Determination of conversion factors of SPECT hot images respect to hot objects in bone medium: preliminary study using in house phantom

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Abstract. The purpose was to determine conversion factors (CF) of SPECT hot images respect to the original size of hot objects in the bone medium. In house phantom has been made in the form of a cubical acrylic (37cm x 15cm x 15cm) provided with cylindrical channel filled with bovine bone powder with the diameter (1.5; 3.5; 5.4; 7.4 cm). As hot objects, a mixture of bone powder and $^{99m}$Tc source with various activity and diameter were embedded in filled bone channels. Image acquisitions were carried using Intevo Symbia E Siemens SPECT/CT and LEHR collimator, with surface collimator distance 9.6 cm. There were 6 different in activities and diameter of hot objects in each channel. Conversion factor (CF) was defined as the ratio between FWHM of hot object image profile and the original hot object size. CF value for each diameter channel was varied with the activity and size of the object diameter. The source activities used were 0.1–0.2 mCi and the observed object diameters were 7–12 mm. For hot object size less than resolution stated in SPECT specifications (4 mm), CF values were in the range 1.7–3.4 for 1.5 cm and 3.5 cm channel diameter. For hot objects diameter, 7.5–12 mm, CF value was mostly independent of channel diameters, with the value of (1.1±0.2). This preliminary study informs that CF values of SPECT hot images independent with the size of the host bone medium. Whereas for object diameter ≤ 7.5 mm very relatively higher and influenced by the size of the host bone medium.

Keywords: nuclear medicine, imaging, conversion factor, $^{99m}$Tc, bone

1. Introduction

SPECT (Single Photon Emission Computed Tomography) is a modality in nuclear medicine that can be used for medical imaging. This SPECT can be used as gamma camera by scanning technique to generate 2D image and by tomography to produce 3D. Bone scan is one of the common clinical procedure using planar (2D) image. SPECT has high sensitivity in detecting primary cancer and metastasis in bone [1][2][3].

For nuclear medicine planar imaging which has poor resolution, to improve quality image some research have been conducted to determine the optimum parameter image acquisition. Nyathi determined the optimum parameters for planar imaging with objects size less than the resolution of gamma cameras using Jaszczak phantom with hot inserts [4]. Zingerman et all determined the spatial linear coefficient function (LRCs) as ratio between apparent size over true size of object [5]. In this the study, measurements were carried out with in-house phantom that contained bovine bone powder as medium and hot objects that simulating cancer metastases in bone.
The radiopharmaceuticals used in this study was $^{99m}$Tc. Cancer cells will absorb $^{99m}$Tc higher than healthy bone tissue [6][7]. SPECT sensitivity in detecting radiopharmaceutical uptake is influenced by various factors, including the distance of the hot object to the detector [8], the radiopharmaceutical concentration, and the size of the hot object that absorbs the radiopharmaceutical.

Compared with CT images, SPECT images which is a functional image has lower resolution and edge visualization [9]. Therefore, the size of the hot object in the SPECT image will differ from the size of the actual object. In this study, an in-house phantom has been constructed with hot bone object material to determine the image conversion factor of the hot SPECT object to the size of the actual object. The value of conversion factors will be useful for clinical diagnosis and for supporters of radiotherapy planning if needed.

Therefore, the purpose of this study is to determine the conversion factor of the diameter of the object image to the actual diameter in the bone medium. The size of the hot object defines as FWHM [3]. Conversion factor (CF) was defined as a comparison between the diameter of the object in the image of the actual value.

### 2. Material and Method

#### 2.1. Detector sensitivity measurement

This measurement was performed by Siemens Intevo E SPECT which equipped with 2 detectors. For planar imaging, information about the sensitivity of both detectors was required. With tools provided by vendors, sensitivity testing was determined using point source containing 1 mCi $^{99m}$Tc placed at a distance of 10 cm from the detector. Sensitivity which is the ratio of the rate of counting with activity is then used as the basis for selecting the detector that will be used in the study.

#### 2.2. In house phantom construction

An in-house phantom was constructed of acrylic (polymethylmethacrylate (PMMA)) (37cm x 15cm x 15cm) consisting of 4 channels with varied diameter of 1.5; 3.5; 5.4; 7.4 cm, as displayed at Figure 1. Each channel was filled by bovine bone. Hot objects were the mixture of bovine bone powder and $^{99m}$Tc, then embedded in the bone medium.

![Figure 1. In-house phantom with (a) cylinder channel and (b) cover with pusher to compact bovine bone](image)

#### 2.3. Conversion factor measurement

Hot objects were the mixture between bovine bone powder and $^{99m}$Tc. For each bone medium were embed with 2 hot objects that varies in activity and diameter. Hot object activity concentration were varied from 0.0094 – 0.0357 mCi/mg, whereas the object diameter were varied from 7 – 12 mm. In this preliminary study, hot objects made manually by wrap the hot object material in flexible plastic with a shape close to the ball shape then embedded in bone medium. The size and activity given in Table 1.
### Table 1. Size and mass of hot objects for each cylinder tubes

| Concentration (mCi/mg) | Channel 1.5 cm | Channel 3.5 cm | Channel 5.4 cm | Channel 7.4 cm |
|------------------------|----------------|----------------|----------------|----------------|
|                        | D (mm)         | Mass (mg)      | D (mm)         | Mass (mg)      | D (mm)         | Mass (mg)      |
| 0.0094                 | 11             | 9.41           | 12             | 14.03          | 11             | 14.35          | 13             | 15.64          |
| 0.0187                 | 12             | 11.05          | 12.7           | 12.5           | 11.6           | 12.22          | 13             | 16.74          |
| 0.0222                 | 9.1            | 7.25           | 9.9            | 6.88           | 9.1            | 7.93           | 10.3           | 10.26          |
| 0.0173                 | 7              | 4.49           | 9.1            | 8.3            | 10             | 8.94           | 10             | 9.74           |
| 0.0218                 | 8              | 3.51           | 9              | 5.96           | 8.5            | 4.66           | 10             | 7.21           |
| 0.0357                 | 8.1            | 4.67           | 8              | 4.56           | 8              | 5.44           | 8.3            | 5.68           |

#### 2.4. Imaging protocol
The image acquisition process was done using bone scan protocol. In house phantom positioning on SPECT as shown in Figure 2. LEHR collimator was used, with surface collimator distance 9.6 cm, and scan speed was set to 10 cm/min. Image was stored in 256 x 1024 matrices corresponding to 0.208 pixels/mm.

![Figure 2: In house phantom positioning on SPECT/CT on the couch](image)

#### 2.5. Image analysis
Images were quantified by using imageJ 1.46r (64 bits). The image diameter determination by measuring the FWHM of image [5]. The CF was calculated by Equation (1).

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CF = \frac{FWHM}{d_{true}}
\]  

#### 3. Results
Results of planar sensitivity measurement summarized in Table 2. The sensitivity of each detector shows relatively the same value. Both detectors can be chosen during this study.

Planar image from acquisition shown in Figure 3. This planar image shows two hot objects in each channel that varies in diameter and activity. From Table 1, activity in each sphere hot object was calculated from its mass and the result was shown as value A (mCi) in Table 3. The diameter of hot images was represented as the value of FWHM image profiles. Table 3 shows the CF value for each object.
Table 2. Planar sensitivity of detector 1 and detector 2

| Activity (µCi) | Distance to surface collimator (cm) | Counts (cpm) | Planar sensitivity (cpm/µCi) |
|----------------|-------------------------------------|--------------|-----------------------------|
|                |                                     | Detector 1   | Detector 2                  | Detector 1 | Detector 2 |
| 1274.86        | 10                                  | 368400       | 365500                      | 288.97     | 286.70     |
|                | 15                                  | 255000       | 255800                      | 200.02     | 200.65     |
|                | 25                                  | 145100       | 144700                      | 113.82     | 113.50     |

Figure 3. Planar image from in-house phantom scanning with 2 objects for each diameter channel (a) 7.4 cm (b) 5.4 cm (c) 3.5 cm (d) 1.5 cm.

Table 3. Diameter of hot objects: true diameter, object image diameter, and CF for each channel diameter.

| D channel = 1.5 cm | D channel = 3.5 cm |
|--------------------|--------------------|

| Mass (mg) | A (mCi) | Dtrue (mm) | Dimage (mm) | CF |
|-----------|---------|------------|-------------|----|
| 9.41      | 0.09    | 11.00      | 9.40        | 0.85 |
| 11.05     | 0.21    | 12.00      | 10.18       | 0.85 |
| 7.25      | 0.16    | 9.10       | 10.20       | 1.12 |
| 4.49      | 0.08    | 7.00       | 9.30        | 1.33 |
| 3.51      | 0.08    | 8.00       | 10.20       | 1.28 |
| 4.67      | 0.17    | 8.10       | 11.20       | 1.38 |

| Mass (mg) | A (mCi) | Dtrue (mm) | Dimage (mm) | CF |
|-----------|---------|------------|-------------|----|
| 14.03     | 0.13    | 12.00      | 12.31       | 1.03 |
| 12.50     | 0.23    | 12.00      | 11.20       | 0.93 |
| 6.88      | 0.15    | 9.90       | 9.70        | 0.98 |
| 8.30      | 0.14    | 9.10       | 9.90        | 1.09 |
| 5.96      | 0.13    | 9.00       | 10.10       | 1.12 |
| 4.56      | 0.16    | 8.00       | 9.61        | 1.20 |

| Mass (mg) | A (mCi) | Dtrue (mm) | Dimage (mm) | CF |
|-----------|---------|------------|-------------|----|
| 14.35     | 0.14    | 11.00      | 9.50        | 0.86 |
| 12.22     | 0.23    | 11.60      | 9.61        | 0.83 |
| 7.93      | 0.18    | 9.10       | 10.40       | 1.14 |
| 8.94      | 0.15    | 10.00      | 10.30       | 1.03 |
| 4.66      | 0.10    | 8.50       | 10.10       | 1.19 |
| 5.44      | 0.19    | 8.00       | 9.60        | 1.20 |

| Mass (mg) | A (mCi) | Dtrue (mm) | Dimage (mm) | CF |
|-----------|---------|------------|-------------|----|
| 15.64     | 0.15    | 13.00      | 11.53       | 0.89 |
| 16.74     | 0.31    | 13.00      | 11.20       | 0.86 |
| 10.26     | 0.23    | 10.30      | 11.00       | 1.07 |
| 9.74      | 0.17    | 10.00      | 10.83       | 1.08 |
| 7.21      | 0.16    | 10.00      | 11.20       | 1.12 |
| 5.68      | 0.20    | 8.30       | 9.40        | 1.13 |
In this study, the source activities used were 0.1 – 0.2 mCi and the observed object diameters were 7 – 12 mm. From Figure 4, the CF have the same trend for all channel diameter except for diameter 5.4 cm. The CF value were high at the beginning and then decrease with the increasing hot objects diameter. For this interval, CF value was mostly independent from channel diameters, with the value of (1.1±0.2).

4. Discussion
The planar image of in-house phantom as shown at Figure 3 was a blur image because of limited spatial resolution of gamma camera [10]. This phenomenon will give difficulty to predict the true size of hot object. Conversion factor needed to predict the true size of hot object. By phantom study, our preliminary study will focused on determining the CF value.

This phantom study using in-house phantom that simulate bone metastasis. Bone diameter represented as channel diameter. Four variations in diameter were chosen to study about the effect of
From Table 2, we can calculate the CF value for each channel diameter. The CF value were (1.14±0.24) for 1.5 cm channel diameter, (1.06±0.10) for 3.5 cm channel diameter, (1.04±0.16) for 5.4 cm channel diameter, and (1.03±0.12) for 7.4 cm channel diameter. This result informs that the CF values were independent with the size of channel diameter.

The CF value also has a correlation with the true diameter object and activity. In this study also used variations on true object diameter and activity. From this study found that diameter of hot object and activity of $^{99m}$Tc affect to CF value. Correlation of CF with object diameters was independent on the diameter of host channels and could be represented in the form of second-order polynomials (Figure 4). In general most of these polynomials indicated having a high coefficient correlation with the value of 0.941, 0.859, 0.971, 0.961 for 1.5 cm, 3.5 cm, 5.4 cm, and 7.4 cm host cylinder diameter respectively.

Whereas for object diameter < 7 mm, the CF value was determined by calculating the chart equations in Figure 4. CF values were in the range 1.7–3.4 for 1.5 cm and 3.5 cm channel diameter. This CF values relatively higher and influenced by the size of the channel diameter.

This study was the preliminary study about the effect of gamma camera spatial resolution to the planar image. Further study will observe the effect of scattering media on CF value and CF values for the material of different densities.

5. Conclusion
This preliminary study inform that CF values of SPECT hot images independent with the size of host bone medium. The CF value influenced by the true size of hot object and its activity.

6. References
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