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Original Article

Quantification of Liver Fat by Tissue Attenuation Imaging and Tissue Scatter Distribution Imaging: A Cross-Sectional Comparison of Quantitative Ultrasound with Conventional B-Mode Grading of Hepatic Steatosis

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ABSTRACT

Background: Conventional grey-scale B-mode ultrasonography grades hepatic steatosis subjectively and performs less specifically at the mild end of the fat spectrum. Quantitative ultrasound (QUS) derives objective acoustic parameters from the raw radiofrequency signal. This study quantified liver fat using Tissue Attenuation Imaging (TAI), Tissue Scatter distribution Imaging (TSI) and the ultrasound-derived fat fraction, and compared these indices with the qualitative B-mode grade.

Methods: This cross-sectional observational study enrolled 494 consecutive adults referred for abdominal ultrasonography at a tertiary-care teaching hospital in southern Rajasthan, India. Patients with alcohol use, gross ascites, focal liver lesions, portal hypertension, steatogenic or hepatotoxic medication, or inability to breath-hold were excluded. All patients underwent B-mode grading (Grade 1-3) and QUS on a single Samsung V8 platform, with the region of interest placed approximately 2 cm below the liver capsule in the right lobe and the median of repeated acquisitions recorded. Parameters were compared across grades by one-way ANOVA and Spearman rank correlation, and diagnostic performance was assessed by ROC analysis with Youden-derived cut-offs.

Results: The mean age was 51.82 ± 14.83 years and 306 patients (61.94%) were male. B-mode grading yielded Grade 1 in 401 (81.17%), Grade 2 in 87 (17.61%) and Grade 3 in 6 (1.21%). TAI rose from 195.65 ± 32.82 dB/m in Grade 1 to 378.57 ± 20.29 dB/m in Grade 3, TSI from 88.57 ± 4.10 to 111.80 ± 3.99, and the fat fraction from 4.05 ± 1.19% to 22.58 ± 2.58% (one-way ANOVA $P < 0.001$ for each). All three correlated significantly with the grade (Spearman $\rho = 0.678$ for the fat fraction, 0.633 for TSI, 0.631 for TAI; $P < 0.001$). For Grade ≥ 2 the areas under the ROC curve were 0.965 (TAI), 0.966 (TSI) and 1.000 (fat fraction). Seventy-one patients (17.7% of the Grade 1 group) had a fat fraction below 3% and were quantitatively normal. No liver-function or metabolic variable differed across grades (all $P > 0.05$).

Conclusion: TAI, TSI and the ultrasound-derived fat fraction increase monotonically with the B-mode grade of hepatic steatosis and discriminate moderate-to-severe from mild disease with high accuracy. QUS adds an objective, reproducible and inexpensive quantitative dimension to routine abdominal ultrasonography and reclassified nearly one in five apparently mild fatty livers as normal.

***Keywords**: Non-alcoholic fatty liver disease; Quantitative ultrasound; Tissue attenuation imaging; Tissue scatter distribution imaging; Hepatic steatosis; Ultrasound-derived fat fraction.*

INTRODUCTION

Non-alcoholic fatty liver disease (NAFLD) is the commonest chronic liver disease worldwide, with a pooled global prevalence of about 25% and well-documented associations with obesity, type 2 diabetes, hyperlipidaemia and the metabolic syndrome [1]. The burden in India exceeds the global figure: a systematic review and meta-analysis estimated the pooled prevalence among Indian adults at 38.6%, rising to 52.8% in high-risk groups [2]. A large proportion of patients attending for routine abdominal ultrasonography in Indian practice will therefore harbour some degree of hepatic steatosis. NAFLD spans a histological spectrum from simple steatosis through steatohepatitis to fibrosis and cirrhosis, and most patients are asymptomatic with normal aminotransferases [3]. Because early steatosis is potentially reversible with weight loss and control of the underlying metabolic derangements, and because the condition carries independent cardiovascular and liver-related risk, its accurate detection and grading have genuine therapeutic implications [4].

Liver biopsy remains the histological reference standard but is invasive and subject to substantial sampling variability, with discordance of at least one fibrosis stage between paired specimens in about 41% of patients[5]. Magnetic-resonance techniques, chiefly the proton density fat fraction (MRI-PDFF), provide accurate and reproducible non-invasive quantification of liver fat but are limited by cost and availability [6]. Grey-scale B-mode ultrasonography is cheap, safe and universally accessible and remains the first-line modality, yet its assessment is qualitative: a meta-analysis of 49 studies found a pooled sensitivity of 84.8% and specificity of 93.6% for moderate-to-severe steatosis but markedly poorer performance for mild disease[7], and observer agreement for severity grading is only 47-59%[8].

Quantitative ultrasound (QUS) analyses the raw radiofrequency backscattered signal to yield objective, system-independent acoustic parameters that are unaffected by post-processing or machine settings [9]. On the Samsung platform these are implemented as Tissue Attenuation Imaging (TAI), which quantifies the loss of ultrasound energy in tissue, and Tissue Scatter distribution Imaging (TSI), which quantifies the statistical distribution of echoes returned from tissue microstructure; an ultrasound-derived fat fraction can additionally be computed from these acoustic parameters [10]. Both rise with hepatic fat content and can be acquired during a routine grey-scale examination without additional hardware or ionising radiation.

Data on these parameters from the Indian subcontinent remain scarce. The present study was therefore designed to quantify liver fat using TAI and TSI in patients undergoing hepatic ultrasonography, to compare these quantitative indices with the conventional qualitative B-mode grade, and to describe the demographic, clinical and biochemical profile of the cohort.

METHODS

Design and Setting:

This cross-sectional observational study was conducted over 18 months in the Department of Radio-diagnosis of a tertiary-care teaching hospital in southern Rajasthan, India. The protocol was approved by the Institutional Ethics Committee and written informed consent was obtained from every participant.

Participants and Sampling:

Consecutive sampling was used. Adults older than 18 years of either sex referred to the department for abdominal ultrasonography, and willing to consent, were eligible. Patients with alcohol abuse, gross ascites, an inability to hold the breath, current steatogenic or hepatotoxic medication, focal liver lesions or portal hypertension were excluded. Age, sex, presenting complaint and past medical history were recorded, together with serum aspartate aminotransferase (SGOT), alanine aminotransferase (SGPT), total bilirubin, random blood sugar and serum triglycerides.

The sample size was calculated from the standard formula for a single proportion, $n = Z^2P(1-P)/E^2$, with $Z = 1.96$ at the 95% confidence level, an expected prevalence P of 6.7% and a margin of error E of 10%; a minimum of 50 patients was required. During the study period 494 consecutive eligible patients were enrolled, far exceeding this requirement.

Ultrasound Examination and Quantitative Measurements:

All examinations were performed by two experienced radiologists on a Samsung V8 ultrasound system. Patients were scanned in the supine or left-lateral position with the right arm abducted above the head to widen the intercostal acoustic window, and the transducer was placed in an intercostal space over the right lobe. Hepatic steatosis was first graded qualitatively on grey-scale B-mode images as Grade 1 (mild), Grade 2 (moderate) or Grade 3 (severe) on the basis of hepatic echogenicity, hepatorenal contrast, beam attenuation and visualisation of the intrahepatic vessels and diaphragm.
TAI (reported in dB/m, on a scale comparable to that of the controlled attenuation parameter), TSI (a dimensionless index) and the ultrasound-derived fat fraction were then acquired during breath-hold from the right lobe. In accordance with published acquisition standards the region of interest was positioned approximately 2 cm below the liver capsule, avoiding

vessels and reverberation artefacts, and the median of repeated acquisitions was recorded [11]; a fixed region-of-interest depth and size are essential because the attenuation coefficient falls progressively with increasing depth[9].

Data Analysis:

Data were entered in Microsoft Excel and analysed with standard statistical software. Continuous variables are expressed as mean ± standard deviation with the median, range and 95% confidence interval, and categorical variables as frequencies and percentages. The quantitative parameters were compared across the three B-mode grades by one-way analysis of variance (ANOVA), supplemented by the Kruskal-Wallis test where appropriate, and their association with the ordinal grade was quantified by the Spearman rank correlation coefficient (ρ). A fat fraction below 3% was taken to indicate the absence of significant hepatic steatosis, in keeping with the operating threshold of the ultrasound system (the corresponding MRI-PDFF threshold is 5%). Diagnostic performance for discriminating higher grades was assessed by receiver operating characteristic (ROC) analysis; the area under the curve (AUC) was computed and the optimal cut-off determined by the Youden index, at which sensitivity, specificity and predictive values were calculated. Categorical associations were tested by the chi-square test. A P value below 0.05 was considered significant.

RESULTS

Demographic, Clinical and Biochemical Profile:

Four hundred and ninety-four patients were analysed. The mean age was 51.82 ± 14.83 years (range 19-87 years); 234 patients (47.4%) were in the fifth and sixth decades and approximately three-quarters were older than 40 years. There was a male predominance, with 306 men (61.94%) and 188 women (38.06%), a male-to-female ratio of 1.63 : 1. Abdominal or flank pain was the commonest presenting complaint (183; 37.04%), followed by lower abdominal pain (94; 19.03%), nausea or vomiting (61; 12.35%) and fever with chills (56; 11.34%), reflecting the incidental detection of hepatic steatosis during scans performed for non-specific abdominal symptoms. No significant past medical history was recorded in 191 patients (38.66%); hypertension (113; 22.87%), chronic kidney disease (76; 15.38%) and diabetes mellitus (30; 6.07%) were the commonest comorbidities (Table 1).

Mean serum transaminases were mildly to moderately elevated (SGOT 56.78 ± 36.00 U/L; SGPT 62.21 ± 38.54 U/L), with the mean exceeding the median for both enzymes, indicating a right-skewed distribution. The mean total bilirubin was 1.40 ± 0.76 mg/dL, the mean random blood sugar 147.01 ± 41.91 mg/dL and the mean serum triglyceride level 141.98 ± 42.39 mg/dL (Table 1).

Table 1. Demographic, clinical and biochemical profile of the study population (N = 494)

Variable	Value
Age (years), mean ± SD	51.82 ± 14.83 (range 19-87)
Age > 40 years, n (%)	380 (76.92)
Male, n (%)	306 (61.94)
Female, n (%)	188 (38.06)
Abdominal / flank pain, n (%)	183 (37.04)
Lower abdominal pain, n (%)	94 (19.03)
Nausea / vomiting, n (%)	61 (12.35)
Fever with chills, n (%)	56 (11.34)
No significant comorbidity, n (%)	191 (38.66)
Hypertension, n (%)	113 (22.87)
Chronic kidney disease, n (%)	76 (15.38)
Diabetes mellitus, n (%)	30 (6.07)
SGOT (U/L), mean ± SD	56.78 ± 36.00
SGPT (U/L), mean ± SD	62.21 ± 38.54
Total bilirubin (mg/dL), mean ± SD	1.40 ± 0.76
Random blood sugar (mg/dL), mean ± SD	147.01 ± 41.91
Serum triglycerides (mg/dL), mean ± SD	141.98 ± 42.39

Note: SD, standard deviation; SGOT, serum glutamic-oxaloacetic transaminase (AST); SGPT, serum glutamic-pyruvic transaminase (ALT). A patient could carry more than one comorbidity, so comorbidity percentages need not total 100.

B-mode Grade and Quantitative Ultrasound Parameters:

Mild (Grade 1) steatosis predominated, being present in 401 patients (81.17%); moderate (Grade 2) steatosis was seen in 87 (17.61%) and severe (Grade 3) steatosis in only 6 (1.21%). For the cohort as a whole the mean TAI was 214.19 ± 52.02 dB/m (median 204.10; range 105.00-390.00), the mean TSI 90.66 ± 6.12 (median 89.55; range 76.00-116.60) and the mean ultrasound-derived fat fraction 5.70 ± 3.86% (median 3.99; range 2.50-26.00).

When the fat fraction was interpreted against the 3% threshold, 71 patients (14.4% of the cohort) had a fat fraction below 3%, indicating no significant hepatic steatosis. Every one of these 71 patients had been graded as Grade 1 on B-mode, so that 71 of the 401 patients graded mild (17.7%) were in fact quantitatively normal; no patient graded Grade 2 or Grade 3 fell below the threshold.

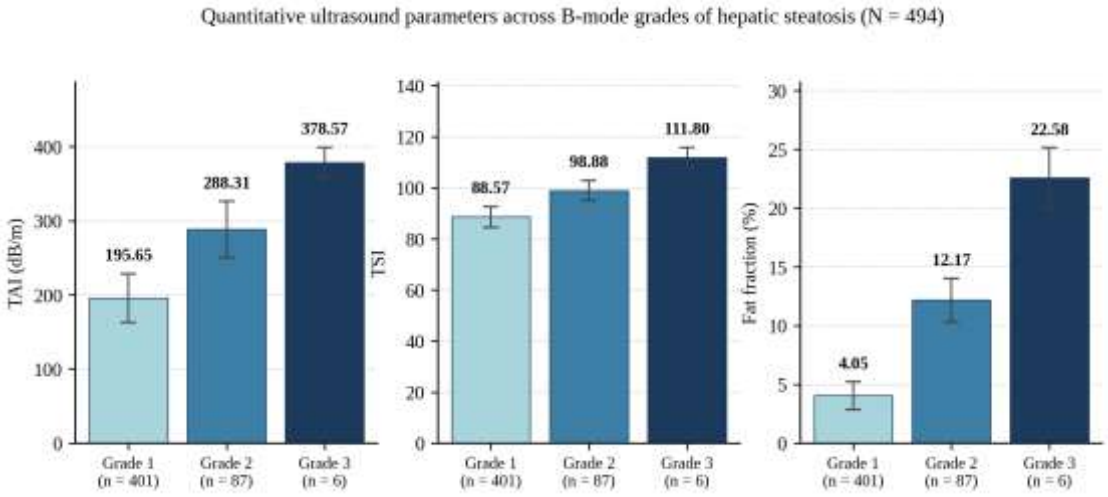
All three parameters increased monotonically across the B-mode grades and the differences were highly significant on one-way ANOVA (TAI F = 343.47; TSI F = 310.47; fat fraction F = 1756.43; $P < 0.001$ for each). Each correlated positively and significantly with the qualitative grade, the fat fraction most strongly ($\rho = 0.678$), followed closely and almost equally by TSI ($\rho = 0.633$) and TAI ($\rho = 0.631$) (Table 2; Figure 1). The fat fraction showed the steepest gradient, rising more than fivefold from Grade 1 to Grade 3, while TAI almost doubled.

Table 2. Quantitative ultrasound parameters across the B-mode grades of hepatic steatosis

Parameter	Grade 1 (n = 401)	Grade 2 (n = 87)	Grade 3 (n = 6)	ANOVA F	Spearman ρ
TAI (dB/m)	195.65 ± 32.82	288.31 ± 37.84	378.57 ± 20.29	343.47	0.631
TSI	88.57 ± 4.10	98.88 ± 3.97	111.80 ± 3.99	310.47	0.633
Fat fraction (%)	4.05 ± 1.19	12.17 ± 1.87	22.58 ± 2.58	1756.43	0.678

Note: Values are mean ± standard deviation. ρ, Spearman rank correlation coefficient with the B-mode grade. $P < 0.001$ for every ANOVA F and every correlation coefficient. TAI, Tissue Attenuation Imaging; TSI, Tissue Scatter distribution Imaging.

Figure 1. Mean values of TAI, TSI and the ultrasound-derived fat fraction across the B-mode grades of hepatic steatosis.



Note: Error bars represent one standard deviation. All three parameters increased progressively across the grades (one-way ANOVA $P < 0.001$ for each).

Diagnostic Performance:

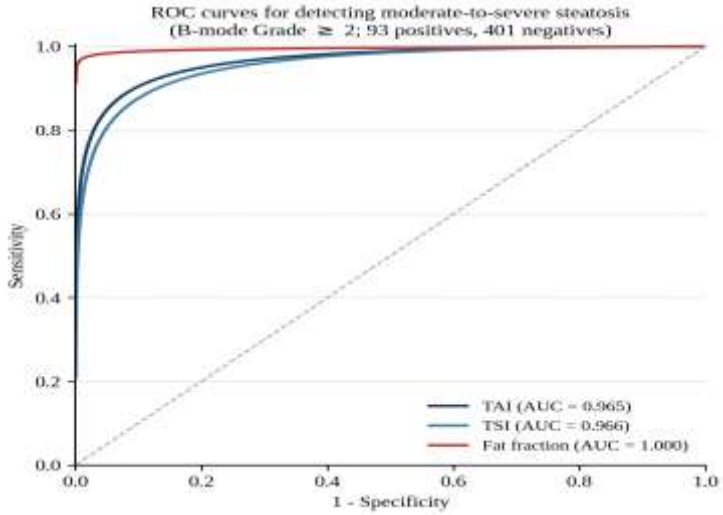
For the discrimination of moderate-to-severe (Grade ≥ 2) from mild steatosis, all three parameters performed excellently, with areas under the ROC curve of 0.965 for TAI, 0.966 for TSI and 1.000 for the fat fraction. At the Youden-derived cut-offs of TAI ≥ 245.70 dB/m, TSI ≥ 93.70 and fat fraction ≥ 8.61%, sensitivity and specificity were both high and negative predictive values exceeded 97%; the fat fraction separated the two categories completely in this cohort (Table 3; Figure 2). The parameters likewise identified the small Grade 3 subgroup with high accuracy (AUC 0.998 for TAI, 0.999 for TSI and 1.000 for the fat fraction), although with only six such patients these estimates are imprecise. The close relationship of TAI and TSI to the fat fraction is shown in Figure 3 ($\rho = 0.564$ and 0.604 respectively; $P < 0.001$).

Table 3. Diagnostic performance of the quantitative ultrasound parameters at the Youden-derived optimal cut-offs

Parameter	Cut-off	AUC	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Moderate-to-severe steatosis (B-mode Grade ≥ 2; 93 positives, 401 negatives)							
TAI (dB/m)	≥ 245.70	0.965	89.2	94.0	77.6	97.4	93.1
TSI	≥ 93.70	0.966	91.4	89.5	66.9	97.8	89.9
Fat fraction (%)	≥ 8.61	1.000	100.0	100.0	100.0	100.0	100.0
Severe steatosis (B-mode Grade 3; 6 positives, 488 negatives)							
TAI (dB/m)	≥ 338.00	0.998	100.0	98.6	46.2	100.0	98.6
TSI	≥ 106.00	0.999	100.0	99.4	66.7	100.0	99.4
Fat fraction (%)	≥ 18.50	1.000	100.0	100.0	100.0	100.0	100.0

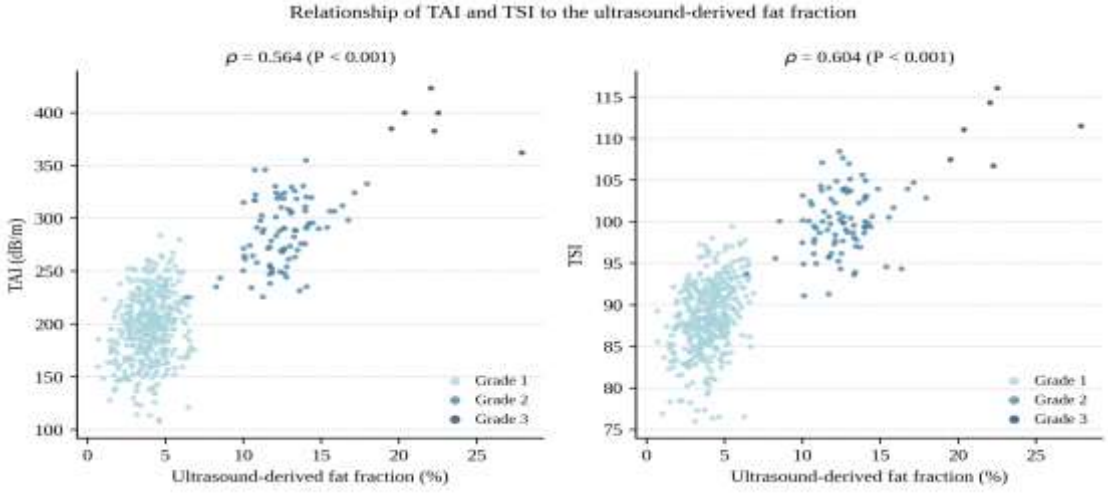
Note: AUC, area under the receiver operating characteristic curve; PPV, positive predictive value; NPV, negative predictive value. Cut-offs were derived by the Youden index.

Figure 2. Receiver operating characteristic curves of TAI, TSI and the ultrasound-derived fat fraction for detecting moderate-to-severe steatosis (B-mode Grade ≥ 2).



Note: The area under the curve for each parameter is the value obtained in this cohort. The plotted curves are binormal reconstructions computed from the reported group means and standard deviations, the raw case-level data not being available for re-plotting.

Figure 3. Relationship of TAI and TSI to the ultrasound-derived fat fraction, colour-coded by B-mode grade.



Note: Spearman ρ values are those obtained in this cohort. The plotted points are simulated from the reported group means and standard deviations and are shown to illustrate the distribution and separation of the grades; they are not the raw case-level observations.

Relationship of Biochemical Variables, Age and Sex to the Grade:

In contrast to the acoustic parameters, none of the liver-function or metabolic variables differed significantly across the three B-mode grades (all P > 0.05; Table 4). Neither age nor sex was associated with severity: the sex distribution did not differ across grades (chi-square = 4.37, P = 0.112) and the mean age was comparable between grades (51.6, 52.7 and 57.5 years for Grades 1, 2 and 3; F = 0.65, P = 0.525).

Table 4. Liver-function and metabolic parameters across the B-mode grades of hepatic steatosis

Parameter	Grade 1	Grade 2	Grade 3	F	P
SGOT (U/L)	56.67 ± 36.08	58.22 ± 36.67	43.00 ± 14.38	0.51	0.601
SGPT (U/L)	62.60 ± 39.09	61.09 ± 36.01	52.50 ± 42.57	0.25	0.782
Bilirubin (mg/dL)	1.38 ± 0.75	1.47 ± 0.80	1.30 ± 0.66	0.52	0.598
Blood sugar (mg/dL)	147.18 ± 42.55	145.10 ± 38.73	163.50 ± 47.03	0.56	0.573
Triglycerides (mg/dL)	142.38 ± 41.81	140.60 ± 44.99	135.83 ± 49.06	0.13	0.881

Note: Values are mean ± standard deviation. P values are from one-way analysis of variance across the three grades; none reached statistical significance.

DISCUSSION

In this cross-sectional study of 494 consecutive patients undergoing hepatic ultrasonography, the three quantitative acoustic parameters increased monotonically across the B-mode grades of hepatic steatosis and correlated positively and significantly with the qualitative grade, discriminating moderate-to-severe from mild disease with areas under the curve of 0.965-1.000. Equally informative was the divergence in the other direction: the routine biochemical markers showed no relationship whatever with the grade.

The demographic profile, with a mean age in the sixth decade, three-quarters of patients older than 40 years and a male-to-female ratio of 1.63 : 1, accords with the recognised rise in NAFLD prevalence with advancing age and its higher reported prevalence in men, attributed to differences in body-fat distribution, sex-hormone milieu and visceral adiposity[1][4]. That so large a proportion of an unselected group attending for abdominal ultrasonography had hepatic steatosis is consistent with the high background prevalence reported for Indian adults[2].

Mild steatosis dominated the B-mode distribution (81.17%), which is precisely the range in which conventional grey-scale grading is least reliable[7]. The quantitative fat fraction made this concrete: 71 patients (17.7% of the Grade 1 group) fell below the 3% threshold and were quantitatively normal, so that B-mode grading over-called mild fatty change in nearly one in five such livers, while no Grade 2 or Grade 3 patient was reclassified. This is a direct clinical demonstration of the limited sensitivity of real-time ultrasound for fat infiltration below roughly 20% reported by Dasarathy et al.[12], and of the poor reproducibility of visual grading documented by Strauss et al.[8] and Cengiz et al., whose interobserver agreement was only 39-40%[13]. An objective parameter that separates a genuinely normal liver from true mild steatosis is therefore of real practical value.

Scatter-based Quantification (TSI):

Mean TSI rose from 88.57 in Grade 1 to 111.80 in Grade 3 (ρ = 0.633). The biological basis is that intracellular lipid alters the size, number and spatial arrangement of the acoustic scatterers, changing the statistical distribution of the backscattered signal that TSI quantifies. Our finding closely parallels that of Jeon et al., who reported that the scatter-distribution coefficient derived from TSI correlated with MRI-PDFF at r = 0.727 and achieved areas under the curve of 0.964 and 0.935 for hepatic fat of ≥ 5% and ≥ 10%[14]. Related envelope-statistics indices behave in the same way: the acoustic structure quantification focal-disturbance ratio correlated inversely with the MR-spectroscopy fat fraction (r = −0.87) and reached an AUC of 0.959 for significant steatosis[15], while the normalized local variance correlated with the histological grade (Spearman r ≈ −0.45 to −0.47) with excellent inter-reader repeatability (intraclass correlation coefficient ≈ 0.90)[16].

Attenuation-based Quantification (TAI):

Mean TAI increased from 195.65 to 378.57 dB/m across the grades (ρ = 0.631), a physically plausible finding since lipid droplets absorb and scatter ultrasound more than normal parenchyma. Attenuation imaging has consistently graded steatosis well against histology, with areas under the curve of 0.843-0.926 and the degree of steatosis the only significant determinant of the attenuation coefficient[17], and against MRI-PDFF, where the attenuation coefficient correlated at r = 0.81 and detected any steatosis with an AUC of 0.91 at a cut-off of 0.63 dB/cm/MHz, outperforming the controlled attenuation

parameter[18]. A further histology-referenced series confirmed a strong correlation between the acoustic attenuation coefficient and MRI-PDFF (r = 0.765)[19].

Because the Samsung TAI is reported in dB/m, on the same physical scale as the controlled attenuation parameter (CAP), our values can be compared directly with the CAP thresholds of approximately 248 and 268 dB/m for steatosis grades above S0 and S1 derived in an individual-patient-data meta-analysis[20]. The Grade 1 mean of 195.65 dB/m lies well below the mild-steatosis threshold, in keeping with the many quantitatively normal livers in that group, whereas the Grade 2 mean of 288.31 dB/m exceeds both thresholds. Strikingly, the Youden-derived TAI cut-off for detecting Grade ≥ 2 in the present study (245.70 dB/m) is almost identical to the established CAP cut-off of 248 dB/m. This correspondence on a shared physical scale provides a reassuring external cross-check on the TAI measurements, while the same meta-analysis is a reminder that body-mass index, diabetes and aetiology shift attenuation-based values and must be considered when interpreting them.

The Ultrasound-derived Fat Fraction and Diagnostic Performance:

The composite fat fraction showed the steepest gradient across the grades and the strongest correlation of the three parameters (ρ = 0.678), as expected of an index purpose-built to express hepatic fat directly as a percentage. Comparable agreement between an ultrasound-derived estimate and MRI-PDFF has been reported for the backscatter coefficient (Spearman ρ = 0.80, AUC up to 0.98, sensitivity 87-93% and specificity 91-97% for diagnosing NAFLD)[21], and composite algorithms combining attenuation and backscatter information have been reviewed as agreeing closely with MRI-PDFF[10]. Our areas under the curve (0.965-1.000 for Grade ≥ 2) lie at or slightly above the top of the published range: a meta-analysis of 13 prospective studies reported pooled sensitivity and specificity of 76% and 84% for any steatosis and 87% and 79% for moderate-to-severe steatosis[22]. Part of this apparent superiority reflects the fact that a well-separated three-category ordinal grade is an easier target than a dichotomised continuous fat fraction, and part reflects the partial circularity discussed below. The consistent advantage of radiofrequency-derived parameters lies less in raw accuracy than in reproducibility: interobserver agreement for the attenuation and backscatter coefficients (κ = 0.87 and 0.82) far exceeds that of conventional B-mode scoring (κ = 0.61)[23], and intraclass correlation coefficients of 0.87-0.95 have been demonstrated for repeated acquisitions on a clinical scanner[24]. Our results also align with the largest screening study of these two Samsung parameters, in which TAI and TSI correlated with MRI-PDFF at r = 0.759 and 0.802 and performance improved further when they were combined with the B-mode assessment[25] — supporting a complementary rather than a competing role for quantitative and qualitative ultrasound.

TSI versus TAI:

TSI (ρ = 0.633) and TAI (ρ = 0.631) correlated almost identically with the B-mode grade, with a marginal edge for the scatter-distribution parameter. This near-equivalence, and its direction, mirror the findings of Jeon et al., in whom the scatter parameter also correlated slightly more strongly than the attenuation parameter with MRI-PDFF[14]. Attenuation-based indices nevertheless retain the most extensively validated cut-offs[9], and can be combined with elastographic measures of fibrosis and necroinflammation to characterise the whole spectrum of fatty-liver disease[26]. The two parameters are best regarded as complementary, each capturing a different acoustic consequence of fat deposition.

Biochemical Markers Do Not Track Hepatic Fat:

None of the liver-function or metabolic variables differed across the grades. This deliberately reported negative finding is biologically coherent: the serum transaminases reflect hepatocellular injury and inflammation — the transition to steatohepatitis — rather than the quantity of intrahepatic fat, and are frequently normal despite significant steatosis[3][4]. Serum triglycerides are similarly influenced by diet, fasting state and lipid-lowering therapy; indeed, alanine aminotransferase and triglyceride levels have been identified as covariates that modify, rather than parallel, quantitative-ultrasound measurements[25]. A patient may therefore harbour severe steatosis with normal enzymes, or mild steatosis with raised enzymes. The corollary is that quantitative ultrasound measures the fat itself and complements, but does not replace, the biochemical and elastographic assessment needed to identify the minority with progressive disease.

Clinical Implications:

Because TAI, TSI and the fat fraction are obtained on a standard ultrasound platform without additional hardware, cost or ionising radiation, they are well suited to opportunistic screening, risk stratification and — being continuous and reproducible — to longitudinal monitoring of disease progression or of the response to lifestyle and pharmacological intervention, a role for which qualitative grading is poorly suited. This is of particular value in resource-limited settings where MRI-PDFF is not readily available[6], and it operationalises the quantitative approach set out in international guidance[9].

Limitations:

Several limitations deserve emphasis. First, the reference standard was the qualitative B-mode grade rather than MRI-PDFF or liver biopsy; because B-mode grading is itself partly informed by beam attenuation and echogenicity, and because the fat fraction is computed by the scanner from the same acoustic data, the comparison carries a degree of circularity. The very high areas under the curve — particularly the value of 1.000 for the fat fraction — are therefore best read as evidence

of internal consistency rather than of independent validation. Second, the reference standard is itself imperfect, as shown by the 71 patients graded mild who were quantitatively normal. Third, severe steatosis was uncommon (six patients), so the Grade 3 estimates are imprecise. Fourth, the cross-sectional design cannot assess the ability of these parameters to track change over time. Fifth, the influence of coexisting fibrosis and inflammation on the acoustic parameters was not evaluated, and the study was conducted at a single centre on one manufacturer's platform; while TAI is reported in dB/m on a scale comparable to CAP, the dimensionless TSI and the derived fat-fraction cut-offs are device-specific and may require re-calibration on other systems. Finally, the reported sample-size calculation is internally inconsistent — the stated formula and parameters yield a minimum of about 24 rather than the 50 reported — although the enrolled sample of 494 comfortably exceeds either figure.

CONCLUSION

Tissue Attenuation Imaging, Tissue Scatter distribution Imaging and the ultrasound-derived fat fraction increase progressively and significantly with the B-mode ultrasonographic grade of hepatic steatosis and discriminate moderate-to-severe from mild disease with high accuracy, whereas routine liver-function and metabolic markers do not reflect the quantity of hepatic fat at all. Quantitative ultrasound thus offers an objective, reproducible, inexpensive and radiation-free means of quantifying liver fat that complements conventional grey-scale ultrasonography and reduces its subjectivity, and it reclassified nearly one in five apparently mild fatty livers as normal. These findings support incorporating quantitative ultrasound into routine abdominal scanning for the detection, grading and follow-up of hepatic steatosis. Larger prospective multicentre studies using MRI-PDFF or liver biopsy as the reference standard are needed to establish standardised, device-specific cut-off values.

DECLARATIONS

Ethics Approval and Consent to Participate: The study protocol was approved by the Institutional Ethics Committee of Geetanjali Medical College & Hospital, Udaipur. Written informed consent was obtained from all participants prior to enrolment, and the confidentiality of patient data was maintained throughout.

Conflicts of Interest: The author declares that there are no conflicts of interest.

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Data Availability: The anonymised dataset generated during the study is available from the corresponding author on reasonable request.

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