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Value of Multimodal Imaging Quantitative Parameters for Evaluating ALBI Grades in Liver Cirrhosis

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Abstract: ***Objective:*** ***To compare the discriminative performance of quantitative parameters derived from dual-energy computed tomography (DECT) and magnetic resonance imaging (MRI) in differentiating Albumin-Bilirubin (ALBI) grades in patients with liver cirrhosis.*** ***Methods:*** ***This single-center retrospective study included 93 participants (68 patients with cirrhosis and 25 non-cirrhotic controls). Patients with cirrhosis were stratified by ALBI grade: grade 1 (n = 25), grade 2 (n = 24), and grade 3 (n = 19). All participants underwent upper abdominal DECT and diffusion-weighted imaging (DWI). The following parameters were measured: fractional extracellular volume (fECV), arterial iodine fraction (AIF), and iodine washout ratio (IWR) from DECT; and virtual shear modulus (μDiff) from DWI. Spearman correlation analysis was used to assess associations with ALBI grade, and receiver operating characteristic (ROC) curve analysis was performed to evaluate discriminative performance for adjacent ALBI grades.*** ***Results:*** ***fECV showed the strongest correlation with ALBI grade (r_s = 0.824, P < 0.001) and achieved the highest area under the ROC curve (AUC) values: 0.898 (95% CI: 0.802–0.971) for discriminating grade 1 from grade 2, and 0.862 (95% CI: 0.731–0.965) for discriminating grade 2 from grade 3. IWR was negatively correlated with ALBI grade (r_s = −0.777, P < 0.001), with AUCs of 0.835 and 0.851, respectively. AIF was positively correlated (r_s = 0.756, P < 0.001), with AUCs of 0.838 and 0.827, respectively. μDiff showed a relatively weaker correlation (r_s = 0.645, P < 0.001), with AUCs of 0.732 and 0.800, respectively. All four parameters differed significantly between adjacent ALBI grades (all P < 0.05, Holm-corrected).*** ***Conclusions:*** ***DECT- and MRI-derived quantitative parameters can effectively differentiate ALBI grades in liver cirrhosis. fECV exhibits the best discriminative performance, while IWR and AIF may provide complementary information for assessing hepatic functional reserve.***

Keywords: Liver cirrhosis, Albumin-Bilirubin grade, Extracellular volume fraction, Dual-energy computed tomography, Magnetic resonance imaging.

1. Introduction

Cirrhosis is the end stage of various chronic liver diseases and is characterized by diffuse hepatic fibrosis, regenerative nodule formation, and architectural distortion of the hepatic lobules, ultimately leading to portal hypertension and impaired liver function [1]. Objective stratification of hepatic functional reserve is critical for clinical management, as treatment strategies and prognosis differ substantially between compensated and decompensated stages [2].

The two most widely used tools for liver function assessment are the Child-Pugh classification and the Model for End-Stage Liver Disease (MELD) score. The Child-Pugh classification incorporates ascites and hepatic encephalopathy—variables that are subject to interobserver variability and may be confounded by therapeutic interventions [3]. The MELD score was originally designed for short-term prognosis prediction and liver transplant prioritization in patients with end-stage liver disease and is less suited to routine risk stratification in cirrhosis [4]. The Albumin-Bilirubin (ALBI) score, constructed solely from serum albumin and total bilirubin, offers several advantages: it is computationally simple, continuously quantifiable, and independent of subjective clinical variables. Johnson et al. [5] first proposed ALBI grading for liver function evaluation, and Toyoda et al. [6] subsequently noted that its applicability has extended beyond hepatocellular carcinoma (HCC) to a broader spectrum of chronic liver diseases. Wang et al. [7] further demonstrated that the ALBI score reliably reflects disease severity in patients with hepatitis B virus-related cirrhosis. Thus, in clinical scenarios where histological assessment is unavailable yet objective evaluation of hepatic functional reserve is required, ALBI grading can serve as a stable and standardized reference framework.

In recent years, imaging-based evaluation of cirrhosis has shifted from morphological observation toward quantitative analysis of tissue properties and functional status [8]. DECT enables quantification of hepatic iodine concentration through material decomposition [9]. Among DECT-derived parameters, fECV—calculated as the ratio of hepatic to aortic iodine concentration at the delayed phase corrected for hematocrit—reflects the relative expansion of the hepatic extracellular space [10]; AIF, the ratio of hepatic iodine concentration at the arterial phase to that at the portal venous phase, captures the relative increase in hepatic arterial blood supply [11]; and IWR, the relative decline in hepatic iodine concentration from the portal venous phase to the delayed phase, characterizes contrast agent washout kinetics [12]. Prior studies have shown that fECV correlates with hepatic functional reserve and liver-related outcomes in cirrhosis [10,13], IWR demonstrates good discriminatory ability for liver fibrosis progression [12], and AIF can be used to assess hemodynamic alterations in cirrhosis [11]. On the MRI side, virtual magnetic resonance elastography (vMRE)—which utilizes DWI acquired at high and low b-values to generate a shifted apparent diffusion coefficient (sADC) and derives a virtual shear modulus (μDiff) via a calibration curve—can estimate tissue stiffness without the need for external mechanical vibration [14]. vMRE-derived metrics correlate

with liver fibrosis stage [15,16].

However, existing studies have largely focused on a single modality or a single parameter. To date, no study has systematically compared DECT-derived multiparametric metrics with MRI-based virtual elastography within a single cirrhosis cohort using ALBI grading as a unified reference standard. Each parameter captures a distinct pathophysiological dimension—fECV reflects extracellular matrix remodeling, AIF captures hemodynamic redistribution, IWR characterizes contrast agent kinetics, and μDiff represents tissue stiffness—and their relative contributions and complementarity in stratifying hepatic functional reserve remain unclear. In this study, we used ALBI grading as a unified biochemical reference to compare the discriminative performance of fECV, AIF, IWR, and μDiff for differentiating adjacent ALBI grades in patients with liver cirrhosis. The term "multimodal imaging" as used herein refers to the combination of DECT and MRI-DWI—the former providing three iodine concentration-derived metrics while the latter contributes one stiffness-related parameter.

2. Materials and Methods

2.1 Study Population

This single-center retrospective study was conducted at BaoTou Central Hospital. The requirement for written informed consent was waived owing to the retrospective nature of the study.Participants were enrolled between August 2024 and December 2025. All participants underwent both upper abdominal MRI (including DWI) and DECT, as well as blood sampling for hematological and biochemical tests within 7 days of imaging.

Inclusion criteria for the cirrhosis group were: (1) age ≥ 18 years, (2) a confirmed diagnosis of cirrhosis based on clinical presentation, laboratory findings, and imaging features consistent with cirrhosis, or prior histological confirmation, and (3) complete clinical data. Inclusion criteria for the control group were: (1) age ≥ 18 years, (2) contemporaneous upper abdominal MRI and DECT examinations, (3) no clinical or imaging evidence of cirrhosis, and (4) complete clinical data.

Exclusion criteria were: (1) concomitant HCC or other malignancies; (2) focal hepatic lesions that interfered with region-of-interest (ROI) placement or substantially altered hepatic parenchymal enhancement; (3) acute hepatitis flare, obstructive jaundice, or recent massive blood transfusion; (4) suboptimal MRI or DECT image quality; and (5) missing clinical data or unavailable key variables.

A total of 93 participants were ultimately included: 68 patients with cirrhosis and 25 non-cirrhotic controls.

2.2 ALBI Score and Grading

Serum albumin (Alb) and total bilirubin (TBil) levels were collected. The ALBI score was calculated as: ALBI = 0.66 × $\log_{10}$(TBil [μmol/L]) − 0.085 × (Alb [g/L]). Grading was performed according to the thresholds established by Johnson et al. [5]: ALBI grade 1, ≤ −2.60; ALBI grade 2, > −2.60 and ≤ −1.39; and ALBI grade 3, > −1.39. The cirrhosis group was accordingly stratified into grade 1 (n = 25), grade 2 (n = 24), and grade 3 (n = 19).

2.3 DECT Acquisition and Parameter Measurement

DECT examinations were performed on a SOMATOM Force dual-source CT scanner (Siemens Healthineers, Germany) in dual-energy mode with tube voltages of 100 kV and Sn150 kV and reference tube currents of 190 mA and 90 mA, respectively. The scan range extended from the dome of the diaphragm to the inferior margin of the liver, and all participants were instructed to hold their breath during acquisition.

Following the non-contrast scan, contrast-enhanced imaging was performed. Iohexol (320 mgI/mL) was administered via an antecubital vein at a dose of 1.2 mL/kg body weight with an injection rate of 4.5 mL/s. Arterial, portal venous, and delayed phases were acquired at approximately 30 s, 60 s, and 300 s after injection, respectively.

Post-processing was performed on a Syngo.via workstation (Siemens Healthineers) to generate virtual non-contrast images and iodine maps, from which iodine concentrations (IC) of the hepatic parenchyma and abdominal aorta were measured. ROIs were placed according to the following standardized protocol: five circular ROIs (approximately 1 cm² each) were positioned in the left lateral lobe, left medial lobe, right anterior lobe, right posterior lobe, and caudate lobe, avoiding large intrahepatic vessels, bile ducts, focal lesions, and obvious artifacts; a reference ROI was placed in the abdominal aorta at the same axial level. The mean value of the five hepatic ROIs was taken as the hepatic iodine concentration for each participant. Measurements were independently performed by two radiologists, and the mean of the two measurements was used for subsequent analysis.

The following parameters were calculated according to previously described methods [10,12,13]:

$$fECV\ (\%) = [IC_{liver,\ delayed} / IC_{aorta,\ delayed}] \times (100 - Hct\ [\%])$$

$$AIF = IC_{liver,\ arterial} / IC_{liver,\ PVP}$$

$$IWR\ (\%) = [(IC_{liver,\ PVP} - IC_{liver,\ delayed}) / IC_{liver,\ PVP}] \times 100$$

where Hct denotes hematocrit and PVP denotes the portal venous phase.

2.4 MRI Acquisition and μDiff Measurement

MRI examinations were performed on a 3.0-T scanner (Skyra 3.0 T, Siemens Healthineers, Germany) using a phased-array body coil. DWI was acquired using a free-breathing single-shot echo-planar imaging sequence with b-values of 200 and 1500 s/mm² (NEX, 1 and 4, respectively). Scan parameters were: TR/TE, approximately 8000/63 ms; field of view, 380 × 308 mm²; matrix, 128 × 128; and slice thickness, 5 mm.

Post-processing was performed on the integrated MRI workstation. ADC maps were generated from the DWI images at b = 200 and b = 1500 s/mm². Two circular ROIs (approximately 1 cm² each) were placed in the right and left hepatic lobes, avoiding intrahepatic vessels, bile ducts, and artifacts, on three consecutive slices to obtain the shifted apparent diffusion coefficient (sADC). Measurements were independently performed by two radiologists, and the mean of the two measurements was used. μDiff was calculated according to the calibration formula proposed by Le Bihan et al. [14]: μDiff (kPa) = α × sADC + β, where α = −9.8 and β = 14.

2.5 Statistical Analysis

Statistical analyses were performed using SPSS (version 25.0) and R (version 4.3.2). The normality of continuous variables was assessed using the Shapiro-Wilk test. Normally distributed variables are presented as mean ± standard deviation and were compared between two groups using an independent-samples t-test and among three or more groups using one-way analysis of variance. Non-normally distributed variables are presented as median (interquartile range) and were compared using the Mann-Whitney U test (two groups) or the Kruskal-Wallis H test (three or more groups). Categorical variables are presented as counts (percentages) and were compared using the χ^2 test or the Fisher exact test.

Spearman correlation analysis was performed to assess associations between imaging parameters and ALBI grade. ROC curve analysis was conducted to evaluate the discriminative performance of each parameter for differentiating adjacent ALBI grades, with AUC and 95% confidence intervals (CIs) calculated. Internal validation was performed using bootstrap resampling (1000 iterations). Pairwise comparisons among multiple groups were corrected using the Holm method. All tests were two-sided, and $P < 0.05$ was considered statistically significant.

3. Results

3.1 Participant Characteristics

Among the 93 participants, 25 were non-cirrhotic controls and 68 were patients with cirrhosis (ALBI grade 1, n = 25; grade 2, n = 24; grade 3, n = 19). Age and sex did not differ significantly between the control and cirrhosis groups (both $P > 0.05$). Alb, TBil, ALT, AST, Hct, and PLT all differed significantly between the two groups (all $P < 0.05$) (Table 1).

3.2 Comparison of Imaging Parameters Between Controls and Cirrhosis

μDiff, AIF, and fECV were significantly higher, and IWR significantly lower, in the cirrhosis group than in the control group (all $P < 0.001$) (Table 1).

Table 1: Demographic, laboratory, and imaging characteristics of the control and cirrhosis groups

Variable	Control (n = 25)	Cirrhosis (n = 68)	Statistic	P value
Age (years)	53.12 ± 17.81	58.31 ± 11.99	t = −1.612	0.110
Sex (M/F)	15/10	39/29	χ^2 = 0.000	1.000
Alb (g/L)	43.41 ± 3.99	36.73 ± 7.85	t = 5.379	< 0.001
TBil (μmol/L)	12.00 (10.60, 17.00)	19.50 (14.38, 40.92)	Z = −4.082	< 0.001
ALT (U/L)	17.00 (15.00, 21.00)	30.00 (17.00, 44.50)	Z = −3.466	< 0.001
AST (U/L)	21.00 (18.00, 27.00)	39.50 (24.75, 58.25)	Z = −4.545	< 0.001
Hct (L/L)	0.44 (0.41, 0.47)	0.41 (0.35, 0.45)	Z = 2.110	0.035
PLT (×10⁹/L)	203.00 (169.00, 227.00)	113.50 (75.00, 162.25)	Z = 4.818	< 0.001
μDiff (kPa)	2.62 (2.42, 2.92)	4.65 (3.46, 7.76)	Z = −5.871	< 0.001
AIF	0.17 ± 0.06	0.39 ± 0.15	t = −10.417	< 0.001
IWR (%)	49.70 ± 6.22	33.76 ± 9.95	t = 9.202	< 0.001
fECV (%)	23.23 (21.97, 24.79)	30.41 (27.37, 36.61)	Z = −6.304	< 0.001

Alb, albumin; TBil, total bilirubin; ALT, alanine aminotransferase; AST, aspartate aminotransferase; Hct, hematocrit; PLT, platelet count; μDiff, virtual shear modulus; AIF, arterial iodine fraction; IWR, iodine washout ratio; fECV, fractional extracellular volume.

3.3 Comparison of Imaging Parameters Across ALBI Grades

Within the cirrhosis group, μDiff, AIF, and fECV increased progressively with higher ALBI grade, while IWR decreased progressively. All four parameters differed significantly among the three ALBI grade subgroups (all $P < 0.001$). After Holm correction, pairwise differences between grade 1 and grade 2, grade 2 and grade 3, and grade 1 and grade 3 were all statistically significant (all $P < 0.05$). Age and sex did not differ significantly across ALBI grades (both $P > 0.05$) (Table 2).

Table 2: Imaging parameters across ALBI grades in the cirrhosis group

Variable	Grade 1 (n = 25)	Grade 2 (n = 24)	Grade 3 (n = 19)	Statistic	P value
Age (years)	56.08 ± 11.09	62.21 ± 13.02	56.32 ± 11.09	F = 2.025	0.140
Sex (M/F)	16/9	12/12	11/8	χ^2 = 0.984	0.611
μDiff (kPa)	3.44 (2.90, 4.32)	4.61 (4.12, 5.74)	8.63 (7.38, 9.74)	H = 28.262	<0.001[abc]
AIF	0.27 ± 0.08	0.40 ± 0.10	0.54 ± 0.10	F = 42.871	< 0.001[abc]
IWR (%)	42.34 ± 6.03	33.06 ± 7.62	23.34 ± 5.31	F = 46.824	< 0.001[abc]
fECV (%)	26.57 (24.38, 28.31)	31.34 (29.14, 34.17)	37.54 (36.59, 39.37)	H = 45.564	< 0.001[abc]

[a] $P < 0.05$ for grade 1 vs. grade 2; [b] $P < 0.05$ for grade 2 vs. grade 3; [c] $P < 0.05$ for grade 1 vs. grade 3 (all Holm-corrected).

Correlation Between Imaging Parameters and ALBI Grade
Spearman correlation analysis within the cirrhosis group revealed that fECV had the strongest correlation with ALBI grade ($r_s = 0.824$), followed by IWR ($r_s = −0.777$) and AIF (r_s

= 0.756); μDiff showed a relatively weaker correlation (r_s = 0.645) (all P < 0.001) (Table 3).

Table 3: Spearman correlation between imaging parameters and ALBI grade in the cirrhosis group

Parameter	r_s	P value
μDiff	0.645	< 0.001
AIF	0.756	< 0.001
IWR	−0.777	< 0.001
fECV	0.824	< 0.001

ALBI grade was coded as 1, 2, and 3.

3.4 Discriminative Performance of Imaging Parameters for ALBI Grades

For discriminating ALBI grade 1 from grade 2, fECV achieved the highest AUC (0.898; 95% CI: 0.802–0.971) with a sensitivity of 0.958 and specificity of 0.680, followed by AIF (AUC = 0.838) and IWR (AUC = 0.835); μDiff showed the lowest performance (AUC = 0.732). For discriminating grade 2 from grade 3, fECV again yielded the highest AUC (0.862; 95% CI: 0.731–0.965) with a sensitivity of 0.947 and specificity of 0.708, followed by IWR (AUC = 0.851) and AIF (AUC = 0.827); μDiff achieved an AUC of 0.800 (Tables 4 and 5).

Table 4: ROC analysis of imaging parameters for discriminating ALBI grade 1 from grade 2

Parameter	AUC (95% CI)	Cutoff	Sensitivity	Specificity	Youden index
μDiff	0.732 (0.582–0.870)	> 4.12 kPa	0.792	0.680	0.472
AIF	0.838 (0.708–0.943)	> 0.35	0.708	0.880	0.588
IWR	0.835 (0.719–0.940)	≤ 36.89%	0.708	0.840	0.548
fECV	0.898 (0.802–0.971)	> 27.46%	0.958	0.680	0.638

Table 5: ROC analysis of imaging parameters for discriminating ALBI grade 2 from grade 3

Parameter	AUC (95% CI)	Cutoff	Sensitivity	Specificity	Youden index
μDiff	0.800 (0.657–0.924)	> 5.71 kPa	0.842	0.750	0.592
AIF	0.827 (0.683–0.943)	> 0.46	0.789	0.750	0.539
IWR	0.851 (0.722–0.950)	≤ 28.96%	0.895	0.750	0.645
fECV	0.862 (0.731–0.965)	> 33.86%	0.947	0.708	0.655

4. Discussion

In this study, ALBI grading served as the unified reference for hepatic functional reserve stratification in patients with cirrhosis. μDiff, AIF, and fECV increased progressively with higher ALBI grade, while IWR decreased—all showing statistically significant differences between adjacent grades. This consistent gradient pattern corroborates, from an imaging perspective, the ability of ALBI grading to effectively discriminate among different levels of hepatic functional reserve.

The ALBI score is constructed exclusively from albumin and total bilirubin, thereby avoiding the subjective variables inherent in the Child-Pugh classification [3,5]. Johnson et al. [5] validated the ALBI model in international multicenter cohorts, and Toyoda et al. [6] noted its expanding applicability beyond HCC. Our findings support the use of ALBI grading as an objective reference framework for validating imaging-based quantitative parameters.

We aimed to determine whether imaging-derived quantitative parameters can differentiate among the hepatic functional reserve levels defined by ALBI grading, rather than to propose imaging parameters as a replacement for the ALBI score itself. The value of imaging parameters lies in their ability to provide regional functional information about the hepatic parenchyma—as opposed to whole-liver serological summary indices—in clinical scenarios where venous sampling may be impractical or when spatially resolved functional assessment is needed. In exploratory analyses, the four parameters yielded AUCs ranging from 0.794 (IWR) to 0.814 (fECV) for discriminating non-cirrhotic controls from patients with ALBI grade 1, suggesting a degree of discriminative capacity even between non-cirrhotic individuals and those with mild liver function impairment. However, this comparison conflates the presence of cirrhosis with differences in hepatic functional reserve—the control group was defined by the absence of cirrhosis rather than by normal liver function—and these results should therefore be interpreted with caution. Our study did not include Child-Pugh classification as a parallel reference. Given that Child-Pugh remains the most widely used liver function grading system in clinical practice, future studies incorporating both ALBI and Child-Pugh classifications would permit a direct comparison of imaging parameters across these two frameworks.

The principal finding of this study is that fECV demonstrated the strongest correlation with ALBI grade (r_s = 0.824) and the highest discriminative performance among the four parameters evaluated, with AUCs of 0.898 and 0.862 for discriminating grade 1 from grade 2 and grade 2 from grade 3, respectively.

fECV quantifies the distribution volume of contrast agent within the hepatic extracellular space at the delayed phase (300 s post-injection). As cirrhosis progresses, excessive collagen deposition leads to expansion of the extracellular matrix, and sinusoidal capillarization further increases the extracellular distribution space for contrast material [1]. This structural alteration is directly coupled with the decline in hepatic functional reserve—the greater the extracellular space expansion, the fewer the functional hepatocytes, and the more impaired the synthetic and metabolic capacity. Han et al. [17] employed a similar DECT methodology and reported that fECV was highly correlated with ALBI grade (r_s = 0.908), with AUCs of 0.945 and 0.974 for discriminating grade 1 from grades 2 + 3 and grades 1 + 2 from grade 3, respectively. The slightly lower AUC values in our study (0.898 and 0.862) may be attributable to differences in the grouping strategy—Han et al. employed binary classification tasks that collapsed non-adjacent grades, whereas our study focused on finer discrimination between adjacent grades, which is inherently more challenging. Hong et al. [13] also reported that fECV yielded AUCs of 0.84 and 0.78 for discriminating Child-Pugh class A from B and B from C, respectively, consistent with our findings. Collectively, these data indicate

that fECV plays a central role in the imaging-based assessment of hepatic functional reserve. From a practical standpoint, fECV requires only the addition of a delayed-phase acquisition to routine DECT, without extra contrast material or dedicated hardware.

AIF and IWR both showed significant correlations with ALBI grade (r_s = 0.756 and −0.777, respectively), with AUCs ranging from 0.827 to 0.851—lower than that of fECV but still indicative of good discriminative performance. These two parameters capture pathophysiological dimensions distinct from that of fECV. AIF reflects the redistribution of intrahepatic blood supply: hepatic fibrosis leads to reduced portal venous perfusion and compensatory hepatic arterial dilation, thereby increasing AIF [11]. IWR characterizes contrast agent washout kinetics: sinusoidal capillarization and microcirculatory impairment in cirrhosis result in contrast agent retention and a consequent reduction in IWR [12]. Zhao et al. [11] reported that AIF increased with worsening liver function, and Nagayama et al. [12] demonstrated that IWR decreased with progressive fibrosis and could effectively distinguish fibrosis stages; a more recent study further identified IWR as an independent predictor of severe liver dysfunction [18]. Our findings are consistent with these observations and additionally demonstrate that AIF and IWR can provide complementary information—from the perspectives of hemodynamic redistribution and contrast agent kinetics, respectively—to fECV-based assessment.

μDiff showed a correlation coefficient of 0.645 with ALBI grade and AUCs of 0.732 (grade 1 vs. grade 2) and 0.800 (grade 2 vs. grade 3), placing it at the lower end among the four parameters. μDiff is derived from DWI-based vMRE, first described by Le Bihan et al. [14]; Kromrey et al. [15] subsequently demonstrated good agreement between vMRE and conventional MRE for liver fibrosis assessment, and Yang et al. [16] reported its utility for fibrosis staging. In our study, μDiff showed a statistically significant positive correlation with ALBI grade and moderate-to-good discriminative performance (AUCs, 0.732–0.800), indicating that it can provide tissue stiffness-related information.

The lower performance of μDiff relative to the three DECT-derived parameters may be related to its underlying technical principle. μDiff estimates elastic modulus indirectly from DWI signal characteristics and is likely influenced by inflammatory activity and altered water diffusivity [19]; the inclusion of inflammation-related information likely reduces its concordance with the specific dimension of "hepatic functional reserve" that ALBI is designed to capture. ALBI primarily reflects hepatic synthetic and metabolic function, whereas μDiff primarily reflects tissue stiffness—although these two dimensions are correlated, they differ from a pathophysiological standpoint, which may also account for the relatively lower correlation and discriminative performance.

This study has several limitations. First, it was a single-center retrospective study with a total sample size of 93 participants; the ALBI grade 3 subgroup included only 19 patients, which may have affected the robustness of some intergroup comparisons. Second, ALBI grading served as the reference standard without parallel histological confirmation, and the study did not incorporate hepatic venous pressure gradient measurements or clinical decompensation events as endpoint validation. Third, etiology-specific subgroup analysis was not performed; cirrhosis of different etiologies may differentially affect imaging quantitative parameters. Fourth, the delayed-phase DECT acquisition was set at 300 s—although this interval facilitates adequate contrast equilibration, the relatively long wait time may affect clinical workflow efficiency. Fifth, this study focused on comparing the independent discriminative performance of individual imaging parameters and did not construct multi-parameter combined diagnostic models; consequently, the incremental discriminative value contributed by information complementarity among different parameters could not be assessed.

Future multicenter studies with larger sample sizes should: incorporate histological staging, portal hypertension metrics, and clinical follow-up outcomes for external validation; construct and validate combined multi-parameter models using multivariable logistic regression; evaluate incremental performance metrics such as net reclassification improvement; and explore more streamlined acquisition protocols and etiology-specific subgroup analyses.

5. Conclusion

DECT- and MRI-derived quantitative parameters can effectively differentiate ALBI grades in patients with liver cirrhosis. Among the four parameters evaluated, fECV exhibits the best discriminative performance—with the strongest correlation with ALBI grade (r_s = 0.824) and the highest AUCs for discriminating grade 1 from grade 2 (0.898) and grade 2 from grade 3 (0.862). AIF and IWR can provide complementary information from the perspectives of hemodynamic redistribution and contrast agent kinetics, respectively. μDiff, while reflecting tissue stiffness, demonstrates relatively limited performance for ALBI grade stratification. Multimodal imaging quantitative parameters show promise as objective tools for the noninvasive stratification of hepatic functional reserve in cirrhosis.

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