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Estimation of Organ Activity using Four Different Methods of Background Correction in Conjugate View Method

Ahmad Shanei, Maryam Afshin, Masoud Moslehi, Sedighe Rastaghi[1]

Department of Medical Physics and Medical Engineering, School of Medicine, Isfahan University of Medical Sciences, [1]Department of Biostatistics, School of Health, Isfahan University of Medical Sciences, Isfahan, Iran

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ABSTRACT

To make an accurate estimation of the uptake of radioactivity in an organ using the conjugate view method, corrections of physical factors, such as background activity, scatter, and attenuation are needed. The aim of this study was to evaluate the accuracy of four different methods for background correction in activity quantification of the heart in myocardial perfusion scans. The organ activity was calculated using the conjugate view method. A number of 22 healthy volunteers were injected with 17–19 mCi of ^{99m}Tc-methoxy-isobutyl-isonitrile (MIBI) at rest or during exercise. Images were obtained by a dual-headed gamma camera. Four methods for background correction were applied: (1) Conventional correction (referred to as the Gates' method), (2) Buijs method, (3) BgdA subtraction, (4) BgdB subtraction. To evaluate the accuracy of these methods, the results of the calculations using the above-mentioned methods were compared with the reference results. The calculated uptake in the heart using conventional method, Buijs method, BgdA subtraction, and BgdB subtraction methods was 1.4 ± 0.7% ($P < 0.05$), 2.6 ± 0.6% ($P < 0.05$), 1.3 ± 0.5% ($P < 0.05$), and 0.8 ± 0.3% ($P < 0.05$) of injected dose (I.D) at rest and 1.8 ± 0.6% ($P > 0.05$), 3.1 ± 0.8% ($P > 0.05$), 1.9 ± 0.8% ($P < 0.05$), and 1.2 ± 0.5% ($P < 0.05$) of I.D, during exercise. The mean estimated myocardial uptake of ^{99m}Tc-MIBI was dependent on the correction method used. Comparison among the four different methods of background activity correction applied in this study showed that the Buijs method was the most suitable method for background correction in myocardial perfusion scan.

Key words: *Gamma Cameras, Heart, Myocardium, Radioactivity, Tomography, X-Ray Computed, Rest, Exercise*

INTRODUCTION

The radiation dose estimation is the basis for the use of radiopharmaceuticals in nuclear medicine,[1] and it is also the first step in protection against radiation. For example, in therapeutic applications of radiopharmaceuticals, it is necessary to assess the absorbed dose in the tumor and normal tissues to choose the most appropriate treatment protocol, maintaining doses to vital organs at safe levels.[1,2]

It is important to be stated that the organ dose evaluation deeply depends on the activity quantification of that organ.[3]

The organ activity can be quantified via planar and/or single photon emission computed tomography (SPECT) imaging methods. Activity quantification with tomographic imaging, for example, SPECT, is superior to that with planar imaging, since problems associated with organ overlap may be overcome. Moreover, planar imaging has some distinct advantages such as a simple implementation and that it is less time-consuming than SPECT.[3,4]

The standard method for the quantification of activity in an organ is the conjugate view method, in which generally, one anterior and one posterior image are acquired, and region of interests (ROIs) are manually drawn over the organs of interest.[3,5]

Accurate estimation of the activity in an organ from the measured count rate needs some corrections for physical factors, such as attenuation, scatter, organ- and patient-thickness, and physical decay of the radionuclide used.[6]

Address for correspondence:
Maryam Afshin, Department of Medical Physics and Medical Engineering, School of Medicine, Isfahan University of Medical Sciences, Isfahan 81746-73461, Iran.
E-mail: maryam.afshin1393@gmail.com

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The accuracy of the conjugate view method is sufficient for radiopharmaceuticals distributed in a single region or for isolated regions that do not overlap in the planar projection.[7] The uptake of activity in adjacent tissues, however, imposes a significant issue with background activity present in the organ ROI.

Several types of research were performed to study the activity evaluation using planar images, mainly investigating the attenuation and scatter corrections.[6]

Although the accuracy of different methods for background correction have been studied,[3,4,6-8] there is still a need to find an accurate method; specially in assessing the activity content in organs with low uptake, for example, the heart in myocardial perfusion imaging. It is necessary to optimize the methods of activity quantification to get more accurate internal dose estimations for nuclear medicine examinations and radionuclide therapy.[6,8]

The aim of this study was to evaluate the accuracy of four different methods for background correction in quantification of the uptake of activity in the heart in myocardial perfusion scans.

MATERIALS AND METHODS

Study Population

In this study, 22 healthy volunteers (11 males, 11 females, age range: 26–62 years [mean 48 ± 10 years], and weight range: 50–93 Kg [mean 75.5 ± 14.9 Kg]) were involved after they had given informed consent. The medical history of the subjects was surveyed and their myocardial perfusion scans were found normal. Eleven subjects (5 males and 6 females) were injected at rest and the others (6 males and 5 females) received the injection during exercise.

Measurement Procedure

Images were obtained using a dual-head gamma camera (Philips [ADAC], forte, Netherlands) equipped with parallel-hole, low-energy, high-resolution collimators.

Technetium-99m HEXAMIBI (17–19 mCi) was injected either at rest or during exercise.

The anterior and posterior images were acquired at 15 min, 60 min, and 120 min postinjection (P.I.). Lateral imaging was performed at rest or during exercise to determine the body and organ thickness.

The organ activity was calculated using the conjugate view method. ROI were manually drawn in the anterior and posterior images.

The organ activity was derived from the square root of the product of the anterior and posterior counts [Eq. 1]:

$$A = \sqrt{\frac{I_A \times I_P}{e^{-\infty_e t}}} \times \frac{f}{C} \quad (1)$$

Where A is the organ activity in MBq, I_A and I_P are the count rates in the anterior and posterior views, respectively (cpm), t is the thickness of the body at the position of the heart (cm), μ_e is the effective attenuation coefficient (0.141/cm for ^{99m}Tc),[4,6] f is equal to $(\mu_e t/2)/\sinh(\mu_e)t/2$, and represents a correction for the source region attenuation coefficient (μ_e) and source thickness (t),[6] and C is the system calibration factor (count rate/unit activity). The system calibration factor used in this study (2773 cpm/MBq) was obtained by counting a known activity of ^{99m}Tc for a fixed period of time in air using the same camera, collimators, and camera acquisition setting as for the myocardial perfusion scans.[1]

The following four background correction methods were applied to determine the uptake of activity in the heart.

Conventional background subtraction (Gates)

$$I = I'_{ROIsource} - \overline{I}_{ROIbackground} \times S_{source} \quad (2)$$

I gives the corrected counts in the ROI in the source area, $I'_{ROIsource}$ is the number of counts in the source region, $\overline{I}_{ROIbackground}$ is the mean value of count per pixel in the background region drawn adjacent to the source, and S_{source} is the number of pixels in the source region. The subtraction was performed for each projection, anterior and posterior, before the application of Eq. 1.[4]

Buijs method

A simple and geometrically based subtraction technique was applied to correct for background activity. This method is used to avoid over-subtraction of background activity due to the volume occupied by the organ.[6]

$$I_A = I'_A - I_{BGA} \times F$$
$$I_P = I'_P - I_{BGP} \times F \quad (3)$$

Where I_A (I_P) is the background corrected count rate of the organ in the anterior (posterior) ROI, I_A' (I_P') is the measured count rate in the anterior (posterior) background ROI. F is the fraction of the total background activity (I_{BGA}/I_{BGP}), subtracted from the measured activity in the source organ ROI (I_A'/I_P'), and is defined as:

$$F = 1 - (t/T) \quad (4)$$

Where t is the thickness of the source organ and T is the thickness of the body at the placement of the source ROI.

BgdA subtraction method

A rectangular ROI, small in comparison with the myocardial organ ROI (nine pixels compared to a mean of 2300 pixels), was placed at five different areas adjacent to the myocardial region and a mean value was calculated.[8]

BgdB subtraction method

This method for background correction takes the size of the organ into account (thus the correction for self-attenuation in the organ) and also makes an assumption of a homogeneous background activity concentration. For the anterior view, the total background contribution from over- and underlying tissue, $BgdB_{ant}$ (count/px), is given by:

$$BdgB_{anterior} = \left(\frac{kC}{\mu}\right)\left\{\left(1-e^{-\mu a}\right)+\left(e^{-\mu(T-b)}-e^{-\mu T}\right)\right\} \quad (5)$$

$$= \left\{\frac{\left(1-e^{-\mu a}+e^{-\mu(T-b)}-e^{-\mu T}\right)}{\left(1-e^{-\mu T}\right)}\right\} BdgA_{anterior}$$

For the posterior view, the total background contribution is given as:

$$BdgB_{posterior} = \left\{\frac{\left(1-e^{-\mu b}+e^{-\mu(T-a)}-e^{-\mu T}\right)}{\left(1-e^{-\mu T}\right)}\right\} BdgA_{posterior} \quad (6)$$

Values of T, a and b (cm), were measured from the lateral images of each subject. T is the body thickness at the position of the heart, a is the distance between anterior surface of the heart and of the body, and b is the distance between the posterior surface of the body and the posterior surface of the heart [Figure 1].[8,9]

The amount of ^{99m}Tc-methoxy-isobutyl-isonitrile (MIBI) uptake in the heart is expressed as a percentage of injected activity (I.A.).

To find the most accurate method for background correction, the results of the calculations using the above-mentioned methods were compared with the known results for heart uptake in a myocardial perfusion scan.[3,8,10-14]

The myocardial activity at 15 min, 60 min, and 120 min after injection was calculated using the conjugate view method. The most accurate method of background correction, which was determined in the previous part, was applied to determine the activity at different time-points after injection. The activity in the heart was plotted versus time to show the changes of ^{99m}Tc-MIBI distribution over time.

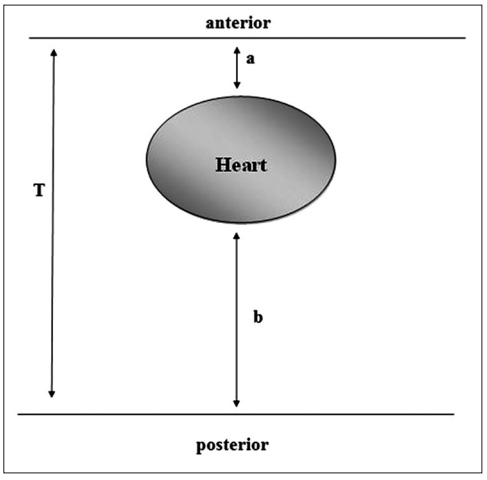

Figure 1: Schematic diagram used for calculating background correction (BgdB)

Data were expressed as mean percentage of I.A. ± standard deviation. Comparison of calculated data in this study and published data was analyzed using one-sample *t*-test. $P < 0.05$ was considered statistically significant.

RESULTS

The heart uptake calculated using conventional, Buijs, BgdA subtraction and BgdB subtraction methods for background correction, respectively, was 1.4 ± 0.7%, 2.6 ± 0.6%, 1.3 ± 0.5% and 0.8 ± 0.3% of I.A. at rest [Table 1], and 1.8 ± 0.6%, 3.1 ± 0.8%, 1.9 ± 0.8% and 1.2 ± 0.5% of I.A. during exercise [Table 2].

Tables 1 and 2 show that there were significant differences between calculated activity in the myocardium and the reference values for all methods ($P \leq 0.05$), except for Buijs method. For Bujis background correction method, there was no significant difference between calculated activity in the myocardium and the reference values during exercise ($P > 0.05$).

Mean uptake in the myocardium was calculated at 15 min, 60 min, and 120 min after injection of ^{99m}Tc-MIBI, using Buijs method for background correction [Table 3].

Table 3 shows a prompt uptake in the myocardium with a gradual decrease with increasing time P.I. However, the uptake in the myocardium was approximately >3% of I.A. up until approximately 120 min P.I, during exercise.

Table 1: Mean uptake in the myocardium during rest, using four methods of background correction at 60 min p.i.

Background correction method	Uptake (% I.A.)
Conventional	1.4±0.7 ($P<0.05$)
Bujis	2.6±0.6 ($P<0.05$)
BgdA	1.3±0.5 ($P<0.05$)
BgdB	0.8±0.3 ($P<0.05$)

P value obtained from one-sample *t*-test. p.i. – Postinjection; I.A. – Injected activity

Table 2: Mean uptake in the myocardium during exercise, using four methods of background correction at 60 min p.i.

Background correction method	Uptake (% I.A.)
Conventional	1.8±0.6 ($P<0.05$)
Bujis	3.1±0.8 ($P>0.05$)
BgdA	1.9±0.8 ($P<0.05$)
BgdB	1.2±0.5 ($P<0.05$)

P value obtained from one-sample *t*-test. p.i. – Postinjection; I.A. – Injected activity

A time-activity curve for the heart after exercise is shown in Figure 2. This figure illustrates the changes of ^{99m}Tc-MIBI activity uptake in the myocardium over time P.I.

Figure 2 shows that the highest level of heart uptake was in the 1st h after injection, and then it decreased gradually over time.

DISCUSSION

Current methods for the quantification of organ activity are sufficiently accurate for single or isolated organs that do not overlap with others in the planar projection. However, in most common clinical situations, organs overlap and the uptake of activity in the background is of such magnitude that it requires some form of background correction to improve the accuracy of the quantification of the activity in the organ of interest.[8]

The results of the present study confirm that the uptake of ^{99m}Tc-MIBI in the myocardium is approximately <3% of the administered activity [Tables 1 and 2]. At this low activity levels, the choice of background correction method is even more important to be able to determine the uptake of activity in the organ of interest at an acceptable level of accuracy.[8]

In a phantom study, Norrgren *et al*. studied several factors affecting the accuracy of activity quantification such as the effective attenuation coefficient, body thickness, and system sensitivity. It should be noted that the effective attenuation coefficient and body thickness could influence the estimation of activity with up to 10%. The corresponding value for the system sensitivity was about ±5%. However, Norrgren *et al*. noted that the correction of background activity was the factor that made the largest influence on the results. Differences in how background regions were defined contributed to as much as ±20% variations of the observed activity values compared to the reference results.[15]

Table 3: Mean uptake of activity in the myocardium at different time points p.i. during exercise, using Bujis method for background correction

Time p.i. (min)	Uptake (% I.A.)
15	3.5±1.0
60	3.1±0.8
120	3.0±0.8

p.i. – Postinjection; I.A. – Injected activity

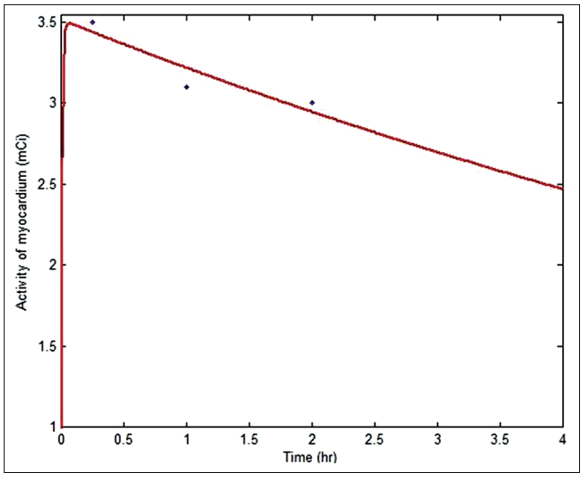

Figure 2: Time-activity distribution of ^{99m}Tc-methoxy-isobutyl-isonitrile in myocardium after exercise, in myocardial perfusion scan

The present study was performed to determine the most accurate method of background correction in myocardial perfusion scans. The accuracy of the activity quantification was evaluated using four different methods of background correction in myocardial perfusion scans.

The most common method used for background correction is the so-called conventional method. Wilhelmina *et al*. reported that the conventional method leads to an over-correction of background activity, since the volume of the organ of interest is not considered.[6] In line with the Wilhelmina *et al*. study, our results showed that there was a significant difference between the calculated activity in the heart using the conventional background correction method and the known results [Tables 1 and 2].

Buijs method for background correction requires a correction factor for the source volume, and thus takes the volume of the organ of interest into account.[6] The calculated values for the myocardial uptake at rest in this study were 2.6% ± 0.6% and 3.1% ± 0.8% of I.A and showed no significant differences compared to reference results ($P > 0.05$). The results for activity uptake during exercise were similar to the calculated myocardial activity using Buijs method by Jonsson *et al*.[3]

The uptake of 99mTc-MIBI in the myocardium is greater after exercise than at rest.[10,12-14] Because the uptake in the myocardium is lower at rest, the activity quantification is less accurate than quantification based on images acquired after exercise, as shown in a study by Smith *et al*.[8] The present study shows that, the results of myocardial activity quantification, using Buijs method for background correction during exercise, had no significant difference with the known results. However, the results for the examination at rest did not show similar accuracy.

According to Smith *et al*., the activity uptake calculated with BgdA and BgdB background correction methods ranged from 1.7 to 1.9% of I.A.[8] This was higher than the values in this study, as our values ranged from 0.8 to 1.9%. Statistical analysis showed significant differences between the results of BgdA and BgdB background correction methods and the reference results.

The comparison between four different methods of background activity correction applied in the present study

showed that the Buijs method was the most appropriate method for background correction in myocardial perfusion scans.

Finally, it should be noted that in patient studies, the low accuracy of activity estimations may be due to variations in background activity concentrations in close vicinity to the organ of interest. It could also be affected of the size of the ROIs used in the data analysis; thus, it is operator-dependent. Inaccurate estimates of body thickness, organ thickness, and organ depth could also affect the results. The use of reference values could also be a source of error, since the uptake values can differ to a certain extent in patients. Some of the above-mentioned issues, such as inaccuracies in body- and organ-thickness, organ depth, and variations in background activity, could be overcome by performing phantom measurements to determine which background correction method is the most suitable for the organ of interest. However, the results of phantom-based studies also show limitations including the inability to accurately simulate irregularities and nonuniformities of the background activity, and also the irregular sizes, shapes, compositions, and consequently linear attenuation coefficients of the source organ.[6] This, in turn, could be overcome by the use of simulated images, that is, mathematical phantoms, in which the distribution of the radiopharmaceutical could be simulated in detail with different values of I.A. depending on the scientific question.[16]

The method used in this study is, however, a simple method which is easily implemented in any clinic with a gamma camera. As it also gives reasonably accurate results, it is a method which could be used as an easily implemented method sufficient for fast activity quantification of planar gamma camera images.

CONCLUSIONS

In this work, mean myocardial uptake of ^{99m}Tc-MIBI in planar gamma camera images was estimated using four different methods of background correction. The calculated mean myocardial uptake ranged from 0.8% to 3.1% of the administered activity, depending on the used correction method. This study showed that using the Buijs method for background correction will provide the most accurate results for the estimation of myocardium activity in myocardial perfusion scan in comparison with the reference values.

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Conflict of Interest

There are no conflict of interest.

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BIOGRAPHIES

Ahmad Shanei holds the position of Assistant Professor of Medical Physics at the Department of Medical Physics and Medical Engineering in the School of Medicine of Isfahan University of Medical Sciences, Iran. He has authored a significant number of papers in the area of Medical Physics, including Sonodynamic therapy, therapeutic applications of nanoparticles, and nuclear medicine.

E-mail: shanei@med.mui.ac.ir.

Maryam Afshin received the B.Sc. degree in Physics at Shahid Beheshti University, Tehran, Iran. She is currently the M.Sc. Student of Medical Physics at Isfahan University of Medical Sciences, Isfahan, Iran.

E-mail: maryam.afshin1393@gmail.com.

Masoud Moslehi graduated as a Medical Doctor from Isfahan University of Medical Sciences in Isfahan, Iran in 1999. He received his specialty in Nuclear Medicine from Tehran University of Medical Sciences in 2005. He is currently Assistant Professor of Nuclear Medicine in the Department of Medical Physics and Medical Engineering at Isfahan University of Medical Sciences, Isfahan, Iran.

E-mail: mmoslehi_m@yahoo.com

Sedighe Rastaghi received the B.Sc. degree in Statistics at Birjand University, Khorasan, Iran, and M.Sc. degree in Biostatistics at Isfahan University of Medical Sciences, Isfahan, Iran. Her research interests include Generalizing Linear Models.

E-mail: sedighe_rastaghi@yahoo.com.