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Hepatic Fat Quantification With Novel Ultrasound Based Techniques: A Diagnostic Performance Study Using Magnetic Resonance Imaging Proton Density Fat Fraction as Reference Standard

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Abstract

Purpose: To assess the diagnostic performances of novel Tissue attenuation imaging (TAI) and Tissue scatter distribution imaging (TSI) tools in quantification of liver fat content using magnetic resonance imaging proton density fat fraction (MRI PDFF) as reference standard. **Methods:** Eighty consecutive patients with known or suspected non-alcoholic fatty liver disease (NAFLD) who volunteered to participate in the study comprised the study cohort. All patients underwent MRI PDFF scan and quantitative ultrasound (QUS) imaging using TAI and TSI tools. The cutoff values of ≥5%, ≥16.3% and ≥21.7% on MRI PDFF were used for mild, moderate and severe steatosis, respectively. Area under the Receiver operating characteristic (AUROC) curves were used to assess the diagnostic performance of TAI and TSI in detecting different grades of hepatic steatosis. **Results:** The AUROCs of TAI and TSI tools in detecting hepatosteatosis (MRI PDFF ≥5%), were 0.95 [95% Confidence Interval (CI): 0.91–0.99] ($P < 0.001$) and 0.96 (95% CI: 0.93–0.99) ($P < 0.001$), respectively. In distinguishing between different grades of steatosis, the values of 0.75, 0.86 and 0.96 dB/cm/MHz have 88%, 88% and 100% sensitivity, respectively, for TAI tool; and the values of 92.44, 96.64 and 99.45 have 90%, 92% and 91.7% sensitivity, respectively, for TSI tool. **Conclusion:** TAI and TSI tools accurately quantify liver fat content and can be used for the assessment and grading of hepatosteatosis in patients with known or suspected NAFLD.

Résumé

Objectif : Évaluer les performances diagnostiques des nouveaux outils d'imagerie d'atténuation des tissus (TAI) et d'imagerie de distribution de diffusion tissulaire (TSI) pour la quantification de la graisse contenue dans le foie en utilisant comme norme de référence la densité de protons de la fraction lipidique en imagerie par résonance magnétique (MRI PDFF). **Méthodes :** quatre-vingts patients consécutifs ayant une stéatose hépatique non alcoolique (NAFLD) ont participé de plein gré à l'étude et ont constitué la cohorte d'étude. Tous les patients ont fait l'objet d'une imagerie par IRM-PDFF et échographie quantitative faisant appel aux outils de TAI et de TSI. Des valeurs seuils ≥ 5 %, ≥ 16,3 % et ≥ 21,7 % de l'IRM-PDFF ont été utilisées pour, respectivement, la stéatose légère, modérée et sévère. L'aire sous les courbes ROC (de l'anglais « receiver operating characteristic ») de la fonction d'efficacité du récepteur a permis d'évaluer la performance diagnostique de la TAI et de la TSI pour la détection des différents degrés de stéatose hépatique. **Résultats :** les AUROC des outils que constituent la TAI et la TSI pour la détection de la stéatose hépatique (MRI PDFF ≥ 5 %) étaient, respectivement, de 0.95 (intervalle de confiance [IC] à 95 % : 0,91 à 0,99 [$P < 0,001$]) et de 0,96 (IC à 95 % : 0,93 à 0,99 [$P < 0,001$]). Pour la distinction entre les différents stades de stéatose, les valeurs de 0,75, 0,86 et 0,96 dB/cm/MHz ont une sensibilité respective de 88 %, 88 % et 100 % pour l'outil qu'est la TAI et les

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valeurs de 92,44, 96,64 et 99,45 ont une sensibilité respective de 90 %, 92 % et 91,7 % pour l'outil qu'est la TSI. **Conclusion :** les outils de TAI et de TSI ont correctement quantifié le contenu adipeux du foie et peuvent être utilisés pour l'évaluation et la stadification de la stéatose hépatique chez les patients ayant une NAFLD connue ou suspectée.

Keywords
hepatosteatosis, liver fat quantification, tissue attenuation imaging, tissue scatter distribution imaging, non-alcoholic fatty liver disease

Introduction

Non-alcoholic fatty liver disease (NAFLD) is an important problem for public health and the estimated prevalance of the disease in the general population is approximately 25%–30%.[1,2] NAFLD not only impairs the patients' life quality but also comprises significant burden on healthcare costs.[3,4] Patients with NAFLD have increased risks for stroke, cardiovascular diseases, chronic liver diseases and hepatocellular carcinoma. Furthermore, the progressive form of NAFLD which is defined as non-alcoholic steatohepatitis (NASH) is a prominent reason for liver transplantation.[2,5-7] Among the patients with NAFLD, the estimated prevalence of NASH is in range between 6.6% and 29.8% and this prevalence demonstrates regional variations.[2,8] Therefore, it is essential to assess liver fat content to identify the patients at risk and to better plan follow-up of these patients.

The existence of intracellular fat in ≥5% of hepatocytes is defined as liver steatosis and historically the fat content of liver is assessed by biopsies.[9] However, liver biopsy is invasive in nature and has disadvantages such as high cost, small sample size that may be affected by uneven fat distribution, large interreader variabilities and risk of complications, which includes uncommon severe bleeding.[10-13] Therefore, it is important to diagnose and follow-up patients with known or suspected NAFLD using noninvasive techniques.

Greyscale ultrasound is frequently used to qualitatively assess the degree of liver steatosis. However, it allows subjective assessment for liver fat content and has limited ability in detecting mild hepatosteatosis.[14,15] Magnetic resonance imaging proton density fat fraction (MRI PDFF) is an imaging technique which allows accurate measurement of hepatic fat content.[16,17] Additionally, MRI PDFF technique is independent from operator variations and it is not affected by body mass index (BMI).[17-19] However, the availability of MRI PDFF is limited and the costs of this technique may not be appropriate in screening purposes. Therefore, there is a strong need for widely available, easy to perform, cheaper, noninvasive quantitative techniques to assess liver fat content. Recently, ultrasound based liver fat quantification techniques have been developed to address these issues and promising results have been reported with first clinical studies.[15,20-25] However, the technical principles of these tools vary between vendors and, therefore, vendor specific cutoff values are required for the detection and grading of hepatic steatosis. Tissue Attenuation Imaging (TAI) and Tissue Scatter Distribution Imaging (TSI) are novel vendor specific (Samsung Medison Co Ltd) tools which are developed to quantify hepatic fat content. Currently, the available data regarding the diagnostic performances of these quantitative ultrasound (QUS) techniques in the literature is limited. In the current study, our main goal was to assess the diagnostic performances of TAI and TSI tools for the detection and grading of hepatic steatosis in patients with known or suspected NAFLD using MRI PDFF as reference standard.

Materials and Methods

The design of this prospective study was approved by an institutional review board and all the included patients signed the informed consent prior to study enrollment. Between February and April 2022, patients with known or suspected NAFLD who were referred to the radiology department and complied with the study protocol were asked if they voluntarily participate in the study. Age under 18 years, presence of liver disease based on clinical, laboratory and histological data apart from NAFLD, history of liver surgery, liver malignancy (primary or metastatic), contraindications for MRI scan and significant alcohol consumption which is considered as alcohol intake more than 20 g/day were used as exclusion criteria. A total of 80 consecutive patients who volunteered to participate in the study and signed the informed consent comprised the study cohort. Figure 1 shows the flowchart for the patient enrollment to the study. Age, gender, body mass index (BMI) and laboratory test results of each participant were noted.

First, the MRI PDFF scans of all patients were obtained at a 1.5 T MRI scanner (Signa Voyager, GE Healthcare, WI, USA) equipped with 16 channel body anterior array coil in a private hospital. A 3D volumetric imaging sequence (IDEAL IQ) in axial scan plane was acquired with a single breath hold. The following scan parameters were used: TR, 10.6 ms; TE, 4.8 ms; Imaging matrix, 160 × 160; slice thickness, 10 mm; field of view, 44–47 cm; and bandwith, 111 kHz. A low flip angle (6°) was used to reduce T1 bias. Elliptic region of interests (ROIs) at 4–5 cm^2 size were used for MRI PDFF measurements. Four ROIs were placed to the 5,6,7 and 8 liver segments and the average value of the 4 ROIs were used as representative MRI PDFF values of liver fat content for each patients. The cutoff values of MRI PDFF for the detection of liver steatosis grades were ≥5%, ≥16.3% and ≥21.7% for mild (S1), moderate (S2) and severe (S3) steatosis, respectively.[26]

After MRI PDFF scans, all patients underwent QUS imaging. Fifty-eight (72.5%) of the included patients were examined with QUS imaging on the same day of MRI PDFF scan. The remaining 22 patients examined with QUS imaging within 1 week of the MRI PDFF scans. A radiologist who has 15 years experience in abdominal ultrasound examinations performed all QUS imaging. The radiologist was blinded to the MRI PDFF scan results of the patients. All patients were examined using 1 ultrasound machine (RS85 Prestige, Samsung Medison Co Ltd) equipped with a convex probe (1-7 MHz). All patients underwent ultrasound examinations with at least 6 hours fasting condition. The QUS imaging of patients were performed in supine position. Right intercostal approach was used for QUS imaging and the right hand of the patients was positioned over the head to increase the width of intercostal spaces. The applicability of both QUS techniques was very good and no patient was excluded based on technical failure or unreliable data. TAI and TSI measurements were performed independently. TAI is a technique that relies on the attenuation coefficient and quantifies the energy loss of ultrasound signals during their movement within the liver depending on the fat concentration. TSI is a technique that relies on the backscatter coefficient and quantifies the distribution of scattered signals depending on the intensity of scatterers. The hepatic fat content can be quantified by using these 2 QUS techniques independently. A ROI with 30 mm, 40 mm and 40 mm sizes for upper border, lower border and height was used for each measurement. The measurements for TAI and TSI tools were obtained by placing the ROIs at least 3 cm deep to the liver capsule. Additionally, for TAI technique, R^2 value of ≥0.6 which is recommended by the manufacturer was used to assess the reliability of measurements. When a measurement was obtained with R^2 value lower than 0.6, the measurement was considered unreliable and a new measurement was obtained. Five measurements at mid breath hold situation were obtained for both QUS techniques and the median of the measurements were noted (Figure 2). Furthermore, to assess the reliability of the data set in all patients, interquartile range (IQR) to median ratio was calculated for both QUS techniques.

Statistical Analyses

The SPSS 22.0 Software (IBM Corp, Armonk, NY) was used to perform statistical analyses. Demographic data of the patients were presented as mean, standard deviation and range values. Kolmogorov–Smirnov test was used to assess the normality of data distribution. The correlation analyses between QUS measurements and MRI PDFF values were assessed using Spearman's correlation test. Receiver operating characteristic (ROC) curves and area under the ROC (AUROC) curves were used to assess the diagnostic performance of TAI and TSI measurements in detecting different grades of hepatosteatosis according to ≥5%, ≥16.3% and ≥21.7% MRI PDFF values for differentiation of sequential steatosis grades from S0 to S3, respectively. The optimal cutoff values for QUS measurements were determined to obtain maximum level of sensitivity and specificity. Furthermore, Kruskal Wallis test was used for the comparison of both QUS measurements according to the hepatosteatosis grades determined by MRI PDFF. The P values less than .05 were considered as statistically significant.

Results

The study cohort consisted of 80 patients (21 female, 59 male). The mean age of the patients was 44.3 ± 10.6 (range,

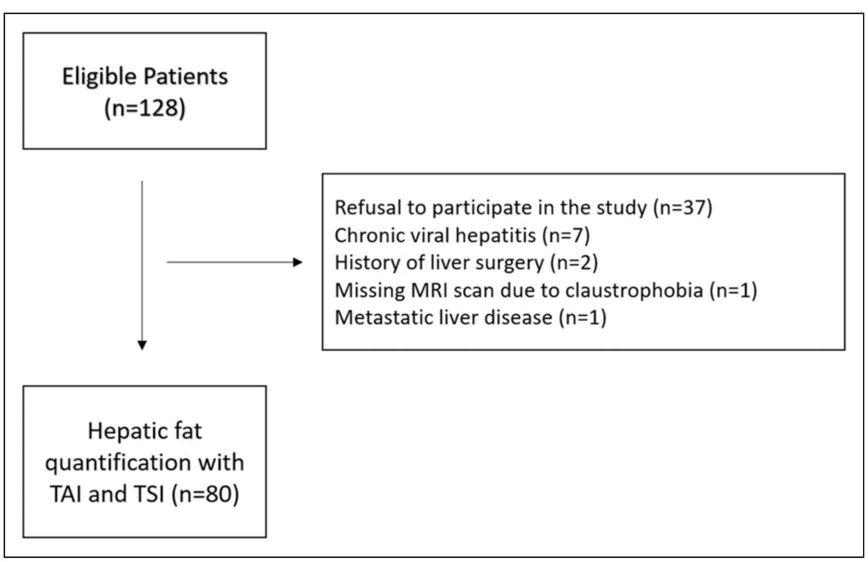

Figure 1. Flowchart of the patient enrollment.

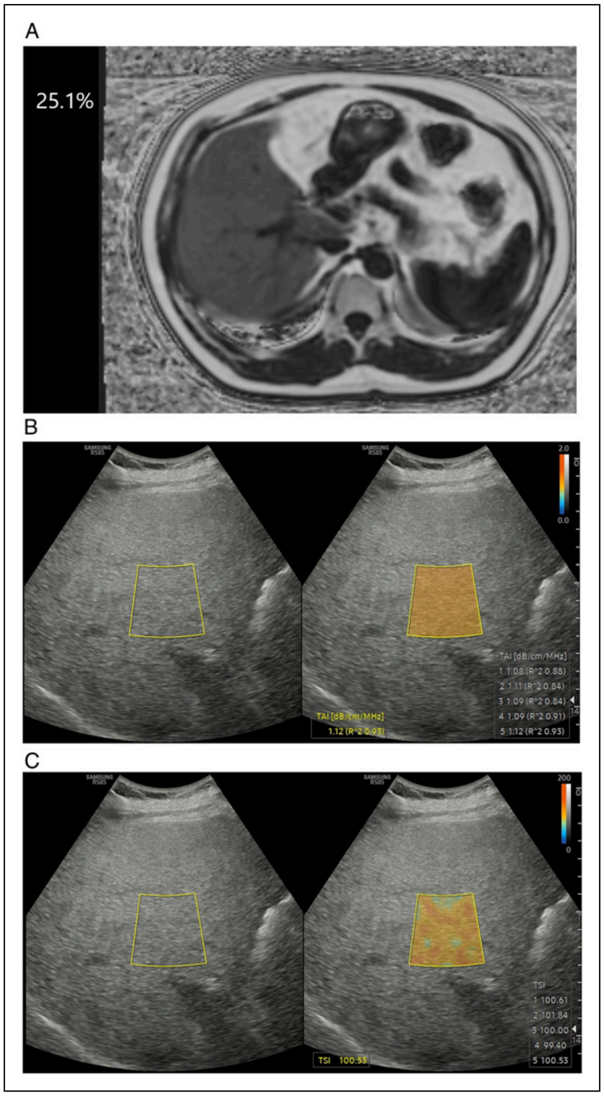

Figure 2. Magnetic resonance imaging proton density fat fraction (MRI PDFF) scan (A) of a 59 years old male patient revealed grade 3 steatosis with MRI PDFF value 25.1%. The patient underwent quantitative ultrasound imaging using Tissue attenuation imaging (TAI) (B) and Tissue scatter distribution imaging (TSI) (C) techniques. The median values of 5 measurements were 1.09 dB/cm/MHz and 100.53 for TAI and TSI techniques, respectively.

23-77 years). The Table 1 represents the characteristics of the patients. The IQR/median ratios for TAI and TSI techniques were below 30% in all patients. TAI (r: 0.899, $P < 0.001$) and TSI (r: 0.881, $P < 0.001$) measurements demonstrated strong correlations with MRI PDFF values. There was a significant difference between both QUS measurements and hepatosteatosis grades ($P < 0.001$). Table 2 shows TAI and TSI values of patients with different hepatosteatosis grades. Figure 3 demonstrates median values of TAI and TSI measurements for each hepatosteatosis grades.

The AUROC of TAI in detecting hepatosteatosis (MRI PDFF ≥5%) was 0.95 [95% Confidence Interval (CI): 0.91-0.99] ($P < 0.001$). The AUROC of TSI in detecting hepatosteatosis was 0.96 (95% CI: 0.93-0.99) ($P < 0.001$). Figure 4 demonstrates ROCs of TAI and TSI techniques for differentiation of hepatosteatosis grades. A value of 0.75 dB/cm/MHz had 88% and 90% sensitivity and specificity, respectively for hepatosteatosis detection (MRI PDFF ≥5%) with TAI technique. A value of 92.44 had 90% of both sensitivity and specificity for hepatosteatosis detection (MRI PDFF ≥5%) with TSI technique. Table 3 represents the performance metrics for TAI and TSI measurements in differentiation of hepatosteatosis grades. Furthermore, according to our results, the values of 0.68 dB/cm/MHz for TAI and 88.44 for TSI can be used to rule out (sensitivity 100%) hepatosteatosis (MRI PDFF ≥5%). Additionally, our results revealed that the values of 0.82 dB/cm/MHz for TAI and 95.95 for TSI can be used to rule in (specificity 100%) hepatosteatosis (MRI PDFF ≥5%).

Discussion

The high prevalence of NAFLD and the risks that attributed to the disease have led to the need for easy to perform techniques in the diagnosis and surveillance of NAFLD patients. With the advancements in ultrasound technology, quantitative ultrasound techniques (QUS) have been emerged to fulfil this gap. In our study, we used MRI PDFF as reference standard as recommended by the experts in the field,[21] and our findings revealed that both TAI and TSI techniques are accurate tools with AUROCs over .9 in the detection of fatty liver. Furthermore, these commercially available QUS techniques demonstrated high performances in differentiating grades of hepatosteatosis which may be considered as important for further stratification of the patients under risk. Therefore, our results support the use of ultrasound based liver fat quantification techniques and are promising for the use of TAI and TSI tools in the assessment of NAFLD patients in daily practice.

TAI and TSI are novel technologies for ultrasound based liver fat quantification. Currently, no sufficient knowledge exists in the literature regarding the diagnostic performance of these novel vendor specific tools. There was only one published study that assessed the value of TAI and TSI tools in the detection of hepatosteatosis. Jeon et al,[27] used MRI PDFF as reference standard and found that both TAI and TSI techniques showed good diagnostic performance with AUROCs 0.86 and 0.96, respectively, in detecting ≥5% liver fat content. They also assessed the diagnostic performances of TAI and TSI techniques in differentiation of ≥10% liver fat content as a secondary outcome and reported that in this condition, TAI and TSI had AUROCs 0.83 and 0.93, respectively. They found that 0.88 dB/cm/MHz cutoff value for TAI technique had 78% and 78.9% sensitivity and specificity, respectively; and 91.2 cutoff value for TSI technique had 85.4% and 97.4% sensitivity and specificity, respectively.[27] In the current study, our findings also revealed that TAI and TSI techniques showed high diagnostic performances in detecting ≥5% liver fat content. Furthermore, our results revealed that both

Table 1. Demographic Characteristics of the Included Patients (n = 80).

Patient characteristics	Value
Age, years (range)	44.3 ± 10.6 (23-77)
Gender	
Male	59/80 (73.75%)
Female	21/80 (26.25%)
BMI, kg/m^2 (range)	28.3 ± 4.7 (19.3-42.5)
Diabetes	8/80 (10%)
Alanine aminotransferase (ALT), IU/L (range)	31 ± 23.2 (7-145)
Aspartate aminotransferase (AST), IU/L (range)	25.4 ± 25.6 (10-206)
Total cholesterol, mg/dl (range)	211.9 ± 47.9 (110-327)
Triglycerides, mg/dl (range)	219.2 ± 232 (60-2003)
MRI PDFF	
<5% (S0)	30/80 (37.5%)
≥5% - <16.3% (S1)	25/80 (31.25%)
≥16.3% - <21.7 (S2)	13/80 (16.25%)
≥21.7% (S3)	12/80 (15%)

Table 2. Tissue Attenuation Imaging (TAI) and Tissue Scatter Distribution Imaging (TSI) Values for Each Hepatosteatosis Grade Determined by Magnetic Resonance Imaging Proton Density Fat Fraction (MRI PDFF).

		TAI (dB/cm/MHz)	TSI
Grade (MRI PDFF)	n (%)	Median (IQR)	Median (IQR)
S0 (<%5)	30 (37.5)	0.68 (0.65–0.73)	83.46 (78.80–90.53)
S1 (≥5%-<16.3%)	25 (31.25)	0.80 (0.74–0.84)	94.95 (92.48–96.79)
S2 (≥16.3%-<21.7)	13 (16.25)	0.94 (0.87–0.98)	99.33 (97.16–100.02)
S3 (≥21.7%)	12 (15)	1.04 (0.98–1.11)	100.93 (100.08–102.53)

IQR, Interquartile range.

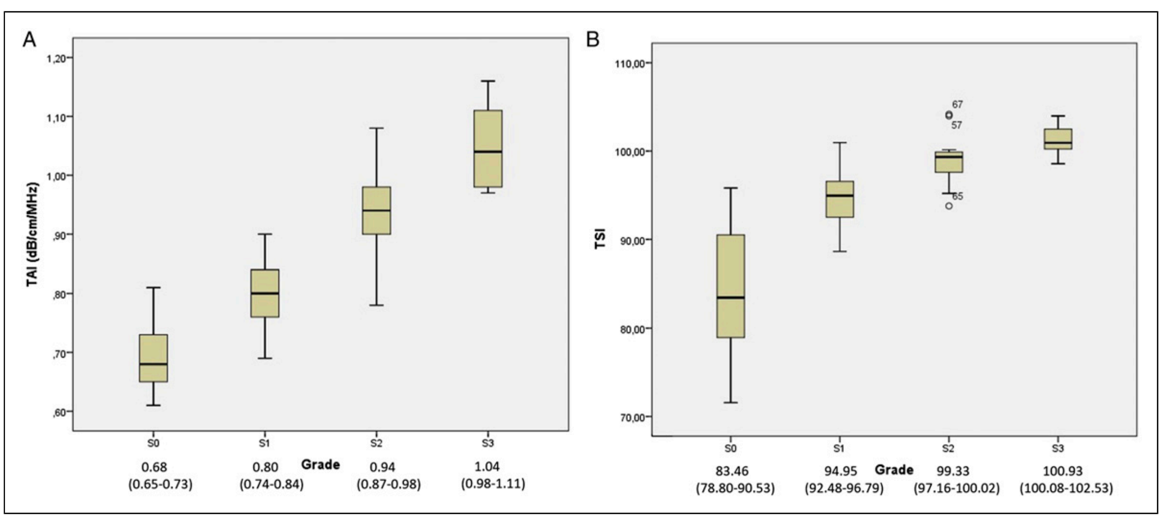

Figure 3. The distribution of median values (interquartile ranges) of Tissue attenuation imaging (TAI) (A) and Tissue scatter distribution imaging (TSI) (B) measurements according to the hepatosteatosis grades determined by magnetic resonance imaging proton density fat fraction. There were significant differences between hepatosteatosis grades and quantitative ultrasound measurements ($P < 0.001$).

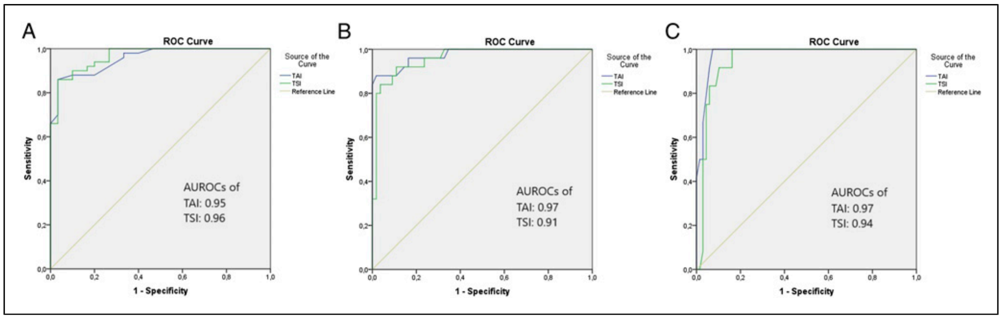

Figure 4. Receiver operating characteristics (ROC) curves for Tissue attenuation imaging (TAI) and Tissue scatter distribution imaging (TSI) techniques in the differentiation of hepatosteatosis grades. (A) S0 vs S1-3, (B) S1-2 vs S2-3 and (C) S0-2 vs S3.

Table 3. Diagnostic Performance of Tissue Attenuation Imaging (TAI) and Tissue Scatter Distribution Imaging (TSI) Techniques in Differentiation of Hepatosteatosis Grades.

Parameter	S0 vs S1-3	S0-1 vs S2-3	S0-2 vs S3
Cutoff value			
TAI (dB/cm/MHz)	0.75	0.86	0.96
TSI	92.44	96.64	99.45
AUROC			
TAI	0.95 (0.91–0.99)	0.97 (0.94–1.00)	0.97 (0.95–1.00)
TSI	0.96 (0.93–0.99)	0.91 (0.93–1.00)	0.94 (0.90–0.99)
Sensitivity			
TAI	88%	88%	100%
TSI	90%	92%	91.7%
Specificity			
TAI	90%	94.5%	92.6%
TSI	90%	89.1%	89.7%
PPV			
TAI	93.6%	88%	70.5%
TSI	93.7%	79.3%	61.1%
NPV			
TAI	81.8%	94.5%	100%
TSI	84.3%	96%	98.4%

PPV, Positive predictive value; NPV, Negative predictive value.

QUS techniques showed high performances in differentiation of all steatosis grades. We found that 0.75 dB/cm/MHz cutoff value for TAI technique had 88% and 90% sensitivity and specificity, respectively; and 92.44 cutoff value for TSI technique had 90% and 90% sensitivity and specificity, respectively. Additionally, Jeon et al.[27] found that TAI (r = 0.659) and TSI (r = 0.727) techniques had significant correlations with MRI PDFF, whereas we found that TAI (r = 0.899) and TSI (r = 0.881) had higher correlations with the same reference standard. In our study we placed 4–5 cm^2 ROIs on right liver lobe segments because QUS measurements only included right liver lobe segments. However, Jeon et al.[27] placed ROIs with diameter of 1 cm to the 9 Coinaud segments of the liver. We consider that different ROI placement criteria on reference standard MRI PDFF scans and using different cutoff MRI PDFF values for grading hepatosteatosis may influence the diagnostic performance of the TAI and TSI techniques. On the other hand, in the current study, for TAI technique cutoff values were 0.75 dB/cm/MHz, 0.86 dB/cm/MHz and 0.96 dB/cm/MHz in differentiating sequential steatosis grades from S0 to S3, respectively. However, Jeon et al.[27] reported that cutoff values for steatosis grades using TAI tool were 0.829 dB/cm/MHz, 0.915 dB/cm/MHz and 1.006 dB/cm/MHz in differentiating patients with MRI PDFF values <5%, 5%–10% and ≥10%, respectively.[28] Although our results can be considered in line with the results of Jeon et al,[27] differences in designs of the studies especially cutoff values used for steatosis grades and ROI placement criteria on MRI PDFF scans, and potential impact of observer variations on ultrasound techniques may be possible explanations for the differences between the results of the studies.

There are various ultrasound based vendor specific tools for quantifying liver fat content on the market. Attenuation coefficient techniques that include TAI calculate the loss of energy during propagation of sound waves in the tissue.[15,20,21] Attenuation imaging (ATI, Canon Medical Systems, Japan), Attenuation measurement (ATT, Fujifilm, Japan) and Ultrasound guided attenuation parameter (UGAP, General Electric, USA) are some of the vendor specific tools for ultrasound based liver fat quantification using attenuation coefficient parameter. In a study conducted by Ferraioli et al.[24] where MRI PDFF was the reference standard, ATI demonstrated a good diagnostic performance with a 0.91 AUROC value for the detection of ≥S1 (MR PDFF ≥5%). In another study where the diagnostic performance of ATT was assessed and liver biopsy was used as reference standard, the ATT tool demonstrated 0.79, 0.87 and 0.96 AUROCs for differentiation of sequential steatosis grades from S0 to S3, respectively.[28] Fujiwara et al.[25] reported that UGAP tool showed AUROCs in range between 0.87 and 0.96 for differentiation of steatosis grades. Additionally, they found that UGAP had high correlation (r = 0.78) with fat percentage detected at liver biopsies.[25] In our study, TAI tool also demonstrated high diagnostic performance in differentiation of hepatosteatosis grades and high correlation with liver fat content measured at MRI PDFF. Thus, our results revealed that the vendor specific TAI tool had a good diagnostic performance in the assessment of fatty liver similar to the other ultrasound based liver fat quantification tools from the other vendors. On the other hand, backscatter coefficient techniques that include TSI measure the energy of sound waves those returned from the examined tissue.[15,20] Lin et al.[29] found that AUROC of backscatter coefficient technique on training group was 0.98 in detecting liver steatosis (≥5%) using MRI PDFF scan as reference standard. Our study revealed that the AUROC of TSI tool was 0.96 in detecting patients with ≥5% MRI PDFF value. Therefore, our results are in agreement with the results of aforementioned study.[29] We think that with the accumulation of evidences in the literature for QUS techniques in terms of correlation with MRI PDFF and accuracy of diagnostic performance where MRI PDFF used as reference standard, QUS techniques has potential to replace MRI PDFF for liver fat quantification. Furthermore, Ozturk et al.[30] found that shear wave elastography (SWE), another ultrasound based quantitative imaging technique, may be helpful in the detection of high risk NASH existence among patients with NAFLD. They reported that a cutoff value of 8.4 kPa has 77% and 66%, sensitivity and specificity, respectively.[30] Therefore, given that SWE is commonly performed in conjunction with fat quantification in order to assess liver stiffness, it may be considered as an additional advantage of ultrasound based techniques for the risk stratification of NAFLD patients.

In the current study, the cutoff values (0.75 dB/cm/MHz, 0.86 dB/cm/MHz and 0.96 dB/cm/MHz, respectively) in differentiating sequential steatosis grades with TAI technique seem a little bit higher compared with previously published studies which used the other vendor specific attenuation coefficient tools.[15,31-33] These results suggest that there may be differences in quantifying hepatic fat content between TAI tool and other vendor specific tools. This was proved by another study conducted by Jeon et al.[34] where attenuation coefficient values obtained with TAI, ATI and UGAP tools were compared. That study revealed that the measured values with various vendor specific tools showed significant differences.[34] Therefore, we consider that our cutoff values are not generalizable for devices from other manufacturers and can be used for ultrasound devices that include TAI and/or TSI tools in differentiation of steatosis grades.

Several limitations are recognized for our work. First, the number of the included patients is small. However, the evidences for diagnostic performance of these novel QUS techniques in the detection of hepatosteatosis are limited in the literature. Therefore, our results can be considered as important. Second, the liver fat content measurements were obtained by a single observer in a single institution. For wide acceptance of new technologies, multicentric studies with multiple observers are required inevitably. Lastly, we consider that different cutoff values used for steatosis grading or various ROI placement criteria on reference standard MRI PDFF scans may also have an influence on diagnostic performance studies of these novel technologies. Therefore, a standardized approach for reference standard endorsed by the experts in the field may be valuable.

In conclusion, our findings revealed that TAI and TSI techniques accurately measure liver fat content and can be used to differentiate grades of hepatosteatosis. These promising results need to be confirmed in multicentric studies with larger numbers of patients before QUS techniques can be used in daily practice as a substitute for MRI PDFF.

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Declaration of Conflicting Interests

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IRB Statement

This prospective study was approved by an institutional review board and written informed consent was provided by the all patients.

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