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Original Research Article

Diagnostic Performance of Diffusion-Weighted MRI and Apparent Diffusion Coefficient in Differentiating Benign and Malignant Focal Liver Lesions

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Conflict of interest: Nil

Abstract:

Background: Accurate differentiation of benign and malignant focal liver lesions (FLL) is essential for appropriate clinical management. Diffusion-weighted magnetic resonance imaging (DWI) provides functional information regarding tissue cellularity and water molecule diffusion, which can be quantified using apparent diffusion coefficient (ADC) values.

Objectives: To evaluate the diagnostic performance of diffusion-weighted MRI and ADC values in differentiating benign and malignant focal liver lesions.

Methods: This prospective observational study was conducted at GSL Medical College, Rajahmundry, between January 2021 and December 2022. Fifty patients with focal liver lesions detected on imaging were evaluated using conventional MRI sequences and diffusion-weighted imaging. ADC values were measured from representative areas of each lesion, avoiding necrotic or hemorrhagic regions. Lesions were categorized as benign or malignant based on imaging features, clinical data, and histopathological or follow-up findings. Statistical analysis included comparison of mean ADC values and ROC curve analysis to determine optimal ADC cut-off values.

Results: Among the 50 lesions analyzed, 16 (31%) were benign and 34 (69%) were malignant. Diffusion-weighted imaging detected all lesions, whereas routine MRI missed four malignant lesions. Benign lesions demonstrated significantly higher mean ADC values ($2.01 \pm 0.67 \times 10^{-3}$ mm²/s) compared with malignant lesions ($0.89 \pm 0.12 \times 10^{-3}$ mm²/s; $p < 0.0001$). An ADC cut-off value of 1.3×10^{-3} mm²/s showed sensitivity of 97.06%, specificity of 87.50%, and diagnostic accuracy of 94%.

Conclusion: Diffusion-weighted MRI with ADC measurement is a reliable noninvasive technique for differentiating benign and malignant FLL.

Keywords: Diffusion-weighted MRI, Apparent diffusion coefficient, Focal liver lesions, Hepatic tumors, Diagnostic imaging.

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Introduction

Focal liver lesions (FLL) include a wide spectrum of benign and malignant entities, and accurate noninvasive characterization is essential because management differs markedly between innocuous cysts or hemangiomas and aggressive primary or secondary hepatic malignancies [1]. Diffusion-weighted MRI (DWI) has emerged as a valuable adjunct to conventional liver MRI because it reflects tissue cellularity and membrane integrity, while the apparent diffusion coefficient provides a quantitative marker that generally remains higher in benign lesions (BLs) and lower in malignant lesions (MLs) due to restricted diffusion [1, 2]. Recent studies have shown that DWI can achieve useful sensitivity and specificity for lesion discrimination, and newer technical advances such as deep-learning reconstruction and abbreviated non-contrast protocols may further improve image quality, efficiency, and diagnostic performance [2, 3]. Against this background, the present study was undertaken to evaluate the diagnostic performance of DWI and apparent diffusion coefficient (ADC) values in differentiating benign from malignant FLL, and to determine whether ADC can serve as a reliable quantitative threshold in lesion characterization.

Methods:

A prospective observational diagnostic accuracy study was conducted in the department of Radiodiagnosis, GSL Medical College, Rajahmundry, from January 2021 to December

2022. Patients of any age and either gender who were found to have FLL on ultrasonography, computed tomography (CT), or incidentally on MRI during the study period were considered for inclusion. The study was undertaken after obtaining approval from the Institutional Ethics Committee, and informed consent was obtained from all participants or their guardians wherever applicable. Patients with lesions smaller than 1 cm, lesions showing hemorrhagic or necrotic components, prior chemotherapy or radiotherapy, or contraindications to MRI such as pacemakers, aneurysm clips, cochlear implants, or other incompatible metallic devices were excluded. The final diagnosis of FLL was established by correlation with clinical findings, other imaging modalities, histopathology wherever available, known primary malignancy in metastatic disease, and follow-up findings in BLs.

MRI examinations were performed using a standard whole-body MR scanner with routine liver imaging sequences. Conventional MRI protocol included axial and coronal T2-weighted sequences, T1-weighted fat-suppressed images, in-phase and opposed-phase imaging, T2-weighted turbo spin-echo, short tau inversion recovery sequences, and contrast-enhanced dynamic imaging whenever clinically indicated. DWI were obtained in all cases using echo-planar imaging in the axial plane with appropriate diffusion gradients, and apparent diffusion coefficient maps were generated from the acquired data. Breath-hold technique was used whenever feasible, while respiratory gating was applied in patients who were unable to sustain breath-holding adequately. Conventional MRI images were first assessed for lesion detection and characterization. Subsequently, DWI and ADC maps were analyzed. Only lesions measuring $\geq$1 cm was included for ADC quantification in order to minimize partial volume effects. For each lesion, three ADC measurements were obtained from representative solid areas while carefully avoiding regions of necrosis, hemorrhage, or artifacts, and the mean ADC value was calculated. In patients with multiple lesions of similar imaging morphology, up to three representative lesions were selected, and their ADC values were averaged for analysis. ADC values of adjacent normal liver parenchyma were also recorded for comparison.

The number of lesions detected on routine MRI sequences and on DWIs was documented and compared to assess lesion conspicuity. Lesions were categorized as benign or malignant based on final diagnosis, and the mean ADC values of the two groups were compared to determine the discriminatory value of diffusion restriction. Quantitative data were expressed as mean and standard deviation, whereas categorical variables were summarized as frequencies and percentages. Statistical analysis was performed using SPSS software. Normality of continuous variables was assessed before comparison. Student's unpaired t test was used to compare mean ADC values between benign and MLs. Receiver operating characteristic curve analysis was performed to identify the optimal ADC cut-off value for differentiating malignant from benign FLL, and sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy were calculated. A p value of less than 0.05 was considered statistically significant.

Results

A total of 50 FLL patients were analyzed, 16 lesions (31%) were benign and 34 (69%) were MLs. Lesion detection analysis showed that DWI detected all 92 FLL identified before ADC-based exclusions, whereas routine MRI missed 4 MLs. This indicates superior lesion conspicuity of DWI for MLs. Quantitative diffusion analysis demonstrated a clear separation between benign and malignant groups. The mean ADC value of BLs was $2.01 \pm 0.67 \times 10^{-3}$ mm^2/s, whereas MLs had lower mean ADC, $0.89 \pm 0.12 \times 10^{-3}$ mm^2/s ($p < 0.0001$). Subtype-wise evaluation further showed that hydatid cysts ($3.05 \pm 0.05 \times 10^{-3}$ mm^2/s) and simple cysts ($2.44 \pm 0.59 \times 10^{-3}$ mm^2/s) had the highest ADC values, while metastases ($0.81 \pm 0.09 \times 10^{-3}$ mm^2/s) and hepatoblastomas ($0.86 \pm 0.05 \times 10^{-3}$ mm^2/s) had the lowest. Diagnostic performance analysis demonstrated that, at an ADC cut-off of 1.0×10^{-3} mm^2/s, sensitivity, specificity, and accuracy were 85.29%, 100%, and 90%, respectively. However, the best performance was obtained at 1.3×10^{-3} mm^2/s, with 97.06% sensitivity, 87.50% specificity, and 94% accuracy (Fig 1). It was supported by the ROC curve, confirming excellent discriminatory ability of ADC for differentiating benign and malignant FLL.

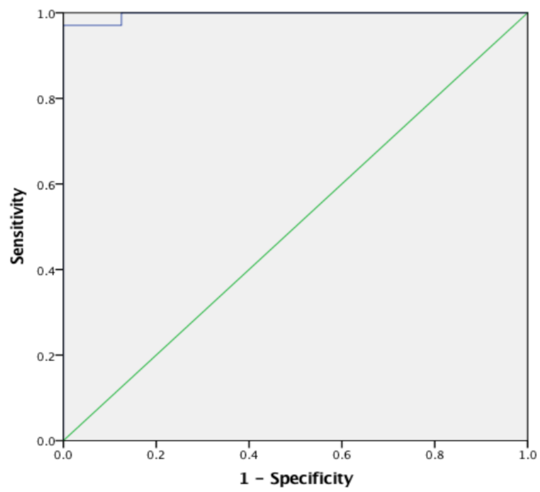

Figure 1: ROC curve analysis

Discussion:

DWI has increasingly emerged as a valuable tool in the characterization of FLL, particularly in differentiating benign from malignant hepatic pathology. In the present study, MLs constituted 69%, indicating a higher burden of malignant hepatic pathology among patients undergoing MRI evaluation. Similar observations have been reported in earlier radiological studies where hepatocellular carcinoma and metastatic lesions were the predominant MLs detected during imaging evaluation of FLL [4]. The ability of MRI to provide both morphological and functional information makes it superior to conventional imaging modalities such as ultrasound and CT in lesion characterization. DWI adds an additional layer of functional imaging by evaluating the movement of water molecules within tissues, which reflects cellular density and membrane integrity. MLs typically demonstrate restricted diffusion due to high cellularity and reduced extracellular space, resulting in lower ADC values compared with BLs that contain more free fluid and less cellular restriction [5]. These physiological differences form the basis for using ADC measurements in differentiating benign from MLs.

The present study demonstrated that DWI detected all FLL identified before ADC exclusion criteria were applied, while routine MRI sequences failed to detect 4 MLs. This observation highlights the superior sensitivity of DWI for lesion detection, particularly for MLs. Previous investigations have also shown that DWI improves lesion conspicuity and detection rates compared with conventional T2-weighted imaging. Parikh et al. reported that the detection rate of FLL was significantly higher with DWI (87.7%) compared with T2-weighted imaging (70.1%), emphasizing the diagnostic advantage in hepatic imaging [6]. Similarly, Bruegel et al. demonstrated that DWI significantly improved the sensitivity for detecting hepatic metastases, especially small lesions <10 mm [7]. The improved detection capability is attributed to the “black-blood effect” of diffusion imaging and the increased contrast between lesions and surrounding hepatic parenchyma. Therefore, the integration of DWI into routine liver MRI protocols provides additional diagnostic confidence for radiologists when evaluating focal hepatic lesions.

Quantitative analysis of ADC values in the present study revealed a significant difference between benign and MLs. The mean ADC values were 2.01 ± 0.67 $\times10^{-3}$ mm²/s and 0.89 ± 0.12 $\times10^{-3}$ mm²/s, respectively for benign and MLs ($P< 0.0001$). These findings are consistent with previous reports that have documented significantly higher ADC values in BLs such as cysts and hemangiomas compared with MLs such as hepatocellular carcinoma or metastases. It was reported that malignant hepatic tumors showed significantly lower ADC values compared with BLs due to restricted diffusion caused by increased cellular density [8]. Similarly, Demir et al. observed that the mean ADC value of BLs was significantly higher, further supporting the diagnostic value of ADC measurements [9]. Subtype-wise analysis in the current study demonstrated that hydatid cysts and simple cysts showed the highest ADC values, reflecting the presence of fluid-rich environments that allow unrestricted diffusion of water molecules. On the other hand, metastases and hepatoblastomas exhibited the lowest ADC values due to high cellularity and increased nuclear-to-cytoplasmic ratios within tumor tissue. Comparable results were also found, it was reported that hemangiomas and cysts had significantly higher ADC values compared with hypervascular MLs such as hepatocellular carcinoma and neuroendocrine metastases [10]. Thus, ADC values provide a quantitative biomarker that can assist radiologists in distinguishing benign from malignant FLL.

Diagnostic performance in the present study demonstrated that an ADC cut-off value of 1.0 $\times10^{-3}$ mm²/s yielded sensitivity, specificity, and accuracy values of 85.29%, 100%, and 90%, respectively. However, the optimal diagnostic performance was achieved at an ADC cut-off value of 1.3 $\times10^{-3}$ mm²/s, which resulted in 97.06% sensitivity, 87.50% specificity, and 94% accuracy. These results indicate that ADC measurements have excellent discriminatory power in differentiating benign from malignant FLL. Similar diagnostic thresholds have been reported in other studies. Kim et al. suggested that an ADC cut-off value of approximately 1.6 $\times10^{-3}$ mm²/s provided high sensitivity and specificity for differentiating malignant hepatic lesions from BLs [11]. Likewise, Latif et al. demonstrated that ADC threshold values between 1.0 and 1.5 $\times10^{-3}$ mm²/s produced diagnostic accuracy exceeding 90% for the differentiation of malignant tumors [12]. The ROC curve analysis in the present study further confirmed the strong diagnostic capability of ADC measurements in hepatic lesion characterization. Nevertheless, it is important to recognize that some degree of overlap may occur between certain lesion types, particularly between atypical hemangiomas and hypervascular malignancies. Therefore, DWI should always be interpreted in conjunction with conventional MRI sequences and clinical information to ensure accurate diagnosis. Recent literature also suggests that combining ADC measurements with other advanced MRI techniques, such as hepatocyte-specific contrast imaging or radiomics-based analysis, may further improve diagnostic accuracy and lesion characterization [13]. Small sample size, single centric research, limited availability of histopathology confirmation, overlap in ADC values between lesion subtypes, non-evaluation of MRI techniques are the limitations of the study.

Conclusion: The present study demonstrated that DWI and ADC measurements play a significant role in the detection and characterization of FLL. MLs showed significantly lower ADC values compared with BLs due to restricted diffusion associated with increased cellularity. Diffusion-weighted imaging also improved lesion detection compared with routine MRI sequences. The study findings suggest that ADC measurement provides a reliable quantitative parameter for differentiating benign from malignant hepatic lesions. Therefore, diffusion-weighted imaging should be incorporated into routine liver MRI protocols as a noninvasive and effective technique for improving diagnostic accuracy and guiding appropriate clinical management.

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