A Study on the Size of Bore on Signal to Noise Ratio (SNR) in Magnetic Resonance Imaging (MRI)

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Abstract

Background/Objectives: An objective of this study is to analyze the size of bore on signal to noise ratio in magnetic resonance imaging. Methods/Statistical Analysis: During this process, the magnetic field also shows irregularity due to the environmental factors. Therefore in this study, magnetic field non-uniformity according to the bore size of MRI will be examined as well as the influence on the image through SNR measurement. Findings: Avanto with bigger bore size has shown higher SNR value, and especially, it has shown 6 times or greater difference in TSE (Turbo Spin Echo) technique. Improvements: It would be imperative to conduct a test with a small bore size and a uniform magnet when the MRI test failure rate is high due to claustrophobia.

Keywords: Bore size, Claustrophobia, Magnetic field, Magnetic Resonance Image (MRI), Pulse sequence, Signal to Noise Ratio (SNR)

1. Introduction

Areas to be examined can be positioned in the MRI where the image is created by detecting the release of energy generated by the interaction of the hydrogen nuclei and the radio wave which is non-ionizing radiation. In other words, when the energy level of particles having nuclear magnetic moment is separated into the main magnetic field, it uses oscillating magnetic field of frequency which corresponds to such distance or the resonance phenomenon generated between the electromagnetic wave

All tests should distinguish the signal of tissue in accordance with the location, represent the location in video and signal the accurate point. However, magnetic resonance signal does not contain any information on direction. Therefore, it is required to use additional gradient magnetic field for identifying signal location. Gradient magnetic field can acquire desired videos from diverse directions of a patient. Moreover, it offers a lot of data based on its high resolution. Video resolution depends on the strength of magnet. Recently, 3.0T MRI system for clinical use can offer high-quality video over all body on the basis of the high signal-to-noise (SNR) and the innovative technology development of RF coil. Therefore, there is a significant increase in clinical use of 3.0T MRI system.

Currently, diverse devices ranging from 0.2T to 3.0T are being used. The size of bore has also increased. This is required for the purposes of obtaining high-resolution information and conducting comfortable tests on patients with a more stable posture. That is to say, the proportion of those cases in which discomfort and claustrophobia have a negative impact on patient diagnosis due to the restrictions associated with the structure and noise of magnet is approximately 5 to 10 percent. Hence, these cases were improved. Claustrophobia refers to the symptom that heart rate increases and dyspnoea occurs in an enclosed space. Even an anxious emotion is induced. As a result, people with claustrophobia have difficulty staying in an enclosed space. If this symptom persists, patients with this symptom will suffer from claustrophobia permanently. As a result, they may have to undergo psychological treatment. Hence, it is very important to ensure that it will be a
comfortable test to those patients who must undergo this test. To this end, it is required to increase the size of bore so that patients can avoid claustrophobia as much as possible. However, the distortion of main magnetic field is relatively increased because the size of bore is increased and the magnet depth is shortened. Therefore, the non-uniformity of main magnetic field should inevitably get worsened and SNR should be influenced when it gets farther from the isocenter.

The size of magnetic field which magnetizes the protons within the human body has a disadvantage of being distorted in some part of the image due to non-uniformity according to the inside position, and this problem is caused by an artifact attributed by the internal body and artifactitious chemical shift during the signal acquisition process, magnetic susceptibility which is an artifact attributed by the magnetic field and the artifact attributed by the radio wave and the gradient magnetic field. In addition, these problems increase more as the subject becomes distant from the isocenter which is the center of magnetic field, and the artifact can also be generated according to non-uniformity of magnetic field within the bore of MRI device.

Therefore in this study, SNR value of each pulse sequence commonly used in clinical will be compared and studied according to the width of the MRI bore.

2. Materials and Methods

2.1 Materials

Two 1.5T MRI devices made by SIEMENS were used[Figure 1][Figure 2].

1) MRI device
   1) MAGNETOM Avanto I-class 1.5T(Siemens, Germany) : bore size 60 cm
   2) MAGNETOM Espree 1.5T(Siemens, Germany) : bore size 70 cm

2) Phantom and Coil
   1) Siemens water phantom 2000 ml
   2) Siemens spine array

Figure 1. MRI(Avanto and Espree).

Figure 1. Spine coil and Water phantom.
2.2 Methods

2.2.1 MRI scan According to each sequence
TR and TE was fixed and the 3mm scan was applied to each pulse sequence (SE, TSE, STIR, FLAIR, TSE Fat saturation) used in clinical to obtain the image [Table 1] [Figure 3].

2.2.2 Evaluation of SNR
SNR value was obtained, compared and evaluated by obtaining the average pixel value from PACS based on the DICOM file image obtained from each pulse sequence (SE, TSE, STIR, FLAIR, TSE Fat saturation) [Figure 4].

In regard to the background signal for measuring SNR, it was measured by a mean value of three measurements of the signal on the left and right sides of the magnetic field and the front and rear sides thereof. In regard to the main signal, SNR value was measured after measuring the center of the phantom. SNR images was compared and evaluated by image j program.

3. Results

3.1 Evaluation of SNR
SNR on each pulse sequence according to the bore width was compared and evaluated. All conditions were the same, and the pulse sequence has used SE (Spin Echo), TSE (Turbo Spin Echo), TSE_FS (Turbo Spin Echo Fat Saturation), STIR (Short Time Inversion Recovery) and Diffusion [Table 2][Figure 5].

In regard to SE sequence SNR, Avanto is 49.6, whereas Espree is 47.6. In regard to TSE sequence SNR, Avanto is 13.3, whereas Espree is 2.8. In regard to TSE_FS sequence SNR, Avanto is 120.8, whereas Espree is 63.2. In regard to STIR sequence SNR, Avanto is 35.2, whereas Espree is 18.8. In regard to Diff. sequence, Avanto is 9.2, whereas

Table 1. Test pulse sequence parameter

<table>
<thead>
<tr>
<th>SEQ.</th>
<th>TR(ms)</th>
<th>TE(ms)</th>
<th>Matrix</th>
<th>FOV(mm)</th>
<th>Thick(mm)</th>
<th>Gap(%)</th>
<th>NEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE</td>
<td>500</td>
<td>8.7</td>
<td>192x256</td>
<td>500</td>
<td>3</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>TSE</td>
<td>4000</td>
<td>103</td>
<td>192x256</td>
<td>500</td>
<td>3</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>TSE_FS</td>
<td>3900</td>
<td>81</td>
<td>192x256</td>
<td>500</td>
<td>3</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>STIR</td>
<td>5000</td>
<td>33</td>
<td>192x256</td>
<td>500</td>
<td>3</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Diff.</td>
<td>6200</td>
<td>161</td>
<td>192x256</td>
<td>500</td>
<td>3</td>
<td>10</td>
<td>2</td>
</tr>
</tbody>
</table>

Figure 3. Scan of water phantom in MRI.

Figure 4. Measurement of pixel value in PACS.
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Espree is 5.4. Avanto, whose bore size was smaller, showed a larger difference by approximately 2 to 6 times than Espree.

3.2 Evaluation of Images

Avanto SNR image with smaller bore size has shown higher pixel value, and especially, it has shown greater difference in TSE (Turbo Spin Echo) sequence [Figure 6].

4. Conclusions

In this study, SNR value was measured using a pulse sequence which is commonly used in clinical in order to examine the magnetic field changes according to the MRI bore size. Avanto with smaller bore size has shown higher SNR value, and especially, it has shown 6 times or greater difference in TSE (Turbo Spin Echo) technique. This was thought to be created by receiving constant RF pulse in the unrecovered state of hydrogen nuclei which caused more severe non-uniformity of the magnetic field.

In the future, I hope the study on the magnetic field non-uniformity can be conducted by adding other external factors besides the bore size.

5. Discussion

The intensity of magnetic field in MRI determines the signal-to-noise ratio (SNR) of MR image. To obtain high-quality MR image, SNR must be high. It is possible to improve SNR by increasing the intensity of magnetic field or other parameters. As compared with the commercially available 1.5T MRI, 3.0T MRI offers high-quality video. In addition, the recently developed MRI has a larger size of cylindrical magnet bore, thereby bringing more comfort to patients. As a result, it minimized test resistance resulting from obesity, claustrophobia, etc. Claustrophobia

Table 2. Evaluation of SNR in MRI sequence

| SEQ. | Avanto | | | Espree | | |
|------|--------|--------|--------|--------|--------|
|      | Back ground | Mean±Std. | SNR | Back ground | Mean±Std. | SNR |
| SE   | 12.6 | 629.1±81.2 | 49.6 | 13.6 | 646.7±95.9 | 47.6 |
| TSE  | 46.3 | 616.3±103.3 | 13.3 | 37.1 | 1020.8±155.3 | 2.8 |
| TSE_FS | 6.7 | 811.6±47.2 | 120.8 | 12.8 | 809.6±18.1 | 63.2 |
| STIR | 2.8 | 99.8±24.7 | 35.2 | 10.4 | 195.4±43.0 | 18.8 |
| Diff | 6.1 | 56.2±4.3 | 9.2 | 10.9 | 59.5±4.7 | 5.4 |

Figure 5. Diagram evaluation of SNR in MRI sequence.

Figure 6. Surface plot of SNR images in TSE sequence. Left Avanto image and right Espree image.
that may appear in MRI test may be worsened only by RF heating, gradient noise (65-96dB) and magnet⁴. Most of these effects are temporary. However, there are many cases that general patients are unable to get the test properly. Also, there are some patients who suffer from claustrophobia permanently. Therefore, these patients require psychological treatment⁵. In the study of Young-soo Kim et al., 98 percent of the participants in this study responded that they enlarge the size of a round cylinder or minimize sound as a way to reduce claustrophobia⁶. Hence, it is very important to reduce claustrophobia and also keep patients feel comfortable by enlarging the size of magnet bore.

That is to say, it is recommended to minimize claustrophobia by conducting a test after enlarging the bore size from 60 cm to 70 cm while receiving RF pulse. Nonetheless, subsequent changes in SNR cannot be ignored. In this study, an additional method should be proposed in order to increase SNR given the fact that SNR was reduced when the bore size was enlarged. Pulse sequences, which rely on processionial frequency that is relatively uniform with fat suppression pulse sequence, do not generally work well with high magnetic field intensity⁷. This is consistent with the result of this study that there is a larger difference of SNR in not only TSE pulse sequence but also fat suppression pulse sequence. On that account, it is necessary to improve MRI pulse sequence further by securing the uniformity of magnetic field that is the evaluation index of image quality rather than increasing the intensity of magnetic field for increasing SNR.

The preceding studies revealed that a distortion in the main magnetic field would become more severe when getting farther from the isocenter and when the intensity of magnetic field became higher. In this study, it was confirmed that this problem was corrected by utilizing the software called 2D Gradient Distortion Filter⁸. Although SNR cannot be an absolute evaluation index, SNR showed the results that were closely related to the overall image quality⁹. Therefore, it would be imperative to conduct a test with a small bore size and a uniform magnet when the MRI test failure rate is high due to claustrophobia. It is also required to develop pulse sequence that is less influenced by magnetic field so that magnetic field inside a bore can become uniform even though its bore size becomes enlarged.

6. References

14. YH Park. A study on the influence of main magnetic field inhomogeneity on signal to noise ratio(SNR) in magnetic resonance imaging(MRI). Korean university, 2011