Study of Image Quality From CT Scanner Multi-Detector by using Americans College of Radiology (ACR) Phantom

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Abstract. In this study, the image quality of CT scan using phantom American College of Radiology (ACR) was determined. Scanning multidetector CT is used to know the image quality parameters by using a solid phantom containing four modules and primarily from materials that are equivalent to water. Each module is 4 cm in diameter and 20 cm in diameter. There is white alignment marks painted white to reflect the alignment laser and there are also "HEAD", "FOOT", and "TOP" marks on the phantom to help align. This test obtains CT images of each module according to the routine inspection protocol of the head. Acceptance of image quality obtained for determination: CT Number Accuracy (CTN), CT Number Uniformity and Noise, Linearity CT Number, Slice Technique, Low Contrast Resolution and High Contrast Resolution represent image quality parameters. In testing CT Number Accuracy (CTN), CT Uniform number and Noise are in the range of tolerable values allowed. In the test, Linearity CT Number obtained correlation value above 0.99 is the relationship between electron density and CT Number. In a low contrast resolution test, the smallest contrast groups are visible. In contrast, the high resolution is seen up to 7 lp/cm. The quality of GE CT Scan is very high, as all the image quality tests obtained are within the tolerance brackets of values permitted by the Nuclear Power Control Agency (BAPETEN). Image quality test is a way to get very important information about the accuracy of snoring result by using phantom ACR.

1. Introduction

The CT Scan (Computed Tomography Scanning) imaging technology was first introduced in 1972 by Sir Godfrey Newbold Hounsfield and Allan Cormack. The first CT scan was produced by EMI Mark 1, with image resolution using an 80 x 80-pixel matrix, each pair of slices taking 4.5 minutes per scan. Due to the length of the examination, it is unable to perform cardiac and respiratory examinations. This first-generation CT scan is only capable of performing a head examination (brain) only [1].

CT Scan is a fairly complex medical imaging system so there is a risk of calibration error, failure of generating system function and X-ray detection as well as the risk for the patient. Therefore, CT Scan aircraft require QC (quality control) program to ensure image quality while maintaining the dose is still below the allowable limit [2,3].

Quality assurance program on the use of CT Scan aircraft using phantom ACR (gammex). This program has the highest radiation safety standards and has basic details, enabling optimal achievement of results [4].

2. Materials

2.1. CT Scan. The CT used as an object is a CT Scan dual slice (General Electric, GE)
2.2. Phantom ACR. The ACR CT accreditation phantom (Gammex 464) is a solid phantom containing four modules and is constructed primarily from a water-equivalent material. Each module is 4 cm in depth and 20 cm in diameter. There are external alignment markings scribed and painted white (to reflect
alignment lights) on EACH module to allow centering of the phantom in the axial (z-axis, cranial/caudal),
coronal (y-axis, anterior/posterior), and sagittal (x-axis, left/right) directions. There are also “HEAD”,
“FOOT” and “TOP” markings on the phantom to assist with positioning [5].

Figure 1. Phantom ACR.

There are 4 phantom ACR CT modules as follows:

Figure 2. Phantom ACR of module.
a). Module 1 is used to assess positioning and alignment, CT number accuracy, and slice thickness, b). Module 2 is used to assess low contrast resolution, c). Module 3 consists of a uniform, tissue-equivalent material to assess CT number uniformity, d). Module 4 is used to assess high contrast (spatial) resolution.

Figure 3. "HEAD" and "FOOT" for phantom.
1). Module 1 is used to assess positioning and alignment, CT number accuracy, and slice thickness, 2). Module 2 is used to assess low contrast resolution, 3). Module 3 consists of a uniform, tissue-equivalent material to assess CT number uniformity, 4). Module 4 is used to assess high contrast (spatial) resolution.

3. Method
We observed seven images of the Phantom ACR for the head protocol. We analyzed the image in May 2017 at the Testing laboratory, BPFK Makassar, Indonesia.

3.1. Scanning Procedures. The parameters used in all of the following tests, derived from the Accredited Phantom Instructions of ACR Instructions.

3.1.1. Compatibility of scanners and phantom. The phantom is aligned with the coronal, sagittal axis and CT Scan plane on the axial axis then centered on the center of the table. Make sure that Phantom will not move [5].

3.1.2. Scanning phantom gammex 464. This study uses axial head protocol.

3.2. Determination of linearity of CT number and slice thickness. To calibrate the CT number, the Phantom is placed at the center of the rotation of the gantry, for "Head" to be placed at the front while the "Foot" is the back than the center point above the module 1. The scanning parameters used are FOV = 22.0 cm, slice thickness = 5 mm and scanning time = 1.5 s. on the monitor, the image is set at WW = 100 HU, WL = 0 HU, ROI = 200.01 mm2. ROI was placed on air, polyethylene, water, acrylic, and bone. Each value of the CT number was recorded. Then made a curve correlation between the electron density with CT number. As for the thickness of the slice setting tested are 3, 5, and 7 mm. to determine the thickness of the slice in the image that is counting the number of bar patterns that appear then divided into two.
3.3. **Determination of low-contrast resolution.** Phantom is placed at the center of the rotation of the gantry, for the "Head" is placed in front while the "Foot" is back then center point above module 2. on the monitor, the image is set at WW = 114 HU, WL = 114 HU, ROI = 105.57 mm². Then place the ROI on a large cylinder image (25 mm) and place also the ROI between the 2 cylinders ie the big and small cylinders. Record the value of CT number and noise into the worksheet. To calculate the low-contrast resolution using the formula of the contrast ratio value to noise. CNR = |A - B| / SD [6].

3.4. **Accuracy, Uniformity CT number and Uniformity Noise**

The phantom is placed in the center of the rotation of the gantry, for the "Head" is placed on the front while the "Foot" is back then the center point above module 3. on the monitor, the image is set at WW = 100 HU, WL = 0 HU, ROI = 208.81 mm². to get the CT number, place each ROI: center, edge 1 (clock 12), edge 2 (clock 3), edge 3 (clock 6) and edge 4 (clock 9). Record the value of CT number and noise into the worksheet.

3.5. **High contrast resolution.** The phantom is placed at the center of the rotation of the gantry, for the "Head" is placed on the front while the "Foot" is back then the center point above module 4. on the monitor, the image is set at WW = 1785 HU, WL = 606 HU. to determine high-contrast resolution is to observe clear and separate bars with each other. And noted in the worksheet.

3.6. **Data Analysis.** The obtained image quality parameters were compared with the tolerance values set by the Nuclear Power Control Agency (BAPETEN). Analysis of image quality parameters using the phantom ACR guide for scanned protocols.

4. **Results and Discussion**

Here’s the result of parameter determination Image quality is obtained by using axial brain protocol.

4.1. **Module 1**

4.1.1. **Linearity CT number.** In this test obtained the value of CT numbers: air, polyethylene, water, acrylic, and bone are strongly correlated with the electron density value of each material. The correlation value that is equal to = 0.996 as shown in figure 6.
4.1.2. Determination of slice thickness. Table 1 shows that all the slice thicknesses measured according to the slice thickness. This indicates that all slice thicknesses tested are still within the tolerance limit.

4.2. Module 2: Measurement of low-contrast resolution on axial head ACR
After evaluated using CNR equation, it turns out the value obtained is $= 1.75$. This can be seen in the figure 7.a.

4.3. Module 3: Determination of Accuracy, Uniformity of CT number and Noise Uniformity
This is shown in figure 7.c.d. the accuracy of CT numbers at center area = -2.26 HU, while the number of CT and noise numbers occupies values of 1.7 and 0.23. Tolerance value for the accuracy of CT number ± 4, uniformity of CT number and noise ± 2. Thus, all parameters tested are still within the tolerance range.

4.4. Module 4: High contrast resolution in Axial brain ACR
In figure 7.b. shows the pattern bar is 7 cm/lp which shows that the resulting image modality is still very good. The tolerance value set is to be 6 lp/cm.

![Module 1, linearity image of CT number and slice thickness.](image_url)
4.5. Discussion. Image quality generated using phantom ACR is acceptable for all test parameters. CT linearity test is accepted due to the CT number is proportional to the electron density in each material ie air, polyethylene, water, acrylic, and bone with a very strong correlation value of 0.997. the allowed tolerance is 0.99. the materials are selected, as they are very close to the tissues of the human body. Slice thickness test is also accepted because for 3 mm thickness the number of wires visible at the top and bottom is divided into two equal to the thickness of the slice. Similarly for the thickness of 5 and 7 mm slices. The allowable tolerance value is (± 0.5 mm). The thickness of the slice has a direct effect on the resulting spatial resolution of the image. Spatial resolution is the ability to reveal objects/organs with high contrast levels. The thinner the image spatial image is getting better, and vice versa. But the thinner the slice, the bigger the noise [7]. The low contrast test is acceptable because the value generated after through the calculation = 1.75, while the tolerable value is permitted 1. Test Accuracy, Uniform CT number, and Noise Uniformity are acceptable. The accuracy of CT number is very influential in determining the density of the organs so as to give a big influence on the diagnosis of a disease. This test is aimed to know the average value of CT in a water medium, uniformity of CT mean value and noise value. In module 4, a high contrast resolution test is accepted, since the Tolerance value of the head protocol for this test is 6 lp/cm and 7 lp/cm visible.

Table.1 The result of measurement of slice thickness.

| Thickness set (mm) | Thickness sett (mm) | Slice (mm) | Tolerance Value | Results  |
|--------------------|---------------------|------------|-----------------|---------|
| 3                  | 3                   | 0.0        |                 | Pass    |
| 5                  | 5                   | 0.0        | 0.5 mm          | Pass    |
| 7                  | 7                   | 0.0        |                 | Pass    |
Figure 7. Citra Phantom ACR a. Low contrast, b. High contrast, c.d. Result of determination of CT number.

6. Conclusions
The quality control of the equipment is very important for the quality of the results, as is the case with the X-ray CT scans. It has obtained satisfactory results on the performance of the equipment so that radiological results can be accounted for. All test results on quality control using ACR Phantom are acceptable.
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