ORIGINAL ARTICLE

DIFFUSION MRI OF FOCAL LIVER LESIONS

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ABSTRACT

OBJECTIVE: To evaluate the diagnostic contribution of diffusion weighted magnetic resonance imaging (MRI) for characterization of hepatic masses and differentiation of benign and malignant lesions. **MATERIALS AND METHODS:** Thirty-eight patients with focal liver lesions that were detected by US or CT scan underwent diffusion-weighted MRI (DWI) in addition to routine MRI. Two b values (b=0 s/mm^2, 1000 s/mm^2) were used and the quantitative analysis of the diffusion (ADC) was calculated. **RESULTS:** The liver masses were diagnosed on histology or had characteristic MRI findings and follow up of more than 6 months. The analyzed lesions were hemangioma (n = 9), cysts (n = 2), hepatocellular cancer (HCC) (n = 20), and metastases (n = 7). **CONCLUSION:** The diffusion-weighted MRI sequence is a useful diagnostic tool and it can contribute to accurate diagnosis and discrimination between benign and malignant hepatic masses. The single-shot EPI with iPAT and fat suppression has produced very satisfactory body diffusion results. DWI can significantly reduce the need for intravenous administration of contrast medium in evaluation of malignancies.

Key Words: DW MRI liver; focal liver lesions; ADC of focal liver lesions

Introduction

Diffusion is the term used for the randomized microscopic movement of water molecules known as Brownian motion. Diffusion is known to be a sensitive parameter in microscopic tissue characterization. Diffusion-weighted imaging can be performed after strong bipolar pulses are added to spin echo or gradient echo sequences with various b-values. The b-value represents the diffusion factor (measured in s/mm^2) and the strength of the diffusion gradients. The ideal b-value for lesion characterization is a trade-off between signal attenuation and perfusion contamination. This is generally possible using b-values between 400 and 1000 s/mm^2 for liver imaging. Pure diffusion contrast is obtained when using b-values above 1000 s/mm^2. However, image quality can be limited by signal loss that occurs at such b-values and higher.[1]

Diffusion-weighted MRI examinations have many technical restrictions such as respiratory, cardiac, or peristaltic physiologic activity, all of which affect image quality and make evaluation, which is very sensitive to motion, more difficult. Consequently, prior to the development of fast MRI techniques, diffusion-weighted imaging was limited to cranial examinations .With the development of echo-planar imaging (EPI), a fast MRI technique, radiologists have overcome the long imaging times and related artifacts of conventional techniques, and diffusion-weighted MRI is now available for abdominal evaluations as well.[2] 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 .[3]

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Material and Methods

Thirty-eight patients (27 men, 11 women; aged 75 to 35 years ,mean age, 48 years) with focal liver lesions

that were detected by US or CT scan underwent diffusion-weighted MRI in addition to routine MRI using 1.5-T whole body Philips machine and a body phased-array coil .The imaging parameters of DW MRI with SE-echo planar imaging (EPI) sequence were set as follows: repetition time ms/echo time ms: 1000/120; matrix: 128 128; field of view: 36 cm 36 cm; section thickness: 8 mm; gap: 2 mm. Two b values (b=0 s/mm^2, 1000 s/mm^2) were used, and scan time of 3 to 4 minutes. The quantitative analysis of the diffusion (ADC) was calculated on a workstation by applying a ROI on the image. Following DWI, contrast enhanced dynamic imaging was performed with an axial 3D gradient-echo T1-weighted MR sequence during and after administration of gadopentetate dimeglumine in a dose of 0.1 mmol/kg of body weight as a bolus injection. All patients included in this study gave informed consent prior to MRI examination.

The diagnosis of all cases of hepatocellular carcinoma and hepatic metastasis was confirmed by ∝-fetal protein, clinical data, ultrasound or CT, MR imaging, and pathology. Whereas the diagnosis of all the cases of cavernous hemangioma and hepatic cyst was confirmed by clinical data, ultrasound or CT , MR imaging, and follow-up observation. The following criteria were used to categorize focal liver lesions on MRI. A lesion was considered benign (mostly cyst and hemangioma) if the lesion was hyperintense on T2-weighted images and on DW images at b-0 s/mm^2 with a strong signal intensity decrease at b-1000 s/mm^2 and an ADC that was subjectively higher than that of the liver. A lesion was considered malignant (mostly metastasis or HCC) if the lesion was mildly to moderately hyperintense on T2-weighted images and on DW images at b-0 s/mm^2 and remained hyperintense compared with liver parenchyma at b-1000 s/mm^2, with an ADC qualitatively lower than that of the surrounding liver .

Results

The liver masses were diagnosed on histology or had characteristic MRI findings and follow up of more than 6 months. The analyzed lesions were cysts (n = 2), hemangioma (n = 9), hepatocellular cancer (HCC) (n = 20), and metastases (n = 7). In the present study, ADC map measurements of benign and malignant hepatic masses were significantly different . Cysts and hemangiomas had the highest ADC values while malignant masses had the lowest. (Tab. 1)

Number of cases	Focal hepatic lesions	ADC
2	Hepatic cyst	3.14 – 0.10 x10-3 s/mm^2
9	Hepatic hemangioma	2.35 – 0.21 x 10-3 s/mm^2
20	Hepatocellular carcinoma	0.90 – 0.20 x10-3 s/mm^2
7	Hepatic metastasis	0.80 – 0.22 x 10-3s/mm^2

Table 1: ADC value in the 38 focal hepatic lesions (b-1000 s/mm^2, mean – SD)

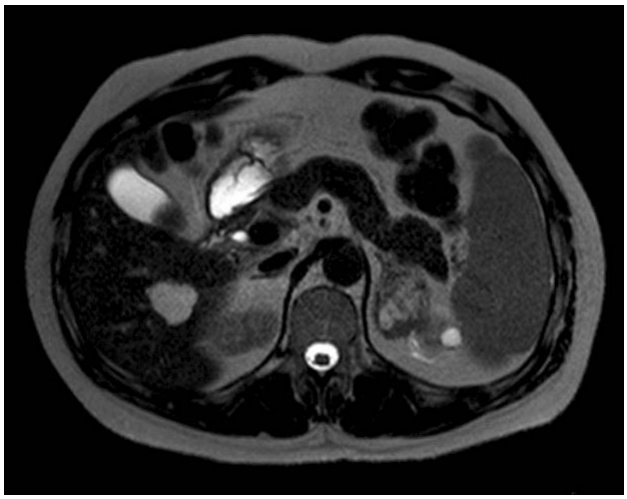


Figure 1A:

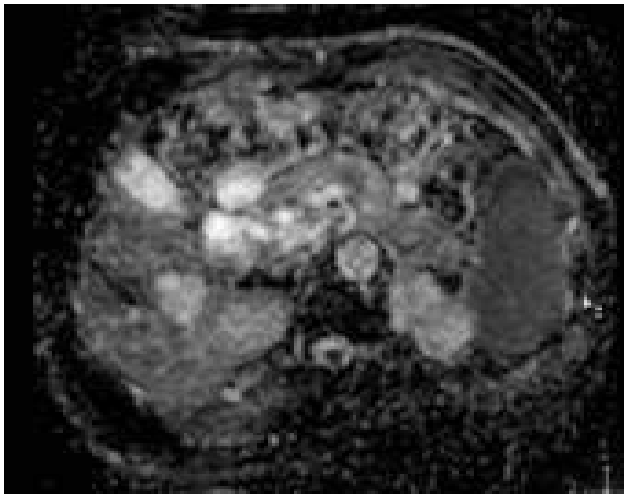


Figure 2A:

Figure 1C:

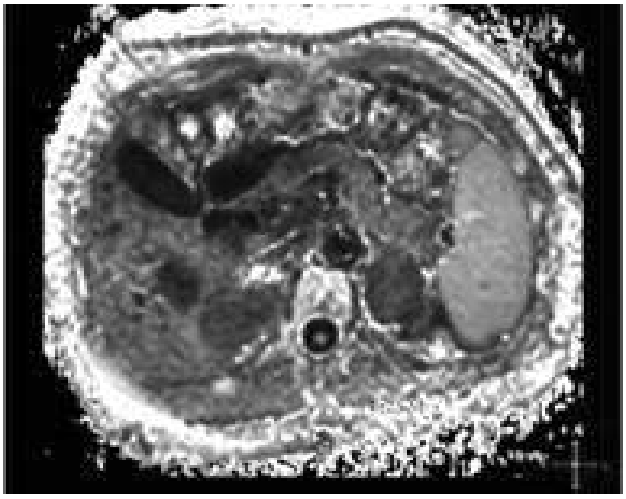


Figure 1A,B,C: MRI of 55-year-old woman with metastatic breast cancer. The solitary metastatic lesion of segment 6 demonstrates restricted diffusion: It is hyperintense on T2 WI (a) and remains hyperintense on DW MRI at b -1000 s/mm^2 (b) with low ADC 0.85 s/mm^2 (c).

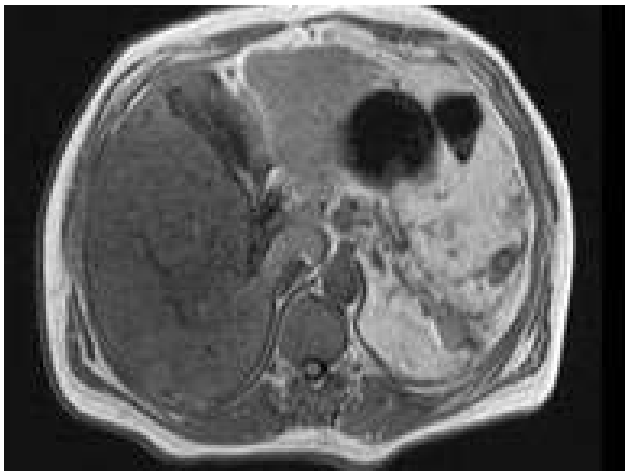
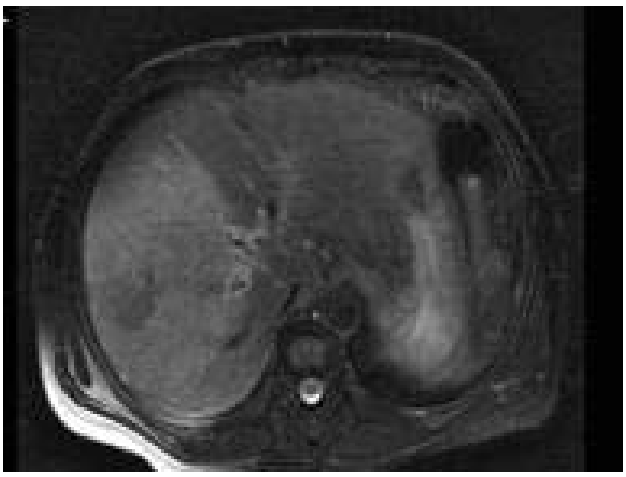


Figure 2A:



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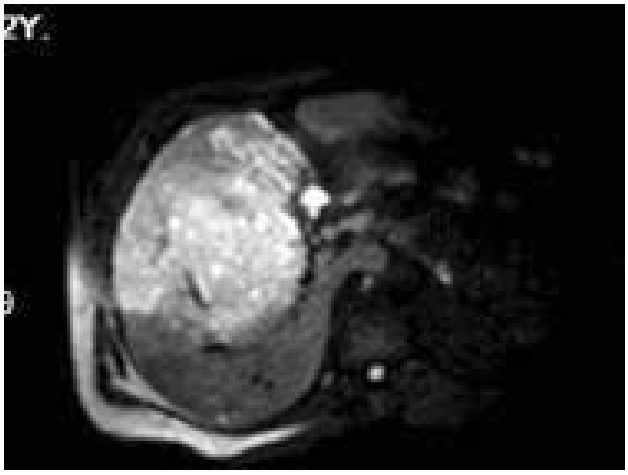

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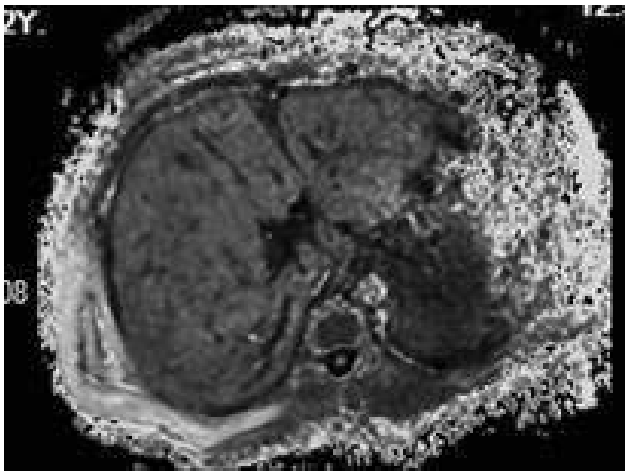

Figure 2D:

Figure 2E:

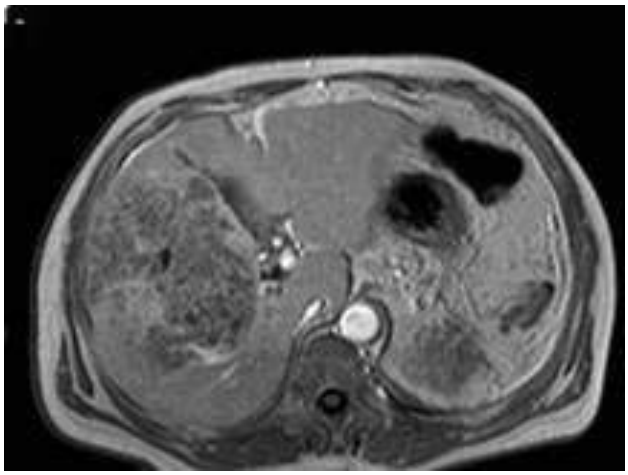

Figure 2A,B,C,D,E: MR images in 68-year-old man with large HCC of the right lobe. The lesion presents low T1 (a), high T2 signal (b), remains hyperintense on DW MRI at b_1000 sec/mm^2 (c), low ADC 0.96 s/mm^2 (d), compatible with a malignant lesion. Postcontrast T1-weighted image (e), confirms arterial-phase vascular non homogenous enhancing lesion.

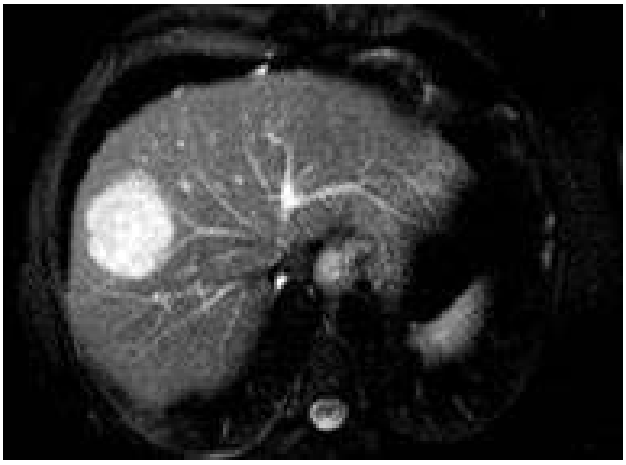

Figure 3A:

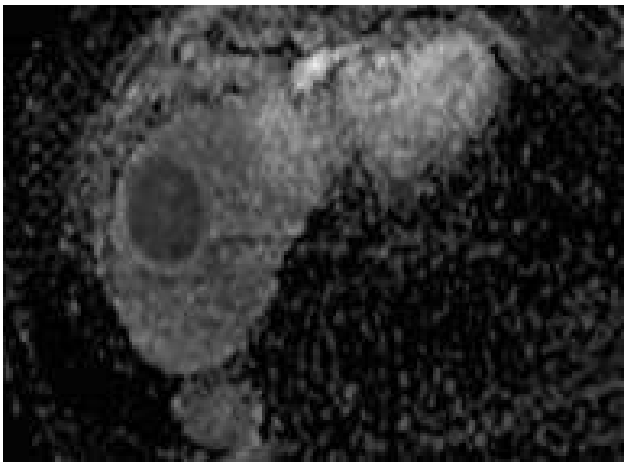

Figure 3B:

Figure 3C:

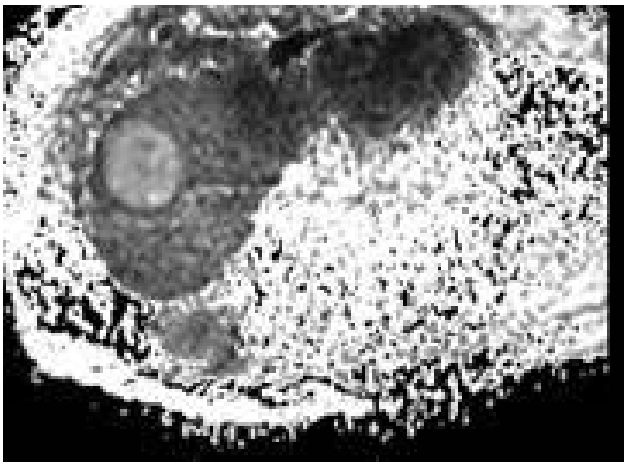

Figure 3A,B,C: MR images in 38 year-old woman man with hemangioma of sgment 5. The hemangioma demonstrates free diffusion: It is hyperintense on T2 WI (a) and hypointense on DW MRI at b-1000 s/mm^2 (b), with high ADC 2.4 s/mm^2 (c).

Discussion

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. Moreover, sometimes it is not possible to distinguish between highly vascular metastases and hemangiomas, even using dynamic examination.[4]

Diffusion imaging is MRI technique that can be used to quantify diffusion of water molecules noninvasively in biological tissues. The random motion of water molecules outside of the body is uninhibited and called free diffusion. However, in vivo, the diffusion is restricted because of macromolecules and intact cell membranes. Diffusion restriction increases in highly cellular tissues. In contrast, it decreases in low cellular tissues with large extracellular space or with broken down cellular membranes.[5]

DW images may be evaluated both qualitatively and quantitatively. The ADC, as a quantitative parameter calculated from DWI, combines the effects of capillary perfusion and water diffusion in the extracellular extravascular space.[6] The effect of perfusion on the ADC is most pronounced with low b values (e.g., b-0-50 s/mm†). By contrast, high b values mostly overcome this effect (e.g., b-1000 s/mm†). Areas of restricted diffusion show low ADC values and appear as a low signal area (opposite to DW images at high b values).[7] Our study was carried out with b values of 0 and 1000 s/mm^2.

The primary application of DWI was neuroimaging, with its greatest use being for detection of acute cerebral stroke.[8] With the advent of the EPI technique, DWI of the abdomen has become possible with fast imaging times minimizing the effect of gross physiologic motion from respiration and cardiac movement.[9] In addition, the use of iPAT (integrated Parallel Acquisition Techniques mSENSE and GRAPPA) has improved the image quality in EPI DWI, by reducing susceptibility artifacts.[10] In our study ,the used single-shot EPI with iPAT and fat suppression has produced very satisfactory body diffusion results. Recent studies have used DWI to characterize liver lesions and have shown that benign lesions, such as liver cysts and hemangiomas,

show higher ADCs than malignant lesions.[11] This is likely related to free water motion in benign lesions, and restricted water motion in the presence of a tumor. However, ADC values often vary from one study to another, partially related to different equipment and different b-values.[12] Fat suppression is also an important issue in achieving best results.[13]

In a study carried by Ichikawa etal,[14] b values were quite low (i.e.,1.6,16,and 55) and ADC values for abdominal organs were high. They reported that when the b value is kept low, factors like perfusion and T2 time have greater relative effect on ADC measurements. For that reason, they concluded that for abdominal diffusion studies, values >400 s/mm^2 might reflect ADC measurements more accurately. However, again, Ichikawa et al. reported that higher b values cause lower quality on diffusion weighted images and make evaluation harder. In our study, DW MRI was carried on using b values of 0 and 1000 s/mm^2. Adequate image quality was obtained by applying the parallel imaging technique, which uses the spatial information from a phased-array multicoil to reduce the number of signals needed for a given spatial resolution, thereby improving the quality of EPI and these results conform with those obtained with Zeich etal,[15] and K I kesmez etal.[16] On low b-value diffusion- weighted MR images, all masses were observed as hyperintense, whereas on high b-value images signals of cysts disappeared and signals of hemangiomas obviously decreased (Fig. 3). In contrast, since there is a limitation of diffusion in solid tumors, they were also observed as hyperintense on high b-value diffusion weighted image (Fig. 1,2) and these results conform with those obtained by several others.[17,18,19] Also, the ADC measurements of benign and malignant hepatic masses were significantly different, which supports similar previous findings.[20,21,22] Cysts and hemangiomas had the highest ADC values while malignant masses had the lowest. The mean ADC value for cystic lesions was 3.14 – 0.10 x10-3 s/mm^2, whereas for hemangiomas it was 2.35 – 0.21 x 10-3 s/mm^2. The lowest ADC values among the malignant masses belonged to metastases 0.80 – 0.22 x 10-3s/mm^2. This data is similar to Taouli et al. findings.[23] Mean ADC value for HCC was 0.90 – 0.20 x10-3 s/mm2 . According to Chan et al, [24] necrotic tumors present high ADC values .In our study, there were no necrotic or cystic lesions among the malignant tumors . Other limitation of our study, was the low number of lesions and the absence of solid benign hepatocellular lesions (e.g., hepatic adenoma, focal nodular hyperplasia), abscesses and parasitic cysts. Benign hepatocellular mass lesions were first evaluated by Taouli et al[23] and their ADC values were found to be lower than cysts and hemangiomas, and higher than malignant masses. In another study carried by Demir etal,[25] the mean ADC values of the 2 hydatid cysts were not significantly different from simple cysts. On the other hand, the mean ADC value was significantly lower for hepatic abscesses compared to simple cysts.

Conclusion

The diffusion-weighted MRI sequence is a useful diagnostic tool with no need to use contrast media, and it can contribute to accurate diagnosis and discrimination between benign and malignant hepatic masses. The single-shot EPI with iPAT and fat suppression has produced very satisfactory body diffusion results. This adds only 3 to 4 minutes to the entire examination and has proven very useful for the detection of primary as well as metastatic malignant tumors, differentiation between benign and malignant tumors. DWI significantly can reduce the need for intravenous administration of contrast medium in evaluation of focal liver lesions.

References

1. Namimoto T , Yamashita Y, Sumi S. Focal liver masses: characterization with diffusion-weighted echo-planar MR imaging . Radiology September 1997; **24:**739-74.

2. Coenegrachts K, Delanote J, Beek LT. Improved focal liver lesion detection: comparison of single-shot diffusion-weighted echoplanar and single-shot T2 weighted turbo spin echo techniques . The British Journal of Radiology 2007; **80:** 524 31.

3. Sandrasegaran K, Akisik FM, C. The Value of Diffusion-Weighted Imaging in Characterizing Focal Liver Masses. Academic Radiology October 2009; **16 (10):** 1208-14.

4. Zheng WW, Zhou KR, Chen ZW, Shen JZ, Chen CZ, Zhang SJ. Characterization of focal hepatic lesions with SPIO enhanced MRI. World J Gastroenterol 2002; **8 (1):** 82-6.

5. Kim T, Murakami T, Takahashi S, Hori M, Tsuda K, Nakamura H. Diffusion-weighted single-shot echoplanar MR imaging for liver disease. AJR Am J Roentgenol 1999; **173:** 393 8.

6. Sun XJ , Quan XY , Fan-Heng Huang FH et al . Quantitative evaluation of diffusion-weighted magnetic resonance imaging of focal hepatic lesions. World J Gastroenterol 2005; **11 (41):** 6535-7.

7. Taouli BB, Ichiba N .Diffusion-Weighted Magnetic Resonance Imaging . Medical Solutions October 2005: 91-5.

8. Lutsep HL, Albers GW, DeCrespigny A, Kamat GN, Marks MP, Moseley ME. Clinical utility of diffusion-weighted magnetic resonance imaging in the assessment of ischemic stroke. Ann Neurol 1997; **41:** 574 80.

9. Ichikawa T, Haradome H, Hachiya J, Nitatori T, Araki T. Diffusion-weighted MR imaging with single-shot echo-planar imaging in the upper abdomen: preliminary clinical experience in 61 patients. Abdom Imaging 1999; **24:** 456 61.

10. Yoshikawa T, Kawamitsu H, Mitchell DG. ADC measurement of abdominal organs and lesions using parallel imaging technique. Am J Roentgenol 2006; **187:** 1521 30.

11. Drew SJ ,LeeVS , Wong S. Focal Liver Lesion Detection and Characterization with Diffusion weighted MR Imaging: Comparison with Standard Breath-hold T2-weighted Imaging. Radiology March 2008 ; **246 (3)**.

12. Bruegel M, Holzapfel K, Gaa J, Woertler K, Waldt S, Kiefer B, Stemmer A, Ganter C, Rummeny EJ. Characterization of focal liver lesions by ADC measurements using a respiratory triggered diffusion-weighted single-shot echo-planar MR imaging technique.Eur Radiol. March 2008; **18 (3):** 477-85.

13. Bruegel M, Jochen G J. Diagnosis of hepatic metastasis: comparison of respiration-triggered diffusion-weighted echo-planar MRI and five t2-weighted turbo spin-echo sequences AJR. American journal of roentgenol. 2008; **191(5):** 1421-9.

14. 14- Ichikawa T, Haradome H, Hachiya J, Nitatori T, Araki T. Diffusion-weighted MR imaging with a single-shot echoplanar sequence: detection and characterization of focal hepatic lesions. Am J Roentgenol. February 1998; **170(2):** 397-402.

15. 15- Zech CJ, Herrmann KA, Dietrich O, Horger W, Reiser MF, Schoenberg SO. Black-blood diffusion-weighted EPI acquisition of the liver with parallel imaging: comparison with a standard T2-weighted sequence for detection of focal liver lesions. Invest Radiol. April 2008; **43(4):** 261-6.

16. K l kesmez O, Yirik G, Bayramoglu S, Cimilli T, Aydin S.Non breath hold high b value D W MRI parallel imaging techniquiewith : ADC determination in normal abdominal organs. Diagnostic and Interventional Radiology. 2008; **14 (2):** 83.

17. Moteki T, Horikoshi H, Oya N, Aoki J, Endo K. Evaluation of hepatic lesions and hepatic parenchyma using diffusion weighted reordered turbo FLASH magnetic resonance images. J Magn Reson Imaging 2002; **15:** 564 72.

18. Nasu K, Kuroki Y, Nawano S. Hepatic metastases: diffusion-weighted sensitivity encoding versus SPIO-enhanced MR imaging. Radiology 2006; **239:** 122 30.

19. Quan XY, Sun XJ, Yu ZJ, Tang M. Evaluation of diffusion weighted imaging of magnetic resonance imaging in small focal hepatic lesions: a quantitative study in 56 cases. Hepatobiliary Pancreat Dis Int. August 2005; **4 (3):** 406-9.

20. Kandpal H, Sharma R, Madhusudhan KS, Kapoor KS. Respiratory-Triggered Versus Breath-Hold Diffusion-Weighted MRI of Liver Lesions: Comparison of Image Quality and Apparent Diffusion Coefficient Values . AJR 2009; **192 (4):** 915-22.

21. Coenegrachts K, Delanote J, Ter Beek L, Haspeslagh M, Bipat S, Stoker J, Steyaert L, Rigauts H.Evaluation of true diffusion, perfusion factor, and apparent diffusion coefficient in non-necrotic liver metastases and uncomplicated liver hemangiomas using black-blood echo planar imaging.Eur J Radiol. January 2009; **69 (1):** 131-8.

22. Coenegrachts K, Matos C, ter Beek L, Metens T, Haspeslagh M, Bipat S, Stoker J, Rigauts H. Focal liver lesion detection and characterization: comparison of non-contrast enhanced and SPIO-enhanced diffusion-weighted single-shot spin echo echo planar and turbo spin echo T2-weighted imaging. Eur J Radiol. December 2009; **72 (3):** 432-9.

23. Taouli B, Vilgrain V, Dumont E, Daire JL, Fan B, Menu Y. Evaluation of liver diffusion isotropy and characterization of focal hepatic lesions with two single-shot echo-planar MR imaging sequences: prospective study in 66 patients. Radiology 2003; **226:** 71 8.

24. Chan JH, Tsui EY, Luk SH. Diffusion weighted MR imaging of the liver: distinguishing hepatic abscess from cystic or necrotic tumor. Abdom Imaging 2001; **26:** 161 5.

25. Demir OI, Obuz F, Sa ol O. Contribution of diffusion-weighted MRI to the differential diagnosis of hepatic masses. Diagn Interv Radiol 2007; **13:** 81-6.