

# Comparative Study of MRI Images in Accordance with Gradient Power Changes

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## ABSTRACT

However, many hospitals conduct examinations based on the initial setting of gradient applied to the equipment, without altering the gradient setting for the area under examination based on its characteristics. Accordingly, this study measures the signal intensity and changes in imaging according to changes in MRI gradient power appropriate for T1 and T2 examination, for possible utilization as basic data for gradient power research and studies in MRI. Bottle Phantom was positioned inside the head & neck coil, and the T1-T2Brain Sequence was used for measurement. In the case of T2, the Repetition TR was fixed at 4,500 msec, and changes were applied to the TE in five incremental steps to obtain the measurement. In addition, for T1, TR 500 msec was fixed, and changes were applied to the TE in four incremental steps in obtaining the measurement. For SNR and CNR, Image J was used and the standard deviation. Matlab was used to measure PSNR and UACI. Image evaluation in accordance with the change in gradient power at T2. In the case of SNR, normal SLT was the highest at TE 60 msec with 581.4 for Fine SLT, at TE 60 msec with 623.1, in the case of Low SAR, at TE 80 msec with 610.2 was the highest. It was evident that SNR decreased with TE increase. 4 Image evaluation at T1 in accordance with the change in gradient power SNR for normal SLT was found to be the highest at TE 40 msec with 495.5, and TE 30 msec was found to be the lowest. Fine SLT was found to be the highest at TE 30 msec with 485.6, and low SAR was found to be the highest at TE 40 msec with 503.0. In the case of PSNR, for Normal SLT, it was the largest at TE 40 msec with 24.1, without any significant difference from TE 10 to 30 msec. Determination of MRI signal intensity in accordance with changes in gradient power suggests that in the case of T2, the intensity of all the signals decreased when the TE was 80 msec and above. In addition, the intensity of all the signals varied after changing the gradient power. In the case of T1, the signal intensity appeared to be strong at TE 40 msec. In T2, the intensity of all of the signals varied with the gradient power.

**Keywords:** Gradient Power, Turbo Spine Echo, Repetition Time, Echo Time, Gradient field.

**Mathematics Subject Classification:** 92C50, 92C55

**Journal of Economic Literature (JEL) Classification:** I19

## Introduction

Radiation is utilized as an aid to diagnose and treat illness in patients. Computed Tomography (CT), a general radiography examination utilized in medical institutions,

uses ionizing radiation<sup>1,2</sup>. However, Magnetic Resonance Image (MRI) uses radio frequency, which is non-ionizing radiation based on the hydrogen nucleus inside the patient's body to produce medical images without exposure to ionizing radiation. MRI medical image is created via a number of factors including gradient field, slice selection, slice thickness, frequency encoding, phase encoding, and Fourier transformation among others<sup>3</sup>. Among these additional factors, gradient has an effect on the time of pulse sequence. Each time gradient is generated, the MRI equipment supplies power until

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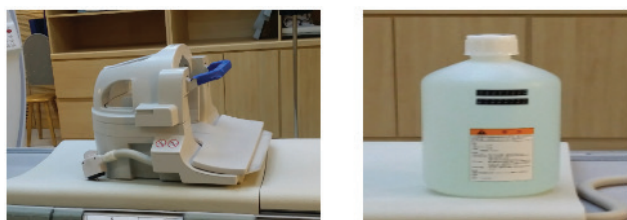
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the maximum amplitude is reached, and the gradient remains for a fixed amount of time and is reversed during the same time. Thus, each time gradient is generated, several msec of dead time result. Accumulation of such dead time increases the examination time for the patient triggering artifacts associated with patient’s movement. Therefore, conducting the MRI by changing the gradient decreases the time and prevents movement artifacts<sup>4, 5</sup>. However, many hospitals conduct examinations based on the initial setting of gradient applied to the equipment, without altering the gradient setting for the area under examination based on its characteristics. Accordingly this study measures the signal intensity and changes in imaging according to changes in MRI gradient power appropriate for T1 and T2 examination, for possible utilization as basic data for gradient power research and studies in MRI.

**Measuring Instrument and Method**

**Measuring Instrument:** We MRI images were measured utilizing Superconducting System 1.5T MRI and Head & Neck Coil (Fig 1). The Bottle (2,000cc) Phantom was used to measure the image (Fig 2). Furthermore, Image J, which was developed by the US National Institutes of Health for the purpose of research analysis, was used to measure the Signal-to-Noise Ratio (SNR) and Contrast-to-Noise Ratio (CNR) in the image obtained from the MRI. Matlab was used for the measurement of Peak Signal-to-Noise Ratio (PSNR) and Unified Average Changing Intensity (UACI).



**Figure 1: Head & Neck Coil** **Figure 2: Bottle Phantom**

**Method of Research**

**Method of Measurement:** Bottle Phantom was positioned inside the head & neck coil, and the T1-T2 Brain Sequence was used for measurement. In the case of T2, the Repetition Time (TR) was fixed at 4,500 msec, and changes were applied to the Echo Time (TE) in five incremental steps (60, 70, 80, 90, and 100 msec) to obtain the measurement. In addition, for T1, TR 500 was fixed, and changes were applied to the TE in four

incremental steps (10, 20, 30, and 40 msec) in obtaining the measurement. Each gradient power was changed to Fine SLT, low SAR, and normal SLT, to determine the changes in image intensity. The parameters used for measurement were FOV 240×240, 1NEX, 1 slice, 1mm thickness, and 256×256 matrix.

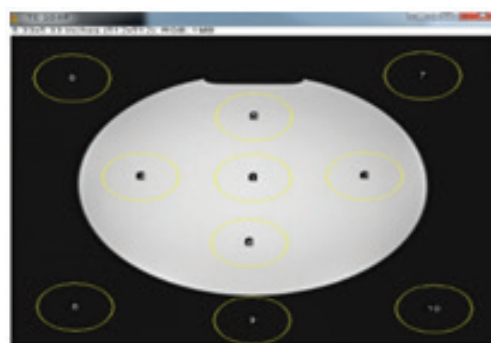
**Image Evaluation:** SNR, CNR, PSNR, and UACI were measured using the obtained image. For SNR and CNR, Image J was used to set up 5 signal and 5 noise areas to measure the mean, minimum, maximum, and the standard deviation (Fig 3). The following formula was used to measure SNR and Matlab was used to measure PSNR and UACI, CNR (Fig 4).

$$SNR = \frac{\text{Background Avg} - \text{Signal Avg}}{\text{Background SD}}$$

$$CNR = \frac{\text{Background SI}_{Avg} - \text{Signal}_{Avg}}{\sqrt{\text{Background SD}^2 + \text{ROI SD}^2}}$$



**Figure 3: Image measurement**



**Figure 4: Signal, Noise measurement**

**Results**

**Signal and Noise measurement in accordance with changes in gradient power in T2:** Normal duration of the spin-lock pulse (SLT) was the highest at TE 60 with 230.4 msec, and was the lowest at TE 80 with 227.8

msec. Noise was the lowest at TE 60 with 21.6msec, and it increased with increase in the TE value. Fine SLT was the highest at TE 60 with 224.8msec, and the signal decreased as the TE value increased. Noise was the highest at TE 60 with 23.6msec, and the noise value

decreased with increased TE value. In the case of low Specific Absorption Rate (SAR), it was the highest at TE 100 with 229.6 W/kg, and the lowest at TE 60 with 228.5 W/kg. Noise was the highest at a TE 60 of 23.4msec, and lower as the TE value increased (Table 1).

**Table 1: Signal and Noise measurement in accordance with changes in gradient power**

Gradient Power		TE 60	TE 70	TE 80	TE 90	TE 100	
Normal SlT	Signal	Max	230.4	228.6	227.8	228.4	228.6
		Min	212.0	211.2	210.6	211.4	211.6
		Mean/S.D	222 ± 4.6	221 ± 4.4	220 ± 4.4	220 ± 4.4	221 ± 47.3
	Noise	Max	21.6	23.0	23.2	23.8	23.4
		Min	17.4	19.0	19.6	20.0	20.0
		Mean/S.D	21.0 ± 0.4	21.7 ± 0.4	22.3 ± 0.4	22.5 ± 0.4	22.5 ± 0.4
Fine SlT	Signal	Max	224.8	222.8	224.2	224.8	224.0
		Min	209.2	207.6	208.6	208.6	208.0
		Mean/S.D	217.7 ± 4.0	216.0 ± 4.0	217.0 ± 3.9	217.5 ± 4.0	216.7 ± 3.9
	Noise	Max	23.6	22.4	21.2	21.0	21.4
		Min	19.4	18.0	17.0	17.0	17.0
		Mean/S.D	22.0 ± 0.3	22.1 ± 0.4	19.7 ± 0.4	19.7 ± 0.4	19.9 ± 0.4
Low Sar	Signal	Max	228.5	229.4	229.4	228.6	229.6
		Min	210.7	212.0	212.0	210.8	211.8
		Mean/S.D	220.0 ± 4.7	221.1 ± 4.5	221.1 ± 4.4	220.1 ± 4.5	221.5 ± 4.5
	Noise	Max	23.4	23.6	22.4	21.8	22.6
		Min	20.4	20.4	19.8	19.0	20.0
		Mean/S.D	22.6 ± 0.4	22.8 ± 0.3	21.8 ± 0.3	21.0 ± 0.3	21.9 ± 0.3

**Signal and Noise measurement in accordance with the change in Gradient Power in T1:** For Normal SLT, the signal was the highest at TE 30 with 229.8msec, and was the lowest at TE 10 with 224.2 msec. In the case of noise, it was found to be the highest at TE 40 with 27.6msec, and was the lowest at TE 10 of 25.4 msec. In the case of Fine SLT, it was the highest at TE 20 of 214.6msec, and the lowest at TE 10 of 211.4 msec. In the case of noise, it was the lowest at TE 30 with 20.8msec, and the highest at TE 10 of 29.6 msec. In the case of Low SAR, the signal was the highest at TE 20 with 226.6 W/kg, and was the lowest at TE 30. The noise was the highest at TE 20 with 27.6msec, and was the lowest at TE 40 of 20.6 msec (Table 2).

**Table 2: Signal and Noise measurement in accordance with the change in Gradient Power**

Gradient Power		TE 10	TE 20	TE 30	TE 40	
Normal SlT	Signal	Max	224.2	225.6	229.8	227.6
		Min	206.6	207.8	210.0	210.4
		Mean/S.D	216.3 ± 4.4	217.2 ± 4.6	220.8 ± 4.9	219.5 ± 4.2
	Noise	Max	25.4	26.2	26.8	27.6
		Min	21.0	21.8	22.2	23.2
		Mean/S.D	23.7 ± 0.4	24.5 ± 0.4	25.0 ± 0.4	25.8 ± 0.4

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Fine Slt	Signal	Max	211.4	214.6	211.3	212.9
		Min	203.2	204.4	201.8	204.2
		Mean/S.D	211.4 ± 3.3	214.6 ± 4.2	211.3 ± 4.0	212.9 ± 4.0
	Noise	Max	29.6	23.8	20.8	21.2
		Min	16.4	19.6	18.8	19.0
		Mean/S.D	21.4 ± 0.8	22.3 ± 0.4	20.1 ± 0.4	20.3 ± 0.4
Low Sar	Signal	Max	224.4	226.6	221.6	222.2
		Min	206.8	209.4	205.2	205.6
		Mean/S.D	216.2 ± 4.6	218.4 ± 4.2	214.2 ± 4.1	214.4 ± 4.0
	Noise	Max	25.2	27.6	20.8	20.6
		Min	20.8	23.2	17.6	18.2
		Mean/S.D	23.5 ± 0.4	26.0 ± 0.4	20.0 ± 0.4	19.4 ± 0.4

**Image evaluation in accordance with the change in gradient power at T2:** In the case of SNR, normal SLT was the highest at TE 60 with 581.4 for Fine SLT, at TE 60 with 623.1, in the case of Low SAR, at TE 80 with 610.2 was the highest. It was evident that SNR decreased with TE increase. For PSNR at normal SLT, it was found to be the highest at TE 60 of 24.09msec, and the Fine SLT was found to be the largest at TE 90 with 24.09 msec, without significant change even with the increases TE. In the case of CNR, normal SLT was the highest at TE 100 with 45.7, and the lowest at TE 60 with 43.9. The Fine SLT was the highest at TE 100 with 50.7 and the lowest at TE 60 with 43.9. In the case of UACI, the normal SLT was the highest at TE 80 with 1.98, and as the TE increased, UACI decreased. In Fine SLT, UACI was the highest at a TE 80 with 5.33 and as TE increased, UACI decreased. In the case of low SAR, it was the highest at TE 90 with 4.0 and as TE increased, UACI decreased (Table 3).

**Table 3: Image evaluation in accordance with the change in gradient power at T2**

	Gradient Power	TE 60	TE 70	TE 80	TE 90	TE 100
SNR	Normal Slt	581.450	542.949	552.046	507.288	505.230
	Fine Slt	623.197	505.064	500.526	517.246	479.005
	Low Sar	548.416	592.893	610.203	592.094	575.312
PSNR	Normal Slt	24.092	24.086	24.084	24.084	24.083
	Fine Slt	24.086	24.086	24.093	24.094	24.092
	Low Sar	24.085	24.084	24.086	24.088	24.085
CNR	Normal Slt	43.900	45.300	44.400	45.280	45.770
	Fine Slt	49.190	48.670	50.320	49.420	50.780
	Low Sar	42.210	44.030	44.880	43.870	44.710
UACI	Normal Slt	1.000	1.311	1.985	1.648	1.189
	Fine Slt	1.000	2.791	5.333	4.771	5.238
	Low Sar	1.000	0.217	1.772	4.007	1.677

**Image evaluation in accordance with the change in gradient power at T1:** SNR for normal SLT was found to be the highest at TE 40 with 495.5, and TE 30 was found to be the lowest. Fine SLT was found to be the highest at TE 30 with 485.6, and low SAR was found to be the highest at TE 40 with 503.0. In the case of PSNR, for Normal SLT, it was the largest at TE 40 with 21, without any significant difference from TE 10 to 30. Fine SLT was the largest at TE 30 with 24.09, and even in case of other TE values, there was no significant difference. In case of low SAR, the

PSNR was the largest at TE 10. However, even in other TE values, there was no significant difference. In the case of CNR, for Normal SLT, it was the highest at TE 40 with 46.0, and fine SLT was the highest at TE 30 with 44.8. Low SAR was the highest with TE 40 at 48.5. In the case of UACI, normal SLT was increased at TE 40 with 21.8. Fine SLT was the highest with TE 30 at 5.4. Low SAR was the highest at TE 30 with 20.6 (Table 4).

**Table 4: Image evaluation at T1 in accordance with the change in gradient power**

	<b>Gradient Power</b>	<b>TE 10</b>	<b>TE 20</b>	<b>TE 30</b>	<b>TE 40</b>
SNR	Normal SlT	474.948	462.214	451.954	495.574
	Fine SlT	236.418	459.141	485.615	459.417
	Low Sar	485.665	496.560	470.298	503.006
PSNR	Normal SlT	24.083	24.083	24.083	24.122
	Fine SlT	24.088	24.088	24.090	24.084
	Low Sar	24.841	24.083	24.090	24.098
CNR	Normal SlT	43.880	41.830	39.770	46.090
	Fine SlT	42.210	44.030	44.880	43.870
	Low Sar	42.030	45.430	47.060	48.570
UACI	Normal SlT	1.000	0.301	0.149	21.880
	Fine SlT	1.000	0.489	5.430	3.662
	Low Sar	1.000	0.100	20.600	18.560

### Discussion

MRI yields outstanding resolution compared with CT, ultrasound, and general radiography. The high contrast resolution can be used to easily distinguish even the soft tissue in the human body via imaging, and facilitates examination anatomical cross sections of the human body in various directions<sup>6</sup>. The MRI technician can control the MRI sequence to adjust various parameters. TR, flip angle, TE and others can be adjusted depending on the area of examination, to obtain highly valuable images for diagnosis<sup>7,8</sup>. Lee Young Dae The relative signal intensity of MRI increases following changes in TE, however, the signal intensity of the image remained unchanged<sup>9,10</sup>. In this study, measurements of changes in TE in 4 phases for T1 and T2, showed no major changes in SNR, PSNR and CNR of T2 despite increased TE. However, when the TE was above 80, the values decreased, and in the case of T2, it was considered not to exceed 80. Similar to T2, in the case of T1, even when the TE value increased by the same amount, no major changes in SNR, PSNR and CNR, occurred, consistent with the results of Lee Young Dae. According to the report of various MRI techniques by Lee Seung Pil, if the Turbo Spine Echo: TES is used, the signal intensity of the joint cartilage was approximately 30% lower, and accurate selection of

pulse sequence in MRI examination enables elucidation of the disease or anatomical structure<sup>11,12</sup>. In this study, the results obtained by changing the gradient power that controls the signal intensity in T2 were as follows: with fine SLT, SNR 623, PSNR 23.09, CNR 50.32, and UACI 5.33 which was found to be the largest, and a normal SLT yielded SNR 581, PSNR 24.092, CNR 45.3, and UACI 1.98. A low SAR yielded SNR 548, PSNR 24.08, CNR 44.8, and UACI 1.77. In the case of T2, the largest fine SLT signal intensity corresponded to normal SLT, and low SAR. In the case of T1, under low SAR, the values were: SNR 503, PSNR 24.09, CNR 48.5, UACI 18.5 which was found to be the largest. In the case of T1, the signal intensity was large in the order of low SAR, normal SLT, and fine SLT respectively, consistent with previously reported results.

MRI equipment used currently provides a stronger magnetic field with 3.0T rather than 1.5T, using equipment with high magnetic field due to short examination time and high resolution. However, with low magnetic field, short examination time and high resolution image can be obtained if the gradient power and additional factors are adjusted appropriately to assist with the patient's disease. The study limitation relates to inability to determine the frequency of gradient power.

## CONCLUSION

The followings are conclusions upon the measurement results of MRI signal intensity depending on changes of gradient power.

1. In case of T2, all the signal intensities of SNR were decreased with normal SLT of 47, fine SLT of 21, and low Sar of 45 if TE 80 or more. PSNR showed similarity with 24 for all, while all the signal intensities of CNR and UACI showed differently after change of gradient power.
2. In case of T1, signal intensity of SNR at TE 40 showed the strongest with normal SLT of 495, fine SLT of 459, and low Sar of 503. PSNR showed with 24 for all, while all the signal intensities of CNR and UACI showed differently after change of gradient power.

Based on the results of this study, it is considered that the patients should be tested with different setting of gradient power by the areas of test and purposes when MRI sequence is prepared

**Ethical Clearance:** Not required

**Source of Funding:** Self

**Conflict of Interest:** Nil

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