Quantitative imaging with commercial SPECT

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Abstract. With the introduction of the Computed Tomography (CT) into the SPECT technology, SPECT-CT is now capable to quantify the uptake to the organ by the introduction of Activity Calibration Factor (ACF). We implemented three different phantoms geometry to obtain the ACF. First acquisition done with uniform cylinder phantom from Data Spectrum, followed with uniform NEMA IEC Body and uniform glass bottle allows the simulation of different type of clinical imaging study. Acquisitions were performed on a Brightview XCT (Philip) gamma camera. All acquisition and reconstruction protocol according to the clinical practice setting with different voxel volume sizes of 0.811 cm³, 0.104 cm³ and 0.012 cm³ to demonstrate the different values of ACFs. The ACFs for Te-99m, I-131 and Lu-177 calculated from 3D segmentation of SPECT-CT images for scaling three different matrix sizes. The results obtained in this study demonstrated that SPECT-CT is able to quantify uptake at the organ, and it has high possibility to be used as quantitative SPECT in clinical practice in the future.

1. Introduction
Unlike Positron Emission Tomography-Computed Tomography (PET-CT) modality, SPECT had limitation to quantify the photon received from the patient’s body due to the attenuation correction and calibration issues. However, these issues had resolved with the introduction of CT component into the SPECT system. This hybrid modality has ability to quantify the organ uptake by using Activity Calibration Factor (ACF) and it is beneficial to quantify activity concentration within patient’s body and leads to radionuclide therapy dosimetry [1], [2]. A radionuclide agent administered to a patient would participate in the body’s metabolism and distribute accordingly. Hybrid SPECT equipped with CT modality had a good advantage, and able to perform CT attenuation for 3D SPECT dosimetry. This study aimed to propose a simple method to measure SPECT ACF (cps/kBq) from conventional commercial SPECT-CT does not have quantifications features. The common SPECT radionuclide such as Te99m, Lu177 and I131 were used to in this study to demonstrate phantom studies in which the accuracy of the reconstructed SPECT data.

2. Materials and Methods
We implemented three different phantoms geometry SPECT images to produce a suitable ACF for commercial SPECT camera does not have the quantitative features. Different size of phantom would represent the variation of patient sizes from pediatric to adult size. First acquisition done with uniform cylinder phantom from Data Spectrum, followed with uniform PET NEMA IEC body phantom and uniform 1.1 litter glass bottle to allow the simulation of different shapes in clinical imaging study. All acquisitions performed on a Brightview XCT (PHILIP) gamma camera according to the clinical setting.
Then ACF was then validated by using PET NEMA IEC body phantom consisted of six sphere sizes of 0.5 cm$^3$, 1.14 cm$^3$, 2.75 cm$^3$, 5.60 cm$^3$, 11.56 cm$^3$ and 27.02 cm$^3$ with 10:1 Tumor Background Ratio (TBR). The image quality parameter, such as Coefficient of Variance (COV) derived to evaluate the noise. The activity accuracy referred as Background Activity Accuracy (BAA) was evaluated using a ratio between the activity concentration measured in the reconstructed SPECT phantom background and the expected activity concentration known from the phantom preparation as shown in Equation 2. The sphere volume inside PET NEMA IEC body phantom used to determine actual percentage threshold to obtain Sphere Threshold Volume (STV) for all radionuclides.

2.1 SPECT Calibration Factor

The SPECT calibration factor known as ACF calculated from the total count inside phantom divided within the total activity in specified scan duration inside the phantom as shown below;

$$ACF = \frac{\text{total count}}{\text{total activity (kBq)/acquisition (s)}} \quad (1)$$

The acquisitions protocol was set according to the clinical setting. Each phantom study corresponded to the time of calibration of the activity used for phantom preparation. The phantom images were analyzed with MIM Version 6.9.4 by drawing Volume of Interest (VOI) 100% as recommended by [1] shown in Figure 1.

![Figure 1. (A) VOI for Bottle Phantom, (B) VOI for NEMA IQ Phantom, (C) VOI for 20 cm Cylinder Phantom](image)

The phantom acquisition was repeated three times for every voxel size for each of radionuclides and a total of 27 acquisitions were performed. The background activity accuracy was calculated in equation 2. The image quality for SPECT was evaluate in equations 3 and the lesion volume was obtained by using the equation 4.

$$BAA = \frac{\text{Mean Derived Activity concentration at Background}}{\text{Actual Background Activity Concentrations}} \quad (2)$$

$$\text{COV} = \frac{\text{SD Background}}{\text{Mean Derived Activity concentration at all VOI}} \quad (3)$$

$$\text{STV} = \sqrt[6]{S_1 \cdot S_2 \cdot S_3 \cdot S_4 \cdot S_5 \cdot S_6} \quad (4)$$

3. Results and Discussion

The ACF of Tc-99m, Lu-177 and I-131 radionuclides with three different voxel sizes were obtained from 3D segmentation of SPECT-CT images, as shown in Table 2. The STV, BAA, COV, and variance between different voxel sizes for Tc-99m, Lu-177 and I-131 radionuclides shown in Figure 3.

![Table 2. ACF for Tc-99m, Lu-177 and I-131 radionuclides](image)
The conventional gamma camera demonstrated the quantitative SPECT by the introduction of ACF. This study was in line with several calibration methods that had been proposed by previous researchers [3], [4] to give more options on how to obtain ACF. This study also proved the current Gamma Camera with low dose CT, reconstructed with iterative reconstruction system (exposure factors of 120 kV and 20 mAs) produced consistent CT values and comparable with others study [5], [6]. SPECT quantifications for diagnostic radionuclide such as Tc-99m and Lu177 less tolerance because the peak energy is less than 200 keV [3]. However, I-131 tolerance is higher than Tc-99m and Lu-177 because of the spatial resolution is poor compared with both radionuclides and need other techniques to obtain better result. Our present results showed the level of accuracy was less than 6% for Tc-99m radionuclide with all voxel sizes and it was comparable with other previous study (10,11) as shown in Figure 3 (Center). However, for Lu-177 activity quantification, the 0.104 cm\(^3\) voxel produced 2% tolerance which is lower compared with 0.811 cm\(^3\) and 0.012 cm\(^3\). For image quality evaluations (COV) as shown in Figure 3(Center), smaller voxel size improved the image quality for all radionuclides due to less statistical count. Lu177 has higher deviations due to the less percentage of photon energy compared with Tc99m and I131. The bigger SPECT voxel images have poor image quality and consist of higher noise compared with CT imaging [7]. It is also difficult to quantify the SPECT without correction from CT images. Many studies had conducted to improve the SPECT quantification by the introduction of several approaches like phantom activity correction factor, scatter acquisition correction, CT attenuation correction and lesion recovery coefficient methods [1], [8]. The low dose CT has several issues such as a high noise in CT images and may lead the higher tolerance in SPECT images. However, the SPECT images corrected with CT image and reconstructed with iterative algorithm in this study able to produce

![Figure 2](image_url)

**Figure 2.** (Left) BAA, (Center) COV and (Right) STV for Tc-99m, Lu-177 and I-131 radionuclides

| Voxel Size (ml) | Tc-99m  | Lu-177 | I-131   |
|----------------|---------|--------|---------|
| 0.811          | 0.106   | 0.013  | 44.511  |
| 0.104          | 0.103   | 0.013  | 55.125  |
| 0.012          | 0.101   | 0.012  | 59.434  |
a good result, especially for Tc-99m; as shown in Figure 3 (Center). For SPECT lesion volume, partial-volume effects (PVE) always the limitation for the quantitative SPECT imaging. As shown in Figure 3 (Right), STV For Tc-99m demonstrate higher threshold percentage for all voxel sizes followed with Lu177 and I131. SPECT had limitation to determine lesion sizes due to the poor resolution compared with PET images. I-131 SPECT quantifications is very challenging because the images degraded by the poor spatial resolution obtained with typical high-energy collimators and also NaI detector capability. Tc-99m has lot of advantages compared with Lu-177 due its physical property. Generally, beta-decay of Lu177 emits 113 keV and 208 keV gamma rays. SPECT quantification in radionuclide therapy dosimetry is crucial to determine the activity in the selected organ or lesion and Lu-177 has capability to perform SPECT imaging of up to five days according to their physical property. The actual fix adaptive threshold method was calculated based on percentage of maximum voxel value in the initialization of VOI. The percentage for SPECT radionuclide was varying from 40%-42% [9], [10]. Our results demonstrated the Tc-99m threshold level was between 38%-45% while Lu-177 was between 26%-28%. The lower threshold level can be improved with the small voxel size. This study was limited with phantom experiment with single TBR and had good potential to be implement in routine clinical applications.

4. Conclusions
The results obtained in this study demonstrated the conventional SPECT-CT is able to quantify uptake at the organ, and it has high possibility to be used in clinical practice in the future. Small voxel size would give higher accuracy radioactivity. Tc-99m is the best SPECT quantification radionuclide followed with Lu-177 and I-131.

5. References
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