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Effect of acquisition parameters of SPECT gamma camera system on image quality

SPECT gama kemera sistemi için çekim parametre değişikliğinin görüntü kalitesine etkisi

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Abstract

Introduction: Quality control testing of a SPECT gamma camera is crucial in assessing the suitability of the camera for use in nuclear medicine department. The aim of the present study was to investigate the effect of gamma camera acquisition parameters on image quality.

Methods: Camera scanning was carried out using a double-headed gamma camera on a total of 48 patients (29 female and 19 male, mean age: 47.4±11.1) referred to our department for myocardial perfusion scintigraphy and thyroid scintigraphy. Then, camera acquisition parameters were changed (for myocardial perfusion scintigraphy from 64x64 to 128x128 matrix change and for thyroid scintigraphy from 5 cm to 10 cm distance change), and scanning was repeated and images were analyzed.

Results: Left ventricle ejection fraction (EF) value in 64x64 matrix was calculated to be 62.7±8.8%. EF value of 48.9±10.3% was obtained in 128x128 matrix for the same patients. 99mTc-pertechnetate uptake percentage was 3.8±2.3% in measurements carried out at a distance of 10 cm. On the other hand, a higher uptake percentage of 6.2±3.6% was found for the same patients measured at a distance of 5 cm.

Discussion and Conclusion: In order to obtain proper imaging in SPECT gamma camera system, correct acquisition parameters should be used along with quality control tests for intrinsic flood-field uniformity and relative sensitivity.

Keywords: Acquisition parameters; quality control test; SPECT gamma camera; ^{99m}Technetium.

Özet

Amaç: Bu çalışmada amacımız gama kamera çekim parametre değişikliklerinin görüntü kalitesi üzerine etkilerini araştırmaktır.

Gereç ve Yöntem: Miyokard perfüzyon sintigrafisi ve tiroid sintigrafisi tetkiki için gönderilen toplam 48 hastanın (K:29, E:19, Yaş ortalaması: 47,4±11,1) çift başlı gama kamerada çekimleri yapıldı. Ardından gama kamera çekim parametreleri değiştirilerek (Miyokard perfüzyon sintigrafisi için 64x64 ve 128x128 matrix değişikliği, tiroid sintigrafisi için 5cm ve 10cm uzaklık değişikliği) hastaların yeniden çekimleri yapıldı. Hastaların görüntüleri analiz edildi.

Bulgular: 64x64 matrikste sol ventrikül ejeksiyon fraksiyonu (EF) değeri: %62,7±8,8 olarak hesaplandı. Aynı hastaların 128x128 matrikste yapılan görüntülemesinde ise EF değeri: %48,9±10,3 olarak bulundu. 10 cm uzaklıktan yapılan 99mTc-perteknetat uptake sonucu %3,8±2,3 olarak bulundu. Aynı hastaların 5 cm uzaklıktan yapılan uptake sonucu ise %6,2±3,6 olarak yüksek bulundu.

Sonuç: SPECT gama kamera sisteminde doğru görüntüleme yapabilmek için intrinsik düzlemsel homojenite testi ve relative sensitivite değerleri yanında, doğru çekim parametreleri de göz önünde bulundurulmalıdır.

Anahtar Sözcükler: Çekim parametreleri; kalite kontrol test; SPECT gama kamera; ^{99m}Teknesyum.

Single photon emission computed tomography (SPECT) is a major non-invasive diagnostic tool in nuclear medicine departments today. Collimated cameras, originally proposed by Hal Anger, have mostly been used for routine clinical applications.[1] As a result of mechanical collimation, system's geometrical properties limit and fix detection efficiency and energy acceptance. In conventional nuclear medicine applications, gamma rays emitted from various radiopharmaceuticals, especially ^{99m}Technetium (^{99m}Tc), are detected by systems called gamma cameras. Presently used gamma camera systems have

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necessary hardware to process, visualize and store the data.

Quality control test of a SPECT gamma camera is critical for suitability of the camera for clinical use in nuclear medicine.[2] The relative sensitivity is the parameter characterizing the stability response of gamma camera system to gamma radiation. Relative sensitivity of the system could deviate from the optimum due to electronic instability (sub-optimal discriminator window setting, deviation of photomultiplier tubes' high voltage and/or gain, poor energy resolution, etc.) or yellowing of the gamma-camera thallium-doped sodium iodide crystal. A dual detector-device could improve sensitivity in several ways such as shorter acquisition times, improved signal-to-noise ratios, and reduced dose administering.[3] Camera should be evaluated and compared for uniformity on a daily basis before using for clinical practice. Any non-uniformity must be corrected to eliminate artifacts which may result in false-positive or false-negative patient results.[4]

The aim of the present study was to determine the effects of gamma camera acquisition parameters on image quality.

Materials and Method

Double-headed gamma camera scans (Siemens Symbia, Siemens Medical Solutions, USA) of 48 patients (29 female and 19 male, mean age 47.4±11.1) referred to nuclear medicine for myocardial perfusion scintigraphy and thyroid scintigraphy and uptake study were carried out. Uptake was calculated by camera method. Energy window was centered at 140 keV and discriminator window was 20% of total width (Figure 1).

Myocardial Perfusion Scintigraphy Parameters: Gamma camera acquisition parameters were changed for myocardial perfusion scintigraphy from 64x64 to 128x128 matrix and images were taken again.

Thyroid Scintigraphy Parameters: The pinhole acquisitions were carried out using a pinhole collimator which is 205 mm tall, with a 295-mm-diameter circular base and a 5-mm-diameter aperture. The energy window was centered at 140 keV with a total width of 20%. Acquisition was made using a circular orbit of 50-mm and 100-mm radius. Projection pixel size was 128x128 matrix and a hardware zoom of 2.0 was used.

Images of the patients were analyzed. Differences in image quality were studied semi-quantitatively.

No additional radiation exposure dose occurred for the patients due to our study.

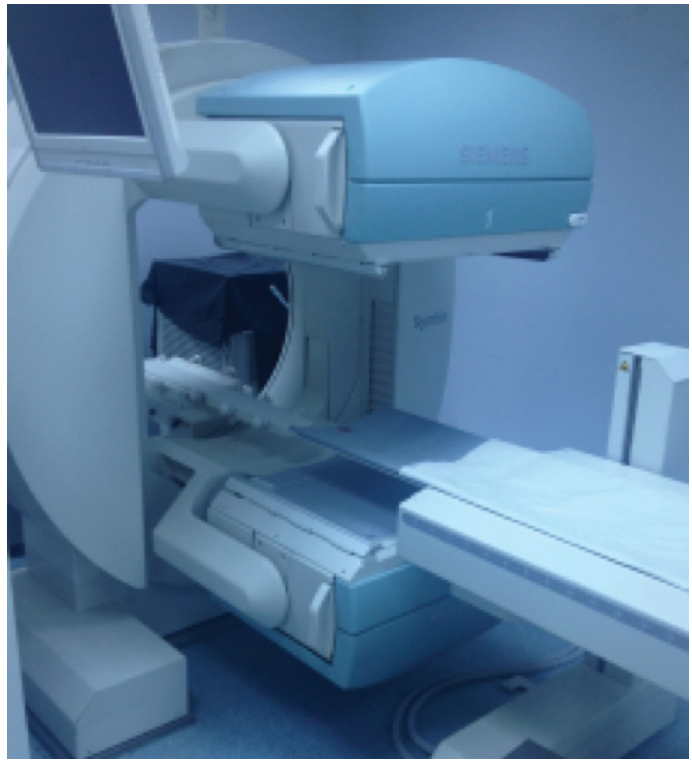

Figure 1. Double headed gamma camera employed in the study.

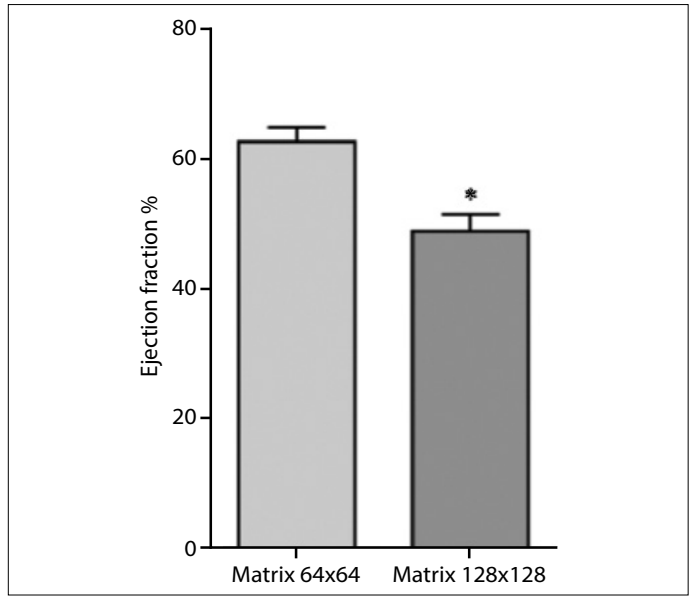

Figure 2. Ejection fraction values of 64x64 and 128x128 matrices.

Results

Matrix Changes

Images of 27 patients (16 female and 11 male, mean age 49.8±10.9) having myocardial perfusion scintigraphy were obtained using 13-15 mCi (481-555 MBq) ^{99m}Tc-methoxyisobutyl isonitrile (^{99m}Tc-MIBI) on 64x64 and 128x128 matrix. Left ventricle ejection fraction (EF) was measured 62.7±8.8% in 64x64 matrix. Average EF value of the same patients was somewhat lower as 48.9±10.3% on 128x128 matrix (2way ANOVA p=0,04, Figure 2). Results of a patient were given in Figure 3.

Distance Changes

Twenty-one patient (13 female and 8 male, mean age 44.2±10.5) had thyroid scintigraphy and uptake examination using 4-6 mCi (148-222 MBq) ^{99m}Tc-pertecnetat with a pin-hole

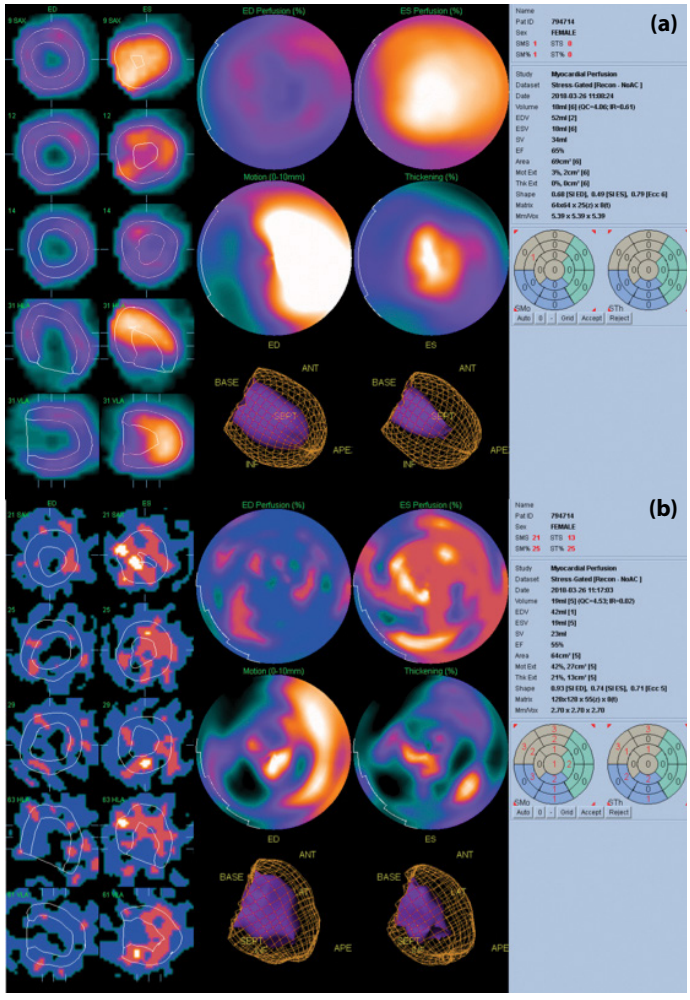

Figure 3. Fifty-three years old female patient referred to our department for myocardial perfusion scintigraphy had imaging on 64x64 matrix. **(a)** Left ventricle EF value was calculated as 65% using stressed images. **(b)** EF was calculated as 55% for the same patient from images taken on 128x128 matrix.

collimator at a distance of 10 cm and 5 cm. ^{99m}Tc-pertecnetat uptake result was 3.8±2.3% at 10 cm distance. A five-cm distant exam yielded an average uptake of 6.2±3.6% (two-way ANOVA p=0.01, Figure 4). Results of a patient were given in Figure 5.

Discussion

Developments in gamma cameras over the last 10 years have improved image quality. With more sophisticated systems, both technologist and physician need to recognize various types of artifacts observed in gamma camera systems and their complications. Assessment of the uniformity of gamma cameras is a task performed on a daily basis, and is critical in evaluating the status of the gamma camera. Image uniformity can determine most artifacts involving detector head, computer system, and printing device.[5] Regular quality control is a critical operation for accuracy of diagnostic imaging.[6] Each camera in a double-headed system should be evaluated separately. Kappadath et al.[7] proposed measured variability as a way to determine nominal performance values of Symbia gamma cameras for planar and SPECT scans.

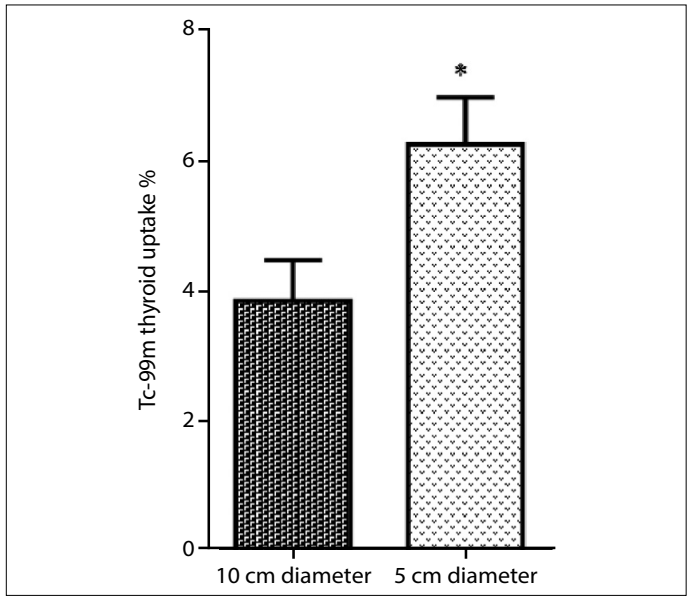

Figure 4. ^{99m}Tc-pertecnetat thyroid uptake values of 10 cm and 5 cm diameters.

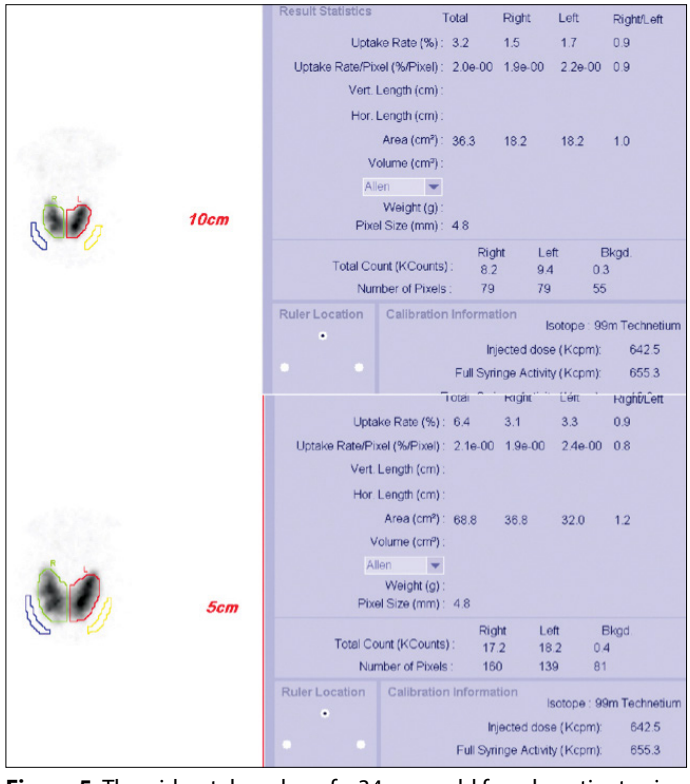

Figure 5. Thyroid uptake value of a 34 years old female patient using a pinhole collimator was 3.2% at a distance of 10 cm and 6.4% at a distance of 5 cm.

Introduction of radiation detectors that can capture spatial information from gamma ray interactions has been the key

technology for imaging in nuclear medicine and for SPECT.[8] Using a three-dimensional diagnostic tool allowing separate visualization of adjacent structures, SPECT produces nuclear medicine images with better resolution in disease localization. Effect of matrix differences on myocardial perfusion examination using SPECT was investigated in the present study. SPECT allows improved spotting of radioactivity within the body of a patient. Nuclear medicine laboratories employ multiple quality control procedures to evaluate the proper functioning of SPECT gamma cameras. Among them are daily checks of uniformity and spatial resolution, and center-of-rotation and SPECT phantom evaluations.[9] Non-uniformity level of gamma cameras is difficult to determine, because reproducibility of quality control measurements and service adjustments are not well-established. Adjustment precision of gamma cameras could be performed by assessing the uniformity of 10 gamma cameras immediately after service adjustment at monthly intervals over a period of one year.[10] Regular daily, weekly and monthly maintenance procedures were carried out for gamma cameras used in the present study. Changes in acquisition parameters were investigated.

Gamma cameras have two important extrinsic features for use in nuclear medicine imaging: their counting efficiency and sensitivity. These are among the quality criteria set by international standards (IPSM, 1992; NEMA, 1994) along with uniformity, contrast, spatial resolution.[11] Uniformity is corrected using an acquisition computer considering high-count flood and mean counts per pixel. The computer employs a pixel-by-pixel correction factor using count variations within matrix from the correction flood. A uniformity correction table is used to correct non-uniformities of camera for future acquisitions. Different protocols were suggested in quality assessment for intrinsic uniformity and relative sensitivity for a 20% discriminator window around 140-keV gamma camera system.[12–14] Elkamhawy et al. suggested use of 64×64 matrix size, which is the size generally, used in cardiac SPECT studies, instead of 512×512 and 256×256 matrix sizes. The National Electrical Manufacturers Association suggests image matrix sizes which produce pixel sizes of 6.4 mm ±30% in linear dimension corresponding to 64×64 matrix for large FOV cameras. It is important to use uniformity levels acceptable for all clinically used matrix sizes.[4] In the present study, use of 128x128 matrix in myocardial perfusion scintigraphy yielded lower EF values compared to 64x64 matrix.

Quality control procedures of gamma cameras were developed mainly for parallel-hole collimators. When a pinhole collimator is used for SPECT, some parameters may need revision. Potential clinical use of pinhole SPECT has been highlighted for scintigraphic exploration of small organs or small areas in the body such as thyroid, parathyroid glands, breasts, shoulder, and foot joints.[15,16] Pinhole SPECT is especially advantageous with its higher resolution. Decreasing pinhole aperture increases the resolution but decreases the sensitivity. Aperture size preference is limited by this trade-off between resolution and sensitivity. In human studies, apertures of 4-6 mm diameter are generally preferred. Seret et al.[17] investigated reconstruction artifacts in pinhole SPECT using a pinhole aperture of 5 mm and a rotation radius of 10 cm in human studies and found that artifacts originated from intrinsic uniformity defects of the gamma-camera. In the present study dealing with thyroid scintigraphy and uptake, use of a 5 cm measurement distance was found to have higher EF values than 10 cm measurement distance.

Conclusion

In order to make a direct imaging in SPECT gamma camera system, quality control tests for intrinsic flood-field uniformity and relative sensitivity should be considered along with correct acquisition parameters.

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