PHILIPS

Philips Liver Fat Quantification

Accessible, early assessment for patients at risk of metabolic liver disease

Aaron Engel, Senior Scientist
Hua Xie, Principal Scientist

This white paper explores the use of Philips ultrasound-based Liver Fat Quantification to address the need for an accessible, noninvasive tool that can be integrated into existing clinical workflows for the large population of patients at risk for metabolic dysfunction-associated steatotic liver disease (MASLD).[1] Liver Fat Quantification can support clinicians in screening at-risk populations to detect steatosis, stratify fibrosis risk and monitor treatment response over time.

Overview

Metabolic dysfunction-associated steatotic liver disease (MASLD), previously termed non-alcoholic fatty liver disease (NAFLD), is the most common chronic liver disease worldwide, affecting over 30% of the global adult population and as many as 65% of individuals with type 2 diabetes.[2,3] Risk factors include type 2 diabetes, obesity or overweight with at least one additional cardiometabolic risk factor (such as hypertension, elevated triglycerides, low HDL cholesterol, prediabetes or insulin resistance) and elevated aminotransferases.

MASLD includes simple liver steatosis; however, it can progress to more severe forms that include inflammation (metabolic dysfunction-associated steatohepatitis, or MASH) and fibrosis. Both MASLD and MASH are associated with increased liver-related mortality, higher risk of cardiovascular disease and impaired quality of life. Early assessment of fatty liver is key to potentially reversing disease progression.[4] Recent multidisciplinary clinical care pathways recommend screening at-risk populations and using noninvasive tools to detect steatosis, stratify fibrosis risk and monitor treatment response over time.

Liver biopsies have been the traditional method for diagnosis but present the risk of complications and sampling variability.[5] MRI-derived proton density fat fraction (MRI-PDFF) is an accurate, reproducible noninvasive biomarker for quantifying liver fat,[6] but cost and limited access remain barriers for widespread use. Ultrasound-based liver fat quantification addresses the need for an accessible, noninvasive tool that can be integrated into existing clinical workflows for the large population of patients at risk for MASLD.[1] In 2024, the World Federation for Ultrasound in Medicine and Biology (WFUMB) issued formal guidance recommending ultrasound-based fat quantification techniques as reliable noninvasive tools for detecting and grading hepatic steatosis in clinical practice.[7]

The Philips Liver Fat Quantification (LFQ) solution allows the user to measure liver attenuation using the attenuation quantification tool and characterize the relative echogenicity of the liver using the hepatorenal index (HRI) tool.

Principles of ultrasound attenuation estimation

Ultrasound attenuation refers to the progressive loss of acoustic energy as the beam propagates through tissue, caused by absorption and scattering. In the liver, the magnitude of this attenuation is directly influenced by tissue composition, which changes with disease state – making attenuation a valuable biomarker for characterizing liver pathology. The presence of fat in the liver increases the attenuation of the ultrasound beam as it travels through tissue. By measuring how much signal intensity is lost per unit of depth, the attenuation coefficient provides a quantitative indicator of liver fat content where higher attenuation values correspond to greater fat accumulation.

The attenuation coefficient is expressed in dB/cm/MHz and represents the rate at which ultrasound intensity decreases with depth, normalized to frequency. Attenuation can be modeled as follows, where I is the intensity, z is the depth, f is the frequency, and α(f) is the attenuation coefficient (dB/cm):

$$\mathbf{I(f,z) = I(f,z_0) \cdot e^{-2\alpha(f)(z-z_0)}}$$

(Equation 1)

For low frequencies, a linear relationship between the attenuation coefficient and frequency can be assumed:

$$\mathbf{\alpha(f) = \alpha_0 \cdot f}$$

(Equation 2)

where α_0 is the acoustic attenuation coefficient slope in units of dB/cm/MHz. This is the parameter reported by LFQ and is simply referred to as the attenuation coefficient (AC). In normal liver tissue, attenuation is relatively low. As fat content increases, lipid droplets within hepatocytes increase acoustic energy loss, elevating the measured attenuation coefficient.

To guide accurate measurements, LFQ uses a reference phantom-based calibration method that removes the influence of system-dependent factors such as time gain compensation (TGC), overall gain and beam diffraction.[8] This calibration ensures that the reported attenuation value reflects true tissue properties rather than system settings, making measurements reproducible across exams and operators. LFQ estimates attenuation over the full bandwidth of the transducer, further reducing measurement variability. **Figure 1** illustrates this process, showing the estimation of the attenuation coefficient from lines of the acoustic backscattered data after correction for system dependence using the reference phantom.

Principles of the reference phantom method for estimating the attenuation coefficient

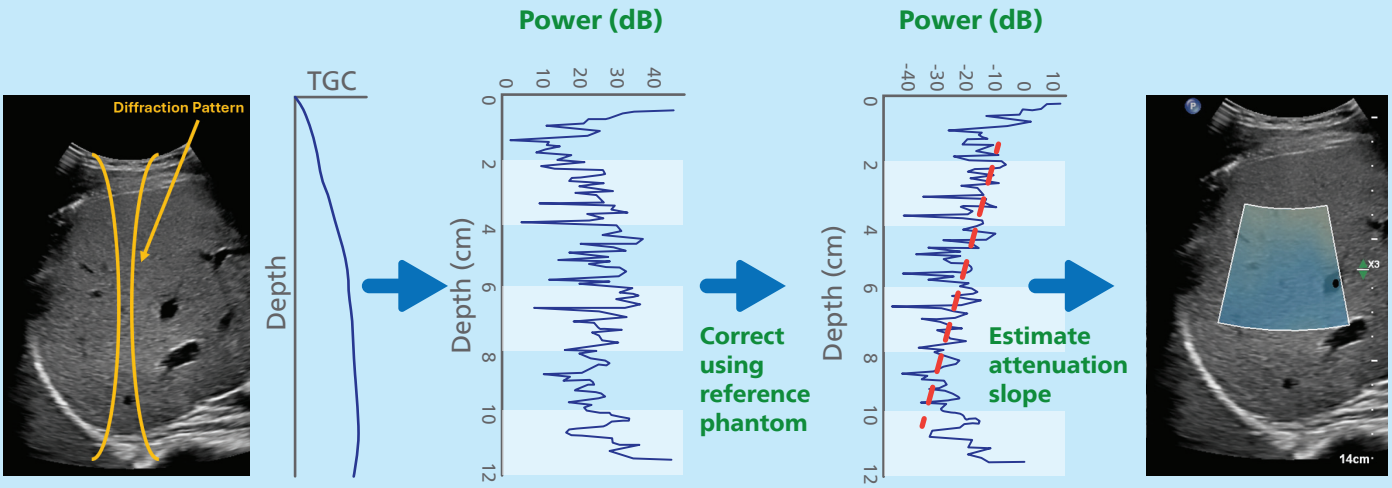


Figure 1
From left to right: B-mode image, time gain compensation profile, uncorrected acoustic backscattered data, corrected acoustic data after removal of system dependence using the reference phantom and the resulting attenuation image. The attenuation coefficient is estimated from the corrected acoustic data.

Attenuation confidence map

The confidence map is a built-in quality indicator that helps guide ROI placement for reliable attenuation measurements. It evaluates the quality of the attenuation estimate at every pixel within the imaging region, using a traffic-light color scheme:

- Green: high-quality measurement; suitable for ROI placement
- Yellow: caution; measurement quality may be reduced
- Red: low quality; avoid placing the ROI in these areas

The confidence score ranges from 0% (very poor) to 100% (excellent). A low score is assigned when the ROI is near anatomic boundaries (e.g., liver capsule, large vessels), when signal-to-noise ratio is poor or when the attenuation estimate is inconsistent across the transducer frequency bandwidth. **Figure 2** shows an example of a high-quality acquisition with uniformly high confidence. **Figure 3** illustrates how the confidence map detects vessels, and **Figure 4** shows the detection of acoustic shadowing and reverberation – both situations where ROI placement should be avoided.

Confidence threshold

A user-controlled confidence threshold (CT) masks pixels below the selected threshold within the attenuation image. Pixels that fall below the CT are excluded from the measurement when an ROI is placed, ensuring that only reliable data contributes to the reported attenuation value. Based on clinical validation, a confidence threshold of 40% is recommended for optimal diagnostic accuracy (see clinical study data section). The confidence map is always active in the background and will exclude low-confidence estimates even when not displayed on screen.

Best practices for attenuation measurement

The following guidelines help ensure high-quality, reproducible attenuation measurements:

- Use an intercostal window to minimize acoustic shadowing from ribs.
- Avoid measuring proximal to the liver capsule, which is prone to reverberation artifacts.
- Avoid placing the ROI near large blood vessels, which alter local backscatter.
- Position the attenuation imaging region approximately 2-3 cm below the liver capsule, deep enough to avoid abdominal wall reverberation, yet shallow enough to allow for the measurement ROI to be placed at its target depth of 3 cm below the liver capsule.

In alignment with WFUMB 2024 guidance,[7] the following additional workflow recommendations apply:

- Fasting is not required for attenuation measurements alone However, if the patient will also undergo an ElastQ liver stiffness measurement during the same visit, as performed by the Philips Shear Wave Elastography solution (ElastQ), fasting for at least 2 hours is recommended.[9] Since fasting does not affect LFQ results but can affect ElastQ, patients scheduled for both liver fat and stiffness assessment should be advised to fast prior to the exam.
- The patient should hold their breath briefly during acquisition to improve measurement repeatability, although free breathing is acceptable.[9]
- A minimum of three valid measurements is recommended to ensure adequate accuracy of the steatosis assessment.
- When performing both attenuation and elastography measurements, acquire them sequentially rather than simultaneously.

High-quality attenuation acquisition

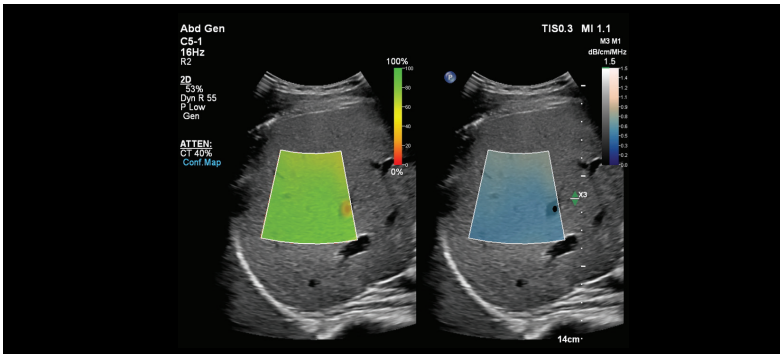


Figure 2
The liver is uniform and artifact-free, and the confidence map shows uniformly high confidence (green) over the entire attenuation imaging region.

Confidence map detecting vessels

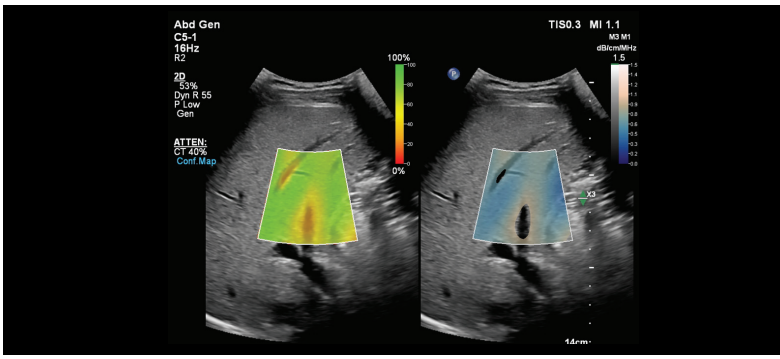


Figure 3
The map identifies several large vessels in the imaging region as low-confidence (red).

Confidence map detecting acoustic shadow

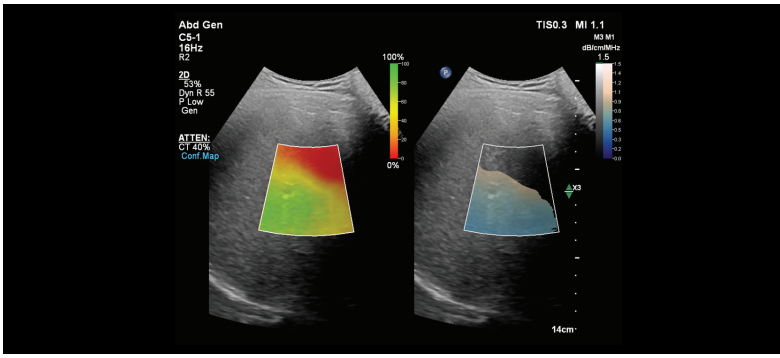


Figure 4
An acoustic shadow on the right side of the attenuation region is identified as low-confidence (red). Abdominal wall reverberation also reduces confidence in the shallow portion.

Attenuation quantification user interface

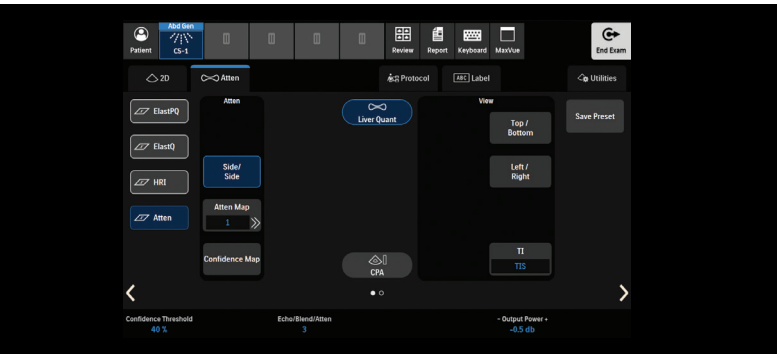


Figure 5
Attenuation quantification touchscreen.

Default screen for attenuation quantification

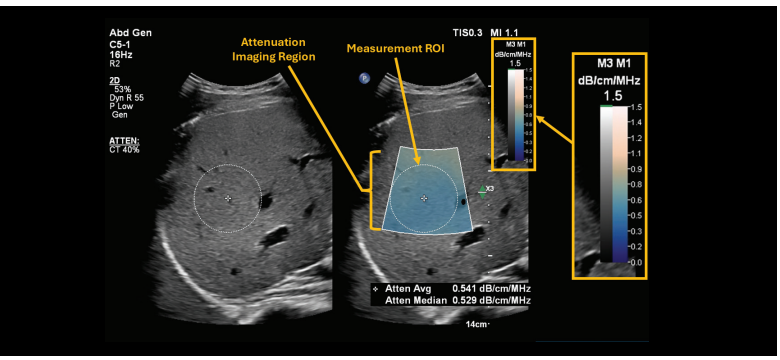


Figure 6
The display range for the attenuation image is shown on the right, from 0 to 1.5 dB/cm/MHz. The attenuation image region is where the color-coded attenuation estimates are shown. The displayed attenuation value is calculated from all the displayed samples within the circular attenuation measurement ROI.

The "Liver Quant" button on the touchscreen **(Figure 5)** provides the user access to the full suite of quantitative ultrasound tools for liver assessment. Once Liver Quant is selected, selecting "Atten" will enable attenuation quantification. The default layout for attenuation quantification is a side-by-side display where the attenuation estimates are shown on the right side, inside the attenuation imaging region **(Figure 6).** To get a quantitative measurement, select "Measure" and place the circular region-of-interest (ROI) over the attenuation image. The attenuation measurement is typically displayed as either the average or median of the values within the ROI. Estimates from locations that are below the confidence threshold are not displayed in the attenuation image and do not contribute to the measured attenuation value. The confidence map can also be displayed or hidden using a button on the touchscreen. It is important to note that the confidence map is always active in the background and will exclude low-confidence attenuation estimates even if the confidence map is not displayed. Attenuation measurements can also be done retrospectively in "Review," using cine loops captured during Atten mode. This conveniently allows the user to repeat a measurement later, if needed, even after the patient is no longer present.

Scanning and measurement tips for attenuation quantification

The patient should be positioned either supine or in a slight lateral decubitus (30°) position with the right arm in extension **(Figure 7)**. The transducer should be positioned in the right intercostal space and aligned with the ribs to minimize any shadowing. Image liver segment 7 or 8 with the scan plane ideally showing uniform liver parenchyma and avoiding major vessels. Pausing breathing may help with getting a good image, although that is not strictly necessary. The top of the attenuation imaging region should be positioned approximately 2-3 cm below the liver capsule, deep enough to avoid reverberation from the abdominal wall, yet shallow enough so the measurement ROI can be placed at its target depth of 3 cm below the liver capsule. Place the measurement ROI so as to maximize the fill within the ROI **(Figure 8)**.

Patient positioning

Figure 7
Patient positioning for measuring liver attenuation.

Attenuation imaging region and measurement ROI

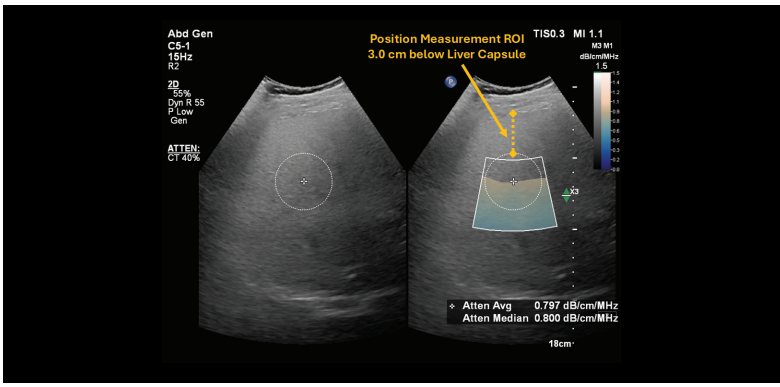


Figure 8
Suggested positioning of attenuation imaging region and measurement ROI.

Principles of measuring the hepatorenal index (HRI)

HRI has been used clinically for fatty liver detection for many years.[10,11] In brief, the ultrasound echo amplitude is calculated by selecting regions of interest (ROIs) within the liver parenchyma and the kidney cortex at the same depth, and by evaluating the ratio between the average echo amplitude in the liver ROI over that of the kidney ROI. Excessive fat infiltration in the liver increases acoustic backscattering, thereby leading to higher echo amplitude values from the liver in the ultrasound 2D image. At a normal state, liver parenchyma and renal cortex have similar echogenicity. With more fat deposits, the liver appears more hyperechoic (i.e., brighter) than the kidney cortex. Conventionally, HRI can be calculated using grayscale 2D images acquired as DICOM images. However, due to multiple system dependencies (gain, dynamic range, gray map), calculating HRI from DICOM images introduces significant variability and makes the result highly dependent on the specific acquisition setting used. The Philips HRI quantification tool works on-cart and within the signal processing chain of the ultrasound system. Operator-dependent system settings such as compression, gain and gray maps are known and can be compensated for prior to calculating the HRI value. The net result is an HRI measurement that is consistent despite different user imaging preferences.

HRI user interface

HRI can be accessed through the "Liver Quant" button on the touchscreen, followed by the "HRI" button, as shown **(Figure 9)**. The HRI label on the main display indicates that you are in the HRI mode and that HRI measurements can be made.

To acquire the HRI measurement, select "Measure" on the control panel. You will be prompted to place the first ROI inside the kidney. Once the ROI is set, the second ROI will be automatically launched, and you will be prompted to place the second ROI in the liver. The HRI result will automatically be calculated.

Some tips for getting a good HRI result **(Figure 10)**.

- Place both ROIs for the liver and kidney at the same depth. This ensures that the influence of TGC and focusing are similar for both ROIs (arrow A).
- Avoid placing the ROI in regions marked by acoustic rib shadows as this will affect the echogenicity of the ROI (arrow B).
- Avoid placing the ROI immediately under the kidney capsule (arrow C).

HRI touchscreen

Figure 9
HRI mode.

HRI image showing the placement of first ROI in the kidney and second ROI in the liver

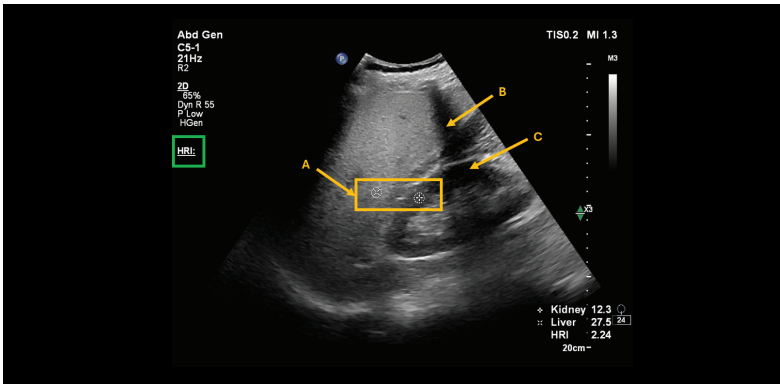


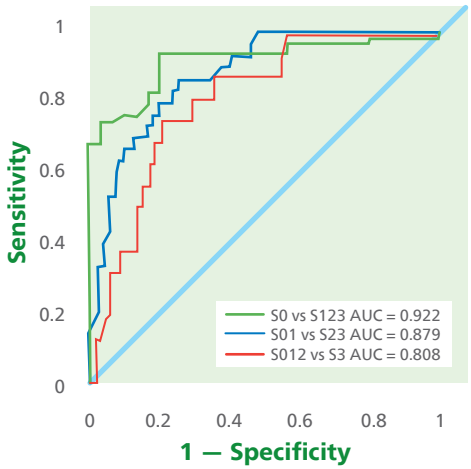
Figure 10
The HRI indicator (highlighted by the green box) shows that HRI is active. Arrow A shows both ROIs at a similar depth. Arrow B shows a region of acoustic shadow.

Summary of clinical study data

The Philips Liver Fat Quantification (LFQ) attenuation coefficient has been validated in clinical studies using MRI proton-density fat fraction (MRI-PDFF) as the reference standard. An initial prospective study enrolled 114 patients suspected of having or diagnosed with NAFLD/NASH across three clinical sites. Each subject underwent an ultrasound exam (Philips EPIQ system with C5-1 transducer) and a standard MRI-PDFF exam. The acoustic attenuation coefficient showed strong correlation with MRI-PDFF (R=0.79, 95% CI 0.71-0.85, p<0.0001). Results from this multicenter study have been published.[12-14]

A subsequent prospective study[15] enrolled 101 adults (62 women, 39 men; mean age 54.5 ± 12.1 years) with known steatosis or risk factors for steatosis including type 2 diabetes, obesity (BMI ≥ 30) or mildly elevated transaminases. All participants underwent ultrasound examination on a Philips EPIQ Elite system (software version 9.0.1) with a C5-1 convex transducer, with the patient positioned supine or in slight lateral decubitus and the transducer in a right intercostal space. MRI-PDFF was obtained on the same day as the reference standard. Based on MRI-PDFF, 30 participants (29.7%) had no steatosis (grade S0, PDFF <6%), 41 (40.6%) had mild steatosis (grade S1, 6% ≤ PDFF <17.1%), 14 (13.9%) had moderate steatosis (grade S2, 17.1% ≤ PDFF <22.1%) and 16 (15.8%) had severe steatosis (grade S3, PDFF ≥22.1%). Two experienced operators independently reviewed cine attenuation acquisitions and placed ROIs across 24 different combinations of ROI depth (2.0, 2.5, 3.0 and 4.0 cm from liver capsule to ROI outer edge), ROI size (3.0, 3.5 and 4.0 cm diameter) and confidence map threshold (20% and 40%). The study demonstrated excellent interoperator agreement (ICC 0.92-0.98) across all combinations, confirming high reproducibility regardless of the measurement parameters chosen.

Importantly, diagnostic performance was not significantly affected by BMI or skin-to-liver capsule distance, supporting reliable use of attenuation measurements across varying body habitus. These validation results establish the clinical readiness of attenuation quantification for routine use. In the context of emerging clinical care pathways for MASLD,[16] ultrasound-based attenuation measurement can serve as an accessible first-line tool for confirming and grading hepatic steatosis in at-risk patients – those with type 2 diabetes, obesity with additional cardiometabolic risk factors or elevated liver enzymes. Attenuation quantification can be performed during a routine ultrasound exam to establish baseline steatosis grade and support decisions about further workup, lifestyle intervention or pharmacologic therapy. When combined with ElastQ liver stiffness measurement in the same session, clinicians can assess both fat and fibrosis, aligning with the two-tier risk stratification approach recommended in current guidelines.



Recommended measurement protocol

Based on clinical validation, the following measurement parameters are recommended for optimal diagnostic accuracy:[15]

- ROI depth: 3.0 cm below the liver capsule
- ROI size (diameter): 4.0 cm
- Confidence map threshold: 40%

This combination achieved the highest overall accuracy (90.1%) for detecting the presence of steatosis (grade ≥S1), with area under the ROC curve (AUC) values of 0.92, 0.88 and 0.81 for detecting steatosis grades ≥S1, ≥S2 and S3 respectively[15] **(Figure 11)**.

Figure 11

ROC curves with associated AUC values using the recommended ROI placement for attenuation measurement: depth of 3.0 cm below liver capsule with a 4.0 cm diameter ROI and confidence map threshold set to 40%.

Clinical interpretation of attenuation values

The following attenuation coefficient cutoffs provide clinical decision support for grading hepatic steatosis.[15] Detailed diagnostic performance for each cutoff, including sensitivity, specificity and accuracy is summarized in **Table 1**.

- Values above 0.63 dB/cm/MHz suggest at least mild steatosis (S1 or higher).
- Values above 0.71 dB/cm/MHz suggest at least moderate steatosis (S2 or higher).
- Values above 0.75 dB/cm/MHz suggest severe steatosis (S3).

Diagnostic performance of attenuation coefficient for staging hepatic steatosis

	Steatosis grade ≥ S1	Steatosis grade ≥ S2	Steatosis grade = S3
AC cutoff (dB/cm/MHz)	0.63	0.71	0.75
AUC	0.922	0.879	0.808
Sensitivity	94.4%	86.7%	75.0%
Specificity	80.0%	74.6%	78.8%
Accuracy	90.1%	78.2%	78.2%

Table 1

Diagnostic performance by cutoff to aid clinical decision-making in grading hepatic stenosis.

These cutoffs were derived using the Youden Index method, which maximizes the summation of sensitivity and specificity. At the 0.63 dB/cm/MHz cutoff for detecting any steatosis, sensitivity was 94.4% and specificity was 80.0%. The high sensitivity at this threshold means that a measurement below the cutoff provides strong confidence that clinically significant steatosis is not present.

For the moderate steatosis cutoff of 0.71 dB/cm/MHz, sensitivity was 86.7% with specificity of 74.6%. These performance characteristics support the use of attenuation quantification as a reliable tool for both screening and grading of hepatic steatosis in clinical practice.

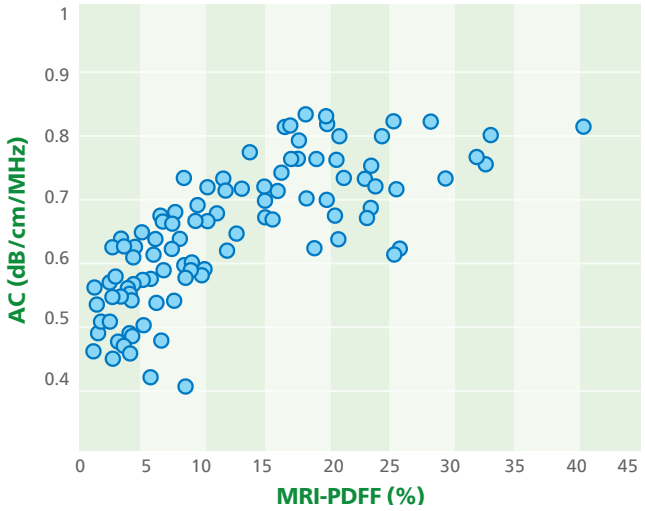


Figure 12

Scatterplot showing the relationship between attenuation coefficient and MRI-PDFF measurements for 101 subjects.

The scatterplot **(Figure 12)** demonstrates the relationship between AC and MRI-PDFF. The box and whisker plot **(Figure 13)** illustrates how attenuation coefficient values distribute across each steatosis grade, demonstrating separation between grades and supporting the use of the recommended cutoffs for clinical decision-making.

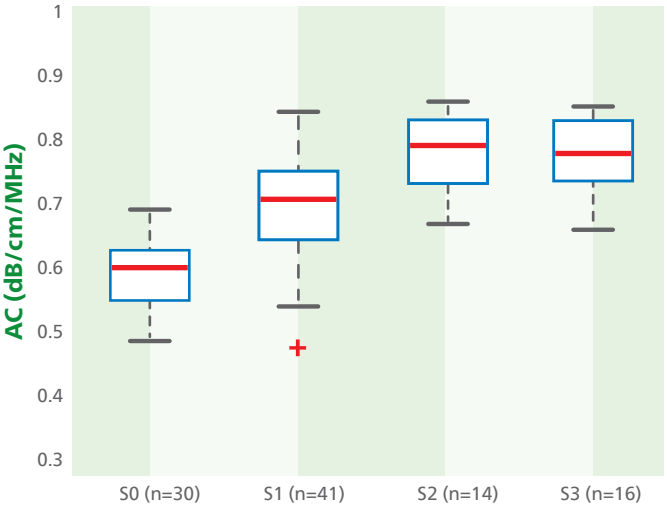


Figure 13

Box and whisker plot showing the distribution of attenuation coefficient values for each steatosis grade (S0, S1, S2, S3). The boxes represent the interquartile range, and the red horizontal lines indicate medians.

These attenuation cutoffs are consistent with the broader published literature. The 2024 WFUMB guidelines summarized cutoff values across multiple ultrasound vendors and studies, reporting similar thresholds for detecting and grading steatosis using the attenuation coefficient measurements.[7] This cross-vendor consistency provides additional confidence that the recommended cutoffs are robust and clinically meaningful.

Conclusion

The Philips Liver Fat Quantification package provides clinicians with a practical, accessible tool for assessing hepatic steatosis during routine ultrasound examinations – without the cost, scheduling delays or limited availability associated with MRI. The combination of attenuation quantification, HRI and the confidence map gives users a complete workflow: acquire, assess quality, measure and interpret – all within a single exam session. For patients who also require liver stiffness assessment, LFQ integrates seamlessly with ElastQ to support comprehensive evaluation of both fat and fibrosis in a single exam session. Together, these capabilities position ultrasound as a frontline tool for early detection, longitudinal monitoring and treatment response assessment in the growing population of patients with metabolic liver disease.

References

1. Ferraioli G, Berzigotti A, Barr RG, et al. Quantification of Liver Fat Content with Ultrasound: A WFUMB Position Paper. Ultrasound Med Biol. 2021;47(10):2803-2820.
2. Ajmera, Veeral, et al. A prospective study on the prevalence of NAFLD, advanced fibrosis, cirrhosis and hepatocellular carcinoma in people with type 2 diabetes. Journal of hepatology 78.3 (2023): 471-478.
3. Miao, Lei, et al. Current status and future trends of the global burden of MASLD. Trends in Endocrinology & Metabolism 35.8 (2024): 697-707.
4. Younossi ZM. Non-alcoholic fatty liver disease - A global public health perspective. J Hepatol. 2019;70(3):531-544.
5. Nalbantoglu IL, Brunt EM. Role of liver biopsy in nonalcoholic fatty liver disease. World journal of gastroenterology : WJG. 2014;20(27):9026-37.
6. Middleton MS, Van Natta ML, Heba ER, et al. Diagnostic accuracy of magnetic resonance imaging hepatic proton density fat fraction in pediatric nonalcoholic fatty liver disease. Hepatology. 2018;67(3):858-872.
7. Ferraioli G, Barr RG, Berzigotti A, et al. WFUMB Guidelines/Guidance on Liver Multiparametric Ultrasound. Part 2: Guidance on Liver Fat Quantification. Ultrasound Med Biol. 2024;50(7):1088-1098.
8. Yao LX, Zagzebski JA, Madsen EL. Backscatter coefficient measurements using a reference phantom to extract depth-dependent instrumentation factors. Ultrason Imaging. 1990;12(1):58-70.
9. Barr RG, Wilson SR, Rubens D, Garcia-Tsao G, Ferraioli G. Update to the Society of Radiologists in Ultrasound Liver Elastography Consensus Statement. Radiology. 2020;296(2):263-274.
10. Webb M, Yeshua H, Zelber-Sagi S, et al. Diagnostic value of a computerized hepatorenal index for sonographic quantification of liver steatosis. AJR Am J Roentgenol. 2009;192(4):909-914.
11. Marshall RH, Eissa M, Bluth EI, Gulotta PM, Davis NK. Hepatorenal index as an accurate, simple, and effective tool in screening for steatosis. AJR Am J Roentgenol. 2012;199(5):997-1002.
12. D'Hondt A, Rubesova E, Xie H, Shamdasani V, Barth RA. Liver Fat Quantification by Ultrasound in Children: A Prospective Study AJR 2021; 217:996–1006.
13. Pirmoazen, Amir M., et al. Diagnostic performance of 9 quantitative ultrasound parameters for detection and classification of hepatic steatosis in nonalcoholic fatty liver disease. Investigative Radiology 57.1 (2022): 23-32.
14. Kaliaev, Artem, et al. Quantitative ultrasound assessment of hepatic steatosis. Journal of Clinical and Experimental Hepatology 12.4 (2022): 1091-1101.
15. Ferraioli G, Roccarina D, Barr RG. Attenuation Coefficient for Hepatic Steatosis Using a Single Ultrasound System: Associations of Measurement Parameters With Interoperator Agreement and Diagnostic Performance. AJR Am J Roentgenol. 2025.
16. Kanwal F, Bril F, Wong VWS, et al. Clinical Care Pathway for the Risk Stratification and Management of Patients with Metabolic Dysfunction-Associated Steatotic Liver Disease. Gastroenterology. 2026.

CE
2797

PHILIPS

www.philips.com/healthcare

Printed in the Netherlands.
00001463-00-02 * AUG 2026