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Variation of Contrast Values for Myocardial Perfusion Imaging in Single-photon Emission Computed Tomography/Computed Tomography Hybrid Systems with Different Correction Methods

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ABSTRACT

Objectives: Single-photon emission computed tomography/computed tomography (SPECT/CT) hybrid systems have the advantage of performing various scans using the same imaging setting. Absorption and scattering of the gamma rays by the patient's body significantly affect images obtained from scintigraphy, especially in myocardial perfusion imaging. An important parameter for image quality in SPECT is image contrast which is defined as the difference in density between regions of the image corresponding to different levels of radioactive uptake in the patient. The objective of the study was to evaluate the influence of applying different correction methods on image contrast of myocardial SPECT/CT images.

Material and Methods: A total of 114 patients, 43 females and 71 males, patient's raw data were processed and analyzed using attenuation correction (AC), scatter correction (SC), both attenuation and scatter correction together (ACSC), and no correction (NC). The short axis (coronal) slices resulted from the raw data reconstruction were chosen to perform the processing for hot and cold spheres for contrast values measurement. Statistical analysis was made for the measured contrast values for AC, SC, ACSC, and NC to determine the best image contrast.

Results: When applying SC alone, it yields better contrast value (0.834), compared to AC (0.677) and ACSC (0.739). Both ACSC and AC had better image contrast compared to NC (0.592).

Conclusion: The intercomparison study between the correction conditions indicates that the counts in SPECT/CT are highly affected by all correction methods. The image contrast has been significantly improved by using SC, AC, and ACSC when compared with the NC image. Furthermore, SC is superior in the image contrast than the other correction conditions in the reconstruction of SPECT/CT MPI.

Keywords: Single-photon emission computed tomography/computed tomography, Attenuation correction, Scatter correction, Image contrast, Myocardial perfusion imaging

INTRODUCTION

Myocardial perfusion imaging (MPI) using single-photon emission computed tomography (SPECT) is a non-invasive technique that helps in the diagnosis of coronary artery disease.[1-3] In MPI using SPECT, quantification accuracy is affected by a physical process including scattering, attenuation, partial volume effect, and the imaging characteristics including spatial and energy resolution, contrast, sensitivity, uniformity, as well as reconstruction methods.[4] One of the major problems in SPECT imaging is the containment of scattered photons within the photopeak energy window used for projection images acquisition, which may occur in two ways either as coherent scatter or Compton scatter. Compton scattering plays a substantial role in the nuclear medicine imaging. In addition, the probability of its occurrence in the energy range used in nuclear medicine studies is more than coherent scattering.[5]

Detecting the exact localization of physiologic data obtained from nuclear medicine studies is now possible with hybrid SPECT/CT systems.[6] Absorption and scattering of the gamma rays by the patient's body significantly affect images obtained from scintigraphy. This phenomenon is particularly relevant in cases of MPI. Image contrast is one of the physical parameters used to evaluate the image quality of SPECT. Improving the image contrast has an impact on the diagnosis. Tissue attenuation hinders the precise interpretation of MPI.[7] The most common attenuation artifacts are caused by effects of breast and diaphragmatic soft-tissue attenuation, which results in suboptimal specificities of conventional SPECT imaging.[8-11] Due to these circumstances, introduction of correction of gamma-ray attenuation with an external source of radiation led to assessments of the effectiveness of imaging procedures for MPI.[6]

A radioactive source (X-rays in hybrid SPECT/CT cameras) was used for attenuation correction (AC). Both diagnostic benefits and additional artifacts resulted from such corrections.[7] In addition, a relatively long time interval between acquiring data on SPECT and CT is a drawback of CT-derived corrections, as it increases chances of patient movement.[12] SPECT/CT hybrid systems overcome this drawback by scanning the organs using the same imaging setting, thereby limiting patient motion.

There are many scatter correction (SC) methods of SPECT images which have been proposed by several investigators. Some of them are rely on a spectral analysis that is implemented by setting additional energy windows in Tc-99m spectrum, and others based on a spatial analysis that is performed by convolution and deconvolution procedures such as dual-energy window (DEW) method, photopeak energy distribution analysis, dual-photopeak window, cannel ratio method, and three energy window. DEW method was the option for SC, as it was viewed the most suitable as well as the main supported correction technique for the system used.[13]

Image contrast of SPECT is the difference in densities between regions of the image corresponding to different levels of radioactive uptake in the patient. In nuclear medicine, it is the lesion-to-background uptake or concentration ratio. In general, image contrast is the ratio between the signal change of an object of interest, such as a lesion (region of interest [ROI]), and the signal level in the surrounding parts of the image.[14]

For multi-head systems, tomographic contrast is an important indicator of the efficacy of a system to detect small lesions. The contrast for a radioactive sphere on a background can be calculated as follows:[15]

$$C = \frac{(\text{Counts}_{\text{sphere}} - \text{Counts}_{\text{background}})}{(\text{Counts}_{\text{sphere}} + \text{Counts}_{\text{background}})} \quad (1)$$

Other possible explanations of image contrast have been employed. However, the fundamental concept is to estimate the ability of the system to detect a known change in the activity concentration for a given size of a spherical object. Tomographic contrast is also important in determining the detectability of small lesions, but it may be affected by different physical factors, which limit the quality of SPECT images.[16]

MATERIAL AND METHODS

Patients selection

A total of 114 patients were recruited retrospectively from January 2017 till September 2019. The patients were injected with ^{99m}Tc-tetrofosmin at a dose of 20–30 mCi (Myoview, GE Healthcare AS; Oslo, Norway). They were asked to fast 4 h and advised to stop caffeine containing drinking tea, coffee, and cola drinks as well as avoid chocolate at least 12 h before study. They discontinue calcium channel blockers for 48 h and beta-blockers for 72 h before the study.

Study acquisition protocol

An interval of 30–45 min was allowed between injection and imaging. Patients were asked to lie down in the supine position with arms over their heads. SPECT acquisition parameters included 30 frames, 20 sec/each, body contouring orbital motion with step-and-shoot acquisitions, and 180 rotation arcs (90 degrees for each head) from right anterior oblique 45" to left posterior oblique 135". The SPECT study was followed immediately by low-dose CT for AC and anatomical localization. CT is performed (110 kVp, 15 mAs) to obtain an attenuation map. Their raw data were processed and analyzed to study the effect of applying AC, SC, both AC and SC together (ACSC), and no correction (NC) on image contrast.

Image reconstruction

A GE Healthcare Xeleris Workstation (version 3) located at nuclear medicine laboratory at Inaya Medical College was used to reconstruct and apply different correction methods, including AC, SC, attenuation and scatter correction combined (ACSC), and NC.

After acquiring the raw data, images were checked for coregistration accuracy and applying reregistration if required. The images were processed and reconstructed using the Butterworth filter with a cutoff value of 0.5. Furthermore, the order, which is another parameter used to control the slope of the frequency curve, can be specified for Butterworth filters to equal 10.0. AC, SC, ACSC, and NC were applied during the processing to generate images with different correction techniques. Processing was performed on a Xeleris Workstation using Myovation cardiac software (GE Healthcare). The different correction schemes with ordered subset expectation maximization (OSEM) with 5 iterations and 10 subsets were applied: AC, SC, ACSC, and NC. Reconstruction resulted in vertical long axis, horizontal long axis, and short axis represents sagittal, transverse, and coronal slices, respectively.

SC

In SPECT imaging, a significant fraction of the detected photons is scattered in the body. This is due to the finite energy resolution of the gamma camera, which results in imperfect energy-based scatter rejection. SC requires estimating the scatter component of the projection data combined with a compensation method. Most frequently, the scatter component is estimated using data acquired in auxiliary energy windows.

DEW method was our choice for SC, as it was considered the most appropriate as well as the main supported correction technique.[13] Jaszczak *et al*. proposed this method for SC. In which, an additional energy window below the photopeak window is used to observe the number of scatter counts distort the total count within the photopeak window.[17]

This method measures the scatter in an energy window immediately below the main energy peak window, then performing correction by subtracting the scatter image from the main peak image. The subtraction, which is a pixel-by-pixel operation, uses a weighting factor, which depends on the width of the main peak and scatter energy windows used.

AC

The CT data were used for the correction of tissue attenuation in the SPECT studies on a slice by slice technique. Because the CT data are acquired with higher resolution than the SPECT data, it is essential to diminish the resolution of the CT information to match that of SPECT. This means that CT acquired data become blurred to be matched with the SPECT data. According to the attenuation coefficient data that have been acquired from CT, correction factors were determined, then it can be used to correct the SPECT data for attenuation, yielding the attenuation-corrected images.[18,19]

Contrast value measurements

After image reconstruction, the coronal short axis slices resulting from the raw data reconstruction were chosen to draw the hot spots and background spheres. Place a sphere of known size, but with a size much greater than the spatial resolution of the system to minimize partial volume effects, within ROI containing a uniform concentration of activity. In the reconstructed image estimate the counts value of pixels within the region corresponding to the sphere (C_{sph}) as well as the counts value of pixels in the neighborhood of the sphere (C_{bgd}), but outside the region corresponding to the sphere itself. Counts of the sphere pixels and the background area were tabulated and contrast for this size lesion may then be calculated as Equation 1.

The total counts were measured by ROI button for AC, SC, ACSC, and NC [Figure 1]. The contrast values for AC, SC, and ACSC were compared to evaluate which one provides the best contrast.

To account for potential bias, three different independent specialists in nuclear medicine, with 12, 13, and 19 years of experience processed the raw data images and calculated the contrast values for each correction method [Figure 2]. Their results were then received by a blinded statistician for data analysis.

Statistical analysis

Data were analyzed with the Statistical Package for the Social Sciences 23.0, IBM Corp, Armonk, NY. Descriptive statistics were run for frequencies, mean, median, standard deviations, and normality. The intraclass correlation coefficient (ICC) was used for assessing the closeness between the three nuclear medicine specialists contrast measurements. Demographic data associations with our study outcome were examined using nonparametric tests. Since the data were not normally distributed, non-parametric tests were

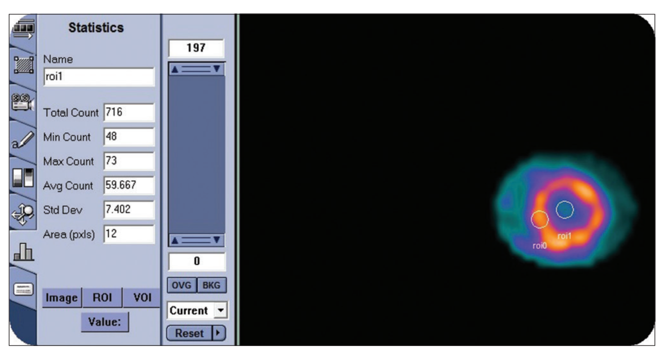

Figure 1: An example for counts measurement.

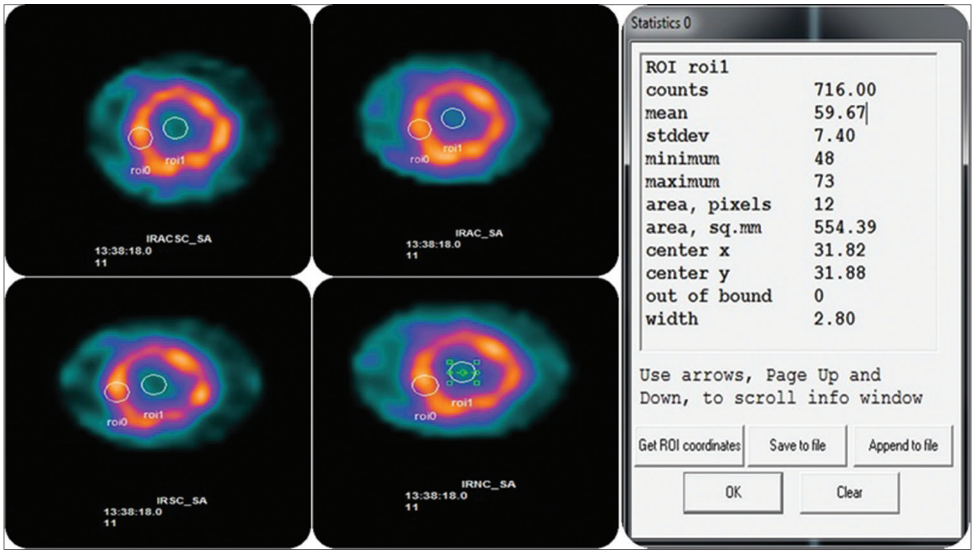

Figure 2: Values of hot and cold sphere counts for attenuation correction, scatter correction, both attenuation and scatter corrections, and no correction.

used. Freidman test was used, as alternative to the one-way ANOVA, with repeated measures to test for differences between groups. Predefined *post hoc* comparisons of contrast between different correction methods were preformed when a significant difference was identified with Freidman test using the Wilcoxon signed-rank test. Based on our literature review, power analysis was conducted in G Power. Running a power analysis on repeated measures with four different correction techniques, a power of 0.80, an alpha level of 0.05, and a medium effect size (f = 0.20), the minimum required total sample size was 100.[20]

RESULTS

A total of 114 patients (71 males and 43 females) were successfully enrolled into the study with a mean body mass index (BMI) of 26.1 kg m^{-2} (±2.41) [Table 1].

All the four conditions were applied during image processing and contrast value was calculated for each one. Table 2 shows that counts are depending on the applied correction methods, the higher count value was for NC in both target and background spheres and the lowest counts achieved by SC, as shown in Figure 3.

Three different readings were obtained from the three nuclear medicine specialists for each contrast value. The average result from the three nuclear medicine specialists was highly reliable (ICC = 0.991, 95% CI of 0.989–0.994, $P < 0.0001$).

Table 3 illustrates the mean contrast values for the studied correction conditions as measured by each nuclear medicine specialists. The combined contrast means values and standard deviation (SD) for the studied four correction conditions were NC (0.592, SD = 0.14), SC (0.834, SD = 0.12), AC (0.677, SD = 0.13), and ACSC (0.739, SD = 0.13) [Figure 4]. We did not record any significant associations between either gender or BMI and contrast values for our correction methods.

Friedman's test for repeated measures showed a significant difference between the studied correction methods in terms of contrast values (Chi-square = 223.926, df = 3, $P < 0.0001$). Then, a non-parametric *post hoc* test was conducted, in which we examined further the difference between each two groups. Based on positive ranks, a Wilcoxon signed-ranks test indicated that the SC technique achieved a significant higher contrast values than ACSC (Z = −9.267, $P < 0.0001$), AC (Z = −9.267, $P < 0.0001$), and NC (Z = −9.199, $P < 0.0001$) methods. Moreover, contrast values using ACSC technique were significantly higher compared to AC

Table 1: Patients' characteristics.

	Number	Percentage
Male	71	62.3
Female	43	37.7
	Mean	**SD**
Age, years	53.5	6.32
BMI, kg/m^2	26.1	2.41

Table 2: Mean counts for each correction condition.

	ACSC	AC	SC	NC
Sphere (hot)	5498	5679	3814	6132
Background (cold)	825	1095	346.2	1427

ACSC: Attenuation and scatter correction combined, AC: Attenuation correction, SC: Scatter correction, NC: No correction

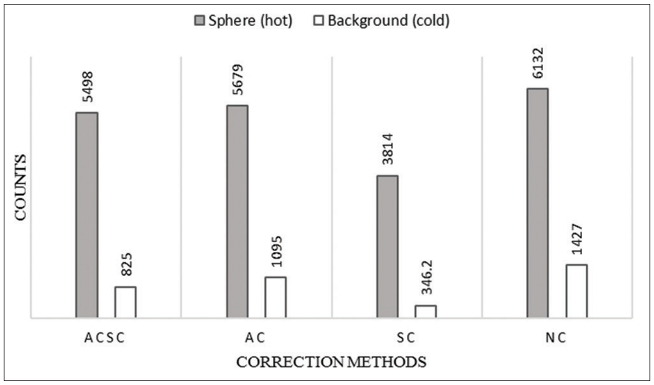

Figure 3: Comparison of the counts among the four correction conditions.

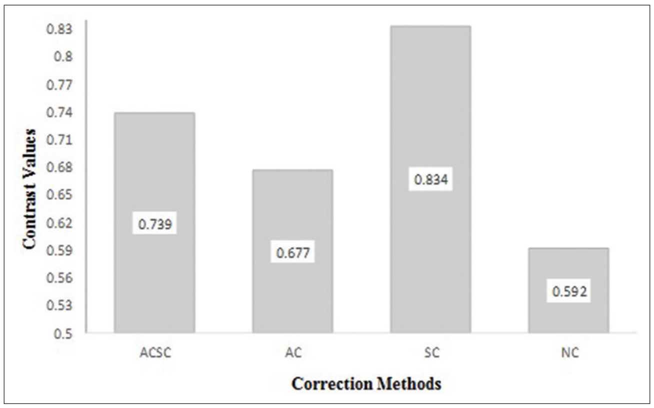

Figure 4: Comparison of the contrast value among attenuation correction, scatter correction, no correction, and both attenuation and scatter corrections.

Table 3: Contrast mean values and their standard deviations.

Correction method	NMS 1*	NMS 2*	NMS 3*	Combined**
ACSC, mean (SD)	0.735 (0.12)	0.746 (0.15)	0.737 (0.14)	0.739 (0.13)
AC, mean (SD)	0.673 (0.11)	0.685 (0.13)	0.675 (0.14)	0.677 (0.13)
SC, mean (SD)	0.83 (0.11)	0.841 (0.12)	0.831 (0.11)	0.834 (0.12)
NC, mean (SD)	0.595 (0.13)	0.607 (0.14)	0.577 (0.14)	0.592 (0.14)

ACSC: Attenuation and scatter correction combined, AC: Attenuation correction, SC: Scatter correction, NC: No correction, *Nuclear medicine specialist. **Average contrast scores from the three independent nuclear medicine specialists

($Z = -6.802$, $P = 0.0001$) and NC ($Z = -6.279.$, $P = 0.0001$). Finally, when compared between AC technique and NC technique, contrast values using AC technique were significantly higher ($Z = -5.346$, $P = 0.0001$).

DISCUSSION

Image quality refers to the accuracy with which an image represents the imaged object. The basic method for characterizing or evaluating image quality is the quantitative measurement of calculation of physical characteristics of the image or imaging system. In nuclear medicine, image contrast (difference in image density or intensity between areas of the imaged object showing different concentrations of radioactivity) is the most effective parameter for evaluating image quality.

A study by Huang *et al*. found that the image quality and semi-quantitative results of the left ventricular ischemic myocardium under different correction conditions are significantly different. SC can significantly improve the display of ischemic myocardium, especially in CTAC images.[21]

This finding matched with our results as the contrast value for MPI was the greatest using SC method, but, on the other hand, it showed the lowest counts in both sphere and background due to the effect of elimination of scattering photons.

Chuanyong *et al*. found that all studies showed improvement in image quality with SC, and 15 out of 20 studies showed significant improvement in myocardium-to-chamber contrast.[22] These results match the results obtained from our study, which showed that applying SC alone yields the best cardiac image contrast compared to AC, ACSC, and NC.

Different studies have shown that AC is beneficial in both obese and non-obese patients and that the benefit is greater in patients with high BMI.[23-25] In this work, we included only patients with low BMI <30 kg m^{-2} to avoid obese patients and eliminate extra soft-tissue fat attenuation and artifacts as well as reduce any motion defects resulting from difficult breathing.[26] It was found that AC alone improved the image resolution when compared with non-corrected image.

Tamam *et al*. found that AC with OSEM iterative reconstruction significantly improves the diagnostic accuracy of stress-only SPECT MPI in patients, but the improvement is significantly greater in obese patients.[27] These results match with our results regardless the obesity because applying AC during image reconstruction enhance the image contrast in patient with BMI <30 kg m^{-2}.

Another study assessing the attenuation, resolution, and SCs on SPECT cardiac images using a triple-headed SPECT system aligned with a ^{153}Gd as an external transmission line source was used to acquire simultaneously emission and transmission data. They found that OSEM with AC + SC + resolution compensation (RC) outperforms FBP reconstructions and improves the accuracy of detection of CAD with cardiac perfusion SPECT reconstructions.[28]

This result does not match our results as it used an external transmission line source for AC while, in our study, we use CT for AC in SPECT/CT hybrid system. Furthermore, we found that SC alone enhances the contrast value of MPI more than ACSC together.

Knoll *et al*. compared image contrast between SC and NC and found better sphere and sector contrast with SC than with NC.[29] These results match the results obtained from our study, which showed that SC improved image contrast better than other methods.

Kalantari *et al*. studied the effects of ACSC on image quality and found that they provide better contrast compared to uncorrected images, so the lesions were better defined in the scatter and attenuation-compensated images.[30] These results match the results obtained from our study, which showed that applying ACSC during image reconstruction provided increased image contrast value.

Oloomi *et al*. proposed the maximum likelihood expectation maximization formula for ACSC during reconstruction. With this formula, contrast was better compared to the uncorrected images, with a mean increase of 25%, allowing better delineation of the lesions in the scatter and attenuation-compensated images.[31] These results match the results obtained from our study, which showed that applying ACSC provided better image contrast compared to NC.

Our study has some limitations, including, the assessment of two physical parameters, counts, and image contrast, without measuring the effect of the correction conditions on other physical parameters of image quality. Furthermore, we did not evaluate the interaction of these correction conditions with the clinical data and reporting accuracy.

On the other hand, the novelty of our study included, large sample size, processing on the same workstation model and processed uniformly using the same protocol. The clinical images have been used to determine and calculate physical quantitative parameters for measurement of the counts and the image contrast as well as it was verified by involving three independent observers for calculating both counts and image contrast to avoid any bias.

CONCLUSION

The intercomparing study between the available correction conditions indicates that the counts of MPI using SPECT/CT are highly affected by all correction methods. The image contrast has been significantly improved using SC, AC, and both methods together when compared with the non-corrected image. Furthermore, it was found that the SC condition is superior in the image contrast than the other correction condition in the reconstruction of SPECT/CT myocardial perfusion images.

Declaration of patient consent

The study protocol was in accordance with the ethical standards of the institutional and national research committees and with the Helsinki Declaration of 1970 as amended in 2000.

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Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Anagnostopoulos C, Harbinson M, Kelion A, Kundley K, Loong CY, Notghi A, *et al*. Procedure guidelines for radionuclide myocardial perfusion imaging. Heart 2004;90:i1-10.
2. Niu X, Yang Y, Jin M, Wernick MN, King MA. Effects of motion, attenuation, and scatter corrections on gated cardiac SPECT reconstruction. Med Phys 2011;38:6571-84.
3. Yokota S, Mouden M, Ottervanger JP, Engbers E, Knollema S, Timmer JR, *et al*. Prognostic value of normal stress-only myocardial perfusion imaging: A comparison between conventional and CZT-based SPECT. Eur J Nucl Med Mol Imaging 2016;43:296-301.
4. Buvat I, Rodriguez-Villafuerte M, Todd-Pokropek A, Benali H, Di Paola R. Comparative assessment of nine scatter correction methods based on spectral analysis using Monte Carlo simulations. J Nucl Med 1995;36:1476-88.
5. Staelens S, Strul D, Santin G, Vandenberghe S, Koole M, D'Asseler Y, *et al*. Monte Carlo simulations of a scintillation camera using GATE: Validation and application modelling. Phys Med Biol 2003;48:3021-42.
6. Seo Y, Mari C, Hasegawa BH. Technological development and advances in single-photon emission computed tomography/computed tomography. Semin Nucl Med 2008;38:177-98.
7. Masood Y, Liu YH, Depuey G, Taillefer R, Araujo LI, Allen S, *et al*. Clinical validation of SPECT attenuation correction using x-ray computed tomography-derived attenuation maps: Multicenter clinical trial with angiographic correlation. J Nucl Cardiol 2005;12:676-86.
8. Fricke E, Fricke H, Weise R, Kammeier A, Hagedorn R, Lotz N, *et al*. Attenuation correction of myocardial SPECT perfusion images with low-dose CT: Evaluation of the method by comparison with perfusion PET. J Nucl Med 2005;46:736-44.
9. Tonge CM, Manoharan M, Lawson RS, Shields RA, Prescott MC. Attenuation correction of myocardial SPECT studies using low resolution computed tomography images. Nucl Med Commun 2005;26:231-7.
10. Utsunomiya D, Tomiguchi S, Shiraishi S, Yamada K, Honda T, Kawanaka K, *et al*. Initial experience with X-ray CT based attenuation correction in myocardial perfusion SPECT imaging using a combined SPECT/CT system. Ann Nucl Med 2005;19:485-9.
11. Wolak A, Slomka PJ, Fish MB, Lorenzo S, Berman DS,

Germano G. Quantitative diagnostic performance of myocardial perfusion SPECT with attenuation correction in women. J Nucl Med 2008;49:915-22.
12. Goetze S, Wahl RL. Prevalence of misregistration between SPECT and CT for attenuation-corrected myocardial perfusion SPECT. J Nucl Cardiol 2007;14:200-6.
13. Asl MN, Sadremomtaz A, Bitarafan-Rajabi A. Evaluation of six scatter correction methods based on spectral analysis in (99m) Tc SPECT imaging using SIMIND Monte Carlo simulation. J Med Phys 2013;38:189-97.
14. Cherry SR, Sorenson JA, Phelps ME. Physics in Nuclear Medicine. Philadelphia, PA: Elsevier Saunders; 2014. p. 453-5.
15. Ibrahim ES, Nadia LH, Mohie ED, Rizk AM. Evaluation of varying acquisition parameters on the image contrast in SPECT studies. Int J Res Rev Appl Sci 2012;13:485-91.
16. International Atomic Energy Agency. Quality Assurance for SPECT Systems, IAEA Human Health Series No. 6. Vienna, Austria: International Atomic Energy Agency; 2009. p. 148.
17. Jaszczak RJ, Greer KL, Floyd CE, Harris CC, Coleman RE. Improved SPECT quantification using compensation for scattered photons. J Nucl Med 1984;25:893-900.
18. Patton JA, Turkington TG. SPECT/CT physical principles and attenuation correction. J Nucl Med Technol 2008;36:1-10.
19. Kheruka S, Naithani U, Maurya A, Painuly N, Aggarwal L, Gambhir S. A study to improve the image quality in low-dose computed tomography (SPECT) using filtration. Indian J Nucl Med 2011;26:14-21.
20. Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. Behav Res Methods 2013;41:1149-60.
21. Huang K, Feng Y, Yu F, Liang W, Li L. Effect of scattering correction on SPECT/CT myocardial perfusion imaging. J Nucl Med 2019;60. Available from: http://jnm.snmjournals.org/content/60/supplement_1/2009.
22. Chuanyong B, Babla H, Conwell R. Emission-based scatter correction in SPECT imaging. Tsinghua Sci Technol 2010;15:1-10.
23. Grossman GB, Garcia EV, Bateman TM, Heller GV, Johnson LL, Folks RD, *et al*. Quantitative Tc-99m sestamibi attenuation-corrected SPECT: Development and multicenter trial validation of myocardial perfusion stress gender-independent normal database in an obese population. J Nucl Cardiol 2004;11:26372.
24. Gaemperli O, Kaufmann PA, Alkadhi H. Cardiac hybrid imaging. Eur J Nucl Med Mol Imaging 2014;41:S91103.
25. Shawgi M, Tonge CM, Lawson RS, Muthu S, James J, Arumugam P. Attenuation correction of myocardial perfusion SPET in patients of normal body mass index. Hell J Nucl Med 2012;15:2159.
26. Zammit C, Liddicoat H, Moonsie I, Makker H. Obesity and respiratory diseases. Int J Gen Med 2010;3:335-43.
27. Tamam M, Mulazimoglu M, Edis N, Ozpacaci T. The value of attenuation correction in hybrid cardiac SPECT/CT on inferior wall according to body mass index. World J Nucl Med 2016;15:18-23.
28. Narayanan MV, King MA, Pretorius PH, Dahlberg ST, Spencer F, Simon E, *et al*. Human-observer receiver-operating-characteristic evaluation of attenuation, scatter, and resolution compensation strategies for (99m)Tc myocardial perfusion imaging. J Nucl Med 2003;44:1725-34.
29. Knoll P, Rahmim A, Gültekin S, Šámal M, Ljungberg M, Mirzaei S, *et al*. Improved scatter correction with factor analysis for planar and SPECT imaging. Rev Sci Instrum 2017;88:094303.
30. Kalantari F, Rajabi H, Saghar M. Quantification and reduction of attenuation related artifacts in SPET by applying attenuation model during iterative image reconstruction: A Monte Carlo study. Hell J Nucl Med 2011;14:278-83.
31. Oloomi S, Eskandari HN, Zakavi SR, Knoll P, Kalantari F, Saffar MH. A new approach for scatter removal and attenuation compensation from SPECT/CT images. Iran J Basic Med Sci 2013;16:1181-9.

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