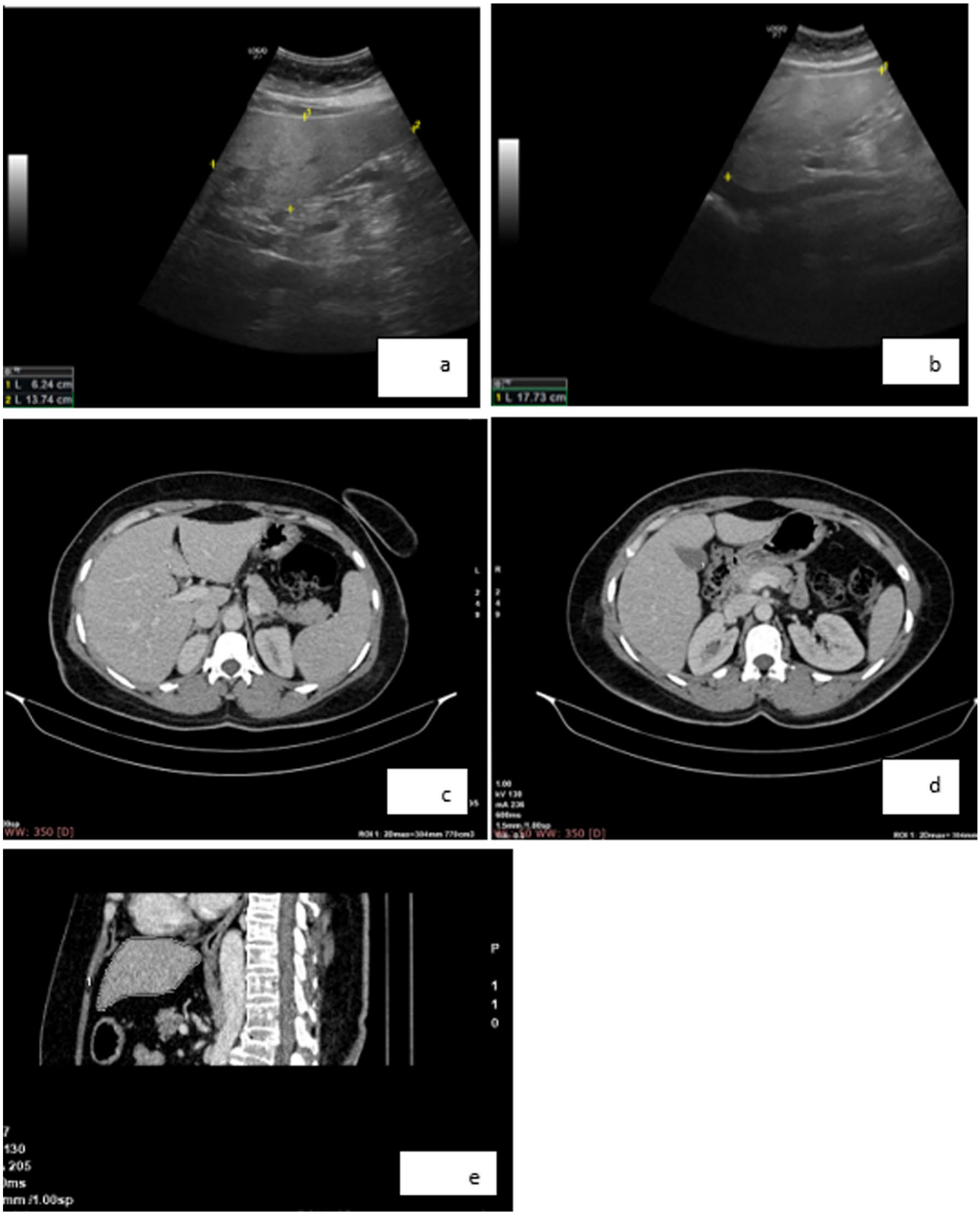

Fig. 5 **a**–**e** US and CT images for 28 years old female with a BMI = 51. **a** and **b** US images measuring the height, length, and width with the estimated LHL volume by ultrasound = 781.8 cm^3. **c** and **d** axial CECT images and **e** sagittal CECT image estimating the LHL volume = 770 cm^3

However, according to Silva et al., there is no statistically significant Pearson's correlation coefficient (0.01) between BMI and the liver measurement obtained by the US [23].

The means of the LHL volume measurements made by CT and US were found to be remarkably comparable in our analysis (Figs. 1, 2, 3, 4 and 5). Hence, US is a great substitute for CT in the preoperative evaluation of obese patients before bariatric surgeries with the benefits of saving time and money as well as avoiding ionizing radiation, the side effects of contrast media administration, and other complications as well as the weight limitations of table/gantry of CT machines.

Smith et al. demonstrated that the mean LHL volume measured by the US was 1048 ± 227 cm^3, but the mean volume measured by CT was 1058 ± 229 cm^3, which is consistent with our results. There was a high positive correlation between the two techniques, as indicated by the correlation coefficient of 0.96 (p value < 0.001) [24].

Similar results were also reported by Farghaly et al. where the average liver volume measured by the US was 1572.10 ± 326.43 cm^3, while the average liver volume measured by semi-automated CT was 1559.30 ± 381.02 cm^3, with a p value of 0.798 indicating that there was no statistically significant difference between the two [6].

Childs et al. stated that all data showed nearly perfect agreement (r = 0.9) between the two modalities [21]. The authors used ICC to test the accuracy of the simple linear US with comparisons made to linear CT readings. Variances in the US and CT techniques of measurement were shown to be statistically insignificant, according to Sarathi et al. [25].

Alomari et al. observed that there was a significant degree of consistency between US and CT data, indicating that US was a very reliable and precise method for evaluating LHL volume [26]. A study conducted by Elstein et al. investigated the accuracy of CT measurements versus the US for estimating hepatic size in individuals with Gaucher disease. They found that the measurement had an acceptable level of correlation across a wide range of hepatic volumes. Their findings supported the notion that US precision and CT looked to be comparable [27].

Alshati et al. study evaluated the accuracy of the US in measuring the LHL. They eventually concluded that, with a high degree of agreement between measures obtained during surgery and by the US, the US was a credible and accurate tool for measuring the LHL [28], additionally, Merino et al. found that the US was a very reliable and accurate choice for assessing the LHL volume and suggested using it as a routine diagnostic tool [29].

However, Seppelt et al. demonstrated considerably poorer inter-rater reliability in the US compared to CT, which was opposing to our findings [30], it's noteworthy that Hernaez et al. showed that the US may reliably and effectively detect moderate to severe fatty liver, outperforming histology in this regard. After considering the lower cutoffs for recognizing the presence of histologically defined fat, they discovered that the US may detect ≥ 10% steatosis with a diagnostic accuracy of 91–93% and a specificity of 88–99% [31].

In identifying hepatic steatosis in older adults, De Lucia et al. study found a strong positive correlation between the US and other imaging modalities like magnetic resonance spectroscopy (MRS). It also revealed that 25% of participants had hepatic fat levels measured by MRS that were consistent with a steatosis diagnosis. Although there was overlap in the MRS hepatic fat content across the US categories, the sensitivity and specificity of US in detecting hepatic steatosis (mild/moderate/severe versus normal) were 96% (95% CI 87–99.6%) and 94% (95% CI 73–100%), respectively [32].

When it comes to its usefulness in preoperative planning, CT is superior to other imaging modalities. The CT technique has several drawbacks, including high costs, limited accessibility, ionizing radiation exposure for the patient, and restrictions on the maximum weight and size that the CT table and gantry can accommodate, on the other hand, the US stands out due to its low cost, no risk, non-invasive nature, and convenience of use in clinical and research settings. Also, it is not constrained by CT table/gantry restrictions. Finally, it is considered a diagnostic technique that is fundamental to all aspects of clinical practice.

The present study has certain limitations, including the inability to find comparable studies due to a relative lack of literature with a similar aim to ours. As a result, we strongly recommend further research in this area. Other limitations include the weight and diameter limits of the CT table and gantry, which drove us to exclude any patients who couldn't fit the gantry diameter. Despite these limitations, we still recommend further research to evaluate the left hepatic lobe volume reduction after surgery.

Conclusions

US offered a unique diagnostic tool in preoperative LHL volume measurement in morbidly obese patients since it is low cost, low risk, non-invasive, and simple to use in clinical and research settings. Additionally, it isn't restricted by the requirements of the CT table or gantry and avoids the CT potential risks.

Abbreviations

BMI	Body mass index
CECT	Contrast-enhanced CT
CT	Computed tomography
ELV	Estimated liver volume
ELW	Estimated liver weight
ICC	Intraclass coefficient
LHL	Left hepatic lobe
MSCT	Multi-slice computed tomography
MRS	Magnetic resonance spectroscopy
US	Ultrasound

Acknowledgements
Not applicable.

Author contributions
AAB: the corresponding author contributed by supervising the ultrasound examinations, and interpretation of the CT examinations, and in the final editing and submission of the manuscript, AMH did the ultrasound examinations and interpretation of the CT findings for the comparison and shared in the manuscript editing and reference collection, AFS had done the clinical & laboratory assessment of the patients, AEA: introduced the idea of the current study and helped in the image selection and revised the final version of the submitted manuscript. All authors have read and approved the manuscript.

Funding
All authors had no funds for this research and had no competing interests.

Availability of data and materials
All data are available on a software system owned by each of the authors and the corresponding author has the authority to respond if there is any query.

Declarations

Ethics approval and consent to participate
The protocol was reviewed and approved by the local ethics committee of the radiology department, at Kasr Alainy Hospital, Cairo University. The reference number: Code is Ms-388-2021, its date of approval is 20-10-2021. All patients had given their written consent to participate in this work.

Consent for publication
All patients had given their written consent for publication of this work.

Competing interests
All authors had no competing interests.

Received: 23 December 2023 Accepted: 23 February 2024
Published online: 08 March 2024

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