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Evaluation of the ACR MRI Phantom for Quality Assurance Test of 1.5 T MRI Scanner in Awal Bros Hospital Makassar

Purwanto[1,2,3,*], B. Abdullah[3], S. Dewang[3] D. Tahir[3]

[1] Department of Radiology, Dr. Wahidin Sudirohusodo Hospital, Makassar, Indonesia
[2] Department of Radiology, Awal Bros Hospital, Makassar, Indonesia
[3]Department of Physics, Hasanuddin University, Makassar, Indonesia
E-mail: [*]purwanto.wahidin@gmail.com; bualkarabdullah@gmail.com; dtahir@fmipa.unhas.ac.id

ABSTRACT

Image quality of Magnetic Resonance Imaging (MRI) using phantom standard American College of Radiology (ACR) at Awal Bros Hospital Makassar have been studied by using MRI GE type Brivo 355 with strong magnetic field 1.5 Tesla. Phantom heads and standard protocols use the (ACR) standard with an evaluation of seven parameters. Geometric accuracy test results by measuring the height of phantom cylinder in 129.5 mm while the diameter of cylinder in phantom with three measurements obtained value 202.7 mm, 203.0 mm and 202.2 mm. The measurement of high-contrast spatial resolution to distinguish the smallest object on the image is that three rows of holes can be distinguished. Test for determination of the thickness of the slice by calculating the length of the upper and lower signal lane obtained the thickness value of 5.414 mm and 5,439 mm. The measurement of uniformity of image intensity by measuring the value of PUI (Percent Uniformity Integral) for T1W image weighting is 94.3% while for weighting T2W image yields 95.9%. For value of percent signal ghosting obtained value 0.01706. The last parameter of object detection with low contrast is found 30 rows of holes can be evaluated.

Keyword: Magnetic Resonance Imaging, ACR MRI phantom, MRI image quality, Quality Assurance
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1. INTRODUCTION

Development of Magnetic resonance imaging (MRI) imaging technology in Makassar is slower when compared to big cities in Indonesia. The first MRI installed in Makassar was in the radiology department Dr. Wahidin Sudirohusodo hospital in 2004. The MRI specification is a permanent magnet with strength of 0.3 Tesla open gantry that serves an average examination of 2,400 checks annually. In 2012 along with the establishment of Siloam hospital attached MRI with superconductive specifications with magnetic field strength 1.5 Tesla manufacture Philips, followed in the next year 2013, Awal Bros Makassar hospital also installed MRI equipment with the same specification.

MRI imaging is relatively new in the world of applied medical science (medic). MRI imaging is a prime examination to show the soft tissue structure in the human body and its metabolic processes, so this image has a major position in the use of biomedical science applications in medicine. MRI becomes a superior imaging modality due to its flexibility and sensitivity to various network properties. Another factor is that MRI imaging is considered safer because non-invasive imaging and magnetic fields allow diagnostic diagnostics for all ages that produce simultaneous axial, sagittal and coronal multi planar images [1-2].

The problem in MRI imaging is the image quality that is vulnerable to change, while the performance of MRI tools is required to always have high diagnostic accuracy. To ensure consistency of the same (constant) image result, a quality assurance method of MRI image quality, known as MRI quality assurance (QA), must be done regularly and continuously [3-4].

The quality assurance evaluation standard on MRI tools was introduced by American Collage Radiology (ACR) using specialized phantom aids. Seven important assessments of MR image quality were included: geometric accuracy, high-contrast resolution, slice thickness accuracy, slice position accuracy, image intensity uniformity, percent signal ghosting, and low-contrast object detectability [5-7].

Thus the phantom test for ACR MRI Accreditation may represent an ideal QA program for clinical MRI scanners. In comparison with other MR QA tests, the ACR phantom tests use only one phantom, which means that each test can be accomplished in a reasonably short period of time (within one hour in our cases). Both quantitative and qualitative approaches are utilized to analyze the performance of clinical MRI scanners. According to the results of the tests, medical physicists and service engineers are able to correct the inadequate items and thus obtain images with improved quality.

Radiology department at Makassar city hospital quality assurance MRI image quality is difficult to do, because of the standard phantom difficulties for MRI. Image quality evaluation is generally only done by the tool manufacturer at the start of installation. The research for the evaluation of image quality using ACR standard phantom was first performed in radiology department of Makassar city hospital, that's why we made this research.

2. MATERIAL AND METHOD

A. MRI ACR Phantom

The study used a standard phantom created by the ACR used to assess the performance of MRI devices in the radiology department of Awal Bros Hospital Makassar. There are two types of MRI phantom that is large phantom to represent the head and phantom objects of small size to represent the extremities in this case of the knee. Type of coil used is body coil, considering if using head coil size or diameter of phantom bigger.

The characteristic of the phantom ACR MRI used in the study of cylinder-shaped acrylic plastic material, the inside cylinder diameter of the height is 130 mm and the inside cylinder diameter is 204 mm, and the inside contains the nickel chloride solution as well as the sodium chloride. Different diameters of phantom ACR MRI were used by Doris Kaljuste and Mait Nigul, in which they used the dimensions of the respective MRI ACR phantom 148 mm and 190 mm [8].

B. MRI scanner

This study used MRI equipment available at Awal Bros Makassar hospital of General Electric Healthcare (Brivo MR355 1.5 Tesla) manufacturer installed since 2012. T1W and T2W spin echo axial are used, using the following parameters: A T1-weighted scanning series is recommended since these typically do not require a long scan times. The T1-weighted series used for the ACR MRI Accreditation Program (a single spin-echo series, TR = 500 ms (millisecond) , TE = 20 ms) is a good choice since it can be performed readily on almost any scanner. Slice thickness 5 mm, slice gap 5 mm, number of excitation (NEX) 1, field of view (FOV) 25 cm, matrix 256x256, total number slice 11 and total time scanning 2:16 (min:sec). T2W parameter TR 2000 ms, TE 80 ms and total time scanning 8:56 (min:sec). ACR sagittal locator used, pulse sequence spin echo TR 200 ms, TE 20 ms, FOV 25 cm, number of slice 1, slice thickness 20 mm, NEX 1, matrix 256 x 256 and total time scanning 0.56 (min:sec) **[**9-10].

3. RESULT AND DISCUSSION

The procedure of MRI 1,5 Tesla image quality imaging was done in the radiology department of the initial hospital of Makassar Bros by using MRI phantom standard ACR result as follow.

A. Geometric accuracy

Geometric accuracy in principle to assess the dimensions of the object size imaged in this case the diameter of the phantom MRI. In MRI imaging the geometric accuracy is one way to verify that the MRI image is scaled equal to the actual object size [11].

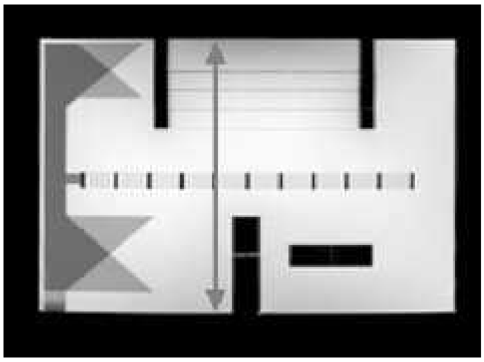

Fig. 1. MRI image results to measure the high dimensions of the inner cylinder of the phantom MRI (arrow).

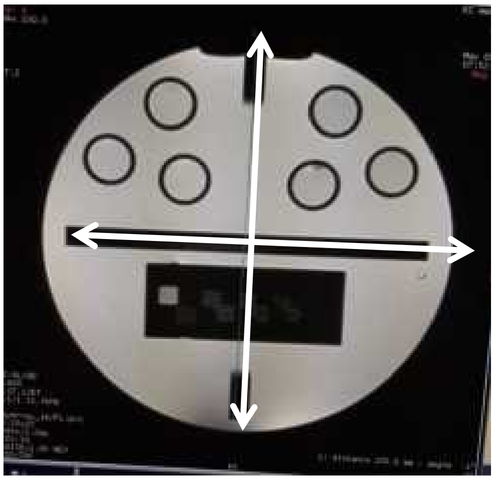

Fig. 2. Slice 1 MRI image inside diameter cylinder of the phantom MRI (arrows)

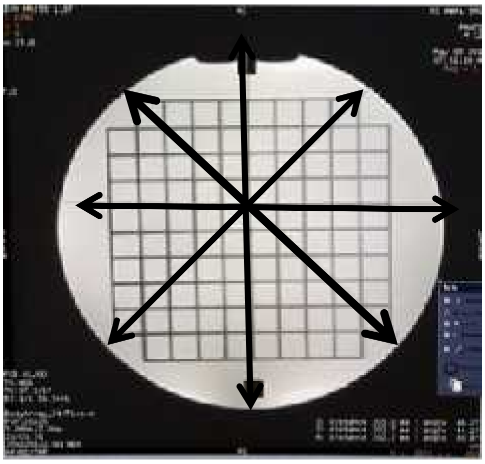

Fig. 3. Slice 5 MRI image inside diameter cylinder of the phantom MRI (arrows)

Here are the measurement results of inside diameter and height phantom MRI ACR MRI machine in hospital radiology department Awal Bros Makassar.

Table 1. Inside diameter and height measurements for the geometric accuracy test.

Result Image	Phantom diameter (mm)	Measurement results (mm)	Difference in measurement (mm)	ACR standard (mm)
Image 1	130.0	129.5	0.50	± 2.0
Image 2	240.0	240.0	0.00	± 2.0
Image 3.1	240.0	238.7	1.30	± 2.0
Image 3.2	240.0	238.2	1.80	± 2.0
Image 3.3	240.0	239.0	1.00	± 2.0
Image 3.4	240.0	238.9	1.10	± 2.0

B. High contrast resolution

One of the important variables of MRI image quality is the height-contrast spatial resolution. The height contrast spatial resolution function in the MRI image shows a small object clearly when the contrast-noise ratio are high. A failure of this test means that for a given field of view (FOV) and acquisition matrix size the scanner is not resolving small details as well as normal for a properly functioning scanner. The smallest object that can be visualized by the MRI ACR phantom ranges from 0.9 mm to 1.1 mm [7].

For this test, one visually assesses the distinguishability of individual small bright spots in arrays of closely spaced small bright spots. The results of high contrast spatial resolution research.

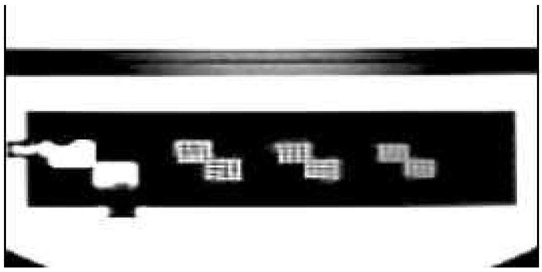

Fig. 4. Slice 1. The MRI image is the smallest object that can be evaluate

Table 2. The MRI image smallest object that TIW and T2W can evaluate

Axial T1W image		Axial T2W image	
Upper left (UL) hole array	ower right (LR) hole array	pper left (UL) hole array	ower right (LR) hole array
1.0	1.0	0.9	0.9

C. Slice thickness accuracy

One of the important parameters in MRI imaging is the slice thickness of the object to be checked. Thin slices are selected for small size objects such as MRI sella turcica examination for evaluation pituitary gland, while wide slices for objects with large diameter. The selection of thickness slices and field of view (FOV) affects the primary image quality of MRI image resolution [11].

The purpose of the accuracy test of the slice thickness at the MRI's imaging quality control is to assess the accuracy of the slice thickness piece determined by the MRI operator with the specification of the thickness achieved. To measure slice thickness accuracy in MRI images with phantom ACR, first display the first slice MRI image. Enlarge the first slice image with a magnification factor of 2 to 4 times magnification, keep the MRI image of the resolution well preserved by adjusting the lower window width (WW) and window level (WL). Adjust until the ramp area can be clearly visible, then measure the top and bottom ramps that are visible using the post processing image measurement tool MRI. Measurements were made on MRI T1W and T2W images and slice thickness is measured using the formula [5-6]:

$$S\ thi\_ = \frac{0.2 \times (t \times b)}{t + b}$$

Standard tolerance measurement based on ACR standard is slice thickness 5 mm ± 0.7 mm.

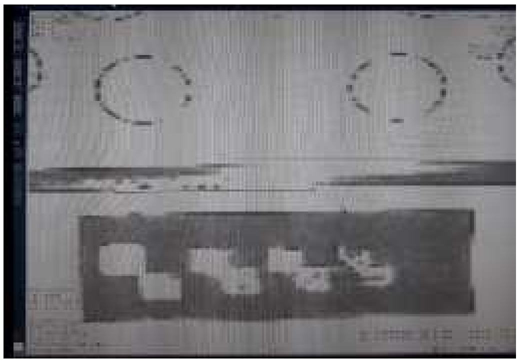

Fig. 5. The MRI image result to determine slice thickness with MRI phantom ACR

Table 3. Measured slice thicknesses in the slice thickness accuracy test

Axial T1W image		Axial T2W image	
Result (mm)	Standard (mm)	Result (mm)	Standard (mm)
4.48	5.0 ± 0.7	4.64	5.0 ± 0.7

D. Slice position accuracy

The accuracy of the object position in the body anatomical imaging of using MRI imaging is an important variable. Error determining the position will be fatal if the MRI image will be used as a guide to medic action such as MRI biopsy guidance action and determination of Treatment Planning System (TPS) radiotherapy.

The purpose of the slice position accuracy test is to determine the accuracy of the given slice using the localizer image as a reference position. A failure of this test means that the actual locations of acquired slices differ from their prescribed locations by substantially more than is normal for a well-functioning scanner.

Evaluation of MRI image slice position accuracy with phantom ACR: measurement by selecting slice 1 and 11 images of MRI T1W and T2W. The MRI image is enlarged to 2 to 4 times magnification until the vertical line end can be defined. Use the long measurement tool on the monitor screen to measure the difference in length between the left and right bars [7]. Standard tolerance measurement based on ACR is bar length difference is less than 5 mm.

Fig. 6. Images of slice 1 (a) and slice 11 (b) with the pairs of vertical bars from the 45° crossed wedges indicated. On these images the length difference between the right and left bars is small and typical of well-positioned slices

Table 4. Measured bar length differences in ACR T1 scans.

	Axial image 1	Axial image 11		
	Result		Different (mm)	Standard (mm)
Top bar length (mm)	27.5	26.0	1.5	5 mm
Bottom bar length (mm)	24.3	23.0	1.3	5 mm

The result of the test of slice position accuracy shows the difference of the length of the top bar in the positions of images 1 and 11 is 1.5 mm while the difference for bottom bar images 1 and 11 is 1.3 mm.

E. Image intensity uniformity

Uniformity of signal intensity at MRI imaging is an important part of the quality control process. The standard material for assessing signal uniformity is the water material inside the phantom which contains many protons of hydrogen and air outside the object containing a small amount of proton hydrogen [12].

Purpose of the test Image intensity uniformity in the process of quality control MRI image is: to measure uniformity of image intensity (do on series ACR T1W and T2W). The measurement evaluation was performed on slice 7 MRI phantom ACR image on T1 and T2 weighted images. n MRI slice image make ROI (region of interest) with measurement area between 195 cm^2 and 205 cm^2 (19,500 to 20,500 mm^2). Set minimum window display, and lower the level until all areas inside the ROI are white (hyper intensity signal MRI) and record the pixel value. In image with low signal intensity determine its pixel value by making ROI circle with area of 1 cm^2 (100 mm^2), record the pixel value. Calculate the percent of integral uniformity with the formula [7]:

$$P = 100\,x\,(1 - \left(\frac{hi\,h - lo}{hi\,h + lo}\right))$$

Standard tolerance measurement based on ACR PIU should be greater than or equal to 87.5% for MRI systems with field strengths less than 3 Tesla. PIU should be greater than or equal to 82.0% for MRI systems with field strength of 3 Tesla [7].

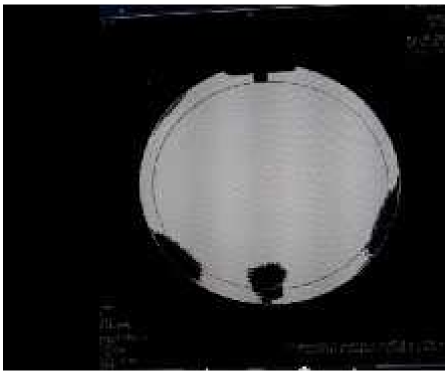

Figure 7. Image of slice 7 showing windowing of the image and placement of small, 1 cm2 ROIs for image uniformity measurements.

Table 5. PIU values in image intensity uniformity test

Axial T1W image		Axial T2W image	
ROI high signal	ROI low signal	ROI high signal	ROI low signal
1236.4	1102.4	1211.4	1115.2

Result of calculation of uniformity integral value (PUI) on weighting of T1W image got value 94.3% while for weighting of T2W image yield value 95.9%. The standard of ACR uniformity integral percent value (PUI) for magnetic field strength under 3.0 Tesla is more than 87.5%.

F. Percent-signal ghosting

Quality of the MRI image in addition to the signal factor associated with the resulting image must meet the standards of distortion and artefact to a minimum. Type of artefact caused by the process of formation is known as the signal artefact ghosting signal. To know the level of ghosting on the picture ghosting is a vague artefact that appears superimposition with image [13-14]. Measurement of the ghosting percent signal begins by selecting the MRI image in slice 7 on the weighting of the T1 image. Placing a circular sphere of ROI between 195 cm^2 and 205 cm^2 (19,500 to 20,500 mm^2) is centered on phantom, but does not include the extent of the existing box in the image. If you can not use the circle ROI, you can use ROI box with an area of 130 cm2 and 140 cm^2 (13,000 – 14,000 mm^2). Record the average pixel value for each ROI 2. Place the ellipse ROI on the 4 right, left, top, and bottom edges. The ROI should have a ratio of length and width of about 4: 1, and a total area of about 10 cm2 (1000 mm^2). Record the average pixel value for each ROI.

The value for the ghosting, as a fraction of the primary signal, is calculated using the following formula:

$$Gho\quad r = \left(\frac{(t + b) - (l + r\ \ ht)}{2\,x\,l\quad R}\right)$$

Standard value of the percent ghosting signal less than or equal to 0.025 .

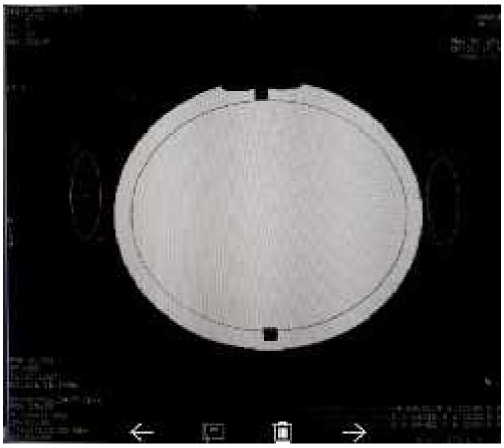

Fig. 8. Image of slice 7 illustrating ROI placement for percent-signal ghosting measurements.

Table 6. Ghosting ratio values in percent signal ghosting test

Axial T1W image				
Great ROI of phantom center circle	ROI ellipse right side of phantom	ROI ellipse left side of phantom	ROI ellipse bottom side of phantom	ROI ellipse top side of phantom
1236.4	20.6	23.3	24.4	22.5

From the table above got the value of ghosting signal percentage is 0.0012131

G. Low-contrast object detectability test

Low-Contrast Object Detectability is defined as the ability of the MRI image to show the contrast of the object to the lowest point. Contrast in MRI image one of the main factors affecting image contrast is intrinsic factor of body tissue that is difference of relaxation time T1 and T2. Body tissues that have a short T1 and T2 relaxation time difference are white and grey matter of the brain. MRI image quality is well defined if it is able to show grey and white matter differences well [15].

An evaluation of the quality of MRI imagery by using the latest variable ACR phantom MRI variable to be assessed is low contrast detectability. Objective: to assess the extent to which low-contrast objects can be seen in the image. For this purpose, phantom has a set of low contrast objects of various sizes and contrast values.

Measurements were made by MRI image evaluation starting from 7 to 10 slices of low contrast imagery, n each slice a low-contrast object appears as a small row of disks, with lines radiating from the center of the circle just like the spokes in the wheel. Begin measurement of slice 10 with the highest contrast object. Set the window width and window level so images can be seen clearly. alculate the number of circles that look complete. Calculate the circle from clockwise 12 clockwise. Report the number of visible circles in each slice. Add each slice to the total number of visible circles per series of images [7,16-17].

ACR standard is visible circle must be more than 9 circles on MRI <3 tesla. The visible circle should be more than 37 circles on MRI 3 tesla. If not meet the above standard ACR protocol standard then can be used series of common head protocol with the same recommendation as above.

Table 7. Detected rows in the low-contrast object detectability test

Axial T1W image	Axial T2W image
Detected rows in the low-contrast object detectability test	Detected rows in the low-contrast object detectability test
28	30

Geometric accuracy test results MRI 1.5 Tesla Department of Radiology RS Awal Bros Makassar obtained the size of cylinder height 129.5 mm in diameter while the inside diameter of the cylinder in five points of measurement yield values ranging from 238.3 mm to 240 mm. The tolerance value of ACR for geometric accuracy test is ± 2.0 mm. The implementation of geometric accuracy test is done every weekly. milarly, six other quality control test parameters such as high-contrast resolution, accuracy slice thickness, accuracy slice position, intensity uniformity image, ghosting percent signal, and low-contrast object detectability test results are still in acceptable conditions.

The same study was conducted by Doris Kaljuste and Mait Nigul, using an ACR phantom with a sample of 6 MRI 1.5 Tesla machines for quality assurance purpose is a feasible way to detect if the tested MRI scanners full fill the standards of a well-functioning MRI scanner. Even though manufacture specific service programs are used, it is important to use standard phantoms in MRI quality assurance to ensure that minimum image quality level is equal to all MRI scanners in practice [8].

The use of ACR phantom in the implementation of MRI imaging quality assurance has an advantage when compared to using the previous MagNET test phantom. The (ACR) MRI phantom is independent of manufacturers, providing the possibility to be used in different MRI scanners and to later compare those test results to one another. The image acquisition procedure is fast and with one phantom it is possible to assess seven different important quality parameters. After all (ACR) status has an internationally accrued status as a developer of guidelines and standards for radiology devices and QA procedures [4].

Constraints and barriers during the study were the dimensions and size of the phantom ACR used did not match the size of the coil for head examination. The researchers eventually used another alternative using a coil body, although there was a shortage to set the ACR phantom in the isosenter to be more difficult. For testing of the image quality of MRI image forward is needed to use phantom which dimension and size according to coil size for head MRI. Besides that addition of one parameter of image quality of MRI that is signal to noise ratio parameter is considered necessary. Signal noise to ratio is important to do evaluation considering high noise position can reduce the quality of MRI image.

4. CONCLUSIONS

Evaluation of quality assurance (QC) MRI 1.5 T Departments radiology Awal Bros hospital Makassar using phantom ACR standard indicates device performance under permissible tolerance conditions.

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