Research Article

Ring Artifact on SPECT Image due to Arbitrary Position of PMT Malfunction

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Abstract.
To obtain high-quality images using SPECT (Single Photon Computed Emission Tomography) imaging, quality control (QC) is required. QC is periodically conducted on SPECT based on standard protocol. Ring artifact are one of the factors in determining optimal image quality. Uniformity is a parameter that determines the ring artifact on SPECT image, which can be appeared as full-ring or half-ring. Those artifacts were generated since one or more PMT (photomultiplier tubes) were malfunctioning. A copper sheet with size of 2 × 2 cm^2 and 1 mm thick, attached to LEHR (Low Energy High Resolution) collimator in coordinates (x,y) depending on COR (Center of Rotation) of the gamma camera, was used to generate ring artifact during image acquisition using radioisotope ^{99m}TC and Jaszczak phantom. The image obtained was half-ring shaped, which is not much different from the image results at coordinates (x, 0).

Keywords: ring artifact, SPECT, PMT, malfunction

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1. INTRODUCTION

Single Photon Emission Computed Tomography (SPECT) is an imaging nuclear medicine modality. SPECT image can be generated by using radiopharmaceuticals as a radioactive source. To ensure those SPECT can produce high-quality images, quality control (QC) must be done before it is used [1]. Image reconstruction from the photon attenuation and collimator response on the object will produce artifacts which make image quality decreased [2].

Ring artifact is generated mainly from a detector of SPECT called gamma camera [3]. Those artifact commonly came from photomultipliers (PMT) which have already been degraded or irradiation photon due to not corrected collimator while being used [4]. Ring artifact can be investigated by uniformity measurement from phantom. The

measurement need to be done tomographically. Nevertheless the detailed investigation of ring artifact is challenging until now [5].

Investigation of ring artifact can be done by Monte Carlo simulation. QC SPECT through simulates the attenuation and scattering of photons in the phantom body or metal detector [6] . Collimator shift and the change of radioactive source not uniformly can cause ring artifact's appearance [7]. Some quantitative technique already been conducted to improve the quality of SPECT image, including in Monte Carlo simulation [8].

An image acquisition using SPECT was conducted in this research. The SPECT dual head gamma camera type system with Jaszczak phantom was used as uniformity measurement. Those Phantom used in the form of an empty cylinder without inserts (cold rods & cold spheres). Inside the phantom, it filled with a liquid solution mixture of radiopharmaceutical source Tc-99m (Technetium-99m) to generate the reconstruction image. Copper sheet had been mounted on the surface of LEHR (Low Energy High Resolution) collimator as simulated PMT malfunction to produce ring artifact on image. The position of the copper sheet was placed at the coordinates (3,3) and (-3,-3) based on the center of rotation (COR) gamma camera.

2. RESEARCH METHOD

Image acquisition process was conducted using SPECT dual-head gamma cameras imaging system type Siemens Symbia E. Jaszczak phantom without the insert (cold rods and cold spheres) for measuring the uniformity parameter was used during scan. The phantom, which has height 18.6 cm and diameter 20.4 cm, filled with mixed of radioactive source 3 mCi Tc-99m and water 6.4 L. Uniformly the concentration of mixing radioactive source and water are approximately 16 kBq/mL.

Parameters for acquisition consist of rotation move each gamma camera, distance from gamma camera to phantom and time of acquisition were setting in computer software Syngo MI Application. Two gamma camera rotation moved were set 180° clockwise direction. For the distance between each gamma camera and phantom, it set close each other (gamma camera and phantom) while two gamma cameras still moved freely with positioning phantom at the center of two gamma camera. Time set only 15 minutes for one acquisition. Furthermore, the image reconstruction was done using filtered back projection technique with Shepp Logan filter and Chang's method for attenuation correction. Image generated from its reconstruction had 128 slices, 128 x 128 pixels size and thickness 0.3 cm from each slice.

Ring artifact was generated from the copper sheet on the LEHR collimator surface. Those copper sheet was placed only one of gamma camera with size 2 x 2 cm^2 and thickness 1 mm. The purpose of using copper sheet for simulate one of PMT malfunction in gamma camera. Location of copper sheet depended on hole of collimator as narrow a beam of radiation from phantom. Approximate coordinate position based on detector COR (0,0) of copper sheet as shown in Fig.1 were (3,3) and (-3, -3).

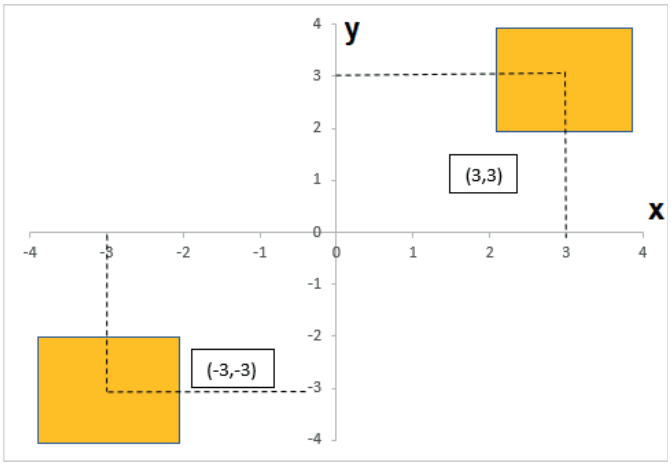

Figure 1: Coordinate position of COR gamma camera with copper sheet position mounted on LEHR collimator surface.

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3. RESULT AND DISCUSSION

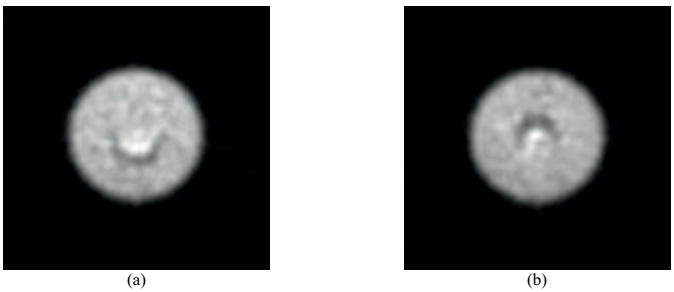
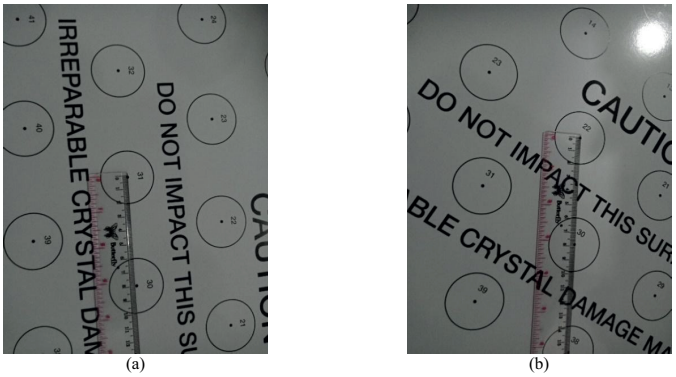


Figure 2: SPECT image reconstruction generated from acquisition with coordinate of copper sheet (a) (3,3) produced bottom half-ring artifact, and (b) (-3,-3) produced upper half-ring artifact.

Some artifact can be seen as a low pixel value compared with each other on the image [9]. Because copper sheet placed on collimator, it created half-ring artifact on selected images. Half-ring artifact generated since gamma camera head only rotate on 180° with copper sheet only placed on one of two head. There are two type of form half-ring artifact, bottom half-ring and upper half-ring. Resulted image reconstruction in

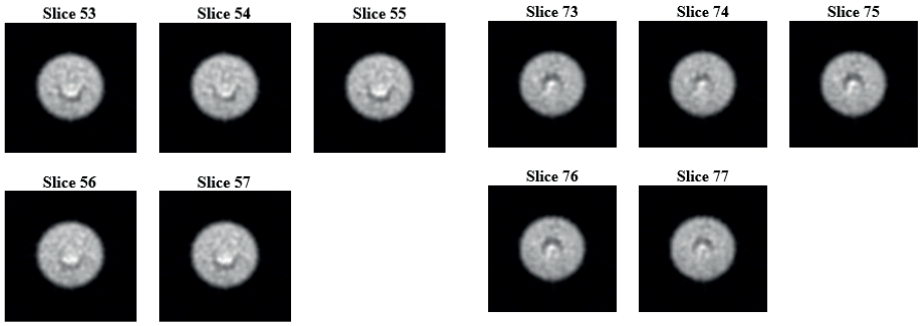
Fig.2 from copper sheet location (3,3) was bottom half-ring, whereas from copper sheet location (-3,-3) was upper half-ring.

As shown in Fig.3 collimator used for acquisition was parallel hole type. Dimension each hole is 4 cm diameter, while distance for each hole to another from point center are 8 cm. The 2×2 cm^2 copper sheet was not entirely covering the hole, but it still generated the artifact. Incoming radiation hitting the copper sheet will attenuate exponentially, wherein the result is low pixel value on reconstruction image [10].



(a) (b)

Figure 3: Size of hole collimator with distance from center point of hole for (a) each holes in horizontal, and (b) each holes in diagonal.



(a) (b)

Figure 4: Number of slice of ring artifact detected from image reconstruction (a) coordinate (3,3), and (b) coordinate (-3,-3).

Some radiation incidentally on copper not attenuated, but rather will be scattered [11]. Those scattered radiation resulting high concentration pixel value around the edge of artifact. It resulting high pixel value classified as artifact and can be seen from the center of artifact on image. Those type of artifact need to be investigated quantitatively furthermore since the qualitative analysis not very accurate.

It has resulting ring artifact on image reconstruction not different when PMT malfunction in location (x,0) for $x \in \mathbb{R}$. It has still below half ring artifact for (3,0) and upper half ring artifact for (-3,0) even if size of copper sheet changed [12]. Nevertheless, the

difference of ring artifact generated for (3,3) and (3,0) or (-3, -3) and (-3,0) is the number of slice artifact appeared in Fig.4. Presently the location of PMT malfunction can be predicted and investigated from the ring artifact formed and its number of pieces on image reconstruction.

4. CONCLUSION

Ring artifact due to PMT malfunction from one gamma camera can be investigated easily from image reconstruction. Measurement of uniformity phantom section was key to understand which PMT had been malfunctioning or degradation. Fixed coordinate of location malfunction PMT could be predicted by analysis the form of ring artifact generated and the number of slice artifact detected. Furthermore, the investigation of the quantitative method must be done to provide those location. The next challenge is if the ring artifact is generated from two gamma camera, with same position or different position, and what happens if the detector's rotation is full 360°. Certainly, reduced those ring artifact is more challenging.

Acknowledgments

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