

Development of MRI Scanning Technique that is Comfortable for Patients with Anxiety Disorder

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The principal objective of this study was to develop a scanning technique that helps patients reduce their anxiety and relax their physical tension in the MRI system. The study targeted 10 healthy persons with no medical history of anxiety disorder in the past and with no current clinically diagnosed anxiety disorder, as well as 10 patients who were currently experiencing an anxiety disorder during the MRI scanning. The focusing board assembly was self-manufactured to conduct a clinical experiment via MRI scans. As a method to confirm the efficacy of the experiment, the bio meter was used to measure brainwaves from the study targets that were divided into the normal person group (A), who felt no anxiety in the MRI system and the experimental group, (B) who did experience anxiety in the MRI system. The two groups were compared between the cases in which the focusing board assembly was used and not used after measurements were conducted using the model MRI system and the bio meter. According to the comparison and analysis results, low measurements of the α wave indicate highly effective relaxation of tension. In the normal person group, the α wave measurement showed almost no difference between cases in which the focusing board assembly was used and cases in which it was not used. In the experimental group, the α wave measurements were lower in cases in which the focusing board assembly was used than in cases in which the focusing board assembly was not used; this was indicative of a profound relaxation effect.

Keywords : anxiety disorder, focusing board assembly, α wave, relaxation effect

1. Introduction

Nuclear magnetic resonance (NMR) systems have been used for the *in vitro* analysis of materials in chemistry for a long time [1]. The magnetic resonance imaging (MRI) system, which is based on the NMR, uses an *in vivo* scanning method; the main advantage of this technique is that it causes no harm to the human body and allows for high-resolution imaging of soft tissues [2]. The MRI

system primarily consists of a permanent magnet or a superconductive and electromagnetic instrument. Externally, the system resembles a computed tomography (CT) machine or a positron emission tomography (PET) machine [3]. The MRI system is advantageous in that gradient (slope) coils (G_x , G_y , G_z) are used for visualization after a selection is made among the three directions (the transverse plane, the coronal plane and the sagittal plane) and the free oblique section [4]. In addition, the scanning time of MRI systems has been significantly reduced compared to past iterations of the system, thanks to the development of quick pulse sequence and information processing pro-

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grams [5]. However, despite its many advantages, the MRI has several factors that hinder the acquisition of images. The most typical example of this is the ferromagnetic element [6]. The ferromagnetic element is a foreign metal material that can enter the human body through an unknown path, remain in the body system of a person who handles ferromagnetic materials, or can be a component of various devices, such as pacemakers, that are installed via surgical operation or artificial teeth inserted into the human body. Other examples include external high frequency, chemical shift, and movement. In particular, if an examinee (patient) feels uneasy and becomes nervous during the MRI scanning, the examinee causes movement, which results in the generation of motion artifacts [7]. Additionally, the gigantic shape of the MRI machine can seem overwhelming to an examinee. Furthermore, it has been demonstrated that the noise and characteristics of the operation of the machine, which suppresses helium evaporation, can cause extreme uneasiness. According to a report, people often experience greater anxiety than was once the case, due to the mental and psychological conflict induced by complex social structures, environment, and stress; at least 15% of the total population suffers from anxiety disorder [8]. In reality, a large number of examinees express anxiety during the MRI scanning procedure. Such anxiety is largely attributable to the overwhelming shape of the machine, the close proximity of the magnetic bore, noise generation, and psychological problems or personality of individual examinees. Therefore, it is important that attention be paid to safety management for both the examinees and the machines. The anxiety symptoms expressed by examinees in MRI scanning show similarity to the criteria for diagnosing psychiatric anxiety disorder. Anxiety is known to be generated mainly by stimulus to visual and auditory senses, which are special senses of human body, and somatic sense, which is transmitted to brain. It has been known that when human body feels danger, anxiety factors are physically expressed through the limbic system, which leads to behavior of avoiding the place where the human body [9]. If an examinee feels increasing anxiety, which ends up with fear, the examinee may escape the MRI system or refuse to take the scanning due to the mental and psychological impact. Sometimes, an examinee may feel dizzy to vomit due to abdominal discomfort or may be severely traumatized, which is why it is necessary to make preparations for safety of the examinee. The MRI in recent days uses the quick scanning technique. However, image acquisition becomes impossible when an examinee feels anxiety, as this can cause the examinee to move within the magnet bore or refuse to enter the mag-

net bore [10]. In this case, scanning can be conducted after the examinee is put to sleep with a sedative or anesthesia is applied based on the doctor's prescription. In the clinical stage, some attempts can be made to reduce anxiety, such as tying up an examinee, covering the eyes of the examinee, or plugging the examinee's ears. Such methods cannot be avoided if the examinee is in a state of extreme anxiety. Another method involves the use of an air blower to spray fragrance. However, it is unlikely that such a method will prove useful, except in cases in which an examinee feels mild anxiety. Besides, an examinee may listen to music with headphones during scanning or may broaden their view with the help of mirrors. Recently, photographic light can be attached to the wall or ceiling of the MRI room for relaxation. However, notwithstanding various attempts, it is reported that such attempts may not be effective to an examinee who experiences severe anxiety [11]. Therefore, it appears to be necessary to conduct a new study to determine how to reduce the anxiety felt by an examinee while ensuring the safety of the MRI system. Additionally, precise image information data are required for the MRI to produce a precise diagnosis for patients; thus, it is necessary to develop a scanning technique to obtain optimal image information data on the anatomical structure of the body part that needs to be displayed.

The principal objective of this study was to develop a new scanning technique to resolve the problems of failure to conduct the MRI scan as the result of dizziness or anxiety and fear felt by an examinee.

2. Materials and Methods

2.1 Selection of Study Participants

This study targeted 10 healthy persons with no past medical history and no current clinical anxiety disorder, and 10 patients who experienced anxiety disorder in the period between November 2009 and December 2010, or who had no medical history in the past but experience anxiety during MRI scanning. For accuracy in study target selection, a survey was conducted on dizziness or anxiety (Table 1), and the survey respondents were placed in the gantry to determine if they were the study targets by using a blood pressure meter.

The healthy persons with no anxiety disorder enrolled in this study included six women and four men. Their age ranged between 40-62 with an average of 50.4 ± 6.41 , their height ranged between 153-178 cm, with an average of 173 ± 5.3 cm, and their weight ranged between 53-75 kg with an average of 66.8 ± 2.12 kg. The patients with anxiety disorder included five women and five men. Their

Table 1. Questionnaire to evaluate dizziness or anxiety

1. Please, check O or writer answer to all of the items that are applicable to you.
 Gender: (Male/Female), Age: () or Year of Birth: (), Height: () cm, Weight: () kg
 Telephone No. or Mobile Phone No.: (- -)

Date of MRI scanning:

- 1) What is the blood pressure recently? (Low blood pressure/Normal/High blood pressure)
- 2) Is there any case where you feel anxiety or fear in everyday life? (Yes/No)
- 3) Do you have the past experience that you felt anxiety or fear? (Yes/No)
- 4) If you do, can you describe such past experience briefly? (Yes/No)
- 5) How often do you feel anxiety?
 (1) One time a day (2) Two times or more a day (3) Often
- 6) Mostly when do you feel anxiety? ()
- 7) Have you ever taken the scan in the CT or MRI system? (Yes/No)
- 8) If you have, did you feel anxiety and what was the pretreatment? (Yes/No) (Pretreatment:)
- 9) If you had or have psychiatric disorder in the past or present, have you had medical examination or treatment in the pertinent department of hospital? (Yes/No)
- 10) Have you ever given up MRI scan because of anxiety? (Yes/No)
- 11) How can you describe your personality?
 (1) Introversive (2) Sociable (3) Positive thinking and active behavior (4) Strong perseverance against physical suffering (5) Strong perseverance against mental and psychological suffering

Table 2. General special qualities of volunteers.

	Group	n	Age [†]	Height (Cm) [†]	Weight (kg) [†]
Mean ± SD	healthy group	10	50.4 ± 6.41	173 ± 5.3	66.8 ± 2.12
	Anxiety disorder group	10	50.4 ± 6.24	169 ± 3.7	67.6 ± 3.32

Note) [†]Data are mean standard deviation

ages ranged from 43 to 57 with an average of 50.4 ± 6.24, their heights ranged from 156 cm to 176 cm with an average of 169 ± 3.7 cm, and their weight ranged from 57 kg to 74 kg with an average of 67.6 ± 3.32 kg (Table 2).

2.2. Manufacturing of Model MRI Machine

The model MRI machine was manufactured for actual measurement in the inside of the magnetic bore of an MRI system that is currently used for clinical purposes. The model MRI machine consists of external supporter and transferring table as major coils in the MRI system used in the clinical stage were removed before the original form of the system was maintained. The brightness of the indoor location where the model MRI machine was installed and that of the inside of the magnetic bore were kept at a level similar to the illumination intensity in the clinical MRI room (Fig. 1).

2.3 Design of Focusing Board Assembly

Fig. 2 illustrates the visual relationship in the position in which an examinee lies prone within the 55 cm diameter magnetic bore, with an aim toward designing a focusing board assembly for the MRI system, which is used mainly in the clinical stage. In general, the proper

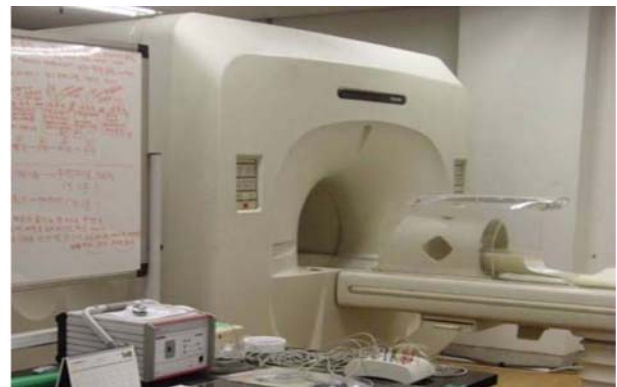


Fig. 1. (Color online) Life-size model of MRI system.

distance required for reading is known to be 2530 cm. However, according to the measurement of the MRI system installed for clinical purposes, the distance was less than 20 cm as shown in the figure, thus demonstrating that the distance was somewhat insufficient. Fig. 3(a) and (b) show the design drawing of a focusing board assembly wherein an examinee is permitted to select the color and size of the focusing board manually inside the MRI machine. In Fig. 3(a), the color of the focusing board was set to green, black, blue, and red. The focusing board was

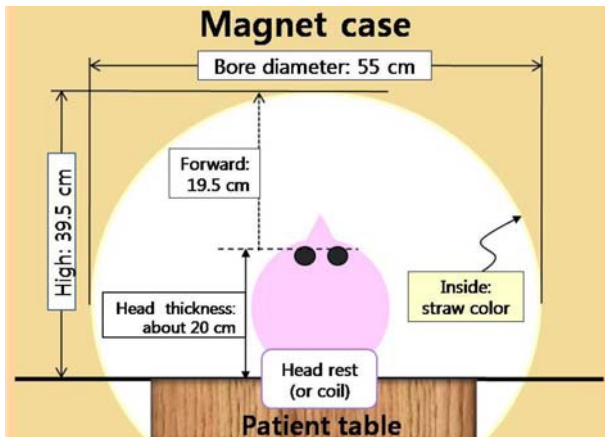


Fig. 2. (Color online) Human body and magnetic bore space.

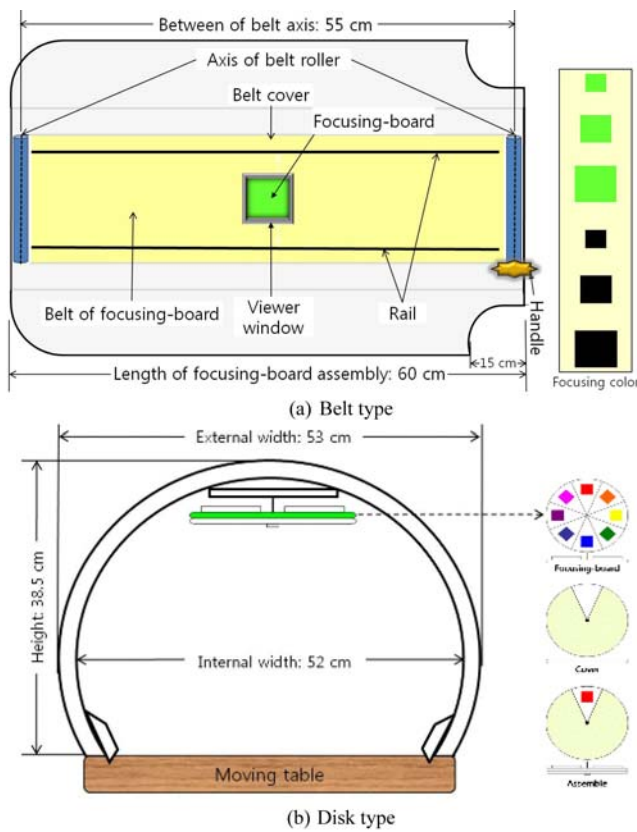


Fig. 3. (Color online) Design of focusing-board assembly.

designed as a belt type, wherein the examinee was allowed to select the size (1 cm², 3 cm², or 5 cm²) for each color as the focusing board rotated; this was targeted toward improving the examinee's concentration. In Fig. 3(b), a fan-shaped focusing board with various colors was designed as a disc type, in which the focusing board rotated to allow an examinee to select one color according to the examinee's preference; this was aimed at helping the examinee's attention. In order to reduce anxiety, the

focusing board assembly was designed to maximize the bio-stimulative effect based on the will of the examinee and the physical force that was applied with regard to somatic senses, including the visual and tactile senses. Because the scan for MRI should be conducted at the center of the internal magnet bore, examining it realistically inside the model device with same conditions with the actual one can obtain more objectivity. In addition, EEG was performed inside the model to compare the control group not feeling anxiety and the experimental group doing it at the same place and to investigate the degree of decrease of anxiety quantitatively before and after the use of the focusing-board assembly.

2.4. Selection of Materials for and Manufacturing of Focusing Board Assembly

Acryl with solid components, which is harmless to humans, was used as the supporter of the focusing board assembly. Acryl has been shown to have no impact on images, and causes no disturbances in the magnetic field generated by the MRI machine. Fig. 4(a) and (b) show the focusing board assembly that was self-manufactured to reduce examinees' anxiety during the MRI scanning. In the figure, (a) is the belt-type focusing board assembly, whereas (b) is the disc-type assembly.

The focusing board assembly was designed taking the visual and somatic senses into consideration. The color of focusing-board assembly to draw attention of a patient was located below due to the width of the support of the focusing-board assembly (1 cm) and the gap of the rotation axis (0.5 cm) as presented in the drawings of Fig. 2 and Fig. 3. Therefore, the distance was observed to be not considerably different from the original distance with maintaining the distance of 17 cm forward from a patient. For the belt-type focusing board, green, red, blue, and black paints were spread on a white fabric as a method to increase visual attention. The focusing board was designed to rotate only when an examinee selected the focusing board to apply manual force. Additionally, the acrylic plate, which can be readily rotated, was attached to the

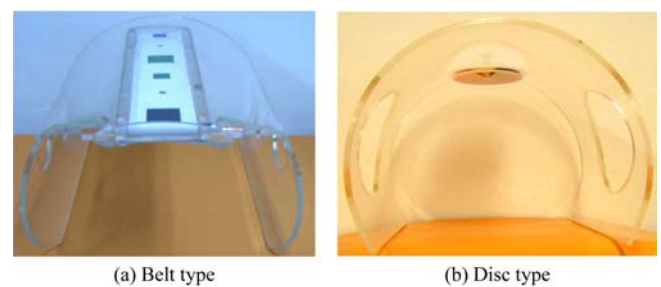


Fig. 4. (Color online) Images of the focusing-board assembly.

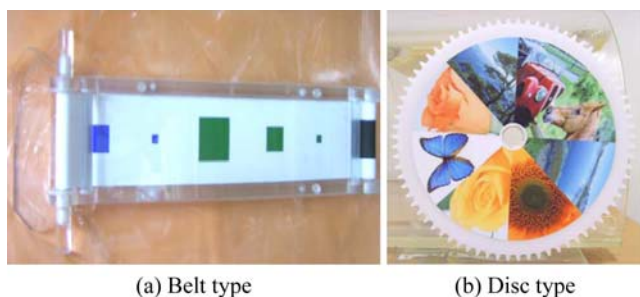


Fig. 5. (Color online) Focusing-board.

disc-type focusing board to ensure that an examinee was allowed to select among various colors and patterns (Fig. 5). In order for an examinee to rotate a plate to select a color in his or her own will, the palpable effect was enhanced by making the edges of the focusing board's supporter slightly uneven. As mentioned thus far, both of the color selection methods in the focusing board were designed to be manually selected. Acryl at a thickness of 10 mm was used as a supporter of the focusing board to prevent the supporter from being deformed under ordinary temperature conditions. Additionally, a colorless and transparent material was selected for the supporter to ensure that an examinee did not perceive the space to be too narrow due to the use of the focusing board assembly. The focusing board assembly was used for MRI scans in the clinical stage with a view toward determining whether the focusing board assembly was capable of alleviating examinee anxiety during the MRI scanning. Furthermore, in the model MRI system, the same focusing board assembly was used to confirm the efficacy of the MR-FBS technique by measuring brainwaves.

2.5. Biological Measurement by Using Focusing Board Assembly

2.5.1. Location and Method to Attach Electrode for Brainwave Measurement

Based on the international 10/20 electrode system, electrodes for brainwave measurement were attached one by one to eight parts in total of the head surface of the study target, and then, brainwaves were measured via the monopolar derivation method. As shown in Fig. 6 locations to which the electrodes were attached for brainwave measurement included the position of the left prefrontal lobe (Fp1), the position of the right prefrontal lobe (Fp2), the position of the left frontal lobe (F3), the position of the right frontal lobe (F4), the position of the left temporal lobe (T3), the position of the right temporal lobe (T4), the position of the left parietal lobe (P3), and the position of the right parietal lobe (P4). The reference electrode was

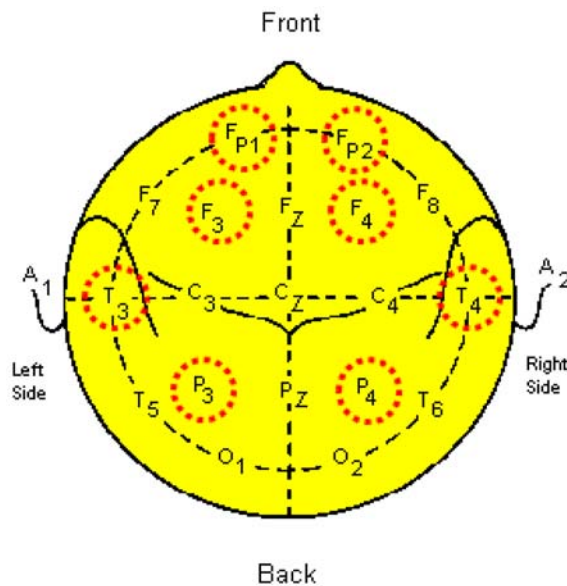


Fig. 6. (Color online) Placement of electrodes for brainwave test.

attached behind the right earlobe while the ground electrode was attached behind the left earlobe. The electrode used was the gold-coated plate-type disc electrode. As a method of reducing resistance deriving from the contact between the electrode and the skin, alcohol cotton was used to clean the head surface before electrode paste (Elefix z-401ce, Nihon Kohden), which was used only for brainwave measurement, was applied to the electrode before attaching it to the head surface. Additionally, the attached electrode was covered with gauze to ensure that it was well affixed to the head surface. EMG, ECG, and respiration were measured simultaneously with the brainwave measurements. The measurement time was 180 seconds equally for each measurement. The attachment location of each electrode and the method for measurement as mentioned above were applied equally to all examinees.

The computerized EEG of PolyG-I (model name; PolyG-I, Laxtha Inc, Korea) was used as the equipment for brainwave measurement. The brainwave measurement recording was initiated when a stable brainwave with no artifacts was measured for 10 seconds or longer.

2.5.2. Brainwave Measurement in the Experimental Group

Brainwaves were measured in the same way for purposes of comparison between cases in which the focusing board assembly was used and not used inside the magnetic bore of the model MRI machine, with a view toward making a quantitative analysis of biological changes caused by examinees' anxiety. The examinees were allowed to

open their eyes while brainwave measurements were conducted in order to take measurements in the arousal phase. When the examinees keep their eyes open, they tend to move their eyes due to dry eye, which may cause artifacts to be introduced from the electrode attached to the prefrontal lobe. To minimize the effects from the artifacts, the examinees were advised not to blink so frequently. Additionally, they were instructed and constrained to move as little as possible for as long as possible. All of the measurement data were saved to the designated computer. For analysis of vital signs, a total of 11 channels were first analyzed. Among these channels, channels 9-11 were measurements of respiration, heartbeat and muscle tension level, which were excluded because the collected signals evidenced significant differences according to individual; they were not consistent, and were thus meaningful for analysis.

2.5.3. Measurement of Brainwaves in the Normal Person Group

Brainwave measurements were conducted inside the magnetic bore of the model MRI machine in the same fashion as the one in the experimental group. Additionally, brainwaves were separately measured for comparisons of changes in cases in which the focusing board assembly was used and when it was not used. All of the measurement data were saved to computer for analysis.

2.5.4. Analysis of Brainwaves in the Experimental Group and Normal Person Group

For the quantitative analysis of brainwave measurement, changes in brainwaves were compared between the cases in which the focusing board assembly was used and when it was not used within the magnetic bore of the model MRI in the experimental group (A) and the normal person group (B). WOFb refers to a case in which the focusing board assembly was not used for brainwave measurement, whereas WFb refers to a case in which the focusing board assembly was used for brainwave measurement. Scanning was conducted in the order of tests 1-4 for analysis (Fig. 7).

2.5.5. Method for Statistical Analysis of Brainwave Data

The average of brainwave measurement values for each position (the eight positions in total) was calculated to objectively confirm the relaxation effect of anxiety in cases in which the focusing board assembly was used and not used as an examinee was aroused. The values from the two cases were compared and analyzed. As a brainwave index, a Spectral Edge Frequency (SEF)-50% was

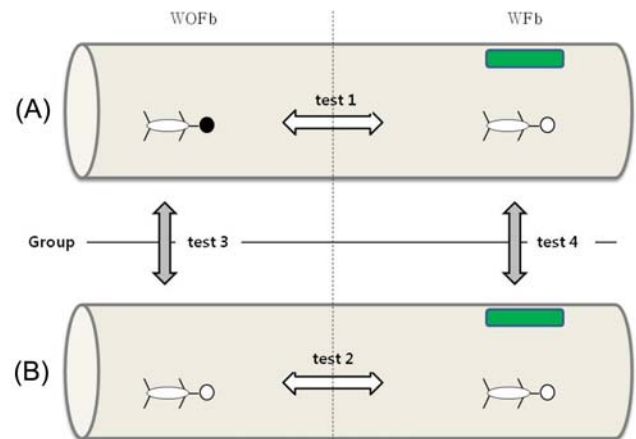


Fig. 7. (Color online) The analysis of brainwave order of before and after use of the focusing-board assembly. (A) experimental group, (B) normal group, WOFb: Without focusing-board assembly.

used. In particular, the SEF-50% of the alpha wave band was observed since it was the major concern with regard to variation, which is generally employed as the index of relaxation. Analyses of measured brainwave data were conducted using a batch processing program provided by Laxtha (Laxtha Inc., Korea). For statistical processing and analysis of the calculated values, SPSS for Windows (18.0) software was utilized under conditions identical to those shown below (a-d). The paired dependent sample t-test was conducted to confirm differences in average value before and after the focusing board assembly was used in the experimental group and the normal person group. When the p-value of significant probability was 0.05 or lower, the difference was regarded as significant (a, b). Additionally, the independent sample t-test was conducted for brainwave analysis in cases in which the focusing board assembly was used and not used in the experimental group and the normal person group. When the P value of significant probability was 0.05 or lower, the difference was also considered significant (c, d).

a: Brainwave analysis before and after the focusing board assembly was used in the experimental group.

b: Brainwave analysis before and after the focusing board assembly was used in the normal person group.

c: Brainwave analysis before the focusing board assembly was used in the experimental group and the normal person group.

d: Brainwave analysis after the focusing board assembly was used in the experimental group and the normal person group.

2.6. Clinical Study of Focusing Board Assembly

Our analysis involved a case in which scanning was

conducted on an examinee who was under medical treatment after being diagnosed with anxiety disorder and who, until recently, tended to sleep after drug administration was injected for the purpose of the MRI scanning. In this experiment, the focusing board assembly was used to allow an examinee to adapt himself or herself to it in advance under the stipulations of an agreement among the examinee, the guardian, the person who performs the scanning, and the doctor in charge before the scanning was conducted. The person who performed the scanning had conducted a prior consultation with the examinee, the guardian (spouse) and the doctor in charge to agree that if the focusing board assembly was used but scanning was not successful, the drug would be injected as usual. The information on progress was sent to the doctor in charge for approval, and the MR-FBS technique was used for scanning in the presence of the doctor responsible for patient care. Fig. 8 shows an examinee who takes brain MRI scanning, where the focusing board assembly is used, for a regular examination at the department of radiology at the Y university hospital. In Fig. 8, ① shows that an examinee diagnosed with anxiety disorder is waiting for the MRI scan while Fig. 8, ② shows that the examinee, who has agreed to participate in the clinical experiment, listens to instructions regarding the use of the focusing board assembly before operating it. Fig. 8, ③ shows that the examinee becomes fully aware of how to use the focusing board assembly and becomes accustomed to the environment as a method to reduce anxiety prior to the performance of the MRI scan. Fig. 8, ④ shows that the mirror is attached to the head coil, which is used only for the MRI scan of the head as a method to alleviate the

anxiety of the examinee. In Fig. 8, ⑤ first of all, the mirror attached to the head coil is used to observe response by the examinee to determine if anxiety can be reduced. However, the examinee evidences a rejection reaction immediately, and thus the staff remove the mirror and replace it with the focusing board assembly. In Fig. 8, ⑥ the examinee asks for installation of only the focusing board assembly as the examinee becomes accustomed to the focusing board assembly. The examinee with anxiety disorder uses only the focusing board assembly without drug injection before being transferred to the inside for scanning.

3. Results

3.1. Brainwave Analysis before and after the Focusing Board Assembly was Used in the Experimental Group

Table 3 shows the values of the alpha wave SEF-50% collected from the left side of the prefrontal lobe (Fp1) and the right side of the prefrontal lobe (Fp2) among various brainwaves measured when the focusing board assembly was used and not used in the 6 person experimental group. For verification of the focusing board assembly inside the model MRI system, analyses were conducted of the alpha wave SEF-50% of the brainwave data in the eight channels measured when the experimental group was aroused. Only the data that evidenced significant changes were summarized as follows. The paired difference mean was found to be 0.646 ± 0.434 for the brainwave measured on the left side of the prefrontal lobe (Fp1) and 0.573 ± 0.260 for the brainwave measured on the right side of the prefrontal lobe (Fp2). In terms of

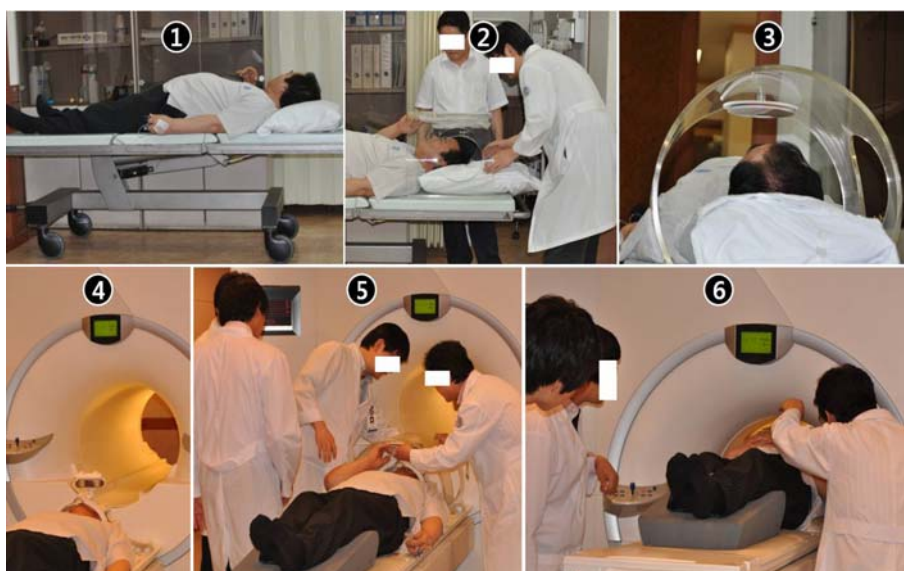


Fig. 8. (Color online) Progression sequence of the appearance in which the anxiety disorder person uses the focusing-board assembly for the MRI scan (①-⑥).

Table 3. The raw brainwave data regarding focusing-board assembly use before and after in the experimental group.

Group	Name	WOFb-Fp1	WOFb-Fp2	WFb-Fp1	WFb-Fp2
A	1	9.46875	9.75000	9.21875	9.12500
A	2	10.28125	10.37500	10.06250	10.18750
A	3	10.90625	10.96875	9.78125	10.09375
A	4	10.81250	10.68750	9.62500	9.87500
A	5	10.21875	10.06250	9.84375	9.68750
A	6	10.71875	10.71875	10.00000	10.15625

Note) A: Experimental group, Fp1 and Fp2: Electrode position of 10-20 system, WOFb: Without focusing-board assembly, WFb: With focusing-board assembly

Table 4. Before and after brainwave data regarding the focusing board assembly.

Division	n	Experimental group		t	p
		Mean ± SD			
WOFb_Fp1 - WFb_Fp1	10	0.646 ± 0.434		3.647	0.015*
WOFb_Fp2 - WFb_Fp2	10	0.573 ± 0.260		5.388	0.003*

Note) Interaction effect using a paired t-test model. Fp1 and Fp2: Electrode position of 10-20 system, WOFb: Without focusing-board assembly, WFb: With focusing-board assembly.

*p < 0.05

significant probability, the brainwave measured on the left side of the prefrontal lobe (Fp1) had a p value of 0.015, whereas the brainwave measured on the right side of the prefrontal lobe (Fp2) had a p value of 0.003, which is indicative of a statistically significant positive correlation (p < 0.05) (Table 4). In other words, the frequencies from the both sides of the prefrontal lobe were lower when the focusing board assembly was used than when the focusing board assembly was not used, thus confirming the relaxation. This survey was conducted with examinees who complained of anxiety during MRI scanning in order to determine how they felt in the scanning apparatus before and after the focusing board was used. The results of the survey were found to be in accordance with the results of brainwave analysis measured prior to and after the focusing board assembly was used. This verified that the anxiety felt by examinees was reduced by the use of the focusing board assembly (Fig. 9).

3.2. Brainwave Analysis before and after the Focusing Board Assembly was Used in the Normal Person Group

Table 5 shows the values of the alpha wave SEF-50% collected from the left side of the prefrontal lobe (Fp1) and the right side of the prefrontal lobe (Fp2) among various brainwaves measured when the focusing board assembly was used and not used in the 10-normal person group. According to the brainwave analysis results, the

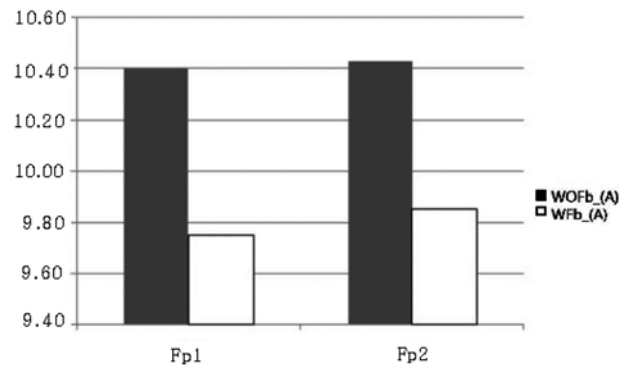


Fig. 9. Before-and-after brainwave data regarding use of focusing-board assembly on experimental group. Fp1, Fp2: Electrode position of 10-20 systems, WOFb: Without focusing-board assembly, WFb: With focusing-board assembly.

Table 5. The raw data of the brainwave regarding the focusing-board assembly use before and after in the normal group.

Group Name		WOFb-Fp1	WOFb-Fp2	WFb-Fp1	WFb-Fp2
B	1	10.90625	10.78125	10.78125	10.87500
B	2	9.25000	9.21875	9.18750	9.15625
B	3	10.15625	10.15625	10.34375	10.28125
B	4	9.09375	9.09375	9.65625	10.21875
B	5	10.06250	10.06250	10.00000	10.25000
B	6	9.87500	9.93750	9.53125	9.37500
B	7	9.68750	9.71875	9.03125	9.25000
B	8	10.15625	10.21875	9.93750	9.65625
B	9	10.15625	10.25000	9.75000	9.71875
B	10	9.34375	9.37500	9.28125	9.46875

Note) B: Normal group, Fp1 and Fp2: Electrode position of 10-20 system, WOFb: Without focusing-board assembly, WFb: With focusing-board assembly

Table 6. Before and after analysis of brainwave data regarding the focusing board assembly.

Division	n	Normal group		t	p
		Mean ± SD			
WOFb_Fp1 - WFb_Fp1	10	0.119 ± 0.333		1.127	0.289
WOFb_Fp2 - WFb_Fp2	10	0.056 ± 0.521		0.342	0.741

Note) Interaction effect using a paired t-test model. Fp1, Fp2: Electrode position of 10-20 system, WOFb: Without focusing-board assembly, WFb: With focusing-board assembly.

paired difference mean was 0.119 ± 0.333 for the brainwave measured on the left side of the prefrontal lobe (Fp1) and 0.056 ± 0.521 for the brainwave measured on the right side of the prefrontal lobe (Fp2). In terms of significant probability, the brainwave measured on the left side of the prefrontal lobe (Fp1) had p = 0.289 whereas the brainwave measured on the right side of the prefrontal lobe (Fp2) had p = 0.741, which showed no statistically significant difference (p > 0.05). In Table 6, since the

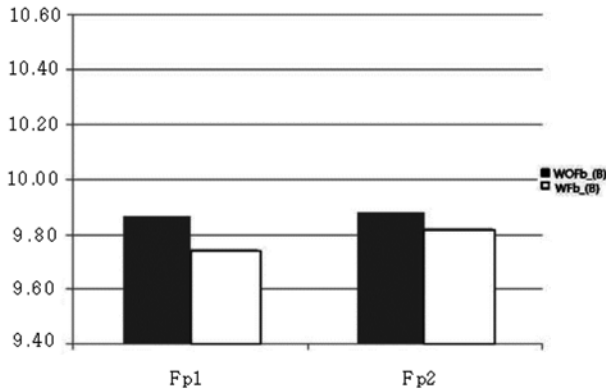


Fig. 10. The graph of brainwaves before and after use of the focusing-board assembly in the normal group. Fp1, Fp2: Electrode position of 10-20 systems, WOFb: Without focusing-board assembly, Wfb: With focusing-board assembly.

normal person group had no anxiety in the MRI system from the starting point to the end point, the data, which were measured before and after the focusing board assembly was used, evidenced no changes such as relaxation or arousal according to the results of alpha SEF-50% analysis (Fig. 10).

3.3. Brainwave Analysis before the Focusing Board Assembly was Used in the Experimental Group and the Normal Person Group

The results of the independent t-test for the alpha wave SEF-50% were as follows in the case in which the focusing board assembly was not used inside the magnetic bore of the model MRI machine in the experimental group and the normal person group. According to the results of brainwave analysis, the mean difference was 0.532 ± 0.279 for the brainwave measured on the left side of the prefrontal lobe (Fp1) and 0.546 ± 0.260 for the brainwave measured on the right side of the prefrontal lobe (Fp2). In terms of significant probability for both sides, the brainwave measured on the left side of the prefrontal lobe (Fp1) had a p value of 0.077 whereas the brainwave measured on the right side of the prefrontal lobe (Fp2) had a p value of 0.055, which showed no statistically significantly positive correlation ($p < 0.05$). In Table 7 the frequencies

Table 7. Brainwave analysis data of the experimental group and normal group before use of the focusing board assembly.

Division	n	Mean \pm SD	t	p
WOFb_Fp1	10	0.532 ± 0.279	1.906	0.077
WOFb_Fp2	10	0.546 ± 0.260	2.098	0.055

Note) Interaction effect using a Independent t-test model. Fp1, Fp2: Electrode position of 10-20 system, WOFb: Without focusing board assembly

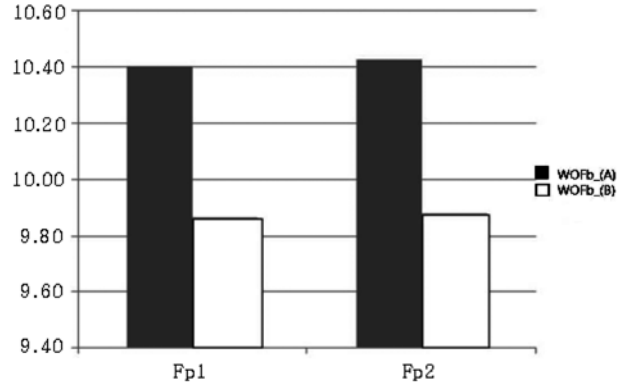


Fig. 11. Graph of brainwaves before use of the focusing-board assembly in experimental group and normal group. Fp1, Fp2: Electrode position of 10-20 systems, WOFb (A): Without focusing-board assembly of group (A), WOFb (B): With focusing-board assembly of group (B).

measured on both sides of the prefrontal lobe were measured to be higher in the experimental group than in the normal person group under identical conditions, which showed some differences. However, the value of the alpha wave SEF-50%, an index that represents the degree of relaxation, was found not to be sufficient to satisfy the correlation with statistical significance (Fig. 11). The significant probability for relaxation and arousal was found to be unsatisfactory according to the analysis results of brainwaves measured when the focusing board assembly was not used in the experimental group and the normal person group. However, the difference between the two groups was ultimately significant, which clearly demonstrates the mental status of the group of the examinees who showed anxiety in the MRI system and the group of persons who remained relaxed, and which provides an objective verification of their anxiety status.

3.4. Brainwave Analysis after the Focusing Board Assembly was Used in the experimental Group and the Normal Person Group

When the focusing board assembly was used within the magnetic bore of the model MRI machine, the paired difference mean was 0.005 ± 0.243 for the brainwave measured on the left side of the prefrontal lobe (Fp1) and 0.029 ± 0.262 for the brainwave measured on the right side of the prefrontal lobe (Fp2) among the brainwaves from the experimental group and the normal person group. In terms of significant probability, the brainwave measured on the left side of the prefrontal lobe (Fp1) had a p = 0.983 while the brainwave measured on the right side of the prefrontal lobe (Fp2) had a p value of 0.913, thus showing no statistically significant difference ($p > 0.05$)

Table 8. Brainwave analysis data of the experimental group and normal group after use of the focusing board assembly.

Division	n	Mean ± SD	t	p
WFb_Fp1	10	0.005 ± 0.243	0.021	0.983
WFb_Fp2	10	0.029 ± 0.262	0.111	0.913

Note) Interaction effect using a Independent t-test model. Fp1, Fp2: Electrode position of 10-20 system, WFb: With focusing board assembly

(Table 8). According to the results of the measurement analysis in cases when the focusing board assembly was used inside the magnetic bore of the model MRI machine, both of the experimental group and the normal person group showed no differences in terms of relaxation or arousal. These results were considered corroborative of the hypothesis that the use of the focusing board assembly in the arousal phase for the experimental group reduced the anxiety to the level of the normal person group. Before the focusing board assembly was used inside the magnetic bore, the analysis results of brainwave measurement in the experimental group showed that the alpha waves appeared to be high as the result of anxiety. However, the alpha wave was lowered as the tension was relaxed after the focusing board assembly was used (Fig. 12).

3.5. Results of Clinical Study on Focusing Board Assembly

Fig. 13 shows image (a) in which the scanning was not successful due to the generation of motion artifacts as deriving from the examinee’s anxiety during the scanning and image (b) in which the scanning in the MR-FBS technique was successful when the focusing board assembly was used and the image could be obtained. When comparing the images, it was possible to readily verify the

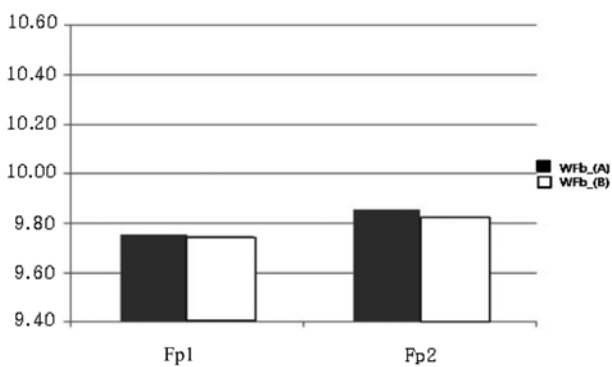
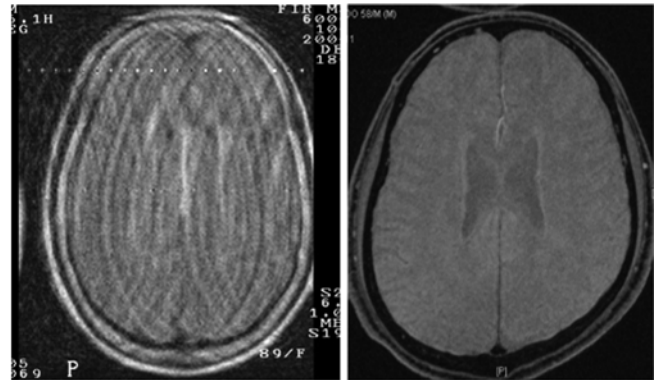


Fig. 12. Graph of brainwaves after use of the focusing-board assembly on experimental group and normal group. Fp1, Fp2: Electrode position of 10-20 systems, WOFb: Without focusing-board assembly, WFb: With focusing-board assembly.



(a) without focusing-board (b) with focusing-board

Fig. 13. Image of failed and successful MRI scans.

efficiency of the MR-FBS technique using the focusing board assembly.

4. Discussion

In brainwave measurements, the alpha wave is the basic wave that reflects a stable brain state in the context of neurophysiology. As it is less profoundly influenced by artifacts, it has traditionally been used to assess the functional status of the cerebral hemisphere in regard to human behavior. Furthermore, alpha waves are indicative of optimal mental processes in human beings. In the case of meditation, the appearance of alpha waves indicates a favorable brain status, with less stress and anxiety. For this reason, alpha waves are frequently considered a proxy for emotional stability [12]. The brainwave measurement experiment conducted using the focusing board assembly was classified into four categories for quantitative analysis of the alpha waves. The analysis results were as follows: in the experimental group of the examinees who felt anxiety inside the magnetic bore, brainwaves were measured in cases in which the focusing board assembly was used and not used, and the results showed that only the brainwaves measured on both sides of the prefrontal lobe were activated. In the normal person group of examinees who did not feel any anxiety, brainwaves were measured in the same place and under the same conditions as the ones for the experimental group. The results of brainwave analysis did not show relaxation or arousal. When brainwaves were measured inside the magnetic bore in the experimental group and the normal person group without the use of the focusing board assembly, the analysis results demonstrated that the frequencies from both sides of the prefrontal lobe were higher in the experimental group. This consequently demonstrated arousal. When brainwaves were measured inside the magnetic bore in

the experimental group and the normal person group as the focusing board assembly was used, the analysis results showed no differences terms of relaxation and arousal, which confirmed the attenuation of anxiety. It is believed that these results are consistent with the results of the study conducted by Bruder *et al.* [13] showing that prefrontal lobe activity was significantly high among patients with anxiety. Heller *et al.* [14] suggested previously that panic or anxiety were related to overactivation of the prefrontal lobe, while Tucker [15] related anxiety to a dysfunction of the forebrain hemisphere. The results of this study also demonstrated that brainwaves were aroused in cases in which the focusing board assembly was not used. The frequency of the alpha wave was low when the focusing board assembly was used, which explains how the brainwave was relaxed to fall into a comfortable state. These results are consistent with the report by Henriques and Davidson [16] that higher alpha wave frequencies, which are indicative of arousal, were measured in the group of patients with anxiety disorder, whereas the opposite alpha wave pattern was noted in the control group of healthy persons. According to the analysis of anxiety reduction based on the brainwave measurement in the experimental group, the alpha wave frequency was lowered on both sides of the prefrontal lobe. This is believed to corroborate the purported anxiety reduction effects of the focusing board assembly. When the focusing board assembly was not used for brainwave measurement in the experimental group and the normal person group, the analysis results did not evidence as significant a difference as anticipated. However, the aforementioned analysis results were considered to significantly satisfy the objective of the study for the following reasons. According to our analysis, the alpha wave frequency measured in the experimental group with the use of the focusing board assembly was lower than the alpha wave frequency measured in the normal person group who felt no anxiety within the magnetic bore even without the use of the focusing board assembly. Additionally, when the focusing board assembly was used, the brainwave analysis results from the experimental group were almost identical to those from the normal person group. This is believed to confirm that the mentally and psychologically anxious status of an examinee who felt anxiety inside the magnetic bore was relaxed and stabilized to the level of the normal person group, thanks to use of the focusing board assembly. Due to the direction and limitations of this study, more biometric information is clearly required. For example, the questionnaire as a tool for self-examination used herein lacked specificity. Moreover, brainwaves were not measured at the same value in the group with claustrophobia and

other types of anxiety disorder. In future experiments, it will be necessary to add more experimental targets to conduct a variety of analyses. The anxiety measurements in this study were conducted to introduce the electrophysiologic measurement method, rather than to rely solely on self-rating scales. However, the configuration environment of the MRI system appears overwhelming, and without the use of the focusing board assembly, it was almost impossible to control claustrophobia in the anxious examinees to a level near normal. For the same reason, the ECG, the EMG and the respiration rate were measured simultaneously along with the brainwave measurements. However, the measurement values differed among individuals, and the data related to artifacts were excluded from the results since they were not analytically meaningful. Furthermore, some examinees in this experiment suffered extreme anxiety, such that they could not even enter the magnetic bore. Therefore, the examinees who used the focusing board to relax before the MRI scanning, were also included for analysis. The measurement and follow-up of brainwaves for examinees generated the following results. The examinees, who in the beginning could not even enter the magnetic bore for scanning, used the focusing board assembly, which later enabled them to take the normal MRI scan also in other places (2 persons). Additionally, it was determined that one of them could undergo an MRI scan or a scan by a similar machine (PET) without using the focusing board assembly in other medical institutions (1 person). However, even though the focusing board assembly was used, it cannot be concluded that the anxiety of all of the examinees was completely removed, since slight differences were observed, depending on the characteristics of the individuals involved. It was reported that 50% or more of the examinees who experienced the MRI system for the first time expressed a slight and vague anxiety prior to undergoing the scan. In consideration of these results, it was believed that the MR-FBS technique that used the focusing board assembly was quite appropriate to conduct MRI scanning in a fashion that was safe and comfortable for the examinee. According to a comprehensive analysis of our results, it was confirmed that the objective of this study had been satisfied, as a result of the following findings. The focusing board assembly was developed based on the survey to determine examinees' color preferences for focusing board assembly, as well as on the basis of data on patients who failed to undergo MRI scanning due to their extreme anxiety when within the magnetic bore of the model MRI machine. Use of the focusing board assembly enabled the patients who had failed or refused to take the scanning due to anxiety in the MRI system, to undergo a normal MR-FBS scan.

According to examination of the image information data obtained using such measurement techniques, the quality of all images was improved without motion artifacts due to the anxiety of the examinee; this was consistent with the analysis results of the survey. The survey results demonstrated that the examinees did not experience dizziness or anxiety, and felt relaxed and comfortable, thanks to the use of the focusing board assembly. The survey results, which demonstrated that examinees felt that their tension had been attenuated, were examined on the basis of analyses of the physiological and behavioral changes of examinees, which were shown in the MRI system, and based on analyses of scanned image data. This method was the only means before the EEG began to be used for verification of examination. In this case, the criteria for determination appear to be subjective for all except the focusing board assembly. For this reason, EEGs were used for objective evaluations regarding the use of the focusing board assembly. The analysis results of the data on brainwaves, which were measured inside the magnetic bore of the model MRI machine in the experimental group and the normal person group, demonstrated the reduction in alpha wave. This enabled the verification of the degree of reduction in anxiety, which has until now been rather vague, via objective means.

In comparison of analysis results of brainwaves from the experimental group and the normal person group, the significant probability did not evidence a satisfactory correlation when the focusing board assembly was not used. However, the results of the paired t-test for the experimental group confirmed that the significant probability was statistically satisfactory. Additionally, the results of the independent t-test demonstrated that the experimental group, who experienced anxiety in the model MRI machine, had brainwave levels similar to those of the normal person group, owing to the use of the focusing board assembly, which confirmed that their tension had been attenuated. As a result, it was determined that the development of the MR-FBS technique using the focusing board assembly sufficiently satisfied the study objective, which could resolve practical issues and provide the anticipated effects, as follows. When the focusing board assembly was used, it was possible to conduct scanning normally for examinees who could not get inside the magnetic bore of the MRI machine or who were transferred to the inside but could not undergo scanning. As a way to determine why the examinees failed to take the scan or had trouble taking the scan in the normal MRI system, attention was paid to the reasons behind the examinee's reluctance; largely, this reluctance was the result of anxiety and fear, as well as dizziness. It was noted that these two phenomena came

into play independently of one another. This problem could be resolved by using the focusing board in different ways for each. The quantitative analysis of the data on the brainwaves was measured when an examinee with anxiety used the focusing board assembly successfully, and the results verified the efficiency of the MR-FBS technique using the focusing board assembly. This technique allowed image information to be precisely obtained, because examinees felt lessened anxiety, and could thus comfortably undergo scanning, thanks to the application of the technique to such patients with anxiety disorder. The technique also could keep examinees from suffering from trauma due to the use of closed-type medical equipment or prevent any accidents, such as damage to image scanning equipment. The examinees, who suffered claustrophobia in the MRI machine, could undergo scanning using similar medical equipment without any problem after having experienced the MR-FBS technique. Therefore, they were able to adapt themselves to a narrow space for scanning, which is the main benefit of this technique. Consequently, it was confirmed that before scanning was performed, it was necessary to help an examinee reduce his or her anxiety and feel comfortable in order to obtain precise medical image information.

The results of this study were analyzed to assess the generation and reduction of anxiety in the MRI scan and were summarized as follows. The surveys were conducted to compile the cases in which an examinee could not overcome dizziness or anxiety during the scanning in the MRI system and eventually failed to take the scan. The cases were then classified depending on the cause of problem, in an effort to systematize solutions to the problem. The next step was to solve the problem using the self-manufactured focusing board assembly and by stimulating the visual and tactile senses. This method can be used to control the flow of information relevant to the examinee's judgments about reality, by sending the information via an external stimulus pathway in the arousal phase of an examinee, thus producing a synergistic effect that can relax the tension induced by dizziness or anxiety. To this end, the MR-FBS technique using the focusing board assembly was developed and clinically applied. Our analysis of the successfully obtained images corroborated the utility of the technique. Additionally, for scientific verification of the efficacy of the focusing board assembly, EEG measurements were taken within the magnetic bore of the model MRI machine in both the experimental group and the group of normal individuals. The analysis of the brainwave measurement data confirmed the excellence effects of the focusing board assembly. The experiment with the use of the magnetic bore of the model MRI

machine could improve such effects at the clinical stage. Under these conditions, brainwave measurement and the analysis results of the measurement, which aimed at the verification of the MR-FBS technique using the focusing board assembly, were believed to satisfy the desired objective of this study.

5. Conclusions

1. The focusing board assembly described herein was self-manufactured to resolve the problems that arose in the MRI scan, which resulted in the development of the MR-FBS technique.

2. The efficiency of the MR-FBS technique using the focusing board assembly was found to be excellent and caused no reluctance by the examinee in the process of applying the technique to the examinee diagnosed with anxiety disorder. Additionally, the MRI image obtained with the examinee sleeping after the drug injection was compared with the images obtained in the MR-FBS technique, which showed no difference between them. This result confirmed the excellence of the technique.

3. According to our analysis of the brainwaves measured on both sides of the prefrontal lobe (Fp1, Fp2) as the focusing board assembly was used, the degree of anxiety reduction in the experimental group was similar to that in the normal person group, which evidenced no statistically significant differences. This result confirmed the excellence of the focusing board assembly, as the mental and psychological anxiety status within the magnetic bore of the MRI machine in the experimental group was stabilized to the level in the normal person group thanks to use of the focusing board assembly. Therefore, the principal objective of this study was considered to have been achieved.

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