Analysis of signal to noise ratio from 1.5 tesla MRI head coil phantom image on daily quality assurance

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Abstract. Signal to Noise Ratio (SNR) is one of the quality control tests for most diagnostic imaging modality, including Magnetic Resonance Imaging (MRI). This study used MRI 1.5T GE Signa Creator type and head coil phantom with variations of Echo Time (TE), Repetition Time (TR), voxel volume and flip angle. 16 data images were obtained from the acquisition process. These images were analyzed using image processing software to calculate the SNR value. It results in four data distribution with the highest value of 36.98 and the lowest value of 32.64. The graphs of voxel volume versus SNR also formed four groups of data with an overall value above SNR baseline value for daily operation.

1. Introduction
Every medical imaging modality needs quality control; this is in accordance with the Minister of Health Decree Number 1014/Menkes/SK/XI/2008 concerning Radiodiagnostic Service Standards in Health Service Facilities [1]. The task of medical physicists in radiological diagnostic services includes radiation protection, Quality Assurance, and Quality Control diagnostic radiology, imaging and interventional equipment, x-ray machine testing and imaging, Quality Assurance and Quality Control imaging modalities, and radiation dosimetry [2]. In accordance with the task of medical physicists, quality control on Magnetic Resonance Imaging (MRI) must be carried out by a medical physicist especially those working in diagnostic radiology services.

MRI is one of the diagnostic imaging modalities that can produce multiplane anatomical slices with contrast to tissues better than CT scans so that MRI is very well used to detect a lesion in soft tissue. By manipulating the MRI parameters, sequences will be produced that are good at assessing certain pathologies [3]. MRI imaging produces images of pieces of the human body using magnetic fields without using x-rays [4]. Quality control on MRI modalities is divided into two, namely daily or weekly tests and annual tests. Daily or weekly tests include the SNR test, center frequency and transmit gain, set up table and positioning accuracy, geometric accuracy, high contrast resolution, low contrast resolution, artifact analysis, film quality control, and visual checklist. While the annual test is magnetic field homogeneity, slice position accuracy, slice thickness accuracy and radiofrequency coil [5].

One of the quality control parameters on MRI is Signal to Noise Ratio (SNR) [6]. SNR is influenced by proton density, voxel volume, TR (Time Repetition), TE (Time Echo), Flip Angle, NEX (Number of Excitation), receive bandwidth and receiver coil [7]. Voxel volume, during the imaging process, tissue slices are divided into the matrix or individual volume units called voxels [8]. Repetition time (TR) is the interval between two successive excitation sequences at the same slice [9]. Reverberation time (TE)
is the interval between applying excitation pulses and collecting MR signals [9]. The flip angle is the amount of rotation of magnetization experienced during RF applications measured in degrees or radians [10].

At one private hospital in Yogyakarta, head MRI examinations during 2018 from January to October reached 613 out of a total of 2138 examinations. Given this, it is very important to measure SNR to ensure the quality of the MRI. During this time at this Hospital, SNR measurements have been carried out every day but these measurements are only carried out to determine the SNR value in general without seeing what factors influence the SNR value. Therefore, SNR testing is needed in order to evaluate the radiological quality of MRI images by using various operational parameters.

2. Method
This research was conducted at the radiology using MRI with the type Signa Creator GE 1.5T and head phantom daily quality assurance for SNR. The phantom was placed in the head coil as shown in Figure 1 and the image was taken with MRI so that it gets the image of the phantom. Image acquisition was done several times with different variations, namely voxel volume, repetition time (TR), echo time (TE) and flip angle. After obtaining an image from each protocol variation, image analysis was then carried out with the image processing software. Each signal image in cropping in the area that has been determined in the machine manual is square in the area of \([x, y, \Delta x, \Delta y]\), \(x\) is the position of the column from the upper left corner, \(y\) is the position row from the upper left corner, \(\Delta x\) is the width of the area and \(\Delta y\) is the height of the area to be cropped. The cropped area of the signal image is \([143 40 80 180]\).

Calculation of image SNR values using equations:

\[
SNR = \frac{\text{Mean of Signal within ROI}}{\text{Mean of Noise within ROI} + 1.253}
\]

The SNR value must be greater or equal to 29.1 [11].

![Figure 1](image1.png)  
(a) Head Coil and Phantom, (b) MRI 1.5 T GE Signa Creator

3. Results and discussion
Data acquisition was done by making variations of several parameters namely TE, TR, voxel volume and flip angle as it showed Table 1.
Table 1. Variation of voxel volume, TE, TR, FA, and Time

| No | Voxel | TE  | TR  | FA  | Time  |
|----|-------|-----|-----|-----|-------|
| 1  | 3     | 1   | 500 | 80  | 0.01.30 |
| 2  | 5     | 1   | 500 | 80  | 0.01.30 |
| 3  | 7     | 1   | 500 | 80  | 0.01.30 |
| 4  | 9     | 1   | 500 | 80  | 0.01.30 |
| 5  | 3     | 80  | 6000| 120 | 0.08.00 |
| 6  | 5     | 80  | 6000| 120 | 0.08.00 |
| 7  | 7     | 80  | 6000| 120 | 0.08.00 |
| 8  | 9     | 80  | 6000| 120 | 0.08.00 |
| 9  | 3     | 100 | 8000| 140 | 0.15.00 |
| 10 | 5     | 100 | 8000| 140 | 0.15.00 |
| 11 | 7     | 100 | 8000| 140 | 0.15.00 |
| 12 | 9     | 100 | 8000| 140 | 0.15.00 |
| 13 | 3     | 1000| 14000| 160 | 0.30.00 |
| 14 | 5     | 1000| 14000| 160 | 0.30.00 |
| 15 | 7     | 1000| 14000| 160 | 0.30.00 |
| 16 | 9     | 1000| 14000| 160 | 0.30.00 |

After scanning the phantom using MRI, the image results are shown below in figure 2.

![Image](image1.png)

(a) (b) (c)

**Figure 2** (a) image noise, (b) signal image before cropping, (c) cropped area image

The image from the phantom scan for each protocol variation is measured by its SNR value and graphed by the sample number on the SNR value. The graph is shown in figure 3.
The SNR value in each sample variation shows different values and tends to form four data distribution (Fig. 3). The first data distribution is sample numbers 1 to 4 with a range of SNR values between 32.64 to 33.40. The second distribution of data is sample numbers 5 to 8 with a range of SNR values between 33.67 to 34.43. The distribution of the third data is sample number 9 to 12 with an SNR value of 35.67 to 36.98. The fourth distribution of data is a sample number 13 to 16 with an SNR value between 35.54 to 36.85. The highest value of 36.98 is in the variation of sample number 9, the lowest value of 32.64 is in the variation of sample number 4. In accordance with the theory that the SNR value must be greater than 29.1, the SNR value as a result of the TE, TR, voxel volume and flip angle protocol is greater than the baseline value of the machine, so the variation of the protocol is feasible for MRI examination.

The time of data collection can also be taken into consideration in MRI examinations because with shorter time of scanning, the SNR value is still above the baseline. Thus, it can speed up the inspection time and reduce operational costs. The graph of voxel volume versus SNR value is shown in figure 4.
There are four groups of in graph of voxel volume versus SNR value (Fig.4). Sample numbers 1 to 4 on the blue graph with □ symbols has lowest SNR values, while sample numbers 5 to 8 on the black with + symbols has medium SNR values, samples 9 to 12 on the green with * symbol and samples 13 to 16 which is red with the Δ symbol has highest SNR value. In sample numbers 9 to 12 and 13 to 16, the SNR value is almost the same so it can be concluded that the higher the variation in TE, TR, voxel and flip angle, SNR values tend to be the same. In theory, a long TE will decrease SNR, whereas longer TR will increase SNR value. While at the flip angle, the smaller the angle, the smaller the SNR value [12]. Figures 3 and 4 show different SNR values because variations in the values of TE, TR, voxel volume and flip angle also vary according to the value of the protocol that is often used in head MRI examination.

4. Conclusion
SNR values measurement using head coils phantom on a GE 1.5 T MRI machine with 16 variations of data was done by analyzing the relationship between images and SNR value. This results in four data distribution with the highest value 36.98 of sample number 9 and the lowest value 32.64 of sample numbers 4. From this study, all SNR values are still above the baseline standard which means that MRI is well performed.

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