Comparison of SPECT quick QC between using in-house hot phantom and Jaszczak phantom: A preliminary study

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Abstract. Quality control in nuclear medicine imaging is very important which regularly carried out before running exam. The most important in QC is to evaluate QC parameter on SPECT images. Phantoms can be useful for evaluate QC parameters. The phantom was designed to quick QC SPECT system. Hot image from in-house hot phantom and cold image from Jaszczak phantom were used in this study with increasing activity concentration in in-house and Jaszczak phantom. This research is aimed to compare measurement results QC parameters of local uniformity and contrast on SPECT image generated with in-house and Jaszczak phantom. Measurement results from in-house hot phantom showed that lowest activity (0.99 MBq/mL) generated hardly visualized hot image for small diameter object (4.2 and 5.6 mm), and starting to be visible for 8.6 mm object with contrast value of 46.44. The same trend occurred to cold images generated by Jaszczak phantom, at lowest activity (0.068 MBq/mL) the ROI 8.6 mm on diameter object of 15.9 mm give rise to nearly the same contrast of that in hot image. No significant difference was found between local uniformity measured with in-house hot phantom and Jaszczak phantom. In-house hot phantom was robust and can be used as quick QC tool for SPECT system.

1. Introduction
Quality control is an important process in nuclear medicine imaging. The purpose of quality control (QC) is to detect degradation in the performance of an imaging device system such as Single Photon Emission Computed Tomography (SPECT) [1]. To prevent false results, QC should be performed periodically include before running the exam [2]. The organization that recommends QC protocol and acceptance test include National Electrical Manufacturers Association (NEMA) publication NU 1-2007 [3], American Association of Physicists in Medicine (AAPM) with publication no 52 1995 [4] and American College of Radiology (ACR) [5].

SPECT is one of the diagnostic modalities in nuclear medicine that provides functional information of the body organ systems [6]. SPECT used for 2D imaging is known as gamma camera, and besides that SPECT is also used for 3D imaging using the tomography method [6] [7].

To ensure that SPECT image is always in high quality and meets clinical requirements, quality control becomes essential [7]. The main QC parameters related to image quality are uniformity and contrast. Uniformity SPECT is strongly influenced by photomultiplier tubes (PMT) and detector
performance [7] [8]. The contrast is highly correlated with the concentration activity of the source object and the environment.

Not all nuclear medicine centers in Indonesia have been equipped with this Jaszczak phantom. Therefore in-house phantom was designed, even though as preliminary can only be used for measurements of contrast and local uniformity. The main objective of this study is to compare contrast and local uniformity on SPECT images measured by in-house and Jaszczak phantom.

2. Material and Method
2.1. Material
In this work, we used Siemens SPECT/CT dual-head series Symbia Intevo Excel Series. This SPECT provides two detectors which were furthermore called as detector 1 and detector 2. Each head has a NaI crystal detectors with the size of 59.1 cm x 44.5 cm and 9.5 mm thickness. The photomultiplier (PMT) number is 59 which are in the shape of hexagonal array. The measurement used a collimator Low-Energy High-Resolution (LEHR), matrix size 128 x 128, and Technetium-99m ($^{99m}$Tc) source.

Quality control measurements were carried out using in-house phantom (Figure 2) and Jaszczak phantom deluxe flangeless type (Figure 3). In-house hot phantom was designed using cylindrical acrylic with diameter of 20 cm and 9 cm length. The phantom has hollow tubes that filled with $^{99m}$Tc, with various outer diameters of 9, 11, 16, 19, 24, 31 mm and inner diameters of 4.2, 5.6, 8.6, 12.2, 18.1, and 23.7 mm (Figure 1). Only one part of Jaszczak phantom that has sphere objects with diameters of 9.5, 12.7, 15.9, 19.1 25.4 and 31.8 mm was used.

![Figure 1](image1.png)  
*Figure 1. The design of the in-house phantom, acrylic cylinder with various diameter consists of insert inner diameters.*

![Figure 2](image2.png)  
*Figure 2. In-house phantom with hot object.*

![Figure 3](image3.png)  
*Figure 3. Jaszczak phantom with cold object.*
2.2. Method

The source activity concentrations of hot objects in in-house phantom were 0.99 MBq/ml, 2.35 MBq/ml, 3.71 MBq/ml, and 6.07 MBq/ml. In Jaszczak phantom the variety of source activity concentration were 0.068 MBq/ml, 0.083 MBq/ml, 0.096 MBq/ml and 0.115 MBq/ml which was used as background. Activity concentration in Jaszczak phantom used ACR recommendation [5] and in-house hot phantom used lower activity concentration than Jaszczak phantom. High and low activity concentration was used to determine possibilities of using low activity concentration in reducing exposure to users who carry out QC and to evaluate QC parameters such as QC parameters on Jaszczak phantom. In this study, contrast and local uniformity of the SPECT images generated using in-house and Jaszczak phantom were evaluated, and subsequently were compared.

3. Results

Hot object images from in-house phantom and cold object images from Jaszczak phantom with various source activity concentration were shown Figure 4 and Figure 5 respectively. All images were reconstructed using Filtered Back Projection with a Shepp-Logan-Hanning reconstruction filter and a cut off frequency of 1.0 x Nyquist and normalized for having pixel value between 0-255.

\[
\text{Contrast} = \text{mean pixel value} - \text{mean background value}
\]

It seems that hot object image with contrast value less than -25 that initially can be visualized as shown in Table 1. Hot object image with 4.2 mm diameter was hardly visualized at all images, and with its 5.6 mm diameter was started vaguely visual at 3.71 MBq/ml concentration. The rest hot images were clearly seen at all source activity concentrations.

The same trend happened with cold object images from Jaszczak phantom (Table 2). Cold object with diameter of 9.5 mm was hardly seen at all source activity concentrations, and with diameter of 12.7 mm was vaguely seen at 0.083 MBq/ml source activity concentration. The other cold object images could be observed visually at all activity concentrations.

Contrast of each either hot object or cold object image in general tends linearly increased with additional source activity concentrations. Exceptional occurred in the highest diameter of hot object image contrast that tend to be constant with increasing source activity concentrations, as it can be seen in Figure 6 and Figure 7.
Table 1. Contrast of hot object images with various diameters and source activity concentrations from in-house phantom.

| Activity Concentration (MBq/ml) | d = 4.2 mm | d = 5.6 mm | d = 8.6 mm | d = 12.2 mm | d = 18.1 mm | d = 23.7 mm |
|---------------------------------|------------|------------|------------|------------|------------|------------|
| 0.99                            | -10        | -20        | -46.44     | -79.25     | -130.48    | -196.88    |
| 2.35                            | -13        | -21.75     | -48.44     | -84.75     | -135.76    | -197.47    |
| 3.71                            | -18        | -28        | -62.89     | -94.33     | -150.67    | -199.88    |
| 6.07                            | -25        | -38.75     | -74.78     | -102.5     | -162.48    | -200.97    |

Table 2. Contrast of cold images with various diameters and source activity concentrations from Jaszczak phantom.

| Activity Concentration (MBq/ml) | d = 9.5 mm | d = 12.7 mm | d = 15.9 mm | d = 19.1 mm | d = 25.4 mm | d = 31.8 mm |
|---------------------------------|------------|------------|------------|------------|------------|------------|
| ROI = 4.2 mm                   | 8          | 21.5       | 37.44      | 46.17      | 74.62      | 106.59     |
| ROI = 5.6 mm                   | 11         | 26         | 39         | 49.75      | 77.52      | 108.25     |
| ROI = 8.6 mm                   | 15         | 31.25      | 44.11      | 52         | 79.67      | 111.97     |
| ROI = 12.2 mm                  | 24         | 43         | 49.22      | 56.67      | 92.38      | 124.56     |
| ROI = 18.1 mm                  |            |            |            |            |            |            |
| ROI = 23.7 mm                  |            |            |            |            |            |            |

Figure 6. Contrast of hot object images.

Figure 7. Contrast of cold object images.

Other QC parameter that has been observed was local uniformity by using the ROI (region of interest) at the same size to hot object diameter. The local uniformity was calculated by the following formula:

\[
\text{Local uniformity} = \text{mean pixel value} \pm \text{standard deviation}
\]  

(2)

Percentage of local uniformity standard deviations for hot and cold object images were illustrated in Table 3 and Table 4 respectively.
Table 3. Percentage of standard deviation of local uniformity of hot objects images from in-house phantom with various source activity concentrations.

| Activity Concentration (MBq/ml) | d = 5.6 mm | d = 8.6 mm | d = 12.2 mm | d = 18.1 mm | d = 23.7 mm |
|---------------------------------|------------|------------|-------------|-------------|-------------|
| 0.99                            | 0.3%       | 1.9%       | 6.3%        | 12.6%       | 58.3%       |
| 2.35                            | 0.7%       | 2.3%       | 6.6%        | 15.5%       | 60.4%       |
| 3.71                            | 0.4%       | 2.4%       | 5.4%        | 22.2%       | 59.5%       |
| 6.07                            | 1.4%       | 3.5%       | 9.0%        | 22.8%       | 60.6%       |

Table 4. Percentage of standard deviation of local uniformity of cold object images from Jaszczak phantom with various source activity concentrations.

| Activity Concentration (MBq/ml) | d = 12.7 mm | d = 15.9 mm | d = 19.1 mm | d = 25.4 mm | d = 31.8 mm |
|---------------------------------|-------------|-------------|-------------|-------------|-------------|
| ROI = 5.6 mm                    | 1.5%        | 4.3%        | 4.9%        | 8.8%        | 11.5%       |
| ROI = 8.6 mm                    | 2.9%        | 4.5%        | 4.8%        | 6.2%        | 11.9%       |
| ROI = 12.2 mm                   | 2.1%        | 4.0%        | 6.9%        | 7.1%        | 11.4%       |
| ROI = 18.1 mm                   | 2.9%        | 6.1%        | 6.2%        | 8.8%        | 12.7%       |
| ROI = 23.7 mm                   |             |             |             |             |             |

Figure 8. Local uniformity standard deviation of hot object images.

Figure 9. Local uniformity standard deviation of cold object images.

Percentage of standard deviation of local uniformity tends to increase with diameter objects and source activity concentrations which occurs in both of hot image and cold image. The uniformity in Jaszczak phantom is relatively higher considering that uniformity measurements are carried-out in hot background. It means uniformity decreases with increasing diameter objects and source activity concentration, as it can be seen in Figure 8 and Figure 9.

4. Discussions and Conclusions
Jaszczak phantom is already well-known tool for performing QC of SPECT unit. Measurements with this phantom that based on cold object images require long time preparation (25 minutes for Jaszczak phantom and 8 minutes for in-house hot phantom), particularly in ensuring the homogeneity of source
activity concentrations within relatively large volume. Sometimes tricky technique is needed for time shortening of this preparation. Therefore, in-house phantom was designed as a solution for nuclear medicine center which have been not equipped with Jaszczak phantom. This in-house phantom is relatively smaller size and additionally hot object required relatively smaller amount of source activity. The image quality hot objects is easier in evaluating small object diameters compared to cold object images. The smallest objects detectability can be seen visually with low activity concentration in hot images.

In summary, we have studied hot image from in-house hot phantom and cold image from Jaszczak phantom. Hot image and cold image show increasing contrast and local uniformity with additional source activity concentration. From this study, in-house phantom can be used for exclusive quick QC for measurement of contrast and local uniformity, which results are comparable to results of measurements using Jaszczak phantom.

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