Evaluation of contrast and recovery coefficients as performance parameters in planar and SPECT imaging

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Abstract. The study focused on the performance evaluation of the gamma camera on the planar and SPECT imaging mode in nuclear medicine imaging. Several parameters were studied including the partial volume effect, contrast evaluation at different radiopharmaceutical size of localizations and the recovery coefficients. The localizations of Technetium-99m (99mTc) radionuclide were achieved by using Perspex® vials with different diameter sizes between 1.3 and 3.5 cm in a Jaszczak phantoms filled with water. The images were obtained in both planar and SPECT modes. The contrast in planar images showed no significant change when different activity of radionuclide was used. The contrast in SPECT images showed that the higher contrasts were achieved when higher time of projection used when lower activity of 99mTc were used. The contrast at higher 99mTc activity however was the highest when lower time of projection was used. The recovery coefficient in planar images showed a linear relationship to the size of radionuclide localizations and did not significantly affect the activity of the radionuclide. The recovery coefficient of SPECT images however were significantly affected by activity of the radionuclide. The recovery coefficient in SPECT increased dramatically when higher activity of the radionuclide was used. The overall results showed that the measurement of contrast and recovery coefficient can be used as performance parameters for both the planar and SPECT imaging in nuclear medicine.

1. Introduction

The performances characteristic of the gamma camera system is related to the partial volume effect (PVE) and recovery coefficient (RC) [1]. The partial volume effect is important in qualitative and quantitative of the image [2][3]. The small sized image that is near to the resolution limits of the imaging device are often appears to show smaller activity and concentration in comparison to the actual value. The ratio between the apparent activity concentrations to the true activity concentration is known as recovery coefficient (RC). Image contrast also plays an essential role in both qualitative and quantitative aspects of the image quality in nuclear medicine imaging. Contrast in radiography is defined as the ratio of signal change of an object interest to the signal level in surrounding part of the images [4]. It is an important indicator to the imaging system’s performance with respect to detection of small lesions.

Single photon emission computed tomography (SPECT) is an imaging technique used in nuclear medicine imaging by producing cross-sectional or three-dimensional nuclear medicine image with multiple slices [5]. This imaging technique is in-vivo imaging and conducted by using the unsealed
sources commonly the Technetium-99m ($^{99m}$Tc). The SPECT image has advantages to give lesion detection image compared with planar imaging by removing the out of plane information for increase the contrast of the image [6]. The SPECT system has several parameters that would affect performance and image produces by that machine. The common problem occurs to SPECT system including the limitation of spatial resolution and contrast. As general, spatial resolution is the ability of system to differentiate two or more size of tumour according to the radionuclide uptake. The limitation of spatial resolution leads to the PVE [7]. PVE occurs when the activity at region of interest increase or decrease from the actual activity. However, the PVE can be corrected by using partial volume correction (PVC) or by using RC correction.

This study is focused on determination of the recovery coefficient and image contrast for varying cylindrical diameters phantom with known activity concentration in planar and SPECT images. The ratio of the apparent concentration to the true activity concentration and the ratio of signal change in object interest to the signal level in surrounding were calculated.

2. Methodology

2.1. Phantom Preparation
The localization of radiopharmaceutical of different sizes were simulated by using an cylindrical vials of different diameters between 1.3 and 3.5 cm based from the study by [8] as shown in Figure 1. The vials were made up from Perspex® with approximate length of 6 cm made compatible for Jaszcak phantom commonly used in quality control of SPECT imaging. All vials were attached on the circular Perspex® plate having the same diameter with the internal diameter of Jaszcak phantom. The details of the cylindrical vials are presented in Table 1. The cylindrical vials were filled with $^{99m}$Tc of three different activity levels of 3, 10 and 18 µCi. The Jaszcak phantom was filled with water and an amount of $^{99m}$Tc with activity ratio of 1:12 to the activity used in the vials.

![Figure 1. (a) The cylindrical vials and (b) the Jaszcak phantom used in the study.](image)

2.2. Contrast and Recovery Coefficient Analysis
The phantom was scanned by using gamma camera machine model NM/CT 670 Pro at planar and SPECT mode. The planar mode was performed by using the matrix size of 128 x 128. The SPECT mode was performed the incremental view 3 degree per rotation and matrix size of 128 x 128 [9,10]. The SPECT images were reconstructed by using Ordered-Subset Expectation Maximization (OSEM) algorithm and Butterworth filter at 0.50 cut-off frequencies and 10.0 order value at all experimented time of acquisition per projection set up based on the standard scanning protocol in the Department of Nuclear Medicine HUSM.

The contrast of SPECT/CT image was evaluated based on the volume of interest (VOI) on each of vials and the around the background region. The contrast of SPECT/CT image was calculated based on the equation:
\[ \text{contrast} = \frac{c_{\text{vial}} - c_{\text{background}}}{c_{\text{background}}} \]  

(1)

with \( c_{\text{vial}} \) is count per pixel of vial and \( c_{\text{background}} \) is the count per pixel in background region. The graph diameter of vial vs contrast was plotted [3].

The recovery coefficient was calculated based on the equation:

\[ \text{Recovery coefficient} = \frac{A_o}{A_t} \]  

(2)

with \( A_o \) is apparent activity of radionuclide concentration radionuclide and \( A_t \) is actual activity of concentration radionuclide [3]. The apparent activity concentration of radionuclide was calculated by using equation:

\[ \text{Apparent activity, } A_a = \frac{R_{\text{vol}}}{S_{\text{vol}}} \times \frac{VS}{T_{\text{acq}}} \]  

(3)

with, \( R_{\text{vol}} \) is count per pixel of volume of interest vial, \( S_{\text{vol}} \) is volume sensitivity, \( VS \) is voxel size and \( T_{\text{acq}} \) is total time of scanning [9,10]. The count per pixel for each vial was measured by manually drawn the VOI at each vial based on the CT image using the Volumetric MI Evaluation software on the Xeleris workstation. The value of volume sensitivity is 2.667 cps/µCi. While the value voxel size for matrix size 128 x 128 is 4.42 x 4.42 x 4.42 mm\(^3\) was based from the department’s recent quality assurance for the gamma camera. The actual activity concentration of radionuclide was calculated by using the equation:

\[ \text{Actual activity, } A_t = A_o e^{-\lambda t} \]  

(4)

with \( A_t \) is actual activity concentration of radionuclide, \( A_o \) is initial activity concentration of radionuclide source \((^{99m}\text{Tc})\), \( \lambda \) is decay constant of radionuclide and the \( t \) is time elapsed from the initial activity. The value of the decay constant of radionuclide source was \( 2.5 \times 10^{-5} \text{s}^{-1} \).

3. Results and Discussion

The planar and SPECT images of radionuclides in the cylindrical vials of different diameter sizes are illustrated in Figure 2 and 3 respectively. The planar and SPECT images obtained showed good visualisation of radionuclide of different diameters as well as the regions of high and low concentration of the radionuclide. The background image in planar images has better visualization when lower activity level was used compared to that in high activity levels. The background in SPECT images on the other hand did not show any significant different when different activity levels of radionuclide were used.

**Figure 2.** The planar images of radionuclide vials of different diameter of (a) 3 µCi (b) 10 µCi and, (c) 18 µCi.
Figure 3. The SPECT images of radionuclide vials of different diameter of (a) 3 µCi (b) 10 µCi and, (c) 18 µCi.

The contrast values at different diameter sizes of and activity levels of the radionuclide in planar and SPECT images are presented in Figure 4. The results showed that the contrast values in planar and SPECT increased when the diameter of the radionuclide increased [10]. The increment of contrast values in planar images was more significant when higher activity level of radionuclide was used compared to that in SPECT images. This can be observed in the exponential pattern of the contrast curve in planar from low to high activity levels of the radionuclide. The contrast curve in SPECT images was observed to be more linear and shifted upward when higher activity levels of radionuclide were used.

Figure 4. The contrast values at different radionuclide diameter sizes in (a) planar and (b) SPECT images.

The recovery coefficients, RC of planar and SPECT images at different radionuclide diameter sizes are illustrated in Figure 5. The results showed that the RC increased when the size of radionuclide increased for both planar and SPECT images [10]. The values of the RC were also found to decrease when higher activity levels of radionuclide were used. The ideal value of RC in a nuclear medicine image is 1.0 indicating equal ratio between the apparent and actual activity of the radionuclide [11]. The RC at larger sizes of radionuclides had the tendency to exceed the value of 1.0 [8]. Furthermore, the RC values were found to be higher when lower activity levels of radionuclide were used. This condition is called the ‘spill over’ effect occurred due to contamination of activity from the
neighbouring tissue or spot to these ‘hot’ areas or the areas of higher concentration of radionuclide [3]. The results also showed that the ‘spill over’ in planar images were not significant compared to those in the SPECT images. The overall results showed that the planar and SPECT images showed comparable results in the evaluations of contrast and recovery coefficient measurements.

![Figure 5](image)

**Figure 5.** The recovery coefficient values at different radionuclide diameter sizes in (a) planar and, (b) SPECT images.

### 4. Conclusion

The contrast of planar and SPECT images increased when the diameter of the radionuclide increased and the contrast values increased when higher activity levels of radionuclide were used. The recovery coefficient of planar images was consistent to that in the SPECT image. The ‘spill over’ effect in the planar images was lower than those in the SPECT images. The use of lower activity levels in SPECT imaging would increase the ‘spill over’ effect that would disrupt the diagnostic information of the images. The overall results indicated the suitability of the evaluations of contrast and recovery coefficient based on the partial volume effect as image parameters in both planar and SPECT imaging in nuclear medicine.

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