The comparison of the efficacy of diffusion weighted imaging (DWI) sequences with 3 different T2-weighted sequences in the detection of focal liver lesions

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Abstract

Purpose : **In this study we aimed to compare and evaluate the efficacies of the low and high b value diffusion weighted imaging (DWI) sequences with three different T2-weighted (T2W) sequences.**

Materials and Methods : **255 liver lesions of 147 patients who had undergone MR examinations of the upper abdomen were evaluated. A maximum number of 4 lesions was taken for consideration in patients with multiple lesions. Low and high b valued DWI and 3 different T2W sequences (SSFSE, FIESTA, and PROPELLER FSE) were utilized. The evaluations were done by 3 different radiologists, by utilizing the double blind principle.**

Results : **The lesion detection performances of the b 0 DWI, b 600 DWI, FIESTA T2W, SSFSE T2W, and PROPELLER FSE T2W sequences, were 95.7 %, 66.3 %, 94.4 %, 92.8 %, and 93.8 %, in sequence order. The high b value DWI sequence was able to detect malignant lesions with a higher accuracy rate than the T2W sequences. There was a moderate to high rate of agreement among the interpreters, and the lesion-detection rates of the interpreters were in line with their levels of expertise.**

Conclusion : **Even though the higher lesion detection rates of the DWI sequences were not found to be statistically significant, it was concluded that making the evaluations with the addition of DWI to the imaging protocol would certainly decrease the lesion-missing rate, and it would be wise to utilize the DWI technique in routine liver MR imaging.** (Acta gastroenterol. belg., **2019**, 82, **267-272**).

Keywords : DWI, T2W, MRI, liver lesions

Introduction

The importance of MR in the imaging of the liver is on the rise. The high soft tissue-resolution capacity, the supreme detection and characterization capability of focal liver lesions in comparison to ultrasonography (US) and computed tomography (CT), and the lack of ionizing radiation, are all fundamental superiorities of MRI.

DWI was first utilized in neuroradiology. But by time, the utilization of DWI expanded, and this technique was included in upper abdominal MR imaging protocols, for the imaging of focal liver lesions, especially after the development of fast sequences and the elimination of motion artefacts originating from cardiac and respiratory motion and intestinal peristaltism.

One of the basic sequences utilized in upper abdominal MR imaging is the T2W sequence, and various modifications of this technique have been in use for this purpose. When imaging is done by means of conventional T2W sequences, the patients are required to hold their breaths for a considerable period of time, and this creates serious problems in patients who cannot do the task. Recently, some new techniques have been developed in order to overcome such problems.

The value of the DWI and T2W sequences in the imaging of focal liver lesions is well known. These two imaging modalities possess certain advantages and disadvantages. There exist various studies in the literature as to which one of these sequences detects focal liver lesions better. In this study of ours, we made it our purpose to investigate and evaluate the efficacies of the low and high ***b*** value DWI and 3 different T2W MR sequences (FIESTA, SSFSE, and PROPELLER FSE) in terms of detection of focal liver lesions.

Materials and methods

The study was based on the Helsinki Declaration, and an ethical committee approvement was obtained prior to the study. MR imaging of the patients were performed in a 1.5 Tesla scanner (General Electric Optima 360, Milwaukee, USA, 2014), by utilizing 16-channel phase array coils. Low (0 s/mm^2) and high (600 s/mm^2) ***b*** value DWI, and 3 different T2W sequences (FIESTA, SSFSE, PROPELLER FSE), were utilized in lesion evaluation. This study is a retrospective study and as the basis of our study, 255 focal liver lesions of 147 patients who underwent upper abdominal MR examinations between January 1, 2014 and July 31, 2016, were evaulated. The evaluations were made by 2 radiologists and 1 senior radiology resident, who had 16, 6, and 3 years of radiology experience, in order. These interpreters were numbered as 1, 2, and 3, consecutively.

MR examinations were performed in a 1.5 T system (General Electric, Optima 360, Milwaukee, U.S.A., 2014). 16-channel phase array coils were utilized in these examinations. The technical parameters of the DWI and T2W sequences are given in Table 1.

The detailed clinical data of the patients, pathology results in case patients were biopsied, and images and reports from previous US, CT, and MR examinations, were all taken as reference evaluations. Co-evaluation of clinical datas and imaging findings for 15 lesions (5,9 %),

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Table 1. — **The technical parameters of the sequences used in the study**

PARAMETERS	DWI b=0 sn/mm²	DWI b=600sn/mm²	SSFSE T2WI Coronal	PROPELLER FSE T2WI Axial	FIESTA T2WI Aksial
Obtained by	Free respiration	Free respiration	Breath-hold	Free respiration	Breath-hold
Fat suppression	+	+	+/-	+/-	+/-
Repetition time (TR)	7000	7000	700	11250	4
Echo time (TE)	92	92	80	130	1.82
b-value (s/mm²)	0	600	-	-	-
Slice thickness (mm)	5	5	5	5	5
Slice interval (mm)	1	1	1	1	1
Field of view (FOV) (mm)	360-480	360-480	360-480	360-480	360-480
Matrix	128x128	128x128	288x192	288x224	288x192

pathologic diagnosis for 48 (18,8 %), typical MRI findings for 184 (72,2 %), MRI and other imaging method's findings for 8 (3,1 %), were considered as reference evaluation. 1 adenoma, 1 cholangiocellular carcinoma, 1 dysplastic nodule, 5 focal nodular hyperplasia, 4 hepatocellular carcinoma and 36 metastasis by biopsy ; 75 cysts, 108 hemangiomas and 1 abscess with typical MRI findings ; 8 cyst hydatid lesions with MRI and US findings, were diagnosed. 5 hepatocellular carcinomas and 10 metastatic lesions were diagnosed by MRI and CT findings and detailed clinical datas.

The IBM SPSS Statistics Version 20.0 pocket program was used in the analysis of the data. Categorical measurements were summarized as numbers and percentages, whereas numeric measurements were put as mean values and standard deviations. The Kappa test was utilized in order to investigate the agreement among the interpreters, while the Chi square test was administered for the comparison of the positivity rates of the sequences. The statistical significance level was assigned as 0.05.

Results

147 patients were evaluated in the study. 84 (57 %) of the patients were females, while 63 (43%) were males. The mean age of the patients was 55.2 ± 14.7 years. 255 lesions were evaluated as the basis of the study. A maximum number of 4 lesions was taken into consideration in patients with multiple lesions. In such patients, the smallest lesions were evaluated. 56 lesions were malignant, while 199 were benign. The smallest lesion's size was 5 mm, whereas the largest one's size was measured as 170 mm. The mean size of the lesions was 24.3 ± 25.1 mm. 75 cysts, 108 hemangiomas, 46 metastases, 9 hepatocellular carcinomas, 5 focal nodular hyperplasias, 1 abscess, 1 adenoma, 1 cholangiocellular carcinoma, 1 dysplastic nodule, and 8 hydatid cysts, were detected in the course of the study. While some lesions were diagnosed radiologically, some others already had their pathologic diagnoses.

The interpreters performed the most of the diagnoses with the ***b*** 0 DWI, FIESTA, SSFSE, PROPELLER-FSE, and ***b*** 600 DWI, in sequence order. The reference evaluation rates and the lesion detection rates of the 3 interpreters were rather high. These data are being presented in Table 2. On the other hand, segmental dissemination of the lesions, too, was evaluated, and it was found that the segmental lesion detection rates of the interpreters showed similarity with their overall lesion detection rates. The ratios of the lesions according to the segmental dissemination were as follows ; 32 (12.6%) in segment 2, 8 (3.1%) in 3, 25 (9,8%) in segment 4, 7 (2.7%) in segment 5, segment 6, 70 (27.5%), 66 (25.9%) in segment 7 and 47 (18.4%) in segment 8.

The sequences in which the interpreters were not able to detect the malignant focal liver lesions were as follows, from the most to the least, in order : SSFSE,

Table 2. — T**he reference values and focal liver lesion detection rates of all interpreters, in numbers and percentages**

	Sequence	Number	%
Reference	*b* 0 DWI	248	97 %
	b 600 DWI	167	65 %
	FIESTA T2 WI	247	97 %
	SSFSE T2 WI	240	94 %
	PROPELLER FSE T2 WI	243	95 %
Interpreter 1	*b* 0 DWI	245	96 %
	b 600 DWI	172	67 %
	FIESTA T2 WI	242	95 %
	SSFSE T2 WI	239	94 %
	PROPELLER FSE T2 WI	241	95 %
Interpreter 2	*b* 0 DWI	243	95 %
	b 600 DWI	169	66 %
	FIESTA T2 WI	239	94 %
	SSFSE T2 WI	236	93 %
	PROPELLER FSE T2 WI	241	95 %
Interpreter 3	*b* 0 DWI	244	96 %
	b 600 DWI	166	65 %
	FIESTA T2 WI	241	95 %
	SSFSE T2 WI	235	92 %
	PROPELLER FSE T2 WI	236	93 %

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Table 3. — **The reference values and the malignant – benign lesion detection rates of the interpreters in numbers and percentages, in the *b* 0-600 DWI sequence**

Number		Benign		Malignant	
		Percentage	Number	Percentage	Number
b 0 DWI - Reference	Negative	7	4 %	0	0 %
	Positive	192	96 %	56	100 %
b 0 DWI - Interpreter 1	Negative	10	5 %	0	0 %
	Positive	189	95 %	56	100 %
b 0 DWI - Interpreter 2	Negative	12	6 %	0	0 %
	Positive	187	94 %	56	100 %
b 0 DWI - Interpreter 3	Negative	11	6 %	0	0 %
	Positive	188	94 %	56	100 %
b 600 DWI – Reference	Negative	87	44 %	1	2 %
	Positive	112	56 %	55	98 %
b 600 DWI – Interpreter 1	Negative	82	41 %	1	2 %
	Positive	117	59 %	55	98 %
b 600 DWI – Interpreter 2	Negative	82	41 %	4	7 %
	Positive	117	59 %	52	93 %
b 600 DWI – Interpreter 3	Negative	88	44 %	1	2 %
	Positive	111	56 %	55	98 %

Table 4. — **The reference values and the malignant – benign lesion detection rates of the interpreters in numbers and percentages, in the SSFSE T2W, PROPELLER T2W, FİESTA T2W sequences**

Measurements Number		Benign		Malignant	
		Percentage	Number	Percentage	Number
SSFSE T2 WI – Reference	Negative	11	6 %	4	7 %
	Positive	188	94 %	52	93 %
SSFSE T2 WI - Interpreter 1	Negative	11	6 %	5	9 %
	Positive	188	94 %	51	91 %
SSFSE T2 WI - Interpreter 2	Negative	15	8%	4	7 %
	Positive	184	92 %	52	93 %
SSFSE T2 WI - Interpreter 3	Negative	15	8 %	5	9 %
	Positive	184	92 %	51	91 %
PROPELLER FSE T2 WI – Reference	Negative	9	5 %	3	5 %
	Positive	190	95 %	53	95 %
PROPELLER FSE T2 WI- Interpreteri 1	Negative	10	5 %	4	7 %
	Positive	189	95 %	52	93 %
PROPELLER FSE T2 WI - Interpreter 2	Negative	10	5 %	4	7 %
	Positive	189	95 %	52	93 %
PROPELLER FSE T2 WI - Interpreter 3	Negative	15	8 %	4	7 %
	Positive	184	92 %	52	93 %
FIESTA T2 WI – Reference	Negative	5	3 %	3	5 %
	Positive	194	97 %	53	95 %
FIESTA T2 WI - Interpreter 1	Negative	10	5 %	3	5 %
	Positive	189	95 %	53	95 %
FIESTA T2 WI - Interpreter 2	Negative	13	7 %	3	5 %
	Positive	186	93 %	53	95 %
FIESTA T2 WI - Interpreter 3	Negative	11	6 %	3	5 %
	Positive	188	94 %	53	95 %

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PROPELLER FSE, FIESTA, and ***b*** 600. The detection rate of malignant lesions by the ***b*** 0 DWI sequence was 100 %. The evaluations done by all interpreters in all sequences are shown in Tables 3 and 4.

When the agreement among the interpreters was investigated, it was found that the agreements between Interpreters 1 and 2 and Interpreters 2 and 3 were high, while that between Interpreters 1 and 3 was at a moderate level, in the *b* 0 DWI sequence. In the *b* 600 DWI sequence, however, the agreement between Interpreters 1 and 3 was found to be high, whereas the agreements between Interpreters 1 and 2 and Interpreters 2 and 3 were mild. In the SSFSE sequence, a high agreement was found among all interpreters. A perfect congruence was found between Interpreters 1 and 2, in the PROPELLER FSE T2W sequence (their interpretations were exactly the same). On the other hand, in the same sequence, there were still high agreements between Interpreters 1 and 3, and Interpreters 2 and 3. The FIESTA sequence, on the other hand, gave a high agreement between Interpreters 1 and 2, while a moderate agreement was found between Interpreters 1 and 3 and Interpreters 2 and 3. The agreement coefficients among the interpreters are given in Table 5. Also, the agreement coefficients between the interpreters with reference evaluation in the sequences are given in table 6. According to the Kappa values, only moderate agreement was detected between reference-interpreter-2 for b 600 DWI sequence, whereas high agreement was found in other comparisons. In addition, the highest agreement with reference was detected in comparison with Interpreter-3 for the evaluation of the 600 DWI sequence.

When the success rates of detecting lesions smaller than 10 mm were investigated, the sequences were listed as follows, from the most successful to the least : PROPELLER FSE, *b* 0 DWI, FIESTA, SSFSE, and *b* 600 DWI. Table 7 shows the success rates of the sequences in focal liver lesions of sizes less than 10 mm.

Table 5. — **The agreement coefficients among the interpreters in the *b* 0-600 s/mm² DWI, SSFSE T2WI, PROPELLER T2WI and FIESTA T2WI sequences**

		Interpreter 1	Interpreter 2	Interpreter 3
b 0 DWI	Interpreter– 1	1	0.810	0.652
	Interpreter– 2	-	1	0.772
	Interpreter– 3	-	-	1
b 600 DWI	Interpreter – 1	1	0.584	0.790
	Interpreter – 2	-	1	0.591
	Interpreter – 3	-	-	1
SSFSE T2WI	Interpreter – 1	1	0.847	0.881
	Interpreter – 2	-	1	0.806
	Interpreter – 3	-	-	1
PROPELLER FSE T2WI	Interpreter – 1	1	1.000	0.774
	Interpreter – 2	-	1	0.774
	Interpreter – 3	-	-	1
FIESTA T2WI	Interpreter – 1	1	0.744	0.648
	Interpreter – 2	-	1	0.646
	Interpreter – 3	-	-	1

Table 6. — **The agreement coefficients between the interpreters with reference evaluation in the b 0-600 s/mm2 DWI, SSFSE T2WI, PROPELLER T2WI and FIESTA T2WI sequences**

		Kappa value
b 0 DWI	Reference-Interpreter – 1	0,818
	Reference-Interpreter – 2	0,727
	Reference-Interpreter – 3	0,770
b 600 DWI	Reference-Interpreter – 1	0,763
	Reference-Interpreter – 2	0,599
	Reference-Interpreter – 3	0,974
SSFSE T2WI	Reference-Interpreter – 1	0,966
	Reference-Interpreter – 2	0,874
	Reference-Interpreter – 3	0,847
PROPELLER FSE T2WI	Reference-Interpreter – 1	0,919
	Reference-Interpreter – 2	0,919
	Reference-Interpreter – 3	0,760
FIESTA T2WI	Reference-Interpreter – 1	0,752
	Reference-Interpreter – 2	0,652
	Reference-Interpreter – 3	0,716

Discussion

The detection of focal liver lesions is of utmost importance in terms of therapy planning (1). MR technology has evolved enormously, and its lesion detection capability in the liver has increased considerably, thanks to the supreme level of contrast and

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Table 7. The detection numbers and percentages of focal liver lesions of sizes less than 10 mm, in various sequences

Sequences	All lesions (n=255)		Lesion size ≤ 10 (n=80)		Lesion size > 10 (n=175)	
	n	%	n	%	n	%
b 0 DWI	244	95.7 %	69	86.3 %	175	100.0 %
b 600 DWI	169	66.3 %	33.3	41.6 %	135.7	77.5 %
FIESTA T2 WI	240.7	94.4 %	69.7	87.1 %	171	97.7 %
SSFSE T2 WI	236.7	92.8 %	68.7	85.9 %	168	96.0 %
PROPELLER FSE T2 WI	239.3	93.8 %	69.3	86.6 %	170	97.1 %

spatial resolution potential of MR imaging. One of the most striking developments in MR technology has been the introduction of the diffusion weighted imaging (DWI) technique. There exist a lot of studies in the literature which demonstrate the potential and profits of DWI in the evaluation of focal liver lesions (2,3,4).

At the end of our study, results similar to those in the literature were obtained. These results indicated that the low-*b*-value DWI was more effective than other sequences, in terms of focal liver lesion detection. Among the T2W sequences used in our study, however, FIESTA was found as the most successful one in lesion detection. But no statistically significant difference was found between the low-*b*-value DWI sequence and the T2W sequences, in terms of focal liver lesion detection ($p > 0.05$). It has been reported in a similar study conducted by Holzapfel et al, that liver imaging done by DWI has substantially increased the percentage of detecting small focal lesions of the liver (5).

Our study showed that the low-*b*-value DWI sequence was superior to the other sequences used in the study, in the detection of both the benign and malignant focal lesions of the liver. But it is hard to make a benign-malignant differentiation only by means of DWI. Various studies are being conducted with the purpose of understanding if MR imaging performed by the low and high-*b*-value DWI sequences is indeed capable of making a discrimination of benign-malignant lesions, and the issue is still debated (6). It has been reported that by the addition of the apparent diffusion coefficient (ADC) factor to the imaging protocol, it is indeed possible to make a benign-malignant differentiation. The utilization of the low-*b*-value Single Shot Echo Planar Imaging sequence (DW SS-EPI) has eased the detection of small liver lesions. The DW SS-EPI sequence is a very fast imaging modality, but its imaging quality is rather low, and especially when it is done with the high-*b*-value technique, it suffers from substantial spatial resolution loss (7,8). The SS-EPI DWI sequence done by the breath-triggered technique gives much better results than the breath-hold technique, in terms of both image quality and lesion detection capability (9,10). The recently developed parallel imaging technique has reduced the motion artefacts which arise due to intestinal, respiratory, or cardiovascular activity (8,9,11). The parallel imaging technique has also made possible serious increases in the signal-to-noise ratio (SNR) (8,11). In our study, too, the free breathing technique was utilized. The results of our study was in congruence with the literature. But despite all the developments in sequence technology, there still are restrictions to the detection of certain lesions such as those situated at the subdiaphragmatic or subhepatic locations and those with sizes smaller than 10 mm.

Our study revealed that the DWI and T2W sequences showed similar efficacies in the detection of benign focal liver lesions. Yang et al, too have published results similar to ours. In our study, the detection rates of the high-*b*-value DWI sequence has been found to be rather low. The relatively high number of benign lesions in our study may be attributed to this low success rate.

In our study, the FIESTA sequence has been found to be more successful than the other T2W sequences in terms of lesion detection. The FIESTA is a fast sequence, and it is of great value in the detection of focal lesions of the liver, if not in their characterizations (12,13). One of the most valuable results of our study seems to be the fact that the addition of the FIESTA sequence in routine liver protocols will add much to the detection capacity of liver MR imaging.

In our study, the success rate of the SSFSE sequence in the detection of focal liver lesions was found to be lower in comparison to the PROPELLER FSE and FIESTA sequences. The advantage of the SSFSE sequence is its high speed, compared to the other breath-hold sequences. In SSFSE imaging, motion artefacts originating from cardiac and respiratory actions and intestinal peristaltism can be minimized. But according to the results of our study, the success rate of the SSFSE sequence in the detection of benign lesions is slightly lower, compared to other sequences. Certain optimization difficulties, the subdiaphragmatic locations of some lesions, and sizes of some lesions being less than 10 mm, may be among the underlying reasons to this finding.

Generally speaking, the biggest drawbacks faced in upper abdominal MR imaging are the SNR losses originating from various artefacts. These artefacts often impair the contour sharpness of the liver and lead to blurring of the images. This, in turn, makes it more difficult to detect those lesions located in the left lobe of the liver or in those areas of the liver just under the diaphragm (14,15). In order to overcome this problem, certain MR techniques have been developed, such as the

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"respiratory–ordered phase encoding" and the "gradient moment dulling" techniques, and some breath–hold techniques. But there are limitations to these modalities, too (16,17,18). In order to minimize this problem, a technique called PROPELLER has been developed, which was also tried and evaluated in our study. In this technique, overlapping images are reconstructed in order to obtain images of high SNR (19). The most disadvantageous feature of this technique is its rather long examination time.

The lesion-detection success rates of the T2W sequences utilized in our study were found to be high, but still some lesions escaped detection. This may be due to certain factors, some of which may be the differences in the expertises of the interpreters, the iso or hyperechoic natures of some lesions, the sizes of some small lesions being less than 10 mm, and the subdiaphragmatic locations of some lesions.

The fact that the lesion-detection rates of the T2W sequences in malignant lesions may be attributed to the rather low signal intensities of malignant lesions. On the other hand, it is known that the lesion-detection strength of the SSFSE T2W sequence is lower in malignant lesions, in comparison to benign ones. We suggest that the T2W sequences be used in conjunction with the DWI sequence in order not to miss malignant lesions. It is obvious that the co-utilization of these two techniques significantly increases the lesion detection rates.

Another aspect of our study was the issue of congruence among the interpreters. It was found that the most experienced interpreter had performed the highest detection rate, while the least experienced interpreter had the lowest. Thus it was concluded that expertise is a very important factor in this aspect.

Fat suppression was utilized in some T2W sequences, while some other T2W sequences were performed without fat suppression. This, of course, creates a restriction in terms of standardization. The lack of comparison with the contrast-enhanced series, the fact that not all lesions have tissue diagnoses, and the low number of malignant lesions, may be listed as the other factors contributing to the restriction of the study. There is a need for larger series and prospective randomized clinical trials on the issue, in order to obtain more data for evaluation.

Conclusion

The results of our study showed that the low-*b*-value DWI sequence was more effective than the T2W sequences in terms of detection of focal liver lesions. The low-*b*-value DWI sequence is especially valuable in the detection of malignant liver lesions. On the other hand, the study also demonstrated that the high-*b*-value DWI sequence was more successful than the T2W sequences in the detection of malignant focal liver lesions.

As a final conclusion, it must be emphasized that the inclusion of the FIESTA and the low and high-*b*-value DWI sequences in routine upper abdominal MR examination protocols will increase the efficacy of the lesion detection process.

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