Journal of Magnetics 17(2), 158-162 (2012) http://dx.doi.org/10.4283/JMAG.2012.17.2.158

Quantitative Analysis of T1 Weighted Images due to Change in TI by Using the Inversion Recovery in 3.0T Brain MRI Examination

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(Received 16 May 2012, Received in final form 7 June 2012, Accepted 8 June 2012)

Although 3.0T magnetic resonance imaging (MRI) has the advantages of a higher signal to noise ratio (SNR) and contrast than 1.5T MRI, there are limitations on the contrast between white and grey matter because of the long T1 recovery time when T1 images are obtained using the Spin Echo Technique. To overcome this, T1 weighted images are obtained occasionally using the inversion recovery (IR) technique, which employs a relatively long TR. The aim of this study was to determine the optimal TI in a brain examination when a T1 weighted image is obtained using the IR technique. Eight participants (male: 7, female: 1, average age: 34 ± 14.11) with a normal diagnosis were targeted from February 18, 2012 to February 27, 2012, and the contrast between white and grey matter as well as the contrast to noise ratio (CNRs) in each participant were measured. The CNRs of white matter and grey matter were highest at TI = 600, 650, 750, 900, 1050 and 1100 ms when the TR was 1100, 1400, 1700, 2000, 2300 and 2600 ms, respectively. Therefore, as the TIs were 44.425 ± 0.877% of the TRs in the TR range of 1400-2300 ms, the optimal T1 weighted images that describe the contrast between white and grey matter can be obtained if the TIs are compensated for with 44.425 ± 0.877% of the TRs in the time of setting TIs.

Keywords : SNR, T1 recovery time, CNR

1. Introduction

Recently, the use of 3.0T MRI equipment has increased noticeably [1, 2]. 3.0T MRI has the advantage of a higher signal to noise ratio than 1.5T MRI, which means that 3.0T MRI gains double the signal intensity in the same period of time and also obtains images with high resolution and the signal intensity maintained. This may be useful in diseases, such as an acute cerebral infarction that needs rapid image acquisition [3]. In 3T magnetic resonance imaging, while the susceptibility, chemical shift, specific absorption rate (SAR) and T1 recovery time increase, the T2 recovery time decreases. In particular, the increase in T1 recovery time has a considerable effect. Depending on the tissue, the T1 recovery time increases to 25-30% in 3T. This increase in T1 recovery time improves the image quality by improving the contrast in time-of-flight magnetic resonance angiography and increases the T1 contrast effect by contrast media. Therefore, 3T has the same effect as 1.5T with a half of the contrast media used in 1.5T, whereas the T1 contrast among tissues decreases in a regularly repeating period of time. In other words, the T1 recovery time is long in 3.0T MRI. Moreover, the contrast between white and grey matter will decrease if the T1 weighted images are gained using the SE technique that employs a Short TR (400-600 ms) [4, 5].

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As a way to solve this problem, the T1 weighted images can be obtained using the gradient echo technique instead of the spin echo technique. T1 weighted image scan be obtained using the inversion recovery (IR) technique, which uses a relatively long TR. Unlike the spin echo, the IR first inverts the ordinate magnetization axis in the opposite direction and then obtains an echo using the spin echo or turbo spin echo. The contrast of an image varies with the inversion time (TI) [6]. The purpose of this study was to determine the optimal TI when gaining a T1 weighted image in a brain examination.

2. Experiment Materials and Method

Eight adults (male: 7, female: 1, average age: 34 ± 14.11) with a normal diagnosis from February 18, 2012 to February 27, 2012 were enrolled in this study, and 3.0T MR system (Magnetom tim trio, SIEMENS, Germany) was the equipment employed. The following parameters were used: FOV (field of view) = 230 mm, TE (time of echo) = 20 ms, Matrix size = 204 × 256 and NEX (average) = 1. Five TIs (time of inversion) were set with respect to each TR (time of repetition) (Table 1) to gain the optimal TIs when the T1 weighted images were obtained using the IR technique.

The five TIs with respect to each TR value correspond to approximately 40, 45, 50, 55 and 60% of each TR. After gaining each image, the TIs were compared and analyzed using the currently employed TI (TI = TR × 1/2). Quantitative and qualitative analyses of the images were performed. Quantitative analysis measured the white matter, grey matter, signal intensity of the background in the images gained due to a change in TR and the TI. The measurements were taken 5 times on the region of interest of the same size to reduce the error (Fig. 1).

Qualitative analysis adopted the method employing 2 radiology medical doctors and 4 radiology engineers to evaluate the anatomical structure of the brain by a naked eye examination. Eq. (1) was used to determine the contrast to noise ratio.

Table 1. Five TIs were set with respect to each TR.

TR (ms)	TI (ms)
1100	350, 450, 550, 650, 750
1400	500, 600, 700, 800, 900
1700	650, 750, 850, 950, 1050
2000	800, 900, 1000, 1100, 1200
2300	950, 1050, 1150, 1250, 1350
2600	1100, 1200, 1300, 1400, 1500

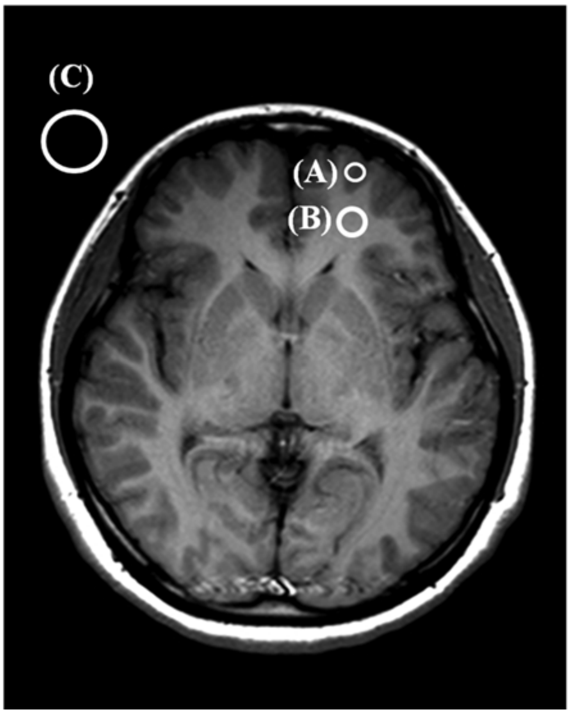

Fig. 1. Image gained due to a change in TR and TI gray matter (A), white matter (B), Background (C) signal intensity and CNR were measured.

$$\text{CNR} = \frac{\text{SI (region)} - \text{SI (surrounding tissues)}}{\text{SDN}} \quad (1)$$

CNR: contrast to noise ratio
SDN : standard deviation of noise in background
SI : signal intensity

For the statistical analysis method, the signal intensity of the white and grey matter in each image gained due to a change in TI depending on the TR, and the contrast to noise ratio (CNR) were measured and compared. The measured values were analyzed using an ANOVA test (SPSS 16.0, USA). A Dunnett test was performed for post-verification. In addition, to determine the relationships between the TR and TI depending on the TR, the presently used TI values (TI = TR × 1/2) were designated as the A-group. The TI values (TI = TR 44.425 ± 0.877%) when the CNR of the white matter and grey matter was highest with each TR were designated as the B-group. The relationship between the A-group and B-group were examined using a nonparametric Wilcox test.

3. Results

3.1. Quantitative Analysis

The CNRs of the white matter and grey matter were

Table 2. Contrast to noise ratio due to a change in TR and TI.

TR	TI (msec)	W.M	G.M	SI (b)	CNR	P
1100 ms	350	120.32 ± 7.23	42.32 ± 7.2	2.3 ± 3.2	33.77	0.025*
	450	204.86 ± 7.83	110.33 ± 9.17	2.6 ± 2.9	36.36	
	550	306.07 ± 8.17	204.07 ± 9.17	2.7 ± 3.1	37.78	
	650	396.9 ± 8.13	294.63 ± 10.33	2.67 ± 3.4	38.30	
	750	476.7 ± 8.26	379.63 ± 11.03	3.13 ± 2.9	31.01	
1400 ms	500	208.9 ± 8	87.33 ± 8.7	3.1 ± 2.6	39.22	0.040*
	600	306.77 ± 7.63	182.63 ± 11.27	3.13 ± 1.3	39.66	
	700	393.23 ± 8.1	274.5 ± 10.33	3.4 ± 2.2	34.92	
	800	468.47 ± 8.1	350.43 ± 12.2	3.4 ± 2.6	34.72	
	900	540.67 ± 9.1	428.9 ± 11.3	3.5 ± 2.5	31.93	
1700 ms	650	317.5 ± 9.6	172.6 ± 14.1	3.2 ± 2.3	45.28	0.025*
	750	397 ± 8.33	253.17 ± 14.07	3.06 ± 3.2	47.00	
	850	469.17 ± 9.5	332.37 ± 13.8	3.3 ± 2.8	41.45	
	950	536.9 ± 10.2	408.13 ± 13.43	3.27 ± 3.5	39.41	
	1050	592.7 ± 8.97	470.6 ± 13.03	4.47 ± 3.9	27.32	
2000 ms	800	408.87 ± 7.67	346.3 ± 15.57	3.42 ± 3.61	47.54	0.035*
	900	476.23 ± 9.47	318.3 ± 17	3.3 ± 2.33	47.86	
	1000	540.73 ± 10.23	395.53 ± 15.17	3.32 ± 4.31	43.73	
	1100	593.87 ± 9.47	457.27 ± 16.53	3.17 ± 2.88	43.09	
	1200	645.5 ± 10.37	521.67 ± 17.37	3.63 ± 5.3	34.11	
2300 ms	950	484.23 ± 7.9	339.23 ± 20.1	3.44 ± 2.99	42.15	0.040*
	1050	548.87 ± 10.63	390.83 ± 21.5	3.34 ± 1.87	47.32	
	1150	597.97 ± 9.4	452.33 ± 20.3	3.47 ± 5.22	41.97	
	1250	647.93 ± 9.03	509.07 ± 18.63	3.52 ± 3.33	39.44	
	1350	690.6 ± 8.7	566.77 ± 19.9	3.54 ± 2.47	34.98	
2600 ms	1100	559.97 ± 9.97	390.87 ± 20.37	3.87 ± 3.39	43.70	0.045*
	1200	608.47 ± 8.83	455.3 ± 17.97	3.73 ± 2.42	41.06	
	1300	659.5 ± 10	512.07 ± 18.33	3.84 ± 4.11	38.39	
	1400	696 ± 10.01	567.8 ± 17.97	4.26 ± 2.99	30.09	
	1500	727.73 ± 11.03	610.4 ± 16.13	3.8 ± 3.33	30.87	

W.M = White Matter, G.M = Gray Matter, SI(b) = Signal Intensity of the Background, CNR = SI (W.M – G.M)/SI(b)
Interaction effect using an ANOVA test and Dunnett test

highest at TI = 650, 600, 750, 900, 1050 and 1100 ms when TR = 1100, 1400, 1700, 2000, 2300 and 2600 ms, respectively (Table 2 and Fig. 2). The currently used TI values (TI = TR 1/2) were designated as the A-group to determine the relationships between the TR and TI due to a change in the TR. The highest TI values (TI = TR 44.425 ± 0.877%) with each TR were designated as the B-group (Table 3). According to the nonparametric Wilcoxon test on the relationships between the A-group and B-group, p = 0.046 when TR = 1400, 1700, 2000 and 2300 ms.

3.2. Qualitative Analysis

To evaluate the images due to a change in each TR and each TI, the TI values in respect to each TR were sorted into A, B, C, D and E in decreasing TI, and the TR values were 1400, 1700, 2000 and 2300 ms when p = 0.046 according to the Wilcoxon test. In an evaluation of the images due to a change in each TR, the assessors reported that group-B not only had a high contrast between the white and grey matter but also the anatomical structure could be distinguished (Table 4).

4. Discussion

The image quality of most neurological images is improved in 3T [7-9]. On the other hand, although the susceptibility, chemical shift, specific absorption rate (SAR) and T1 recovery time increase in 3T magnetic resonance imaging, the T2 recovery time decreases. In particular, the increase in T1 recovery time has a considerable effect, which means that the T1 recovery time is long in 3T MRI. Therefore, when T1 weighted images are gained

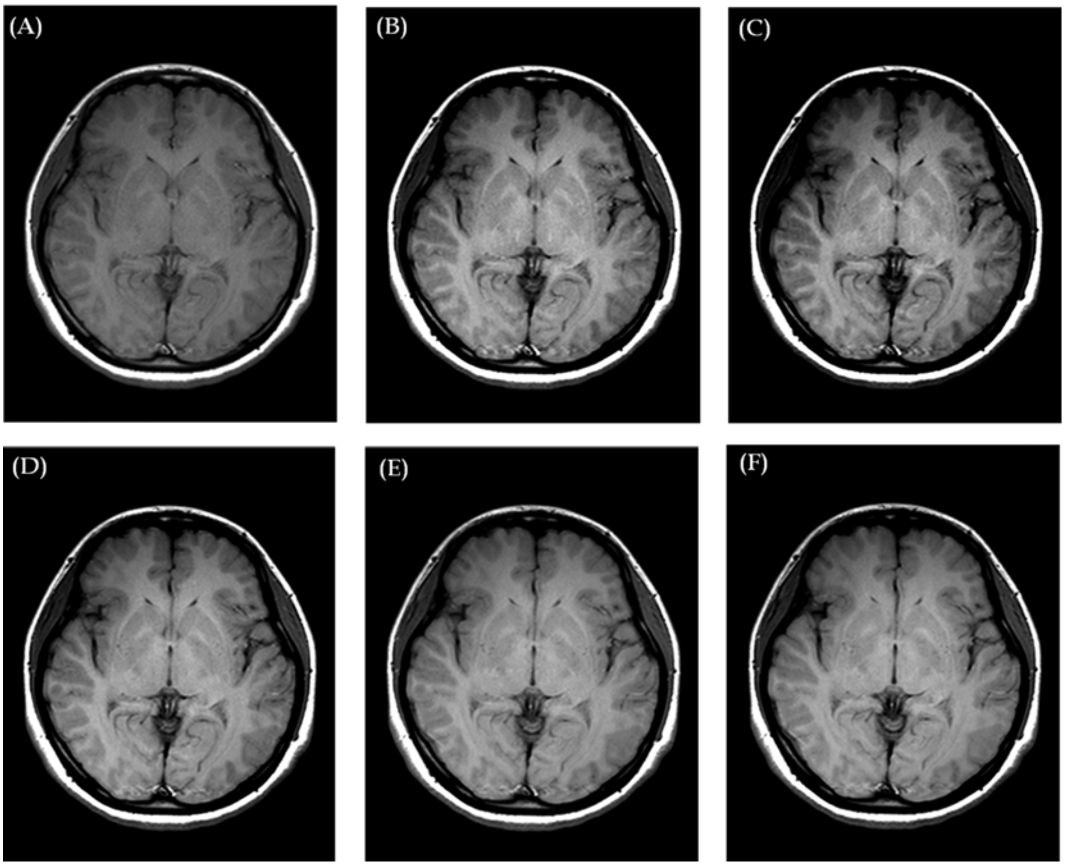

Fig. 2. The CNRs of the white matter and gray matter were highest (A) when TR=1100 ms, TI = 650 ms, (B) when TR = 1400 ms, TI = 600 ms, (C) when TR = 1700 ms, TI = 750 ms, (D) when TR = 2000 ms, TI = 900 ms, (E) when TR = 2300 ms, TI = 1050 ms, (F) when TR = 2600 ms, TI = 1100 ms at these values.

Table 3. TI due to a change in TR.

TR	1100 ms	1400 ms	1700 ms	2000 ms	2300 ms	2600 ms
A	550 ms	700 ms	850 ms	1000 ms	1150 ms	1300 ms
B	450 ms	600 ms	750 ms	900 ms	1050 ms	1200 ms

using a short TR (400-600 ms), 3.0T MRI has the problem that contrast between the white matter and grey matter decreases compared to 1.5T MRI [4, 5]. To solve this problem, T1 weighted images can be obtained using the gradient echo technique instead of the spin echo technique. T1 weighted images can also be obtained using the Inversion Recovery (IR) technique, which employs a relatively long TR. In general, for T1 weighted images that use the spin echo, it is disadvantageous for the scan time, and the gray/white matter differentiation decreases. For this reason, T1 weighted images that employ the IR technique provide better image quality than the T1 weighted images using the Spin Echo technique [10]. On the other hand in 3T Brain MRI, the T1 weighted images are obtained mainly using the Spin Echo and IR. The Spin Echo method has outstanding T1 Contrast but can induce a high SAR and pulsation artifact. In addition, it is sensitive to the patient's movement and requires a long examination time. The IR method can be a time consuming examination with a high SAR, Pulsation artifacts, IR pulse suppressing vascular flow, etc.. Nevertheless, it is used occasionally instead of the Spin Echo because of its outstanding T1 Contrast. For the IR, the contrast of an image varies with the inversion time (TI) [6]. Therefore, the purpose of this study was to acquire an optimal TI when a T1 weighted image is gained through the IR technique. When TR = 1100, 1400, 1700, 2000, 2300 and 2600 ms, its corresponding optimal TI was 650, 600, 750, 900, 1050 and 1100 ms, respectively. At these values, the CNRs of white and gray matter were highest. Statistical analysis of the relationships between the A-group and B-group to determine the optimal TIs, revealed a p value of 0.046, indicating a meaningful difference between the two groups. Even in qualitative analysis, the best evaluation was possible at all TIs corresponding to 44.425 ± 0.877% of the TRs. This study measured the CNRs of the white

Table 4. Image evaluation for a change in TR and TI.

TR		A (TI = 500 ms)	B (TI = 600 ms)	C (TI = 700 ms)	D (TI = 800 ms)	E (TI = 900 ms)
1400 ms	Good	0	5	3	0	0
	Moderate	0	1	3	5	2
	Poor	6	0	0	1	4
1700 ms	Good	0	4	3	1	0
	Moderate	0	2	3	5	1
	Poor	6	0	0	0	5
2000 ms	Good	0	5	4	0	0
	Moderate	2	1	2	2	0
	Poor	4	0	0	4	6
2300 ms	Good	0	6	4	0	0
	Moderate	1	0	2	0	0
	Poor	5	0	0	6	6

matter and gray matter due to a change in TI with respect to a TR. Therefore, diagnostic efficiency should increase if an image can be obtained by setting a proper TI.

5. Conclusions

Statistical analysis on the relationships between the A-group and B-group was performed to determine the optimal TI values. The results revealed a meaningful difference between the two groups. Even qualitative analysis, the best evaluation was possible at all TIs corresponding to $44.425 \pm 0.877\%$ of the TRs. Based on this result, the optimal T1 weighted images showing better contrast between the white and gray matter could be obtained when the images are gained by setting the TIs corresponding to $44.425 \pm 0.877\%$ of TRs, which are in the range of 1400-2300 ms.

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