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ORIGINAL ARTICLE

Diagnostic Accuracy of Conventional T2- Versus Diffusion-Weighted Magnetic Resonance Imaging in Distinguishing Benign from Malignant Liver Lesions

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ABSTRACT

Objective: *The aim of this retrospective study was to compare the diagnostic accuracy of conventional T2-weighted images (T2WI) and diffusion-weighted imaging (DWI) to distinguish between benign and malignant liver lesions.*

Methods: *Lesions were assessed using a 1- to 5-point (1, benign; 5, definitely malignant) scoring system based on T2WI and signal characteristics on DWI. The sensitivity, specificity, and accuracy of T2WI and DWI were calculated for benign and malignant lesions.*

Results: *A total of 587 focal liver lesions in 561 patients were included in the study. There were 449 benign and 138 malignant lesions. The mean ± standard deviation scores of benign lesions obtained in T2WI and DWI were 1.4 ± 0.8 and 1.7 ± 1.0, respectively, while the same scores in malignant lesions were 4.5 ± 0.8 and 4.4 ± 0.9, respectively. The sensitivity, specificity, and accuracy of T2WI in distinguishing benign from malignant liver lesions was 94%, 94%, and 94%, respectively. The same values were calculated as 96%, 85% and 88% for DWI, respectively.*

Conclusion: *Both imaging methods had high efficiency in characterisation of benign and malignant liver lesions. T2WI and DWI can be used safely in characterisation of liver lesions in individuals who cannot be given contrast agents due to reasons such as renal failure and contrast allergy.*

Key Words: *Diagnostic tests, routine; Liver neoplasms; Magnetic resonance imaging; Sensitivity and specificity*

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Data Availability: All data generated or analysed during the present study are available from the corresponding author on reasonable request.

Ethics Approval: This study was approved by our hospital ethics committee (Ref: 2015-182). The need for signed informed consent was waived due to the retrospective nature of the study.

中文摘要

常規T2與彌散加權磁共振成像區分良惡性肝病灶的診斷準確性

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目的：本回顧研究分析磁共振常規T2（T2WI）與彌散加權（DWI）成像區分性良惡性肝病灶的診斷準確性。

方法：使用基於T2WI和DWI信號特徵的1至5分評分系統評估病變（1 = 良性；5 = 絕對惡性）。計算T2WI和DWI對良惡性病變的敏感性、特異性和準確性。

結果：共納入561例患者的587個局灶性肝病變。良性病變449個，惡性病變138個。在T2WI和DWI的積分（均值 ± 標準差）在良性病變分別為1.4 ± 0.8和1.7 ± 1.0，在惡性病變分別為4.5 ± 0.8和4.4 ± 0.9。T2WI鑑別肝良惡性病變的敏感性、特異性和準確性分別為94%、94%和94%。DWI為96%、85%和88%。

結論：兩種影像學方法在鑑別肝臟良惡性病變方面效果良好。對於腎衰竭和造影劑過敏等原因而無法給予造影劑的患者，使用T2WI和DWI區分肝病變是安全的。

INTRODUCTION

Ultrasonography (US), computed tomography (CT), and magnetic resonance imaging (MRI) are the most commonly used imaging methodologies in the detection and characterisation of liver lesions. Advances in MRI technology and faster imaging techniques have made it a problem-solving modality with high soft tissue resolution in cases where CT and US are inconclusive.[1]

Diffusion-weighted imaging (DWI) is a technique that does not require the use of contrast agents. It is often employed in acute ischaemic processes in neuroradiology.[1] Thanks to the development of rapid imaging techniques, the reduction of artefacts caused by respiratory motion has enabled DWI to be used in abdominal imaging, especially in the evaluation of liver lesions.[2-4] MRI is the modality of preference for imaging the central nervous system (except for trauma patients), musculoskeletal system, pelvic organs, and liver. Its advantages include high soft tissue contrast resolution, lack of ionising radiation, and the ability to employ of liver-specific contrast agents.

In this retrospective study, we aimed to investigate the diagnostic abilities of conventional T2-weighted imaging (T2WI) sequences and DWI to distinguish between benign and malignant liver lesions and to compare the diagnostic efficiency of the two examinations.

METHODS

Patients

In the present study, cases with liver lesions were retrieved retrospectively from abdominal MRI reports taken in Health Sciences University, Haseki Training and Research Hospital, Turkey between January 2014 and December 2014 using the hospital database. Cases with no liver lesions, lesion size <1 cm, no T2WI or DWI series, or images of unsuitable quality for evaluation were excluded from the study. In cases with multiple similar lesions, the largest lesion was considered as the representative lesion and was evaluated. In addition, benign regenerating nodules observed as hypointense on T2WI sequences in cirrhotic liver patients were not included in the evaluation.

In hepatocellular carcinoma cases, diagnosis was made by histopathological examination in 11 lesions, and by typical imaging features (e.g., arterial hypervascular lesion showing wash-out, mild hyperintense lesion in T2W series, or nodule within a nodule), clinical and laboratory findings (elevation of serum alpha fetoprotein) and follow-up in 27 lesions. In cholangiocellular carcinoma cases, diagnosis was made by histopathological examination in five lesions, and by typical imaging features (e.g., dilatation of the intrahepatic biliary tract, retraction of the liver capsule, or infiltrative mass that enhances towards the late phases), clinical and laboratory

findings in one lesion. In metastatic cases, 49 lesions were diagnosed by histopathological examination, and 45 lesions were known malignancies and were diagnosed with typical imaging features and follow-up examinations. In benign cases, diagnosis of most lesions was made by typical imaging features (e.g., T2W markedly hyperintense lesions without enhancement for simple parenchymal cysts or T2W hyperintense lesions with flash filling or peripheral discontinuous nodular enhancement for haemangiomas), clinical history, and laboratory findings.

Magnetic Resonance Imaging

In our study, routine abdominal MRI was performed using a 1.5T MRI device (Achieva; Philips Medical Systems, Best, The Netherlands) and a 4-channel phased array coil (SENSE body) directed to the abdomen. In routine examination, T2WI in the axial and coronal planes, fat-suppressed T2WI in the axial plane, DWI, chemical shift imaging, unenhanced T1-weighted images and dynamic axial contrast-enhanced T1-weighted images were acquired.

In our centre, DWI is included in the routine abdominal MRI protocol. Before intravenous contrast agent injection, DWI is acquired using a single-shot echoplanar imaging sequence with parallel imaging technique in the axial plane, (b: 0-50-500-1000 s/mm^2) at the same level and orientation as the routine sequences.

Image Analysis

The images were analysed on a PACS imaging workstation (Infinitt PACS; Infinitt Healthcare, Seoul, Korea) in a separate session, 2 months after the database scan, in order to minimise memory bias. T2WI and DWI images were evaluated based on consensus by two radiologists (ÖK with 15 years of abdominal radiology experience, FÇ with 5 years of radiology experience), who had no knowledge of clinical information or pathologic diagnosis.

Lesions were evaluated according to the signal characteristics on T2WI and DWI apparent diffusion coefficient (ADC) maps at 3-week intervals (the same lesion was evaluated in all sessions in cases with multiple lesions), using a scoring system between 1 and 5 (Table 1, Figures 1-3). Sensitivity, specificity and accuracy were calculated for T2WI and DWI.

Statistical Analyses

All statistical analyses were made using commercial software (SPSS, Windows version 15.0; SPSS Inc., Chicago [IL], United States). The data are presented as mean ± standard deviation, medians (range), minimum, maximum, frequency, and percentages. The diagnostic value of T2WI and DWI in distinguishing benign from malignant liver lesions was evaluated using a two-sample *t* test and the Chi-square test for continuous and discrete variables, respectively. Fisher's exact test was used instead of the Chi-square test in small samples of data. A p value <0.05 was considered statistically significant.

RESULTS

In total, 3523 cases with liver lesions between January 2014 and December 2014 were extracted from hospital records. Cases were excluded if they had no liver lesions (n=2791), lesion size of <1 cm (n=130), no T2WI or DWI series, or images of unsuitable quality for evaluation (n=28). Patients were also excluded from the study

Table 1. Score assessment for T2-weighted imaging (T2WI) and diffusion-weighted imaging (DWI).

Score	Signal characteristics
T2WI scores	
Score 1	Homogeneously and markedly hyperintense lesions
Score 2	Markedly moderately hyperintense lesions
Score 3	Lesions that do not meet features of scores 1, 2, 4, or 5
Score 4	Moderately hyperintense lesions
Score 5	Mildly hyperintense lesions
DWI scores	
Score 1	Lesions that show total signal loss with increasing b values and marked hyperintensity on the ADC map
Score 2	Lesions that show slight signal loss with increasing b values and moderate hyperintensity on the ADC map
Score 3	Lesions that do not meet features of scores 1, 2, 4, or 5
Score 4	Lesions that show no signal loss with increasing b values and moderate hypointensity on ADC map
Score 5	Lesions that show no signal loss with increasing b values and marked hypointensity on ADC map

Abbreviation: ADC = apparent diffusion coefficient.

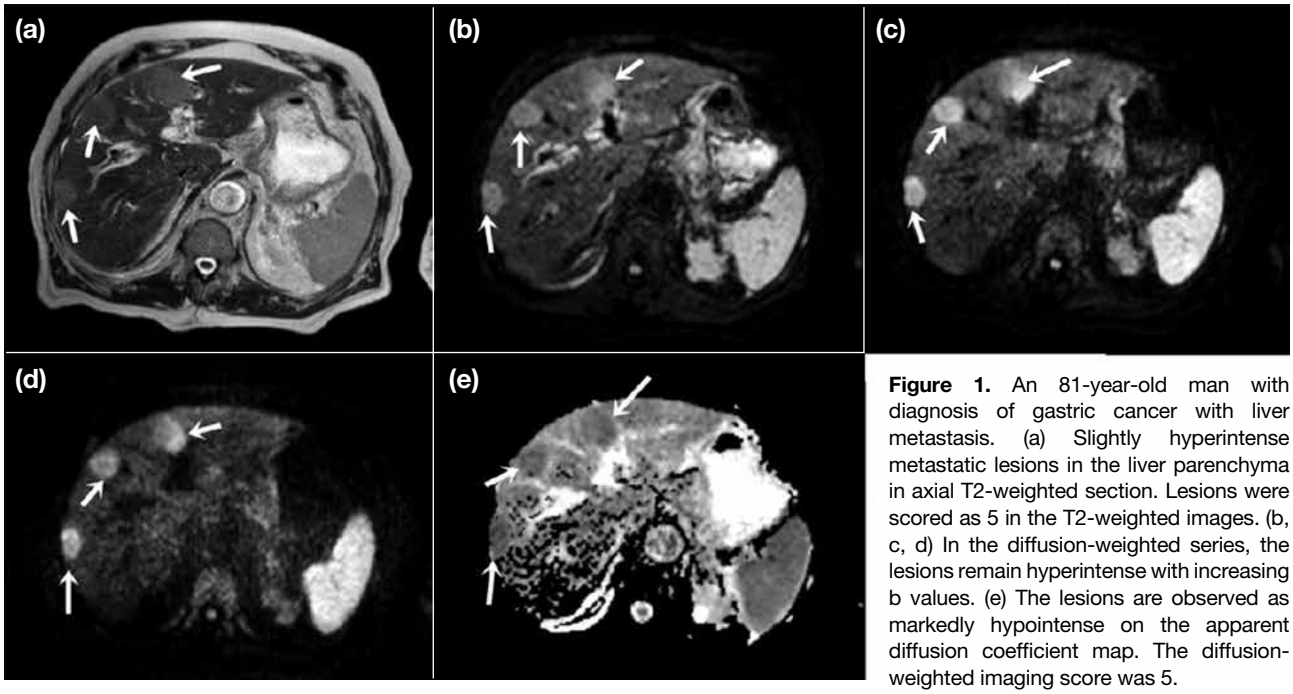

Figure 1. An 81-year-old man with diagnosis of gastric cancer with liver metastasis. (a) Slightly hyperintense metastatic lesions in the liver parenchyma in axial T2-weighted section. Lesions were scored as 5 in the T2-weighted images. (b, c, d) In the diffusion-weighted series, the lesions remain hyperintense with increasing b values. (e) The lesions are observed as markedly hypointense on the apparent diffusion coefficient map. The diffusion-weighted imaging score was 5.

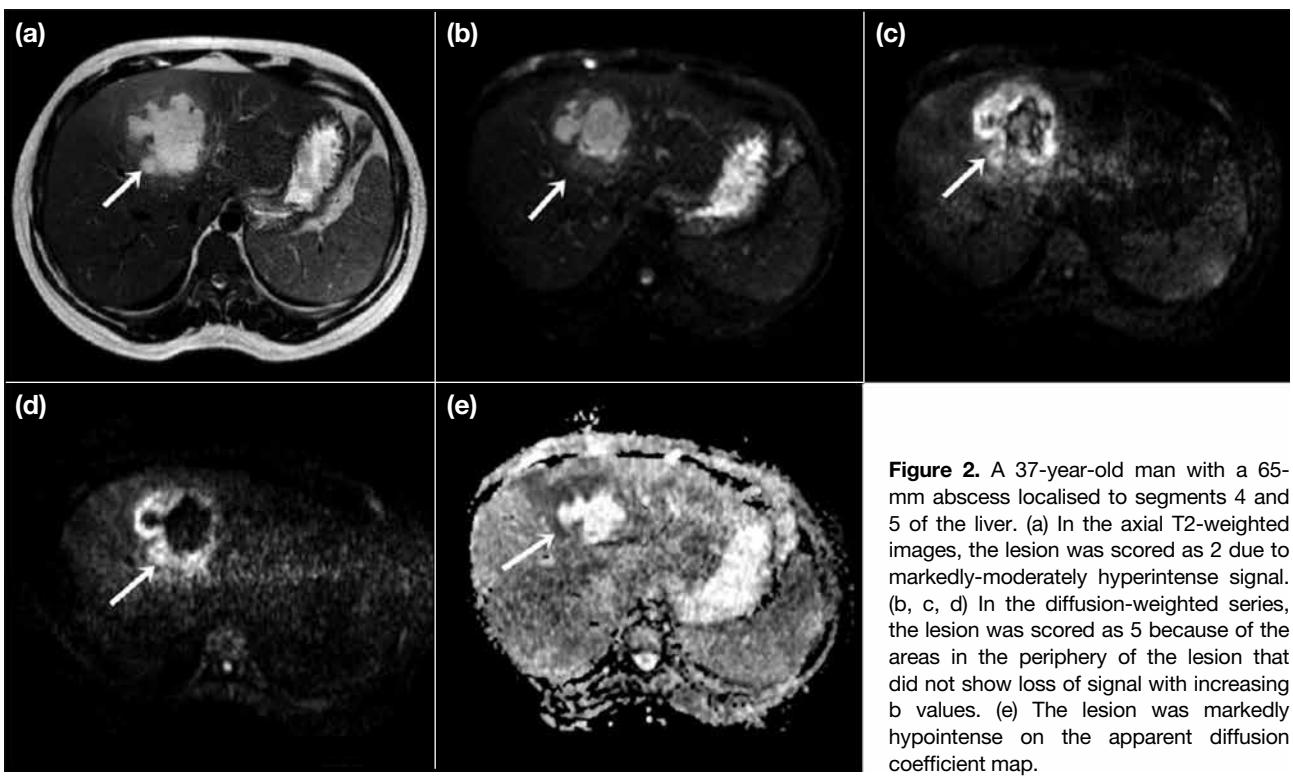

Figure 2. A 37-year-old man with a 65-mm abscess localised to segments 4 and 5 of the liver. (a) In the axial T2-weighted images, the lesion was scored as 2 due to markedly-moderately hyperintense signal. (b, c, d) In the diffusion-weighted series, the lesion was scored as 5 because of the areas in the periphery of the lesion that did not show loss of signal with increasing b values. (e) The lesion was markedly hypointense on the apparent diffusion coefficient map.

who had previously undergone surgical/interventional treatment, chemotherapy, or radiotherapy (n=13).

In total, 587 focal liver lesions in 561 patients (315 female, 56%; 246 male, 44%) aged 54.55 ± 13.68 years (range, 11-95 years) were included in the study (Table 2).

In the characterisation of benign lesions, the mean scores in T2WI and DWI were 1.4 ± 0.8 and 1.7 ± 1.0,

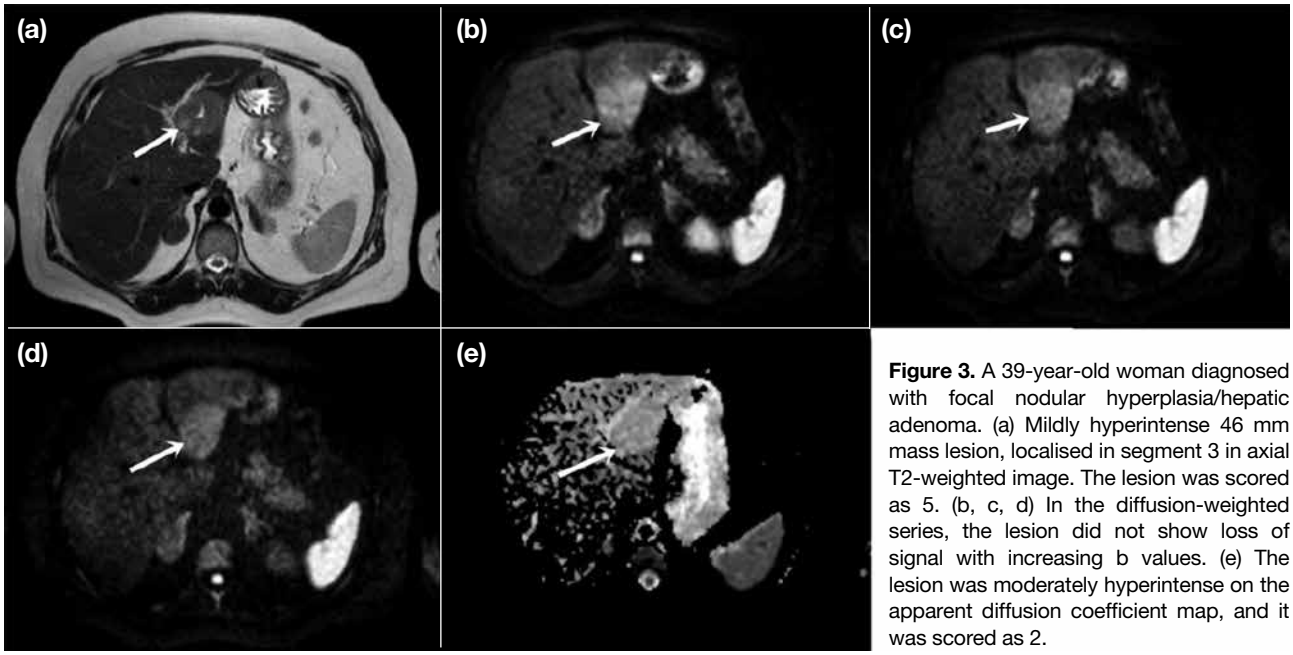

Figure 3. A 39-year-old woman diagnosed with focal nodular hyperplasia/hepatic adenoma. (a) Mildly hyperintense 46 mm mass lesion, localised in segment 3 in axial T2-weighted image. The lesion was scored as 5. (b, c, d) In the diffusion-weighted series, the lesion did not show loss of signal with increasing b values. (e) The lesion was moderately hyperintense on the apparent diffusion coefficient map, and it was scored as 2.

Table 2. Patient demographics.*

	Age, y‡	Tumour size, cm‡	Female/male ratio
Benign lesion (n = 449†)	52 ± 13	3.4 ± 2.7	277/172 (62%/38%)
Haemangioma (n = 252)	5 ± 1.2	3.1 ± 2.1	156/96 (62%/38%)
Simple cyst (n = 119)	5.8 ± 1.3	2.8 ± 1.7	70/49 (59%/41%)
Granular echinococcosis (n = 46)	5 ± 1.6	5.4 ± 3.1	30/16 (65%/35%)
Abscess (n = 13)	5.9 ± 1.8	3.5 ± 1.7	7/6 (54%/46%)
FNH/HA (n = 10)	3.6 ± 1.3	4.4 ± 1.8	10/0 (100%/0%)
Alveolar echinococcosis (n = 5)	5.2 ± 1.5	15.7 ± 6.8	1/4 (20%/80%)
Malignant lesion (n = 138)	6.2 ± 1.2	6.3 ± 4.4	53/85 (38%/62%)
Metastasis (n = 94)	6.2 ± 1.2	5.1 ± 3.2	43/51 (46%/54%)
HCC (n = 38)	6.3 ± 1	8.7 ± 5.5	7/31 (18%/82%)
CCC (n = 6)	6.3 ± 1.2	10.5 ± 3.9	3/3 (50%/50%)

Abbreviations: CCC = cholangiocellular carcinoma; FNH/HA = focal nodular hyperplasia/hepatic adenoma; HCC = hepatocellular carcinoma.
* Data are presented as mean ± standard deviation or No. (%).
† Arteriovenous malformations (n = 2), angiomyolipoma (n = 1) and lipoma (n = 1) are not detailed in this table because of their low number.
‡ Mean age of patients and tumour size were significantly larger for malignant lesions than for benign lesions (both $p < 0.001$).

respectively. The scores in malignant lesions were 4.5 ± 0.8 and 4.4 ± 0.9 (Table 3).

The sensitivity, specificity, and accuracy of T2WI in distinguishing between benign and malignant liver lesions were 94%, 94%, and 94%, respectively. The values for DWI were 96%, 85% and 88% respectively (Table 4).

A total of 23 lesions in T2WI sequence and 17 lesions in DWI could not be visualised; they were not included in the accuracy evaluation. Among these lesions, 11 lesions could not be visualised in both T2W sequence and DWI images. Nine lesions on T2W images and 42 lesions on DWI images were scored as 3. Lesions scoring 3 were evaluated as incorrect reading.

DISCUSSION

Focal liver masses have a wide pathological spectrum from benign lesions to aggressive malignancies, and characterisation of lesions is key. Today, the detection of liver lesions is increasing in parallel with the increasing

use of imaging methods such as US, CT, and MRI. MRI, which does not expose patients to ionising radiation, provides a high level of lesion/liver contrast, and with hepatocyte-specific contrast agent option is considered to be the most successful radiological diagnostic method that can be used in the detection and characterisation of focal liver lesions.[5,6]

Developments in parallel imaging techniques have provided an increase in image quality of DWI, a shortening of scanning time and a decrease in artefacts. These have enabled the DWI to be used in abdominal imaging.[4,5] There are studies with positive results where DWI was used in the detection of liver lesions and ADC measurement in lesion characterisation.[7,8] However, use of DWI in the characterisation of liver lesions is still controversial due to overlap in findings in different types of lesions.[6-16]

T2WI is used in routine abdominal MRI protocols and is very useful in the diagnosis of focal lesions in the cirrhotic and non-cirrhotic liver.[17-19] However, it has some limitations such as difficulty in distinguishing between vascular structures and lesions, and in detecting small lesions.[14] DWI was found to be more successful than T2WI in detecting malignant lesions when evaluated using lower b values (b:0 and 50 s/mm^2).[14-16,20] Higher success of DWI in detecting lesions was attributed to the better contrast-to-noise ratio, and suppression of signals originating from surrounding vascular structures.[5,14] Although high b values (>500 s/mm^2) can be disadvantageous in lesion detection due to artefacts and low signal-to-noise ratio, they contribute positively to lesion characterisation.[20]

Although measuring ADC in DWI is beneficial in terms of lesion characterisation, it has no practical consequence, especially in busy centres such as our clinic. Also, there are wide overlaps in benign-malignant lesions and problems arise on where to take the ADC measurement in heterogeneous lesions. In this study, we reached an accuracy rate of 88% with visual evaluation of DWI in liver lesion characterisation. To our knowledge, there are limited studies in the English-language literature comparing DWI and T2WI MRI sequences in the characterisation of liver lesions by direct visual evaluation.[14,20]

Table 3. Scores of lesions on T2WI and DWI (1-5).*

	T2WI	DWI
Benign lesions	1.4 ± 0.8	1.7 ± 1
Malignant lesions	4.5 ± 0.8	4.4 ± 0.9
Haemangioma	1.3 ± 0.6	2.0 ± 0.9
Simple cyst	1.0 ± 0.3	1.0 ± 0.3
Granular echinococcosis	1.3 ± 0.6	1.5 ± 1
Abscess	3.0 ± 1.2	3.5 ± 1.6
FNH/HA	4.3 ± 0.5	2.7 ± 0.8
Alveolar echinococcosis	3.4 ± 1.3	2.4 ± 1.5
Metastasis	4.5 ± 0.9	4.5 ± 0.9
HCC	4.5 ± 0.7	4.0 ± 0.9
CCC	4.5 ± 1.2	4.7 ± 0.5

Abbreviations: CCC = cholangiocellular carcinoma; DWI = diffusion-weighted imaging; FNH/HA = focal nodular hyperplasia/hepatic adenoma; HCC = hepatocellular carcinoma; T2WI = T2-weighted imaging.
* Data are presented as mean ± standard deviation.

Table 4. Diagnostic values of T2WI and DWI sequences in the distinction between benign and malignant liver lesions.*

	T2WI	DWI	p Value
All lesions (accuracy)	94% (528/564)	88% (500/570)	0.65
Benign lesions† (specificity)	94% (406/434)	85% (370/435)	0.50
Malignant lesions (sensitivity)	94% (122/130)	96% (130/135)	0.88
Haemangioma	97% (235/242)	80% (198/246)	0.20
Simple cyst	99% (117/118)	99% (117/118)	1.00
Granular echinococcosis	98% (45/46)	89% (41/46)	0.51
Abscess	38% (5/13)	42% (5/12)	0.65
FNH/HA	0% (0/7)	50% (3/6)	<0.001
Alveolar echinococcosis	40% (2/5)	80% (4/5)	<0.001
Metastasis	93% (83/89)	97% (89/92)	0.77
HCC	97% (34/35)	95% (35/37)	0.88
CCC	83% (5/6)	100% (6/6)	0.20

Abbreviations: CCC = cholangiocellular carcinoma; DWI = diffusion-weighted imaging; FNH/HA = focal nodular hyperplasia/hepatic adenoma; HCC = hepatocellular carcinoma; T2WI = T2-weighted imaging.
* In the study, 23 lesions in T2A sequence and 17 lesions in DWI could not be visualised, so they were not included in the characterisation evaluation.
† Arteriovenous malformations (n = 2), angiomyolipoma (n = 1) and lipoma (n = 1) are not detailed in this table because of their low number.

In this study, the sensitivity, specificity and accuracy rates of T2WI and DWI in the characterisation of liver lesions were 94%/96%, 94%/85%, and 94%/88%, respectively, with no statistically significant difference between the two sequences. However, in light of these data, the specificity of T2WI was found to be higher compared to DWI in lesion characterisation. This was due to the fact that the T2W sequence had a high specificity rate of 97% in benign lesions, especially in haemangiomas. The fact that some haemangiomas showed increased signal intensity with increasing b values and contained hypointense areas in ADC (probably due to thrombus content in some haemangiomas and a fibrous tissue component in hyalinised haemangiomas) resulted in some haemangiomas receiving malignant scores, which decreased the specificity of DWI to 80%. In a study conducted by Parikh et al,[14] sensitivity, specificity, and accuracy rates of T2WI and DWI in lesion characterisation were 92%/92%, 80%/83%, and 87%/89%, respectively. In a study performed by Yang et al,[20] the same values were calculated as 97%/97%, 86%/88%, and 91%/91%, respectively. Although the values largely overlap, the specificity values of the T2WI were better in our study. This high specificity value was thought to be due to the higher percentage of haemangiomas in our study compared to the other two studies.

In this study, T2WI was found to have higher accuracy rates in cases of haemangioma (97% vs. 80%), whereas DWI had higher accuracy rates in focal nodular hyperplasia/hepatic adenoma (FNH/HA, 0% vs. 50%) and alveolar echinococcosis (40% vs. 80%). In FNH/HA cases, the lesion shows a slightly hyperintense signal intensity on T2WI that can be barely discerned from the surrounding liver parenchyma, and as found in other studies[21,22] these cases can be confused with malignant lesions due to low ADC values on DWI, which decreased the diagnostic value of these sequences in lesion characterisation.

Abscess, FNH/HA, and alveolar echinococcosis cases are benign lesions that can be mistaken for malignant liver lesions in both sequences. In alveolar echinococcosis cases, the DWI value in lesion characterisation was significantly lower compared to other cystic liver lesions and overlapped with malignant lesions. This was thought to be due to the presence of chronic fibroinflammatory, necrotic tissue and a solid component with diffusion restriction.[23] Similar reasons and calcified areas cause the signal to decrease in T2WI, and infiltrative extension to surrounding tissues, as in malignant lesions resulted in the lesion to receive a malignant score in T2WI. The accuracy rates of T2WI and DWI in abscess cases were found to be 38% and 42%, respectively. In these cases, the diffusion restriction due to abscess content[22,24] and the mild hyperintense signal areas in T2WI due to its heterogeneous content resulted in malignant scores and significantly decreased the accuracy rates of both sequences.

Benign and malignant focal liver lesions can be distinguished by measuring ADC in DWI. Although there were overlaps, the ADC value of malignant liver lesions was found to be significantly lower compared to that of benign lesions. The threshold ADC values for differentiation vary in different studies depending on the MRI parameters used and the strength of the diffusion gradient.[8,10,14,16,25-27] According to the literature, there is a significant overlap between hypercellular benign liver lesions such as FNH/HA and malignant liver lesions such as hepatocellular carcinoma and metastases.[28] In this study, measurements made with ADC in lesion characterisation had results similar to those of visual evaluation.

Most benign liver lesions are asymptomatic and are detected predominantly in middle-aged women.[29] In this study, a significant difference was found between the patient groups with benign and malignant liver masses in terms of age and sex. The mean age of patients and size of malignant lesions were found to be significantly greater than those of benign lesions. Benign lesions were mostly seen in women and malignant lesions were mostly seen in men. In addition, although it is a benign lesion, the size in alveolar echinococcosis cases overlapped with that of malignant lesions.

This study has some limitations. First, interobserver variability was not calculated because the observers did not evaluate the cases independently. Second, there were pathologically unconfirmed lesions in the present study. However, we think that the misdiagnosis rate is very low as a result of careful evaluation of other MR sequences and contrast-enhanced images and evaluation of all examinations in the system.

CONCLUSION

In conclusion, although both imaging methods had high efficiency in the characterisation of benign and malignant liver lesions, it was found that conventional T2WI had higher specificity and accuracy rates compared to DWI.

In addition, T2WI was more successful in haemangioma cases, whereas DWI was marginally more successful in FNH/HA and alveolar echinococcosis cases. Both sequences had low success rates in abscess, FNH/HA, and alveolar echinococcosis cases. We think that T2WI and DWI can be used safely for characterisation of lesions in individuals who cannot be given contrast due to reasons such as renal failure and contrast allergy.

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