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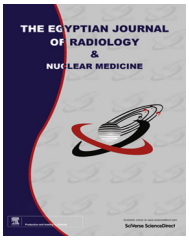

ORIGINAL ARTICLE

Role of Diffusion Weighted Magnetic Resonance Imaging in evaluation of hepatic focal lesions

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KEYWORDS

Liver;
Focal lesions;
DW MRI

Abstract *Objective:* To clarify role of Diffusion Weighted Magnetic Resonance Imaging (DW MRI) in the detection of hepatic focal lesions and its ability to differentiate benign from malignant hepatic focal lesions.

Patients and methods: This study included 40 patients who were referred to our institution from the different medical and surgical departments as well as oncology unit. Patients with chronic renal impairment or previous allergy to the contrast media were excluded from the study. All patients were subjected to careful history taking, general and abdominal examination, laboratory examinations, and liver MRI.

Results: The lowest ADCs were found in metastases, CCA and HCCs and the highest values were found in hemangiomas. The difference between the mean ADC values of benign and malignant lesions was significant. No significant differences in ADC values among the different benign lesions or among the different malignant lesions at both sequences.

Conclusion: In conclusion, DW MRI alone performs equally well as Gd-MRI in detection and differentiation of different hepatic focal lesions. In cases where gadolinium injection is not allowed, dynamic contrast-enhanced imaging can be replaced by a protocol based on unenhanced T1 and T2 weighted imaging combined with DWI. Adding DWI to Gd-MRI is more accurate.

1. Introduction

The liver is considered a common site for many benign, primary malignant and metastatic focal lesions. Accurate detection and characterization of these tumors is crucial before treatment to ensure correct staging, to prevent tumors from being falsely rated as inoperable and patients with inoperable tumors from being scheduled for surgical procedures (1).

Diffusion-weighted imaging (DWI) has been reported to be useful for the early detection of small focal hepatic lesions. Moreover, DWI offers the possibility to obtain criteria for lesion characterization without the need for contrast agent administration by quantifying diffusion effects via apparent diffusion coefficient (ADC) measurements, with better results compared with those of conventional MR imaging (2).

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Diffusion weighted imaging could potentially improve care of patients with cancer in cirrhotic liver by improving lesion detection over that achieved with standard breath-hold T2-weighted imaging (3).

Dynamic three dimensional gradient-recalled-echo MR imaging provides dynamic contrast-enhanced thin-section images with fat saturation which is excellent for the proper evaluation, accurate detection and characterization of various focal hepatic lesions (4).

The aim of this study was to clarify the role of Diffusion Weighted Magnetic Resonance Imaging (DW MRI) in the detection of hepatic focal lesions and its ability to differentiate benign from malignant hepatic focal lesions.

2. Patients and methods

This study included 40 patients over a period of 30 months starting from August 2011 to February 2014. Those patients were referred to Diagnostic Radiology Department at Tanta University Hospital from the different medical and surgical departments as well as oncology unit of Tanta University Hospital. The 40 patients included in this study were 32 males and 8 females with age ranging from 30 to 80 years.

Patients with chronic renal impairment (high serum creatinine) or previous allergy to the contrast media were excluded from the study. This study was approved by the ethics committee of Tanta Faculty of Medicine; an informed consent was obtained from all patients after full explanation of the benefits and risks of the procedure.

All patients were subjected to careful history taking, general and abdominal examination, laboratory examinations, and liver MRI.

2.1. Liver MRI imaging protocol

All MR images were obtained on the available 1.5-T superconducting MRI scanner (Signa HD × 14.0, GE Healthcare) installed in radiology department at Tanta university hospital.

As regards patient preparation, the patient was asked not to eat or drink anything for 4–6 h before the scan. Jewellery of any kind and any metallic objects were removed before examination. Examination was performed in supine position, with comfortable head pillows and the arms positioned comfortably next to the abdomen.

1. **Unenhanced axial T1-weighted acquisitions**. Parameters are repetition time (TR) 150 to 200/msec, echo time (TE) 20 ms, optional fat suppression, matrix 256 × 192, field of view 320 mm, respiratory gating.
2. **T1 (Axial spoiled GRE sequence applied in phase and out of phase)** (repetition time msec/echo time msec, 126/4.6 [in-phase], 2.3 [out-of-phase]; flip angle, 80°; matrix, 179 × 256; section thickness, 8 mm; intersection gap, 2.5 mm; one signal acquired; field of view, 320 mm).
3. **Axial & Coronal T2-weighted** fast spin-echo sequence with spectral fat saturation (TR = 1800, TE = 85; fast spin-echo factor, 16; matrix, 512 × 512; section thickness, 8 mm; intersection gap, 2.5 mm; field of view, 320 mm), fat suppression. Heavily T2-weighted pulse sequences obtained with a minimum TE of 160 ms.
4. **Diffusion weighted sequences** (Respiratory-triggered protocol using b value = 100 and 500 s/mm^2). Before contrast material injection, diffusion-weighted MR sequences were performed with the single shot echo-planar imaging (EPI) technique. These sequences combined diffusion gradient pulses before the 2° and after the 180° pulse. Subsequent measurement of mean apparent diffusion coefficient (ADC) value was done, for evaluation of suspected hepatic masses in selected cases.
5. **Dynamic contrast material–enhanced (Gd-DTPA) imaging (Axial 3D spoiled GRE) was done**. Axial dynamic 3D fat-suppressed GRE sequence, FSPGR LAVA (liver acquisition with volume acceleration) was performed during all phases after bolus injection of 0.2 mL/kg body weight of Gd-DTPA flushed with 20 ml of sterile 0.9% saline solution in the antecubital vein at 20 s (arterial phase), 40 s (portal phase), 60 s (venous phase), 120 s (equilibrium phase) and again at 10 min and may be variable up to one hour after injection (Delayed phase).

For lesion characterization all imaging results were refined against a predefined standard of reference (SOR). The standard of reference was either histopathology (for nine cases) or multi-modality and clinical follow-up (for the remaining thirty-one cases). For each lesion type, the most appropriate and ethically justifiable SOR was used. For 9 patients (HCC 5 cases, secondaries 3 cases and CCA one case) the accepted SOR was biopsy and histopathological verification within a time frame of 3 months after MRI examination. Based on ethical considerations, we did not expect to get SOR result for every lesion detected in patients with multiple lesions. There was no histopathological confirmation for the benign lesions.

For patients presented with benign lesions the accepted standard of reference was close follow up with contrast enhanced MRI or triphasic CT study after few months.

2.2. Imaging evaluation

Images interpretation was done according to the difference in the signal intensity, shape, site, size of the lesions and their relations to the surrounding structures at the noncontrast T1-weighted and T2-weighted pulse sequences. Next we reviewed the dynamic images of our Gd-DTPA MRI study for difference in the pattern of enhancement of the lesions with proper localization. Finally we reviewed diffusion weighted imaging (DWI) study in order to assess the added diagnostic value in the detection and characterization of the hepatic focal lesions. On DWI, restricted diffusion was considered if a lesion showed increased signals to the normal liver parenchyma on increasing b-value images, and when the ADC (apparent diffusion coefficient) map displayed a value lower or equal to liver parenchyma. The readers visually evaluated the ADC map qualitatively, comparing to that of normal surrounding liver parenchyma. Quantitative analysis of ADC calculations based on a threshold of 1.3×10^{-3} s/mm^2. All lesions below that threshold considered to be malignant lesions. Bright signal on both diffusion images and ADC map is considered as T2 shine-through effect which was seen in hemangiomas and cysts.

Evaluation of the fat contents of the lesions was done by the dual in-phase and out-of-phase sequences. Histopatholo-

Table 1 Age and gender distribution of the studied 40 patients.

	No. of patients	Percentage (%)
Gender		
Male	32	80
Female	8	20
Age		
30 < 40	2	5
40 < 50	4	10
50 < 60	20	50
60 < 70	12	30
70 < 80	2	5

Table 2 Pathological classification of the hepatic focal lesions in the present study.

Lesion	Number of patients	Percentage (%)
Hepatocellular carcinoma	16	40
Metastasis	8	20
Multicentric HCC	6	15
Cirrhotic nodules	4	10
Focal fatty infiltration	2	5
Cholangiocarcinoma	2	5
Hemangioma	2	5
Total	40	100

gical correlation was done for 9 cases (5 cases of HCC, 3 cases of secondaries and 1 case of CCA).

2.3. Statistical analysis

The role of Diffusion Weighted Magnetic Resonance Imaging (DW MRI) in detection and characterization of hepatic focal lesions was evaluated and compared with histopathology (for nine cases) and multi-modality with clinical follow-up (for the remaining thirty-one cases) which were considered the gold standard of reference. Data entry was done by SPSS version 16 and analyzed by the same software.

A P value <0.05 was considered significant.

3. Results

Forty patients were examined in this study, including 32 males and 8 females with age range from 30 to 80 year (Table 1).

Among the 40 patients included in this study, males were more than females representing 80% and the females 20%. The age ranged 50 < 60 years was the most common affected followed by age group 60 < 70 years and the less common age affected was between 30 and 40 years.

Hepatocellular carcinoma (HCC) and metastasis are the most common cause of hepatic focal lesions in this study representing 75% of cases (30 cases) followed by cirrhotic nodules that represented 10% of the cases (4 cases), hemangioma 5% (2 cases), and cholangiocarcinoma 5% (2 cases) (Table 2).

HCC and secondaries show low SI in T1 & high SI in T2WI, while CCA shows low SI in T1 and variable SI in T2WI and all of them show restricted diffusion. Hemangioma

Table 3 MR signal intensity characteristics of the hepatic focal lesions in the studied 40 patients.

The lesion	T1	T2	Heavy T2	T1 in phase	T1 out phase	Diffusion	
						Diffusion	ADC map
HCC	↓	↑	↓	Variable intensity	↓	↑	↓
Metastasis	↓	↑	↓	↓	↓	↑	↓
Cirrhotic nodules	Iso/↑	Iso/↓	↓	↓	↓	Free	Isointense
CCA	↓	Variable	↓	↓	↓	↑	↓
Hemangioma	↓	↑↑	↑↑	↓	↓	↑	↑
FFI	↑	↑	–	↑	↓	–	–

Note: Arrows indicate increased (“up” arrow) or decreased (“down” arrow) signal intensity relative to the surrounding normal liver. Doubleup arrows indicate marked hyperintensity. Iso = isointense. Variable = variable intensity (hyperintense, hypointense or isointense). SI = signal intensity.

Table 4 Mean apparent diffusion coefficients (ADCs) values of the hepatic focal lesions in the studied 40 patients.

Lesion	First sequence (*b*-value 100)	SD	Second sequence (*b*-value 500)	SD
HCC	1.168	0.068	1.21	0.05
Metastasis	0.686	0.553	0.75	0.048
CCA	0.925	0.11	0.825	0.11
Hemangioma	3.217	0.155	2.827	0.102
Benign lesions	2.942	0.611	2.879	0.651
Malignant lesions	1.059	0.281	0.991	0.267

shows low SI in T1, very bright signal in T2WI, on heavy weighted T2 still bright signal and on diffusion it shows high signal in both diffusion and ADC map due to T2 shine through. Focal fatty infiltration (FFI) shows high SI in both T1 and T2WI with loss of signal on chemical shift sequence (out of phase). Cirrhotic nodules show iso/high SI in T1, iso/low SI in T2 and free diffusion, and ADC values less than 1.3×10^{-3} s/mm^2 in all the malignant lesions, but ADC values more than 1.3×10^{-3} s/mm^2 in all benign lesions. Diagnosis of malignant lesions based on typical MRI features, specific laboratory tests and histopathology confirmation for 9 cases (5 cases HCCs, 3 cases secondaries and one case Cholangiocarcinoma) as shown in Table 3.

First sequence was done with b value = 100 s/mm^2. Second sequence was done with b value = 500 s/mm^2. Mean ADC value = 1.3×10^{-3} s/mm^2 ± SD (Standard deviation). The lowest ADCs were found in metastases, CCA and HCCs and the highest values were found in hemangiomas. The difference between the mean ADC values of benign and malignant lesions was significant. No significant differences in ADC values among the different benign lesions or among the different malignant lesions at both sequences (Table 4) Figs. 1–5.

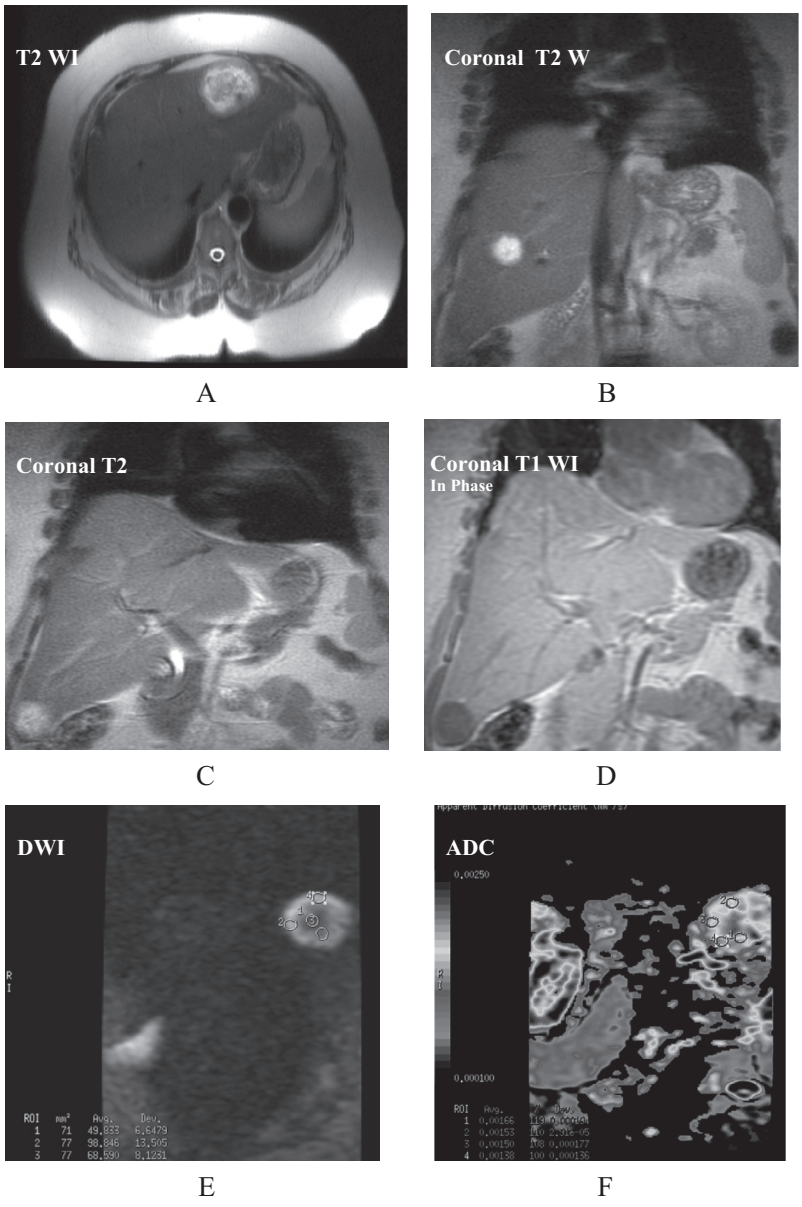

Fig. 1 (A–F) Female patient aged 55 year presented with jaundice, epigastric pain and epigastric swelling with past history of cancer colon resection. MRI study revealed multiple hepatic focal lesions in both right and left hepatic lobes namely segment II of the left hepatic lobe and segment VIII & VI of the right hepatic lobe. All the lesions exhibit hypointense SI on T1WI, markedly hyperintense SI on T2WI & diffusion study (DWI) and hypointense on ADC map with mean ADC value = 0.9×10^{-3} s/mm^2. The largest lesion in the left hepatic lobe exhibits only marginal restricted diffusion due to central necrosis with mean ADC value = 1.7×10^{-3} s/mm^2. The diagnosis was established as metastatic deposits based on the clinical history and the MRI findings.

Six of the twenty-two patients with HCC show multiple lesions (multicentric HCC). All the patients with HCC show cirrhotic liver and elevated α-fetoprotein. The size of the lesions ranges from 1 to 7 cm with mean diameter 4 cm. All the lesions show low SI in T1, high SI in T2WI with restricted diffusion. No significant differences in ADC values among different HCC lesions. Postcontrast all lesions show arterial enhancement with rapid washout (Tables 5 and 6).

4. Discussion

In the stage of malignant disease, metastatic involvement of the liver has to be ruled out in almost all instances. Furthermore, the worldwide increasing number of primary hepatic malignancies directs attention to an early and correct diagnosis of these lesions, mainly hepatocellular carcinoma (HCC). The importance of liver imaging lies in the accurate detection and

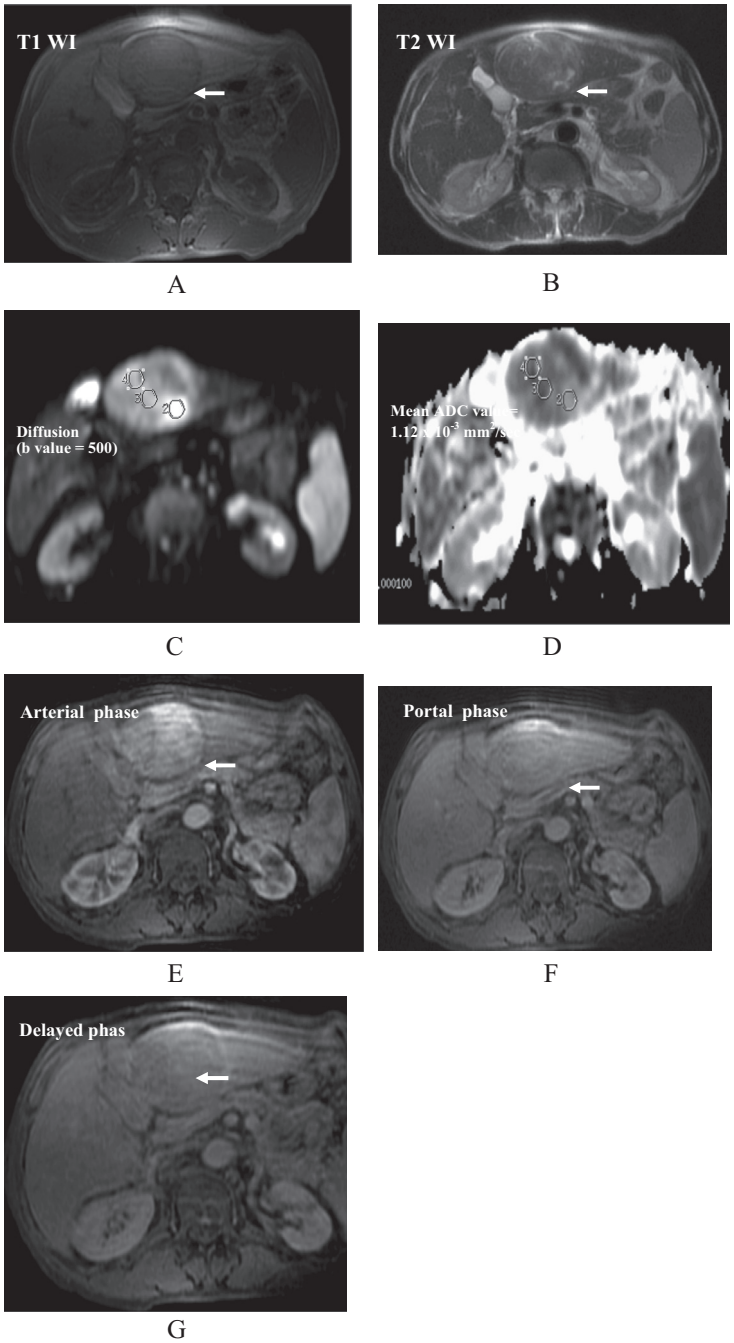

Fig. 2 (A–G) Male patient aged 66 year with liver cirrhosis presented with clinically palpable epigastric swelling. MRI study revealed a left hepatic lobe nearly rounded mass with diameter = 6 cm, and the mass exhibits hypointense SI on T1WI, hyperintense SI on T2WI & diffusion study and hypointense on ADC map with mean ADC value = 1.12×10^{-3} mm^2/s. The mass showed immediate heterogeneous enhancement at the arterial phase with rapid washout at the subsequent porto-venous and delayed phases. The mass showed the typical MRI findings of HCC together with histopathological confirmation after surgical excision (Left lobectomy).

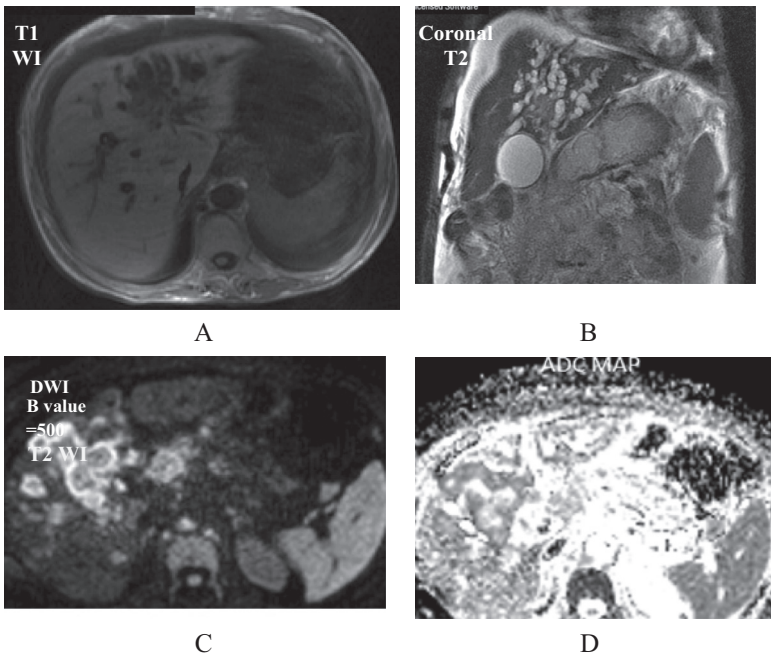

Fig. 3 (A–D) Male patient aged 55 years presented with obstructive jaundice. MRI findings: A tumor mass centralized upon the common hepatic and left hepatic ducts and associated with bi-lobar biliary obstruction. The mass exhibits hypointense SI on both T1WI and T2WI, heterogeneous high signal intensity on diffusion study and low SI in the ADC map with mean ADC value $= 1.2 \times 10^{-3}$ s/mm^2. The lesion showed typical imaging findings of cholangiocarcinoma.

exact differentiation between the above-mentioned malignant lesions and frequent benign lesions (5).

Although dynamic contrast enhanced examinations have become a routine component of abdominal imaging, the high cost/benefit ratio and risk of contrast media side effects remain an issue. MR Imaging has revealed high performance for focal liver lesion detection and characterization during a single examination procedure (6).

Diffusion weighted imaging (DWI) has recently emerged as a tool for detecting cancers in the abdominal organ field. The use of DWI in the liver is relatively new (7).

The amount of diffusion is defined using the diffusion coefficient. Diffusion coefficient measurement in vivo is affected by several factors in biological tissues. Capillary perfusion, temperature, magnetic sensitivity of the tissue, and motion affect the actual diffusion; therefore, the term ''apparent diffusion coefficient'' (ADC) is used rather than ''diffusion coefficient'' (8).

Our study included 40 patients, 32 men and 8 women, with age ranging from 30 to 80 years and mean age of 55 years, which included the age incidence of malignant hepatic focal lesions, which are more predominant after age of 50 which was in line with other studies as follows:

A study was performed by Demir et al. (8) including thirty patients with age ranging from 18 to 88 years and mean age 54.4 years. Parikh et al. (1) performed a study including fifty-three patients with age ranging from 25 to 83 and mean age 60.7 years. Kim et al. (3) carried out a study including forty-nine patients with age ranging from 31 to 73 years and mean age 55.9 years.

As regards patient's sex, our study has male predominance, 32 men and 8 women, that went in line with other studies as hepatic lesions are more common in men. Cui et al. (9) performed a study including 23 patients, 16 men and seven women. Another study carried out by Koike et al. (10) including seventy patients, 52 men and 18 women. Hosny (6) conducted a study including thirty-eight patients, 27 men and 11 women.

Bachir and Dew (11) found that DW MR imaging significantly improved detection of small malignant lesions (< 2 cm) when compared with breath-hold T2-weighted imaging in a study performed on 24 patients. Another study carried out by Parikh et al. (9) showed significantly improved detection rates of both malignant and benign focal lesions when using DW imaging with a small b value compared with standard breath-hold T2-weighted imaging, particularly for small malignant lesions measuring 1–3 cm.

Bruegel et al. (12) compared respiratory-triggered DW MR imaging to T2-weighted sequence for the diagnosis of hepatic metastases in 52 patients with 118 lesions at 1.5T. DW MR imaging demonstrated higher accuracy compared with T2-weighted fast SE techniques. These differences were even more pronounced for small metastatic lesions ($\leqslant 1$ cm).

Zech et al.(13) compared black-blood DW MR imaging ($b = 50$ s/mm^2) with fat-suppressed T2-weighted imaging in 38 patients and observed significantly better image quality, fewer artifacts, and better sensitivity for lesion detection with DW MR imaging.

Vandecaveye et al. (14) concluded that DWI is more sensitive for the detection of HCC < 20 mm compared to conventional contrast enhanced MRI, while DWI did not show significantly better results than conventional MRI in detecting HCC > 20 mm.

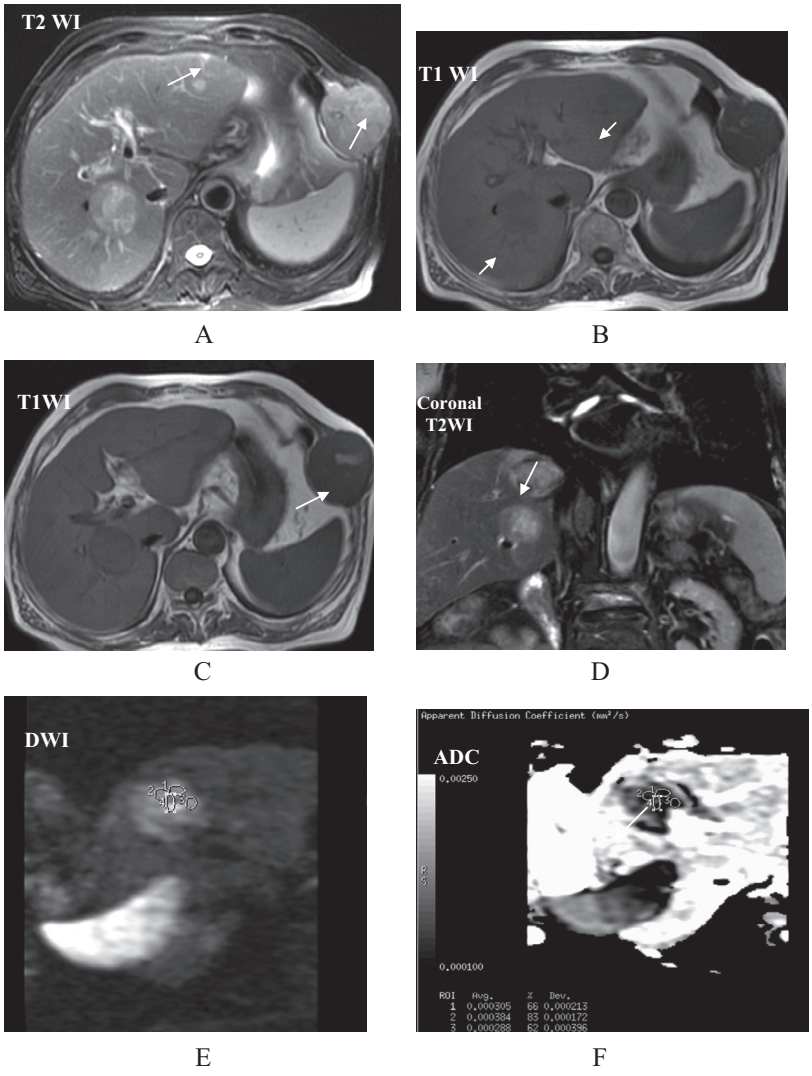

Fig. 4 (A–F) Male patient with history of cancer colon aged 65 years presented with chest wall mass and jaundice. MRI findings: Multiple variable sized focal lesions scattered at both hepatic lobes. The lesions exhibit hypointense to isointense SI on T1WI, Hyperintense signal on T2WI and diffusion study with mean ADC value = 0.38×10^{-3} s/mm^2. The chest wall mass showed areas of high SI in T1WI consistent with areas of hemorrhage. As regards the patient's clinical history and MRI findings, the lesions were diagnosed as metastatic deposits.

These findings can be explained by the better contrast-to-noise ratio and background suppression of normal liver parenchyma and vascular or bile structures in DWI, which make small lesions more visible, especially when they are in close vicinity to vessels or bile ducts.

On T1-weighted MR images, HCC is most often hypointense relative to the liver, although hyperintense lesions or areas of hyperintensity within hypointense lesions may be seen. These hyperintense regions within the HCC reflect the presence of fat, copper, protein, or blood secondary to intralesional hemorrhage. On T2-weighted images, HCC is generally hyperintense, although well-differentiated lesions that are isointense relative to the liver parenchyma may be seen. Most HCCs show intense enhancement on arterial phase contrast-enhanced images with rapid washout at the subsequent phases as reported by Piana et al. (15).

On arterial phase dynamic gadolinium-enhanced images, most small HCCs show intense enhancement with rapid washout at the portal phase. Nishie et al. (16) reported that at diffusion-weighted imaging, HCCs have a variable appearance. Well-differentiated tumors are often isointense, whereas moderately to poorly differentiated tumors are more often hyperintense with low ADC values compared to the well-differentiated tumors.

In this study 22 patients with HCC were evaluated 20 males and 2 females (mean diameter, 4 cm; range, 2–8 cm). Seven cases were found in cirrhotic liver and 1 case was in a noncirrhotic liver. The diagnosis was straightforward and agreed with the previous study as regards characteristic noncontrast MRI signal, typical pattern of contrast enhancement as well as the diffusion study criteria. The other 14 cases were found in cirrhotic liver with multicentric HCC in 6 cases.

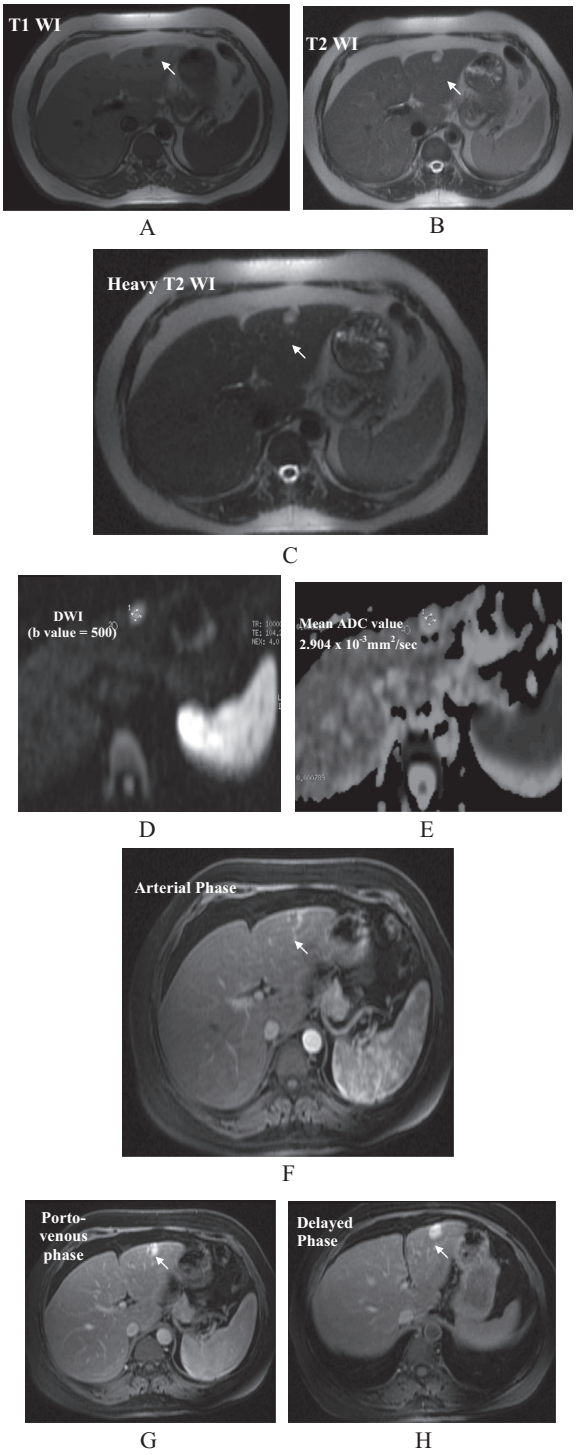

Fig. 5 (A–H) Female patient aged 51 year, presented with hyperechoic left hepatic lobe focal lesion during US checkup. MRI study revealed a small left hepatic lobe subcapsular focal lesion exhibits hypointense SI on T1WI, hyperintense SI on T2 and heavy T2 weighted images. The lesion appeared hyperintense on diffusion study as well as at the ADC map with mean ADC value = 2.9×10^{-3} s/mm^2. The lesion showed incomplete ring of peripheral nodular enhancement at the arterial phase after contrast injection with gradual filling at the porto-venous phase and complete filling with contrast at delayed images. The lesion showed the typical MRI findings of the hemangioma.

Kenis et al. (17) reported that detection and characterization of liver metastases in patients with primary tumors is very important because these patients may have benign lesions that must be differentiated from metastases to avoid unnecessary further diagnostic work-up or errors in patient staging.

Metastatic lesions usually demonstrate low signal intensity on T1-weighted MR images and are iso to hyperintense on T2-weighted images, with delayed enhancement on contrast-enhanced images. Occasionally, they show early ring enhancement. Islet cell tumors, breast cancer, cancer ovary, melanoma, thyroid cancer, and carcinoid tumor are among the most common primary tumors that lead to hypervascular hepatic metastases. Hypervascular metastases are best seen during the arterial phase of enhancement and show washout on delayed images. Most of these lesions have high signal intensity on T2-weighted MR images (Soyer et al.) (18).

In our study, 29 metastatic lesions (mean diameter 4 cm) were evaluated in 8 patients. The primary tumors were colorectal carcinoma in 3 patients, urinary bladder cancer in 1 patient, and unknown primary in 4 patients. The diagnosis of these lesions was straightforward with the previous literatures as regards the clinical history of primary malignancy, characteristic noncontrast MRI features, pattern of contrast enhancement as well as the diffusion study criteria.

Nasu et al. (19) reported that malignant hepatic tumors, especially hepatic metastases, have a lower apparent diffusion coefficient than benign nodules. The hepatic metastases are generally hyperintense on diffusion study with low ADC values.

In our study, four patients were evaluated 2 males and 2 females, and regenerative nodules show low signal intensity on T2 weighted images, variable signal intensity on T1 weighted images, and no enhancement on arterial phase dynamic gadolinium-enhanced images.

These were in agreement with Hussain (20) who stated that on MRI study cirrhotic nodules are seen as low-signal-intensity areas on both T1 and T2 weighted MR images with no enhancement after contrast material administration.

Hemangioma is the most common benign hepatic tumor. On unenhanced MRI, the typical lesion is sharply defined with a geographic or rounded shape, hypointense on T1WI and strongly hyperintense on T2WI images that may be as bright as CSF. On contrast-enhanced images, hemangiomas demonstrate early peripheral nodular enhancement with progressive centripetal enhancement on subsequent images, this comes in agreement with Bozgeyik et al. (21) who reported that early phase images show peripheral enhancement which is typically nodular and discontinuous with centripetal filling during the portal venous and almost completely filled with contrast at the delayed images.

At diffusion-weighted imaging, hemangiomas are hyperintense, not because of restriction, but rather because of T2 shine-through. This is because hemangiomas are characterized by an enlargement of the extra-cellular space compared to the normal tissue. As a result, such lesions are expressed with free diffusion and elevated ADC values. ADCs of hemangiomas are greater than those of solid malignant lesions but are lower than those of cysts, which is probably due to the vascular space and thus blood flow or perfusion within hemangiomas Goshima et al. (22).

The diagnosis of the 2 cases with hemangioma reported in this study was straightforward with the previous literatures as

Table 5 Features of six randomly selected cases of HCCs.

Criteria for differentiation	Case (1)	Case (2)	Case (3)	Case (4)	Case (5)	Case (6)
					Multi-focal	Multi-focal
Cirrhotic liver	+	+	+	+	+	+
Noncirrhotic	–	–	–	–	–	–
α-Fetoprotein	High	High	High	High	High	High
Diameter	4 cm	3 cm	7 cm	2 cm	2–5 cm	3–6 cm
T1WI	↓	↓	↓	↓	↓	↓
T2WI	↑	↑	↑	↑	↑	↑
Arterial phase	↑	↑	↑	↑	↑	↑
Portal phase	↓	↓	↓	↓	↓	↓
Delayed	↓	↓	↓	↓	↓	↓
Diffusion	↑restricted	↑	↑	↑	↑	↑
Mean ADC (b value = 100)	1.22	1.25	1.48	1.39	1.44	1.32
Mean ADC (b value = 500)	1.09	1.09	1.33	1.30	1.31	1.28

Arrows indicate increased ("up" arrow) or decreased ("down" arrow) signal intensity relative to the surrounding normal liver. Iso = isointense. (+) positive for cirrhosis. (−) negative for cirrhosis. 16 patients were evaluated 14 males and 2 females, 6 patients with multi-centric HCC.

Table 6 MR characteristic features of the metastatic lesions in the studied 40 patients.

Lesion	Sequence						
	T1	T2	Heavy T2	Arterial phase	Portal phase	Delayed phase	Diffusion
Colorectal carcinoma	↓	↑	↓	↓	↓	↓	↑restricted
Urinary bladder cancer	↓	↑	↓	↓	↓	↓	↑
Unknown primary	↓	↑	↓	↓	↓	↓	↑

Note: "Up" arrow indicates homogenous enhancement. "Down" arrow indicates washout.

regards characteristic noncontrast MRI signal, typical pattern of contrast enhancement as well as the diffusion study criteria.

Cholangiocarcinoma is the second most common primary malignant hepatic tumor in adults. The tumor can be classified as peripheral intrahepatic, hilar intrahepatic, or extrahepatic depending on its location. Intrahepatic cholangiocarcinoma is usually hypointense on T1-weighted MR images and hyperintense on T2-weighted images. On contrast-enhanced images, it demonstrates initial peripheral enhancement with concentric internal filling on delayed phase images (Manfredi et al.) (23).

Peripheral cholangiocarcinomas in the post-Gd arterial and portal venous phases the lesions show a strongly enhancing rim of glandular tissue with a hypovascular center. Peripheral washout with delayed and prolonged enhancement of the central fibrotic area is seen on later images. Central cholangiocarcinomas tend to present earlier with duct obstruction and are usually smaller at the time of diagnosis. Their margins are typically very ill-defined and there is little or no contrast with the adjacent liver on unenhanced images. The lesions are hypointense on both T1 and T2 weighted images. The characteristic feature is the presence of multiple dilated ducts, all converging and tapering fairly abruptly at the site of the obstructing mass. The tumors are hypovascular in arterial and portal phases with gadolinium, but like peripheral tumors, central lesions show delayed enhancement which persists Khan et al. (24).

In our study 2 male patients were evaluated one patient presented with hilar and one patient presented with peripheral cholangiocarcinoma. The lesions follow the characteristic MRI criteria at the previous studies. Histopathological confirmation was done for the 2 cases with cholangiocarcinoma.

The protocol of DWI in our study was carried out by using respiratory-triggered protocol with b value (100 s/mm^2) for proper detection of the hepatic focal lesions and b value (500 s/mm^2) to overcome the effect of capillary perfusion and water diffusion in extracellular extravascular space with subsequent reduction of signal from moving protons.

Aliya et al. (25) reported that the actual detection of liver tumor is reported to be greater at low b values (50–150 s/mm^2). Parikh et al. (9) reported significant improvement in the detection of focal liver lesions with low b value diffusion-weighted imaging compared with T2-weighted imaging. High b values are considered to be more important for the characterization of focal liver lesions; however, the high signal intensity of a lesion at high b values is most effectively interpreted in conjunction with the lesion characteristics seen with other conventional MR sequences.

The absolute ADC values of the different types of lesions were not similar, which is probably due to differences in techniques applied (b value, breath measurement methods, and mathematical technique applied). This finding was also recorded by Petra et al. (26), and they stated that in spite of increasing number of studies dealing with quantitative measurements of ADC in liver lesions, there are many discrepancies in the reported ADC values where there is no cutoff value for ADC values in normal parenchyma, benign and malignant lesions and this is often associated with many technical parameters such as the use of respiratory-triggered versus

breath-hold diffusion-weighted protocol and significantly b value as high b value results in low ADC value and vice versa. This is agreeing with Bachir et al. (11) who revealed that ADCs tend to be higher when using low b values.

The findings in our study were similar to the previous studies in many aspects as follows: the difference between the mean ADC values of benign and malignant lesions was significant and no significant differences in ADC values among the different benign lesions or among the different malignant lesions which supports similar previous findings where Onura et al. (27) and Latif et al. (28) stated that the mean ADC values of benign lesions were higher than malignant lesions and these differences were significant for all 3 diffusion gradients.

According to the present study it can be concluded that the diffusion-weighted MR imaging alone performs equally well as Gd-MRI in detection and differentiation of different hepatic focal lesions. In cases where gadolinium injection is not allowed, dynamic contrast-enhanced imaging can be replaced by a protocol based on unenhanced T1 and T2 weighted imaging combined with DWI. Adding DWI to Gd-MRI is more accurate, indicating that it should be included in oncologic liver MRI whenever possible.

Conflict of interest

Authors reported agreement and no conflict of interest.

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