

Characterization of Focal Hepatic Lesions Using Diffusion-Weighted Magnetic Resonance Imaging and Its Correlation with Contrast-Enhanced Computed Tomography

Authors:

Dr. Tanya Kathuria¹, Dr. Gaurav Singla², Dr. Anchal Sharma³

¹Senior Resident, Department of Radiodiagnosis, Indraprastha Institute of Medical Sciences, Panipat, Haryana 132108.

²Assistant Professor, Department of Radiodiagnosis, RIMT Medical College and Hospital, Mandi Gobindgarh, Punjab 147301.

³Associate Professor, Department of Radiodiagnosis, Maharishi Markandeshwar Medical College and Hospital, Solan 173229.

Corresponding Author:

Dr. Tanya Kathuria, Senior Resident, Department of Radiodiagnosis, Indraprastha Institute of Medical Sciences, Panipat, Haryana 132108.

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ABSTRACT

Background: Focal hepatic lesions include benign, malignant, and inflammatory entities with overlapping appearances on conventional imaging. Diffusion-weighted magnetic resonance imaging (DWI) and apparent diffusion coefficient (ADC) mapping provide functional information that may improve lesion characterization. **Objective:** To evaluate the role of diffusion-weighted magnetic resonance imaging (DWI) and quantitative apparent diffusion coefficient (ADC) measurements in the characterization of focal hepatic lesions, with correlation to contrast-enhanced computed tomography (CECT) and final diagnosis. **Materials and Methods:** This cross-sectional comparative study included 50 consecutively enrolled patients with focal hepatic lesions examined between April 2023 and November 2024. Magnetic resonance imaging (MRI) was performed on a 1.5-tesla system using conventional sequences, diffusion-weighted imaging (DWI; b values 50, 400, and 800 s/mm²), and apparent diffusion coefficient (ADC) maps. The study-derived ADC threshold of 1.2×10^{-3} mm²/s was evaluated using sensitivity, specificity, predictive values, accuracy, and receiver operating characteristic (ROC) analysis. **Results:** Twenty-eight lesions (56%) were benign/non-malignant and 22 (44%) were malignant. Mean central ADC was significantly higher in benign/non-malignant lesions than in malignant lesions (1.63 ± 0.65 vs $0.84 \pm 0.46 \times 10^{-3}$ mm²/s; $p < 0.001$); corresponding peripheral ADC values were 1.61 ± 0.57 and $0.81 \pm 0.28 \times 10^{-3}$ mm²/s ($p < 0.001$). Peripheral ADC demonstrated 75% sensitivity, 95.45% specificity, 84% accuracy, and an area under the ROC curve (AUC) of 0.975. **Conclusion:** Diffusion-weighted imaging (DWI) with apparent diffusion coefficient (ADC) mapping is a useful adjunct for focal hepatic lesion characterization. ADC values should be interpreted with lesion morphology and enhancement because abscesses and cystic/necrotic malignancies may overlap.

Keywords: *apparent diffusion coefficient, CECT, diffusion-weighted MRI, focal hepatic lesions, liver MRI*

INTRODUCTION

Focal hepatic lesions are among the most frequently encountered abnormalities in abdominal imaging. They range from innocuous entities such as simple cysts and cavernous hemangiomas to primary hepatic malignancies, metastatic deposits, and infective lesions. The clinical consequences of an imaging diagnosis are substantial: a confidently characterized simple cyst may require no further evaluation, a liver abscess may require antimicrobial treatment or drainage, and a malignant

lesion may alter staging, resectability, systemic therapy, or transplant eligibility.

Ultrasonography is often the first imaging examination because it is widely available, inexpensive, and free of ionizing radiation. However, lesion echogenicity is frequently nonspecific, and characterization may be limited by body habitus, lesion depth, overlying bowel gas, or operator dependence. Cross-sectional imaging is therefore commonly required when a lesion is indeterminate or when accurate staging is needed.

Multiphasic CECT has an established role in liver imaging. Lesion attenuation, arterial enhancement, portal venous appearance, delayed behavior, vascular invasion, calcification, necrosis, and extrahepatic disease can all contribute to diagnosis. Nevertheless, CT involves ionizing radiation and iodinated contrast exposure, and some lesions show atypical or overlapping enhancement patterns. Repeated CT examinations may also be undesirable in younger patients or during longitudinal surveillance.

MRI provides superior soft-tissue contrast and a multiparametric assessment of tissue composition. Conventional T1- and T2-weighted sequences, chemical-shift imaging, dynamic contrast-enhanced imaging, hepatobiliary phase imaging where applicable, and DWI can be integrated to improve lesion characterization.

DWI is particularly attractive because it adds functional information without requiring additional contrast material. DWI is based on the random Brownian motion of water molecules. Diffusion becomes impeded when cellular membranes, macromolecules, viscosity, and reduced extracellular space limit microscopic water movement. High-cellularity tumors therefore often remain hyperintense on high-b-value DWI and show low signal on ADC maps. ADC provides a quantitative estimate of diffusion and helps distinguish true restriction from T2 shine-through [1-3].

The relationship between ADC and malignancy is useful but not absolute. Many malignant lesions have low ADC values, yet benign hypercellular lesions may overlap. Abscesses can show striking restriction because viscous pus contains inflammatory cells, microorganisms, proteins, and cellular debris. Conversely, necrotic or cystic malignant lesions may have high ADC values because membrane breakdown increases water mobility. These exceptions make lesion morphology and enhancement indispensable [4-7].

Published work has consistently shown that DWI improves lesion conspicuity and can contribute to characterization, but absolute ADC thresholds vary considerably across institutions. Field strength, echo-planar technique, respiratory strategy, b-values, signal-to-noise ratio, ROI placement, lesion size, and internal composition all affect ADC measurements. Thus, locally generated data remain relevant, particularly when a specific acquisition protocol is used [2,3,8-10].

The present study evaluates focal hepatic lesions using DWI and ADC measurements in correlation with CECT and final diagnosis. Particular attention is given to central and peripheral ADC measurements, the diagnostic performance of a $1.2 \times 10^{-3} \text{ mm}^2/\text{s}$ threshold, and lesion-specific sources of overlap.

Review of Relevant Literature

Evolution of diffusion-weighted liver imaging

DWI was initially established in neuroimaging, where the relative immobility of the brain and strong clinical effect of diffusion restriction in acute ischemia favored rapid adoption. Translation to abdominal imaging was more difficult because respiratory motion, cardiac pulsation, bowel peristalsis, susceptibility differences, and relatively low signal-to-noise ratio degrade echo-planar images. Improvements in gradients, parallel imaging, phased-array coils, respiratory triggering, and post-processing have made liver DWI a routine component of modern MRI. [1-3,24,25]

Low b-values suppress signal from hepatic vessels and can improve lesion conspicuity by creating a 'black-blood' effect. Higher b-values suppress background liver signal and emphasize lesions with impeded diffusion. The ADC map is generated from signal decay across b-values and is necessary for quantitative assessment. Because low b-values contain a perfusion component, ADC is an apparent rather than purely molecular diffusion measurement. [1-3,24,25]

DWI for lesion detection

DWI can increase the conspicuity of small focal liver lesions because high-b-value images suppress much of the normal hepatic background. This can be particularly helpful for metastases adjacent to vessels, at the liver dome, or near the capsule. The sequence is fast and can be added to routine protocols with little additional examination time. [7,10,11,25]

Detection and characterization should be considered separate tasks. A lesion may be conspicuous on DWI but remain nonspecific. Hyperintensity may arise from restricted diffusion, T2 shine-through, hemorrhage, proteinaceous material, or technical factors. Therefore, the diagnostic contribution of DWI is strongest when combined with anatomic and contrast-enhanced sequences. [2,3,9,10]

ADC as a quantitative biomarker

ADC values are generally higher in fluid-containing benign lesions and lower in hypercellular malignant lesions. Simple cysts typically show very high ADC values because water moves relatively freely. Hemangiomas also tend to have high ADC values because of vascular spaces and prolonged T2 relaxation. Metastases and HCC commonly show lower values, although the degree of restriction depends on tumor cellularity, fibrosis, necrosis, hemorrhage, and treatment status. [4-9,13-15]

A single universal ADC cut-off has not been established. Published thresholds differ because acquisition parameters and patient populations differ. This variability is clinically important: a threshold should be

treated as supportive evidence rather than an absolute diagnostic rule. The most defensible use of ADC is to complement a coherent multiparametric pattern. [4-10,13-15,24]

Benign lesions

Simple cysts are typically well-defined, non-enhancing, T1 hypointense, and markedly T2 hyperintense. Their high ADC values help distinguish them from many solid lesions. Hemangiomas classically demonstrate marked T2 hyperintensity and peripheral discontinuous nodular enhancement with progressive centripetal fill-in. High signal on DWI can occur because of T2 shine-through, so ADC correlation prevents false labeling as restricted. [9,10,13,20-22]

Hepatocellular adenoma is more heterogeneous. Fat, hemorrhage, necrosis, inflammatory change, and variable cellularity can influence both conventional signal and diffusion. ADC values may overlap with malignant lesions, particularly when adenomas are hypercellular or hemorrhagic. Focal nodular hyperplasia, although not represented in the present cohort, is another benign solid lesion in which diffusion overlap may occur. [12,16,17]

Malignant lesions

HCC arises most often in a background of chronic liver disease and is characterized primarily through enhancement behavior and ancillary MRI features. Restricted diffusion is an important supportive feature but is not specific. More cellular and poorly differentiated HCCs may show stronger restriction, while necrotic components may increase ADC. [12,17,23]

Metastases are the most common malignant liver lesions in many non-cirrhotic populations. Their appearance varies with the primary tumor. Hypercellular metastases often show low ADC, whereas mucinous, cystic, or necrotic metastases may show high ADC and mimic benign fluid-containing lesions. DWI is particularly useful for detecting small metastases, but characterization requires correlation with enhancement and the clinical history. [7,10,11,26]

Inflammatory lesions and diagnostic pitfalls

Liver abscess is a classic diffusion pitfall. Pus may show intense central restriction, producing ADC values as low as or lower than many malignant tumors. Clinical fever, leukocytosis, inflammatory markers, rim enhancement, perilesional edema, and temporal response to therapy are therefore crucial. [2,3,9]

Other pitfalls include hemorrhage, susceptibility artifact near the diaphragm, cardiac motion affecting the left lobe, partial-volume averaging in small lesions, and inappropriate ROI placement. Necrotic centers should

not be used to represent viable tumor when the purpose is malignancy characterization. [2,3,10,24,25]

MATERIALS AND METHODS

Study design and setting

A cross-sectional comparative study was conducted in the Department of Radiodiagnosis, Jaipur National University Institute for Medical Sciences and Research Centre, Jaipur, Rajasthan, India, from April 2023 to November 2024. The study protocol was approved by the Institutional Ethics Committee (IEC), Jaipur National University Institute for Medical Sciences and Research Centre, Jaipur (Approval No. JNUIMSRC/IEC/2023/75), and written informed consent was obtained from participants.

Study population

A consecutive sampling strategy was used. Fifty consecutive patients with focal hepatic lesions who fulfilled the eligibility criteria and consented to participate were enrolled. The intended sample size was 50 patients, and recruitment was performed over the study period.

Inclusion and exclusion criteria

Inclusion criteria were informed consent; a focal liver lesion already detected on ultrasonography; equivocal findings on contrast-enhanced computed tomography (CECT); or an incidental focal liver lesion detected on computed tomography (CT), including CT of the thorax. Exclusion criteria were an apparent hepatic mass caused by direct invasion from an extrahepatic lesion; traumatic liver injury; pregnancy; severe illness preventing adequate breath-holding; magnetic resonance imaging (MRI)-incompatible metallic implants, defibrillators, cardiac pacemakers, or aneurysm clips; severe claustrophobia; inability to lie supine; uncooperative status or requirement for sedation/anesthesia; and non-diagnostic images because of substantial motion artifact.

Clinical assessment

Age, sex, presenting symptoms, relevant history, occupation, and socioeconomic information were recorded. Potential sources of variability in ADC measurement included lesion size, internal heterogeneity, necrotic or cystic components, inflammatory contents, motion artifact, susceptibility artifact, and region-of-interest placement; these factors were considered during image interpretation.

CT technique

Contrast-enhanced computed tomography (CECT) examinations were obtained on a Toshiba Alexion 16-slice helical computed tomography (CT) scanner and processed on the Alexion platform. Lesions were

evaluated on unenhanced and post-contrast images for attenuation, margins, enhancement, septations, internal heterogeneity, necrosis, hemorrhage, multiplicity, and associated findings.

MRI technique

Magnetic resonance imaging (MRI) was performed on a Siemens Sempra 1.5-tesla system using standardized T1-weighted, T2-weighted, diffusion-weighted imaging (DWI), and apparent diffusion coefficient (ADC) sequences. The study protocol used b values of 50, 400, and 800 s/mm², and images were processed on Siemens Syngo and reviewed using OsiriX software.

Qualitative MRI assessment

Each lesion was assessed for T1 signal, T2 signal, internal heterogeneity, margin, and qualitative DWI appearance. High signal on DWI was not considered sufficient for restriction; ADC maps were reviewed to distinguish true restriction from T2 shine-through.

ADC measurement

Apparent diffusion coefficient (ADC) measurements were obtained using round or elliptical regions of interest (ROIs), with an area of at least 1 cm² when feasible. ROIs were placed in representative solid portions of the lesion, guided by diffusion-weighted hyperintensity with corresponding ADC hypointensity, while avoiding obvious necrosis and air. Central and peripheral ADC values were recorded.

Final diagnosis and grouping

Final lesion diagnosis was based on integration of CECT and MRI findings with available clinical, laboratory, follow-up, and histopathologic information. For the

principal statistical analysis, lesions were grouped as benign/non-malignant or malignant. Inflammatory lesions were retained in the non-malignant group, allowing the study to demonstrate real-world diffusion overlap.

Sample size calculation

The sample size was calculated using Cochran’s formula, $n = Z^2Pq/e^2$, with a 95% confidence level ($Z = 1.96$), an expected population proportion (P) of 0.5, $q = 1 - P$, and an absolute precision (e) of 0.1385. The calculated sample size was approximately 50 participants. Accordingly, 50 consecutive eligible patients were included in the study.

Statistical analysis

Continuous variables were summarized as mean ± standard deviation, while categorical variables were expressed as frequencies and percentages. Mean central and peripheral apparent diffusion coefficient (ADC) values were compared between benign/non-malignant and malignant lesions using independent-samples t-tests. Degrees of freedom (df) and Cohen’s d were reported for these comparisons, with Cohen’s d used as the measure of effect size. A p value <0.05 was considered statistically significant.

The diagnostic performance of the study-derived ADC threshold of 1.2×10^{-3} mm²/s was assessed by calculating sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy. Receiver operating characteristic (ROC) curve analysis was performed to evaluate the discriminatory performance of central and peripheral ADC measurements, and the area under the curve (AUC) was reported.

RESULTS

The study included 50 patients with a broad spectrum of focal hepatic lesions. Twenty-eight lesions (56%) were classified as benign/non-malignant and 22 (44%) as malignant.

Demographic profile

The mean age was 51.24 years. The largest age group was 51-60 years, comprising 15 of 50 patients (30%), followed by 61-70 years, comprising 14 of 50 (28%). There were 30 males (60%) and 20 females (40%). The demographic profile is summarized in Table 1.

Table 1. Demographic characteristics of the study cohort.

Variable	Study finding
Mean age	51.24 years
51-60 years	15/50 (30%)
61-70 years	14/50 (28%)

Male	30/50 (60%)
Female	20/50 (40%)

Clinical presentation

Abdominal pain was the most common presenting symptom and was recorded in 27 of 50 patients (54%). Fever was present in 8 (16%), while ascites and jaundice were each present in 4 (8%). Thirty-five patients (70%) had no documented addiction history; alcohol use and smoking were recorded in 8 (16%) and 7 (14%), respectively.

CT morphology and enhancement

On unenhanced computed tomography (CT), 49 of 50 lesions (98%) were described as hypodense. On contrast-enhanced computed tomography (CECT), 23 (46%) were enhancing, 14 (28%) non-enhancing, 9 (18%) showed peripheral enhancement, and 4 (8%) showed peripheral nodular enhancement. Thirty-five lesions (70%) had well-defined margins and 11 (22%) were ill-defined. These CT features are summarized in Table 2.

Table 2. Principal computed tomography (CT) characteristics.

CECT feature	Frequency
Hypodense on plain CT	49/50 (98%)
Enhancing	23/50 (46%)
Non-enhancing	14/50 (28%)
Peripheral enhancement	9/50 (18%)
Peripheral nodular enhancement	4/50 (8%)
Well-defined margin	35/50 (70%)
Ill-defined margin	11/50 (22%)
No septations	45/50 (90%)

Conventional MRI and qualitative DWI

On T1-weighted magnetic resonance imaging (MRI), 48 of 50 lesions (96%) were predominantly hypointense, while 45 (90%) were hyperintense on T2-weighted imaging. These high frequencies emphasize that conventional signal intensity alone is insufficient for definitive lesion characterization. Diffusion-weighted imaging (DWI) showed hyperintensity in 35 of 50 lesions (70%) and hypointensity in 13 (26%); uncommon patterns accounted for 2 (4%). Lesion-wise final diagnoses and ADC measurements are presented in Table 3.

Distribution of final diagnoses

Table 3. Lesion-wise apparent diffusion coefficient (ADC) measurements.

Final diagnosis	n	Central ADC $\times 10^{-3}$ mm ² /s	Peripheral ADC $\times 10^{-3}$ mm ² /s
Simple cyst	12	2.14 $\pm$ 0.43	2.06 $\pm$ 0.29
Hemangioma	4	1.92 $\pm$ 0.15	1.82 $\pm$ 0.17
Hepatic adenoma	2	0.83 $\pm$ 0.51	1.35 $\pm$ 0.02
Biliary hamartoma	1	1.50	1.80
Abscess	7	0.98 $\pm$ 0.26	0.98 $\pm$ 0.43
Amoebic liver abscess	1	1.70	1.20
Microabscess	1	0.56	0.53

HCC	3	0.70 ± 0.14	0.68 ± 0.28
Metastasis	18	0.76 ± 0.22	0.77 ± 0.18
Cystic metastasis	1	2.70	1.80

Benign versus malignant ADC values

Benign/non-malignant lesions demonstrated significantly higher apparent diffusion coefficient (ADC) values than malignant lesions at both measurement locations (Table 4). Mean central ADC was $1.63 \pm 0.65 \times 10^{-3} \text{ mm}^2/\text{s}$ in the benign/non-malignant group and $0.84 \pm 0.46 \times 10^{-3} \text{ mm}^2/\text{s}$ in the malignant group (independent-samples t-test, $df=48$, $p<0.001$; Cohen's $d=1.37$). Mean peripheral ADC was 1.61 ± 0.57 and $0.81 \pm 0.28 \times 10^{-3} \text{ mm}^2/\text{s}$, respectively ($df=48$, $p<0.001$; Cohen's $d=1.72$).

Table 4. Comparison of apparent diffusion coefficient values between benign and malignant lesions.

ADC location	Benign/non-malignant (n=28), mean $\pm$ SD	Malignant (n=22), mean $\pm$ SD	df	p value	Cohen's d
Central ADC	1.63 ± 0.65	0.84 ± 0.46	48	<0.001	1.37
Peripheral ADC	1.61 ± 0.57	0.81 ± 0.28	48	<0.001	1.72

Diagnostic performance of the ADC threshold

Using $1.2 \times 10^{-3} \text{ mm}^2/\text{s}$ as the study threshold, values at or above the threshold favored benignity and values below the threshold favored malignancy. Central ADC correctly identified 19 of 28 benign/non-malignant lesions (67.86% sensitivity) and 21 of 22 malignant lesions (95.45% specificity), with 40 of 50 lesions correctly classified (80% accuracy). Peripheral ADC correctly identified 21 of 28 benign/non-malignant lesions (75% sensitivity) and 21 of 22 malignant lesions (95.45% specificity), with 42 of 50 lesions correctly classified (84% accuracy). The complete diagnostic performance is summarized in Table 5.

Table 5. Diagnostic performance of the $1.2 \times 10^{-3} \text{ mm}^2/\text{s}$ threshold.

Parameter	Central ADC	Peripheral ADC
Sensitivity	67.86%	75.00%
Specificity	95.45%	95.45%
Positive predictive value	95.00%	95.45%
Negative predictive value	70.00%	75.00%
Accuracy	80.00%	84.00%
ROC AUC	0.914	0.975

ROC analysis demonstrated excellent discrimination. The AUC was 0.914 for central ADC and 0.975 for peripheral ADC. The slightly stronger performance of peripheral measurements may reflect avoidance of central necrosis in malignant lesions, but this interpretation requires caution because the sample was modest and several lesion subgroups were small.

Lesion-specific observations

Simple cysts

Simple cysts were the largest benign subgroup, with mean central and peripheral ADC values of 2.14 ± 0.43

and $2.06 \pm 0.29 \times 10^{-3} \text{ mm}^2/\text{s}$. Their typical well-defined non-enhancing morphology, T2 hyperintensity, and absence of true diffusion restriction are illustrated in Figure 5. Hyperintensity and facilitated diffusion made them relatively straightforward to characterize.

Hemangiomas

Hemangiomas had mean central and peripheral ADC values of 1.92 ± 0.15 and $1.82 \pm 0.17 \times 10^{-3} \text{ mm}^2/\text{s}$. Their typical peripheral nodular enhancement with progressive centripetal filling and T2 shine-through without true restriction are illustrated in Figure 3. High

ADC values were consistent with relatively unrestricted water movement within vascular spaces. DWI hyperintensity could occur because of T2 shine-through, reinforcing the importance of ADC and enhancement pattern.

Hepatic adenomas

The two adenomas were heterogeneous in diffusion behavior. Central ADC averaged $0.83 \pm 0.51 \times 10^{-3} \text{ mm}^2/\text{s}$ while peripheral ADC averaged $1.35 \pm 0.02 \times 10^{-3} \text{ mm}^2/\text{s}$. This wide variation is biologically plausible because adenomas may contain hemorrhage, fat, necrosis, inflammatory change, and variable cellularity.(Figure 6.)

Hepatocellular carcinoma

Hepatocellular carcinoma (HCC) showed low ADC values, with central mean 0.70 ± 0.14 and peripheral mean $0.68 \pm 0.28 \times 10^{-3} \text{ mm}^2/\text{s}$. The characteristic multiphasic enhancement and diffusion restriction of an HCC in a cirrhotic liver are illustrated in Figure 2.

Metastases

Metastases formed the largest malignant subgroup, with mean central and peripheral ADC values of 0.76 ± 0.22 and $0.77 \pm 0.18 \times 10^{-3} \text{ mm}^2/\text{s}$. Most demonstrated true restriction; an example of a hypervascular hepatic metastasis with diffusion restriction is shown in Figure 4.

Abscesses

Abscesses had mean central and peripheral ADC values of approximately $0.98 \times 10^{-3} \text{ mm}^2/\text{s}$, overlapping the malignant range. An illustrative amoebic liver abscess demonstrates peripheral enhancement with central diffusion restriction in Figure 1.

Cystic metastasis

The cystic metastasis demonstrated high ADC values, including a central value of $2.70 \times 10^{-3} \text{ mm}^2/\text{s}$. This represents the opposite pitfall: a malignant lesion may show facilitated diffusion when the sampled tissue is necrotic or cystic.

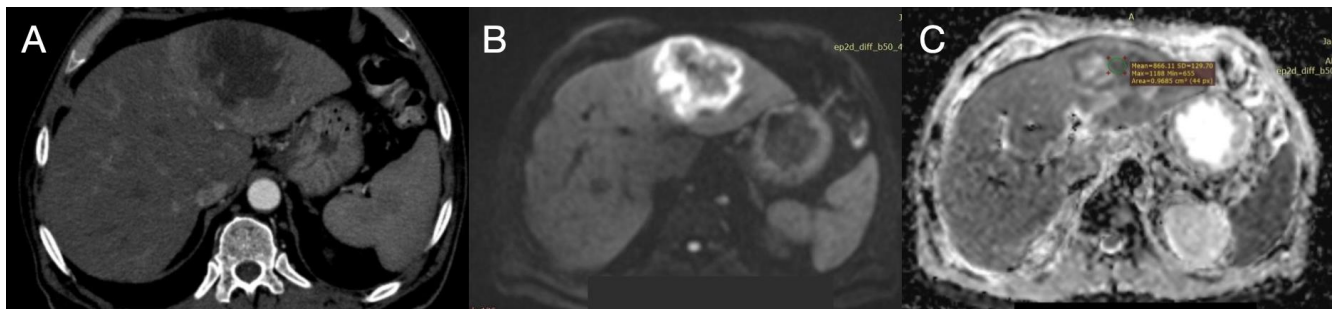


Figure 1. A 60-year-old male with amoebic liver abscess. (A) CECT portovenous phase shows an irregular-shaped hypodense lesion with peripheral enhancement and surrounding perilesional edema involving segments II/III of the left lobe of liver. (B) & (C) DWI b800 and ADC show central diffusion restriction, with mean ADC value of $0.8 \times 10^{-3} \text{ mm}^2/\text{s}$.

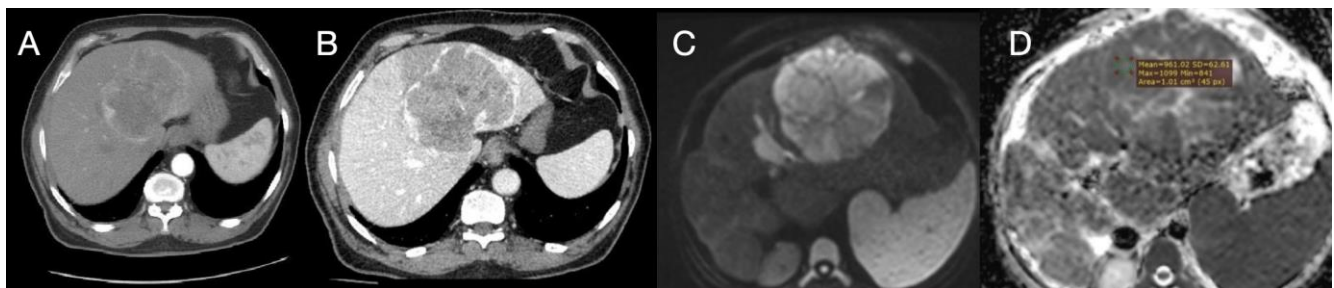


Figure 2. (A) 29-year-old female with cirrhosis and hepatocellular carcinoma. (A & B) CECT arterial phase and CECT portovenous phase show a large hypodense lesion in the left lobe with heterogeneous early arterial enhancement, central necrosis and washout on delayed phases. (C) & (D) DWI b800 and ADC show diffusion restriction in the lesion, with mean ADC value of $0.961 \times 10^{-3} \text{ mm}^2/\text{s}$.

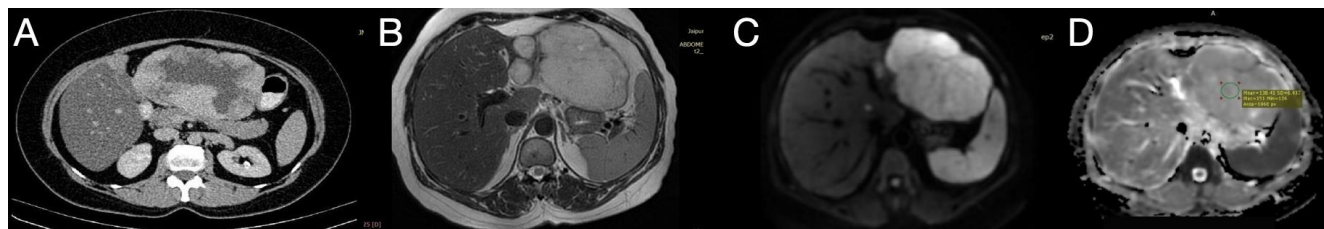


Figure 3. A 59-year-old female with giant hepatic hemangioma. (A) CECT portovenous phase show peripheral nodular enhancement in sync with the blood pool with progressive centripetal filling. (B) Axial T2-weighted MRI shows a hyperintense lesion in the left lobe. (C, D) DWI b800 shows hyperintense signal due to T2 shine-through, whereas ADC shows no true diffusion restriction, with mean ADC value of $13.9 \times 10^{-3} \text{ mm}^2/\text{s}$.

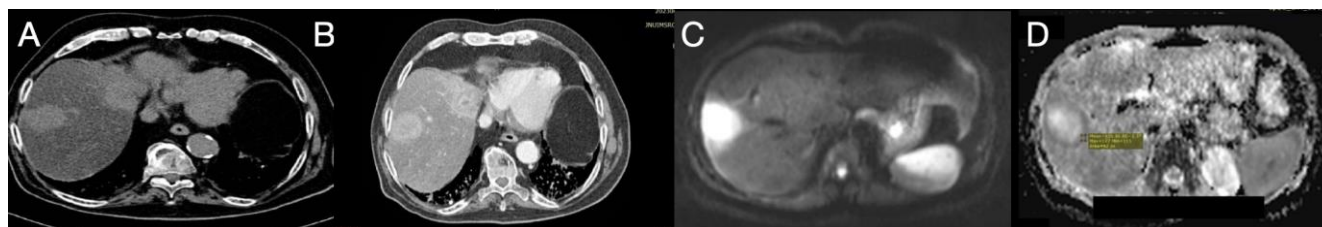


Figure 4. A 58-year-old male with metastatic bronchogenic carcinoma and hypervascular hepatic metastasis. (A) NCCT and (B) portal-venous CECT show a well-defined lesion in the right lobe with enhancement. (C)&(D) DWI and ADC map show diffusion restriction, with mean ADC value of $1.2 \times 10^{-3} \text{ mm}^2/\text{s}$.

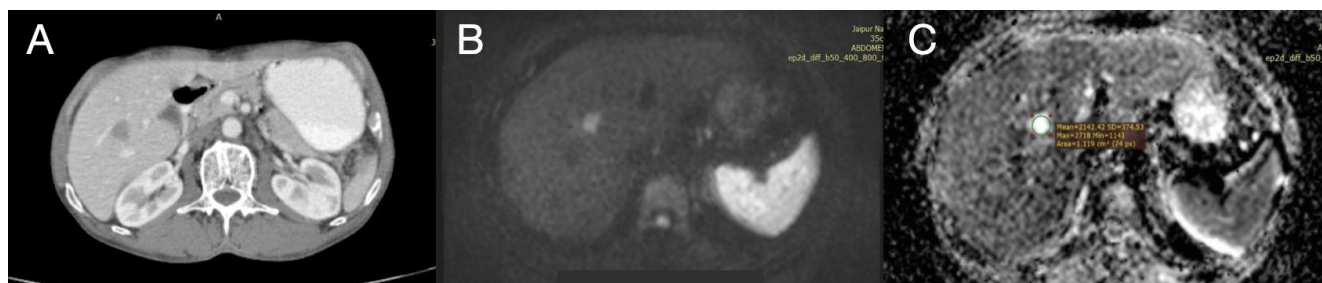


Figure 5. A 31-year-old female with a simple hepatic cyst. (A) CECT shows a well-defined hypodense non enhancing lesion in the right lobe. (B) T2-weighted MRI shows a hyperintense cystic lesion. (C, D) DWI b800 and ADC show no diffusion restriction, with mean ADC value of $2.1 \times 10^{-3} \text{ mm}^2/\text{s}$.

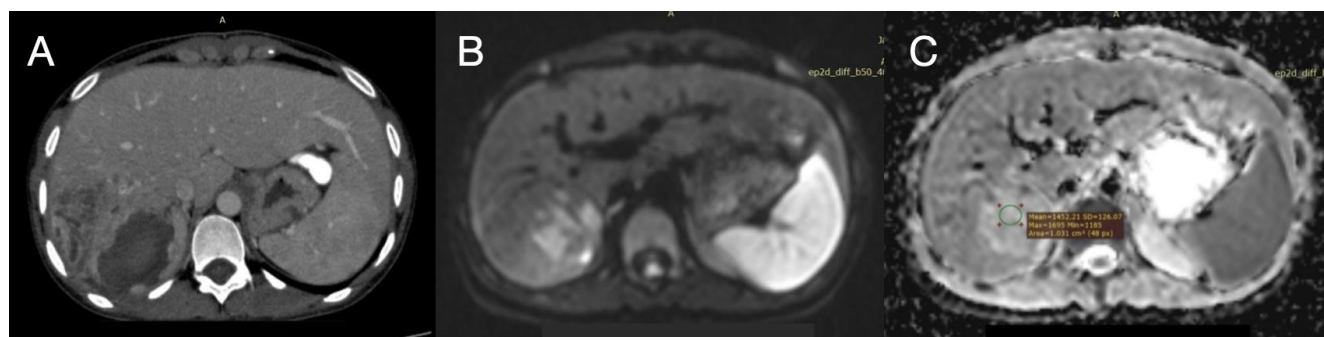


Figure 6. A 20 year old female with hepatic adenoma. (A) Non-contrast CT abdomen shows an irregular shaped heterogeneously hypodense mass lesion with areas of necrosis involving right lobe of liver. (B) CECT shows irregular shaped heterogeneously hypodense mass lesion with areas of necrosis involving right lobe of liver showing arterial enhancement of solid component. (C) & (D) DWI, b800 and ADC shows no diffusion restriction with mean ADC value of $1.45 \times 10^{-3} \text{ mm}^2/\text{sec}$.

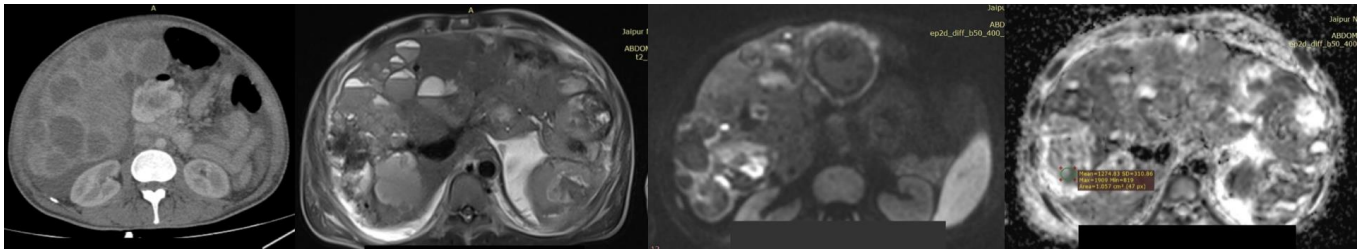


Fig. 7: A 33 yr old male with Ca lung and multiple haemorrhagic metastasis. (A) CECT porto-venous phase shows multiple well defined hypodense peripheral enhancing lesions, few of them showing hyperdense content in dependent portions. (B) MRI T2WI shows fluid- fluid levels within the lesions s/o haemorrhage of different stages. (C) & (D) DWI, b800 & ADC shows some areas of diffusion restriction within the lesions with mean ADC value of $1.1 \times 10^{-3} \text{ mm}^2/\text{sec}$.

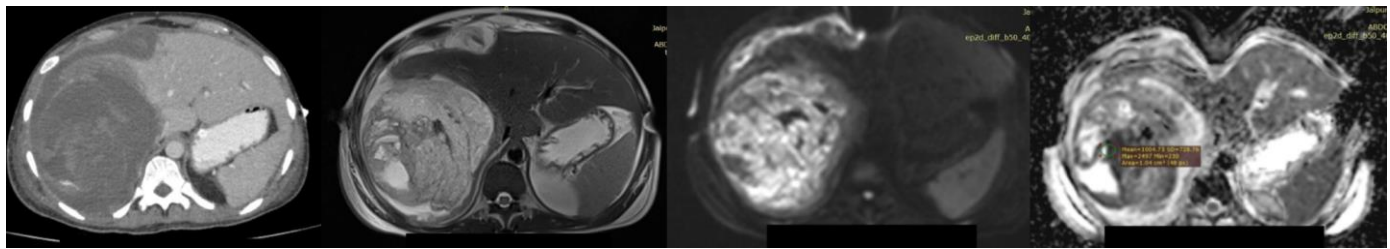


Fig. 8: (A) CECT porto-venous phase shows heterogeneous enhancement with hyperdense areas suggestive of acute haemorrhage. (B) MRI axial T2WI shows heterogeneously hyperintense mass lesion in right lobe of liver. (C)&(D) DWI, b 800 and ADC shows areas of diffusion restriction with mean ADC value of $1.0 \times 10^{-3} \text{ mm}^2/\text{sec}$.

DISCUSSION

The principal finding of this study is that quantitative ADC measurement provides statistically significant separation between benign/non-malignant and malignant focal hepatic lesions at the group level. Both central and peripheral ADC values were substantially lower in malignant lesions, and the selected threshold of $1.2 \times 10^{-3} \text{ mm}^2/\text{s}$ demonstrated high specificity.

The high specificity is clinically useful. When a representative solid portion of a lesion shows an ADC below the threshold, malignancy becomes more likely, particularly when the morphology and enhancement pattern are concordant. However, the moderate sensitivity means that a value above the threshold cannot safely exclude malignancy. This asymmetry is important when ADC is used in reporting practice. Peripheral ADC performed somewhat better than central ADC. The improvement in sensitivity from 67.86% to 75% and in accuracy from 80% to 84%, together with an AUC of 0.975, suggests that peripheral sampling may better represent viable tissue in some heterogeneous tumors. Central portions of malignant lesions are more likely to undergo necrosis or cystic degeneration, which increases water mobility and can falsely elevate ADC.

Despite this observation, peripheral ADC should not automatically be considered superior in every lesion.

The viable tumor may not always be peripheral, inflammatory granulation tissue can alter peripheral measurements, and small lesions may not permit separate central and peripheral ROIs. A more reproducible approach in future studies would be to place multiple ROIs in the most solid enhancing components and report the minimum, mean, or histogram-based ADC.

The lesion-specific data were broadly consistent with the expected diffusion hierarchy. Simple cysts had high ADC values, hemangiomas were also relatively high, and HCC/metastases were low. This supports the basic biological model in which fluid-rich lesions permit greater water motion while hypercellular malignant tissue restricts diffusion [4-7,11-14].

However, the adenoma findings demonstrate why benign-versus-malignant classification is more difficult for solid lesions than for simple cysts. Hepatocellular adenomas can be hypercellular and may contain hemorrhage, fat, necrosis, or inflammatory components. Their ADC values may therefore overlap with HCC and metastases. The absence of focal nodular hyperplasia in the present cohort also means that the study cannot fully address diffusion overlap among benign hepatocellular lesions [15-17].

Abscesses were the most important source of false-positive malignant classification by ADC. Pus is viscous and rich in inflammatory cells and debris, producing true restriction despite the non-neoplastic nature of the lesion. In a patient with fever, leukocytosis, rim enhancement, perilesional edema, and a central low ADC, abscess should remain a leading diagnosis [2,3,9]. Cystic metastasis produced the reverse error pattern. A necrotic malignant lesion can have high ADC because the central non-viable component behaves more like fluid. If only the necrotic center is sampled, ADC may incorrectly favor benignity. Enhancement-guided ROI placement in viable solid tissue is therefore critical.

Qualitative DWI also has limitations. A lesion can be hyperintense on DWI because of T2 shine-through rather than restricted diffusion. Hemangiomas and cysts are classic examples. ADC maps reduce this error, but ADC itself can be noisy in very small lesions or in regions affected by motion and susceptibility [2,3,9].

The study's CT findings reinforce the value of multimodality correlation. Non-enhancement supported simple cysts, peripheral nodular enhancement supported hemangioma, and heterogeneous or rim enhancement provided additional clues in malignant and inflammatory lesions. DWI should therefore be considered complementary to CECT rather than a replacement.

An important practical advantage of DWI is that it does not require intravenous contrast. This can be valuable when contrast is contraindicated, renal function is impaired, or repeated follow-up is required. DWI also increases lesion conspicuity and may identify additional small lesions. Nevertheless, for specific characterization of many focal liver lesions, dynamic contrast-enhanced MRI or CT remains central [2,3,9,10].

The present findings are in keeping with published literature showing lower ADC values in malignant lesions than in benign lesions, while also confirming substantial overlap. Differences between reported ADC cut-offs should not be interpreted as contradictory; rather, they reflect technical and biological variability. Scanner field strength, b-values, respiratory triggering, sequence parameters, ROI strategy, and lesion composition can all shift the measured ADC [4-7,11-14]. Therefore, a threshold derived from one institution should be validated locally before being applied as a rigid decision rule. In this study, $1.2 \times 10^{-3} \text{ mm}^2/\text{s}$ was useful as a high-specificity discriminator, but the most appropriate clinical use is as one component of a multiparametric assessment.

The results also have implications for report wording. Rather than stating that an ADC value 'confirms malignancy,' a more defensible formulation is that the lesion demonstrates true diffusion restriction with a relatively low ADC, supporting a hypercellular malignant process in the appropriate morphologic and

clinical context. Similarly, high ADC should be described as favoring facilitated diffusion rather than excluding malignancy.

From a research perspective, future work could improve on simple mean ADC measurements by using whole-lesion histogram analysis, diffusion kurtosis imaging, intravoxel incoherent motion, radiomics, or machine-learning approaches. Such methods may capture lesion heterogeneity more effectively than a small number of ROIs, although they require standardization before routine clinical adoption [18].

Strengths of the Study

- **Integrated Imaging Assessment:** This study evaluates the role of diffusion-weighted magnetic resonance imaging (DWI-MRI) in the characterization of focal hepatic lesions and correlates the findings with contrast-enhanced computed tomography (CECT), providing a complementary assessment of lesion morphology and tissue characteristics.
- **Quantitative and Qualitative Evaluation:** The assessment incorporates both qualitative DWI findings and apparent diffusion coefficient (ADC) measurements, supporting a more comprehensive evaluation of focal hepatic lesions.
- **Clinical Applicability:** The study explores the potential usefulness of DWI-MRI and CECT in differentiating benign and malignant hepatic lesions, which may contribute to improved imaging-based characterization and clinical decision-making.
- **Ethical Conduct:** The study was conducted following institutional ethical approval, and written informed consent was obtained from the participants.
- **Practical Imaging Correlation:** The correlation between DWI-MRI and CECT findings provides clinically relevant information regarding the complementary value of these imaging modalities in the evaluation of focal hepatic lesions.

CONCLUSION

DWI with ADC mapping provides valuable functional information for focal hepatic lesion evaluation. In the present cohort, malignant lesions demonstrated significantly lower ADC values than benign/non-malignant lesions at both central and peripheral measurements.

At a threshold of $1.2 \times 10^{-3} \text{ mm}^2/\text{s}$, ADC demonstrated high specificity. Peripheral measurements showed slightly higher sensitivity, accuracy, and ROC AUC than central measurements, suggesting potential value in

sampling viable peripheral tissue in heterogeneous lesions.

However, diffusion findings were not disease-specific. Abscesses produced low ADC values and cystic metastasis produced high values, confirming that ADC cannot independently determine benignity or malignancy. The most reliable diagnostic approach remains multi-parametric, combining morphology, conventional MRI, DWI/ADC, enhancement characteristics, clinical information, and histopathology where indicated.

These results support routine incorporation of DWI into liver MRI protocols while emphasizing cautious interpretation of numeric ADC thresholds.

Declarations

Ethics Approval and Informed Consent

The study was conducted at Jaipur National University Institute for Medical Sciences and Research Centre, Jaipur, following approval from the Institutional Ethics Committee (Approval No. JNUIMSRC/IEC/2023/75). Written informed consent was obtained from all participants before their inclusion in the study. No animals or biological tissues were involved in this research.

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Conflict of Interest

The authors declare that they have no financial or non-financial conflicts of interest, or other relationships or activities that could have influenced the work reported in this manuscript.

Author Contributions

All authors contributed to the conception, design, analysis, interpretation of the study findings, manuscript preparation, and critical revision of the manuscript. All authors approved the final version of the manuscript.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to institutional and ethical restrictions.

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AI Use Disclosure:

Generative AI tools were not used for data analysis or interpretation. AI tools were used only for language assistance. The authors remain fully responsible for the content.

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