DOI:10.31557/RRO.2026.12.1.51

ORIGINAL RESEARCH

Diagnostic Performance of Different b-values in Diffusion-Weighted MRI for the Characterization of Focal Liver Lesions in Gaza Strip Governmental Hospitals

Ali Alhoubi[1], Khaled M. Abushab[2], Yasser S. Alajerami[3], Mahmoud Mousa[4], Husam H. Mansour[5], Omar AbuGhali[6]

[1]Department of Radiology, Nasser Medical Complex, Gaza Strip, Palestine. [2]Medical Imaging Department, Al-Azhar University, Gaza-Palestine. [3]Medical Imaging Department, Al-Azhar University, Gaza-Palestine. [4]Department of Radiology, Turkish-Palestinian Friendship Hospital, Gaza Strip, Palestine. [5]Medical Imaging Department, Al-Azhar University, Gaza-Palestine. [6]Department of Radiology, Al Aqsa Myrtaz Hospital, Gaza Strip, Palestine.

Abstract

Objective: To evaluate the diagnostic performance of apparent diffusion coefficient (ADC) mapping for differentiating benign and malignant focal liver lesions (FLLs) using different diffusion-weighted imaging (DWI) b-values. **Methods and Materials:** A retrospective cross-sectional study was conducted among 51 consecutive patients with FLLs at Al-Shifa Medical Complex and European Gaza Hospital between March 2019 and December 2020. Patients underwent 1.5-T magnetic resonance imaging (MRI) with diffusion-weighted imaging using three b-values (0, 500, and 1000 s/mm²). Quantitative ADC measurements were obtained by manually placing regions of interest (ROIs) within the solid components of lesions. Statistical analysis was performed using MedCalc version 19.0.4, including receiver operating characteristic (ROC) curve analysis. **Results:** Quantitative ADC values were significantly higher in benign FLLs compared with malignant lesions at both b = 500 and b = 1000 s/mm² ($p < 0.05$). At b = 500 s/mm², benign lesions showed a mean ADC value of $2.25 \pm 0.50 \times 10^{-3}$ mm²/s, whereas malignant lesions showed a mean value of $1.16 \pm 0.17 \times 10^{-3}$ mm²/s. At b = 1000 s/mm², mean ADC values were $1.25 \pm 0.52 \times 10^{-3}$ mm²/s for benign lesions and $0.83 \pm 0.17 \times 10^{-3}$ mm²/s for malignant lesions. ROC analysis demonstrated that an ADC cutoff value of 1.4×10^{-3} mm²/s at b = 500 s/mm² achieved 99% sensitivity and 85.9% specificity, while an ADC cutoff value of 1.1×10^{-3} mm²/s at b = 1000 s/mm² yielded 95.7% sensitivity and 84.5% specificity. **Conclusion:** ADC mapping provides quantitative imaging biomarkers that may improve the differentiation of benign and malignant focal liver lesions. Standardized ADC cutoff values may enhance diagnostic confidence and support clinical decision-making in the characterization of liver lesions.

Keywords: Apparent diffusion coefficient; Diffusion-weighted imaging; Magnetic resonance imaging; Focal liver lesions

Rep Radiother Oncol, **12 (1)**, 51-55 Submission Date: 05/27/2026 Acceptance Date: 07/05/2026

Introduction

The timely and accurate characterization of focal liver lesions (FLLs) is essential for appropriate oncological management and treatment planning. Early detection and precise characterization of FLLs facilitate accurate diagnosis, staging, and selection of the most suitable therapeutic approach [1]. Patients with suspected FLLs require comprehensive diagnostic evaluation, which may include imaging assessment, pathological confirmation, and staging procedures when clinically indicated [2]. Although ultrasound (US) and computed tomography (CT) remain widely used for initial evaluation, magnetic resonance imaging (MRI) provides superior soft-tissue contrast resolution and multiparametric functional information. Conventional MRI sequences, including T1-weighted (T1WI) and T2-weighted imaging (T2WI), are increasingly complemented by diffusion-weighted

Corresponding Author:
Dr. Ali Alhoubi
Medical Imaging Specialist, Nasser Medical Complex, Gaza Strip, Palestine.
Email: alimnmalhoubi40@gmail.com

imaging (DWI) for improved lesion characterization.

DWI evaluates the Brownian motion of water molecules within tissues [3] and provides a non-invasive, contrast-free method for assessing tissue microstructure. Quantitative apparent diffusion coefficient (ADC) mapping has enhanced the diagnostic potential of DWI by providing objective measurements of water diffusion and facilitating differentiation between lesions with high cellularity and those with less restricted diffusion [4]. ADC values obtained using different diffusion weighting factors (b-values) reflect differences in tissue cellularity, with malignant lesions generally demonstrating lower ADC values due to restricted water diffusion associated with increased cellular density [5].

This study aimed to evaluate the diagnostic performance of ADC measurements obtained at b-values of 500 and 1000 s/mm² for differentiating benign and malignant FLLs among patients evaluated at governmental hospitals in the Gaza Strip, using histopathological diagnosis as the reference standard.

Materials and Methods

Study design

This retrospective cross-sectional study included 51 consecutive patients with FLLs who underwent MRI evaluation at Al-Shifa Medical Complex and European Gaza Hospital (EGH) between March 2019 and December 2020. The final diagnoses were confirmed by histopathological examination of biopsy or surgical specimens.

Inclusion and exclusion criteria

Patients who underwent liver MRI for the characterization or follow-up of FLLs were eligible for inclusion. Patients were excluded if they had received chemotherapy within three months before MRI examination or had imaging evidence of hepatic steatosis or iron deposition. These conditions were excluded because they may influence water diffusion characteristics and potentially alter ADC measurements [6].

MRI technique and imaging parameters

MRI examinations were performed using 1.5-T MRI systems (Philips Intera and Siemens MAGNETOM) equipped with a 16-channel body coil. The imaging protocol included axial and coronal breath-hold T1-weighted imaging (T1WI), fat-saturated fast spin-echo T2-weighted imaging (T2WI), and dynamic three-dimensional T1-weighted imaging following intravenous gadolinium administration (Gd-DTPA). Diffusion-weighted imaging was obtained before contrast administration using a single-shot sequence with b-values of 0, 500, and 1000 s/mm². The imaging parameters included a repetition time (TR) of 1100 ms, echo time (TE) ranging from 67 to 91 ms, a slice thickness of 5 mm, and an interslice gap of 1 mm.

MRI evaluation and quantitative ADC measurements

Two experienced radiologists (with 10 and 14 years of experience in abdominal imaging) independently evaluated the ADC maps. Three manually drawn circumferential regions of interest (ROIs) were placed on axial ADC images using the RadiAnt DICOM Viewer to calculate mean, minimum, and maximum ADC values. ROIs were positioned within the solid components of lesions while avoiding necrotic areas, hemorrhagic regions, and prominent vascular structures. Measurement accuracy was verified using a water phantom, which demonstrated an ADC value of 2.21×10^{-3} mm²/s, consistent with previously reported reference values [7].

Statistical analysis

Statistical analyses were performed using MedCalc software version 19.0.4. Differences in ADC values among lesion subtypes were assessed using one-way analysis of variance (ANOVA), followed by Tukey–Kramer post-hoc testing for pairwise comparisons. Receiver operating characteristic (ROC) curve analysis was performed to determine diagnostic performance, including the area under the curve (AUC), optimal ADC cutoff values, sensitivity, and specificity. A two-sided p-value ≤ 0.05 was considered statistically significant.

Results

Patient characteristics

Histopathological evaluation revealed that 28 patients (54.9%) had benign FLLs, whereas 23 patients (45.1%) had malignant lesions. The majority of patients were aged ≥40 years (35/51, 68.6%). Among patients younger than 40 years, most lesions were benign (13/16, 81.3%), whereas malignant lesions were more common among patients aged ≥40 years (20/35, 57.1%). Regarding sex distribution, 28 patients (54.9%) were male and 23 (45.1%) were female. Malignant lesions were more frequent among male patients (17/28, 60.7%), while benign lesions predominated among female patients (17/23, 73.9%).

Focal liver lesion characterization and subtype differentiation

The characteristics of FLLs and ADC measurements according to lesion subtype are presented in Table 1. The overall mean lesion size was 2.87 ± 1.13 cm. The mean lesion size was comparable between benign and malignant lesions (2.85 ± 0.63 cm and 2.89 ± 1.56 cm, respectively).

Quantitative ADC analysis demonstrated significantly higher ADC values in benign lesions compared with malignant lesions at both diffusion gradients (b = 500 and 1000 s/mm²; $P < 0.001$). The mean ADC values of benign and malignant FLLs were $2.25 \pm 0.50 \times 10^{-3}$ mm²/s and $1.16 \pm 0.17 \times 10^{-3}$ mm²/s at b = 500 s/mm², and $1.25 \pm 0.52 \times 10^{-3}$ mm²/s and $0.83 \pm 0.17 \times 10^{-3}$ mm²/s at b = 1000 s/mm², respectively.

Among benign subtypes, cysts showed the highest ADC values at both b-values, whereas malignant subtypes demonstrated consistently lower ADC values. Significant differences were observed between cysts and adenomas, as well as between cysts and FNH, at both diffusion gradients. Furthermore, FNH and adenoma showed significantly different ADC values compared with HCC

Table 1. Mean ADC Values of Benign and Malignant Focal Liver Lesions According to Diffusion Gradients

Lesion category/subtype	n	Mean ADC at b=500 (×10⁻³ mm²/s), mean ± SD	Mean ADC at b=1000 (×10⁻³ mm²/s), mean ± SD
Benign lesions	28	2.25 ± 0.50	1.25 ± 0.52
Cyst	10	2.61 ± 0.14	1.84 ± 0.06
Hemangioma	8	2.30 ± 0.54	1.75 ± 0.38
FNH	5	1.86 ± 0.47	1.46 ± 0.51
Adenoma	5	1.87 ± 0.49	1.23 ± 0.38
Malignant lesions	23	1.16 ± 0.17	0.83 ± 0.17
HCC	8	1.27 ± 0.17	0.89 ± 0.19
Metastases	11	1.13 ± 0.16	0.81 ± 0.17
Cholangiocarcinoma	4	1.04 ± 0.08	0.74 ± 0.08
All FLLs	51	1.76 ± 0.67	1.06 ± 0.45

FLL: focal liver lesion; ADC: apparent diffusion coefficient; FNH: focal nodular hyperplasia; HCC: hepatocellular carcinoma.

and metastases. No significant differences were observed among malignant subtypes.

Subtype statistical comparisons

Significant differences in ADC values were observed among several lesion subtypes. Cysts demonstrated significantly higher ADC values compared with adenomas at both b = 500 and b = 1000 s/mm² (p = 0.001). Significant differences were also observed between cysts and focal nodular hyperplasia (FNH) at both diffusion gradients (p = 0.001 and p = 0.013, respectively).

Among solid benign lesions, FNH and adenoma demonstrated significantly higher ADC values compared with malignant subtypes. FNH showed significant differences compared with hepatocellular carcinoma (HCC) (p = 0.002 at b = 500 and p = 0.001 at b = 1000), metastases (p = 0.001), and cholangiocarcinoma (p = 0.001). Similarly, adenoma demonstrated significant differences compared with HCC (p = 0.002 and p = 0.034) and metastases (p = 0.001 and p = 0.006) at b = 500 and b = 1000 s/mm², respectively.

No statistically significant differences were observed between adenoma and cholangiocarcinoma at b = 1000 s/mm² (p = 0.101) or among malignant subtypes (HCC, metastases, and cholangiocarcinoma) at either diffusion gradient. Figure 1 presents an example of a benign atypical hemangioma evaluated using ADC mapping.

ROC analysis

The diagnostic performance of ADC measurements for differentiating benign and malignant FLLs is summarized in Table 2. ROC curve analysis demonstrated excellent diagnostic performance at both diffusion gradients. At b = 500 s/mm², an ADC cutoff value of 1.4 × 10⁻³ mm²/s yielded an AUC of 0.970, with a sensitivity of 99.0%, specificity of 85.9%, and accuracy of 85.7%. At b = 1000 s/mm², an ADC cutoff value of 1.1 × 10⁻³ mm²/s achieved an AUC of 0.947, with a sensitivity of 95.7%, specificity of 84.5%, and accuracy of 81.4%. The corresponding ROC curves are presented in Figure 2.

Discussion

The incorporation of multiple b-values into liver MRI protocols enhances lesion characterization by improving organ-to-lesion contrast and may provide valuable diagnostic information, particularly for patients with contraindications to gadolinium-based contrast media [8-10]. In the present study, quantitative ADC measurements demonstrated good diagnostic performance in differentiating focal liver lesions (FLLs), with benign lesions generally showing higher ADC values than

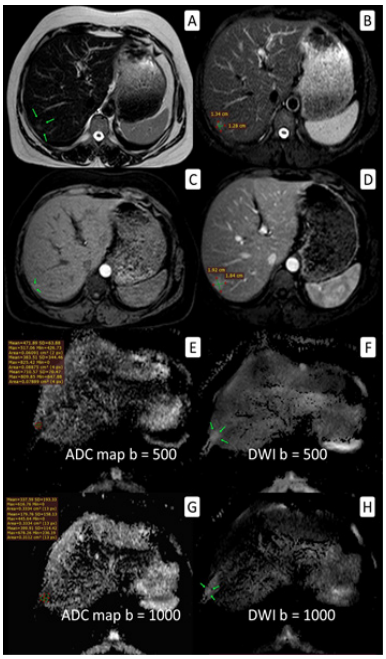

Figure 1. MRI Evaluation of a Benign Atypical Hemangioma in the Right Hepatic Lobe of a 41-year-old Female Patient. T2-weighted images (A, B) and dynamic contrast-enhanced T1-weighted images during arterial and portal venous phases (C, D) demonstrate the characteristic peripheral nodular enhancement pattern. Diffusion-weighted imaging and apparent diffusion coefficient (ADC) maps obtained at b = 500 and 1000 s/mm² are shown in panels E–H. ADC measurements were performed using manually placed regions of interest on ADC maps to quantify diffusion characteristics of the lesion.

Table 2. ROC Performance of ADC Values for Differentiation between Benign and Malignant FLLs

Variable	Cutoff value ($\times 10^{-3}$ mm²/s)	AUC	Sensitivity (%)	Specificity (%)	Accuracy (%)
ADC at b = 500 s/mm²	1.4	0.97	99	85.9	85.7
ADC at b = 1000 s/mm²	1.1	0.947	95.7	84.5	81.4

Abbreviations: ADC, apparent diffusion coefficient; AUC, area under the curve; FLL, focal liver lesion.

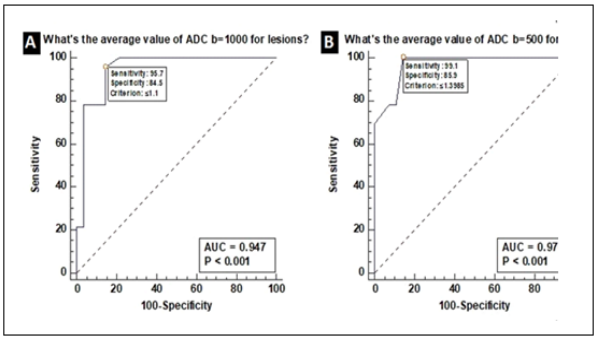

Figure 2. Receiver Operating Characteristic (ROC) Curves Demonstrating the Diagnostic Performance of ADC Values for Differentiating benign and Malignant Focal Liver Lesions. (A) ROC curve for ADC values at b = 1000 s/mm². (B) ROC curve for ADC values at b = 500 s/mm².

malignant lesions. This finding is consistent with the underlying biological differences between benign and malignant tissues, as increased cellular density and reduced extracellular space in malignant lesions restrict water diffusion, resulting in lower ADC values [11-13].

Our findings indicate that ADC-based assessment can effectively differentiate solid benign lesions, including hepatic adenoma and focal nodular hyperplasia (FNH), from solid malignant FLLs. The application of higher diffusion gradients (b-values of 500 and 1000 s/mm²) reduced the influence of perfusion-related signal effects observed at lower b-values, thereby improving the reliability of diffusion measurements. This approach may be particularly beneficial in resource-limited healthcare settings, such as governmental hospitals in the Gaza Strip, where access to advanced hepatobiliary contrast agents may be restricted.

Although benign lesion subtypes demonstrated relatively distinct diffusion characteristics, differentiation among malignant subtypes, particularly hepatocellular carcinoma (HCC) and metastases, remained challenging. This overlap may be attributed to similarities in cellular density and tissue architecture among malignant lesions. Furthermore, careful ROI placement and exclusion of necrotic or cystic components were essential to minimize measurement variability and avoid falsely elevated ADC values that could potentially reduce diagnostic accuracy.

Limitations

This study has several limitations. First, the retrospective design may have introduced selection bias due to reliance on available clinical and imaging records. Second, the relatively small sample size (n = 51) may limit the generalizability of the proposed ADC cutoff values. Third, as a single-center study conducted in governmental hospitals in the Gaza Strip, the findings may reflect local patient characteristics and disease distribution patterns and may not be directly applicable to other populations. Future prospective multicenter studies with larger cohorts are warranted to validate these ADC thresholds. Moreover, combining ADC measurements with advanced diffusion techniques, such as intravoxel incoherent motion (IVIM), or with hepatobiliary-specific contrast-enhanced MRI may further improve lesion characterization and help overcome the diagnostic overlap among malignant subtypes.

In conclusion, quantitative ADC analysis provides useful complementary information for the differentiation of focal liver lesions on MRI. A three-gradient diffusion protocol using b-values of 0, 500, and 1000 s/mm² demonstrated favorable diagnostic performance in this cohort. In the clinical context of the Gaza Strip, ADC thresholds of 1.4×10^{-3} mm²/s at b = 500 and 1.1×10^{-3} mm²/s at b = 1000 showed potential utility for distinguishing benign and malignant liver lesions. Further validation in larger, multicenter populations is required before widespread clinical implementation.

Acknowledgments

Statement of Transparency and Principles

• The authors declare no conflict of interest.

• The study was approved by the Research Ethics Committee of the authors' affiliated institution.

• The study data are available upon reasonable request.

• All authors contributed to the implementation of this research.

References

1. Morana g, mansueto g, coniglio a, et al. Focal liver lesions: A diagnostic algorithm. 2010. Radiol Med;115:331–352.;.
2. Della Corte C, Triolo M, Iavarone M, Sangiovanni A. Early diagnosis of liver cancer: an appraisal of international recommendations and future perspectives. Liver International: Official Journal of the International Association for the Study of the Liver. 2016 02;36(2):166-176. https://doi.org/10.1111/liv.12965
3. Besa C, Lewis S, Pandharipande PV, Chhatwal J, Kamath A, Cooper N, Knight-Greenfield A, et al. Hepatocellular carcinoma detection: diagnostic performance of a simulated abbreviated MRI protocol combining diffusion-weighted and T1-weighted imaging at the delayed phase post gadoxetic acid. Abdominal Radiology. 2017 01;42(1):179-190. https://doi.org/10.1007/s00261-016-0841-5
4. Galea N, Cantisani V, Taouli B. Liver lesion detection and characterization: role of diffusion-weighted imaging. Journal of magnetic resonance imaging: JMRI. 2013 06;37(6):1260-1276. https://doi.org/10.1002/jmri.23947

5. Lewis S, Peti S, Hectors SJ, King M, Rosen A, Kamath A, Putra J, Thung S, Taouli B. Volumetric quantitative histogram analysis using diffusion-weighted magnetic resonance imaging to differentiate HCC from other primary liver cancers. Abdominal Radiology. 2019 03;44(3):912-922. https://doi.org/10.1007/s00261-019-01906-7
6. Poyraz AK, Onur MR, Kocakoç E, Oğur E. Diffusion-weighted MRI of fatty liver. Journal of magnetic resonance imaging: JMRI. 2012 05;35(5):1108-1111. https://doi.org/10.1002/jmri.23519
7. Onur MR, Çiçekçi M, Kayalı A, Poyraz AK, Kocakoç E. The role of ADC measurement in differential diagnosis of focal hepatic lesions. European Journal of Radiology. 2012 03;81(3):e171-176. https://doi.org/10.1016/j.ejrad.2011.01.116
8. Yoon JH, Lee JM, Yu MH, Kiefer B, Han JK, Choi BI. Evaluation of hepatic focal lesions using diffusion-weighted MR imaging: comparison of apparent diffusion coefficient and intravoxel incoherent motion-derived parameters. Journal of magnetic resonance imaging: JMRI. 2014 02;39(2):276-285. https://doi.org/10.1002/jmri.24158
9. Caraiani C, Chiorean L, Fenesan DI, Lebovici A, Feier D, Gersak M, Calin AM, et al. Diffusion Weighted Magnetic Resonance Imaging for the Classification of Focal Liver Lesions as Benign or Malignant. Journal of gastrointestinal and liver diseases: JGLD. 2015 09;24(3):309-317. https://doi.org/10.15403/jgld.2014.1121.243.cca
10. Alwalid O, Wang Y, Fan W, Han P. Value of gadoxetic acid-enhanced MR imaging and DWI in classification, characterization and confidence in diagnosis of solid focal liver lesions. Scandinavian Journal of Gastroenterology. 2021 01;56(1):72-80. https://doi.org/10.1080/00365521.2020.1847314
11. Nalaini F, Shahbazi F, Mousavinezhad SM, Ansari A, Salehi M. Diagnostic accuracy of apparent diffusion coefficient (ADC) value in differentiating malignant from benign solid liver lesions: a systematic review and meta-analysis. The British Journal of Radiology. 2021 07 01;94(1123):20210059. https://doi.org/10.1259/bjr.20210059
12. Schmid-Tannwald C, Dahi F, Jiang Y, Ivancevic MK, Rist C, Sethi I, Oommen J, Oto A. DW-MRI of liver lesions: can a single ADC-value represent the entire lesion?. Clinical Radiology. 2014 05;69(5):492-498. https://doi.org/10.1016/j.crad.2013.12.007
13. Tokgoz O, Unlu E, Unal I, Serifoglu I, Oz I, Aktas E, Caglar E. Diagnostic value of diffusion weighted MRI and ADC in differential diagnosis of cavernous hemangioma of the liver. African Health Sciences. 2016 03;16(1):227-233. https://doi.org/10.4314/ahs.v16i1.30

This work is licensed under a Creative Commons Attribution-Non Commercial 4.0 International License.