Optimization of acquisition parameters of the test of an overall SPECT/CT system performance.

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Abstract— **The purpose of this study was to present the process of optimizing of acquisition parameters of an overall SPECT/CT system performance test, which could be implemented in each nuclear medicine department. All measurements were performed with the use of Symbia T16 SPECT/CT system. The Jaszczak phantom with cold spheres provided for high-resolution gamma cameras was used. A series of SPECT/CT scans with different acquisition parameters were performed. The influence of the duration of a single projection, the number of projections and the size of acquisition matrix on the quality of the resulting image have been analyzed. All images were subjected to visual evaluation (uniformity and spatial resolution). Quantitative evaluation of image contrast was performed as well. Each SPECT image was evaluated with and without attenuation correction, but always with scatter correction. The proposed process of the evaluation of the parameters, that are crucial for the image quality in nuclear medicine, gave a possibility to identify the optimal acquisition parameters for considered test. Image, indistinguishable from the proposed reference, but acquired in the half of time (decrease from 32 min to 16 min, respectively), was obtained with the following parameters: 30 sec per projection, 64 projections and 128x128 matrix, regardless of the use of attenuation correction or not. Reduction of the duration of a single projection, and especially of the size of the matrix, significantly deteriorated image quality. On the other hand, an increase of the duration of a single projection over 30 sec did not bring any significant improvement of image quality, but increased the duration of the test. The methodology of optimization of acquisition parameters for an overall SPECT/CT system performance test has been presented for Symbia T16 SPECT/CT system in terms of time of a single acquisition and quality of the acquired images.**

Keywords— **quality control, overall performance, SPECT/CT, Jaszczak phantom.**

I. Introduction

From the time of introduction of Anger camera mounted on a gantry that rotated about recumbent patients (late 1970s) [1] till today, single-photon emission tomography (SPECT) has become a well-validated method extensively used in a clinic. SPECT is a functional imaging technique that allows a visualization of three-dimensional distribution of the radiopharmaceutical, giving additional information also about quantitative radioactivity distribution in the patient's body. Its limited resolution and the lack of anatomic information (resulting in a lower diagnostic accuracy using SPECT alone) have been improved by the fusion of this modality with computed tomography (CT). In addition to the ability to accurately locate the pathological accumulation of tracer, the undeniable advantage of SPECT/CT multimodal imaging is also an improvement of the quality and speed of functional imaging by using the same CT data for a SPECT attenuation correction (AC) as for getting structural images [2].

However, the more advanced and precise the device is, the more attention should be paid to its control. High quality of information obtained by SPECT/CT could be lost at each stage of examination (image acquisition or its reconstruction), if routine quality control of a device is treated carelessly, especially in terms of long term reproducibility of the tests performance. Recommendations for quality control procedures of SPECT/CT systems have been published. These include the NEMA standards, IAEA report #6, EANM guidelines and AAPM report #22 [3-6]. It is clearly stated in the EANM guidelines that these recommendations must be considered in the light of any national guidelines and legislation, which must be followed [5].

An overall SPECT/CT system performance test provides the most comprehensive information about long term stability of the uniformity and resolution of gamma camera installed in a clinic, but its conducting is time consuming. The frequency of providing such a test is different according to national legislation of each country (e.g. in Poland- annually [7]). Most of recommendations advise to perform this test at half-year intervals and when a problem is suspected. It seems to be too rarely to monitor trends in an instrument stability and to assure the consistency in an evaluation of the test results.

For the purpose of this test acquisition parameters, are suggested by the quoted recommendations [3,4,6]. However, in practice the manner of their implementation varies between different nuclear medicine departments, because of the time which each department could devote to more detailed quality control in clinical conditions.

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The question arises how to get an image with the best quality, in the least amount of time. Is it possible to decrease the time needed for an overall SPECT/CT system performance test execution and in consequence to be able to perform it more often in the clinic, but not to compromise with the requirements of recommendations on the quality of the observed image?

The purpose of this study was to present the process of optimization of acquisition parameters of an overall SPECT/CT system performance test, which could be implemented in each nuclear medicine department.

II. Material

All measurements were performed with the use of Symbia T16 TruePoint dual-head SPECT/CT (by Siemens Healthcare) installed in Nuclear Medicine Unit Department of Endocrinology University Hospital in Krakow.

The Jaszczak SPECT phantom (Deluxe model) filled with 740 MBq of ^{99m}Tc was used. The phantom has the shape of a cylinder which contains rods section (6 different diameters) and 6 solid spheres (cold regions) and could be used in order to assess image quality produced by high-resolution gamma cameras. The phantom is made of clear PMMA material. Specification of the phantom and the full description of its utility could be found in [8].

III. Method

For the purpose of this study, a series of SPECT/CT scans with different acquisition parameters were performed. Three parameters which mostly influence the quality of the resulting image were analysed: the duration of a single projection, the number of projections and the size of the acquisition matrix. The analysed durations of a single projection were: 10, 15, 20, 25, 30, 45, 60 sec per projection, respectively. The analysed numbers of projections were: 64, 96, 128 projections in a full 360-degree rotation, respectively. The analysed sizes of the acquisition matrix were: 64 x 64 versus 128 x 128. Combinations of the parameters that have been used are presented in Table 1. The scans for each combination of the parameters were normally performed three times. The only exceptions were two combinations: (45 sec per projection, 128 projections, matrix size 128 x 128) and (60 sec per projection, 128 projections, matrix size 128 x 128), which were used once.

The study with 30 sec per projection, 128 projections and 128 x 128 matrix was chosen to be a reference. There were two rationales for this choice. These parameters are in accordance with the IAEA recommendations ("acquire a tomographic study using the acquisition time in order to collect 800 000 counts for each projection, 120 projections, a matrix size of 128 × 128 and a 360° angle of rotation") [4].

Table 1 Combination of acquisition parameters that have been used in the study.

	duration of single projection [sec]	number of projections	matrix size	number of examination performed
reference scan	30	128	128 x 128	3
	10	128	128 x 128	3
	15	128	128 x 128	3
	20	128	128 x 128	3
	25	128	128 x 128	3
	45	128	128 x 128	1
	60	128	128 x 128	1
	30	96	128 x 128	3
	30	64	128 x 128	3
	30	128	64 x 64	3

It is also a standard protocol for clinical applications in the Nuclear Medicine Unit Department of Endocrinology University Hospital in Krakow. All SPECT examinations were acquired with CT for AC and reconstructed with the same reconstruction parameters (iterative reconstruction, OSEM 3D Flash, 8 subsets, 10 iterations, scatter correction with the use of a dual energy window method). These are the most effective settings of reconstruction parameters of the iterative algorithm OSEM Flash 3D for 128 projections [9].

Each SPECT image was evaluated with and without attenuation correction, but always with scatter correction. All images were subjected to visual and quantitative evaluation by 2 experienced medical physicists.

Firstly, the images were reviewed carefully in search for ring artefacts or distorted cold spheres and rods. Two parameters were analysed qualitatively: uniformity (whether the image is uniform or nonuniform in the part of the phantom without rods and spheres) and spatial resolution (how many rods sections and spheres were visible).

Next, the quantitative analysis was performed.

The image contrast C for each sphere was calculated using the formula (1), according to [10]:

$$C = \frac{\left| N_l - N_{bg} \right|}{N_{bg}} \tag{1}$$

where:

N_l – the number of counts in the sphere per 1 ml of sphere volume [cts/cm^3],

N_{bg} - the average number of counts in the background per 1 ml of considered volume [cts/cm^3].

In order to calculate the number of counts in the sphere per 1 ml of the sphere volume for each of the reconstructed images, spheres were marked as volume of interests (VOIs). VOIs were drawn on fused SPECT/CT images (boundaries of the sphere according to CT image) and analyzed with the use of volumetric technique. To calculate the average number of counts in the background per 1 ml of the considered volume, 3 additional VOIs were marked in the part of the phantom without rods and spheres.

Quantitative evaluation of an image contrast (comparison of contrasts value between combinations of the analyzed acquisition parameters for each sphere) was performed with the use of Mann-Whitney nonparametric test. The following criterion was formulated to determine statistically significant differences between two images: the difference between two images is statistically significant if the difference between contrasts for the same sphere diameter was statistically significant in the case of two or more out of six spheres. In all statistical analyses, 95% confidence level was assumed ($p < 0.050$ – statistically significant difference).

Additionally, the uniformity of each image was evaluated quantitatively using the formula:

$$COV = \frac{\sigma_{bg}}{N_{bg}} \qquad (2)$$

where:
COV – the coefficient of variation [%],
σ_{bg} - the standard deviation of the average number of counts in the background per 1 ml of considered volume [cts/cm^3].

IV. RESULTS

No ring artefacts - neither distorted cold spheres nor rods were observed on the images. All images were evaluated visually to be uniform in the part of the phantom without rods and spheres.

Five largest spheres were visible in all the images. Four largest sections of rods were visible in most of images. The exception was images with the following settings: (30 sec per projection, 128 projections, matrix size 64 x 64 with AC), (less than 45 sec per projection, 128 projections, matrix size 128 x 128 without AC), (30 sec per projection, 64 projections, matrix size 128 x 128 without AC), and (30 sec per projection, 128 projections, both matrix sizes without AC), on which 3 sections were visible.

Figure 1 presents the average values of contrast for spheres for different duration of a single projection, 128 projections and 128 x 128 matrix size. Figure 2 presents the average values of contrast for spheres for different number of projections, 30 sec per projection and 128 x 128 matrix size. Both diagrams were prepared for images with AC. In table 2 one can find the average values of contrast for spheres acquired with 30 sec per single projection, 128 projections and different matrix sizes. Results for images without AC follows the same trends. However, the average values of contrast for images without AC were about fourfold lower. According to the established criterion to determine statistically significant quantitative differences between two images, only the difference between images acquired with AC and different number of projection was assessed as insignificant. Table 2 and table 3 show the results of quantitative evaluation of images on the basis of contrast average value.

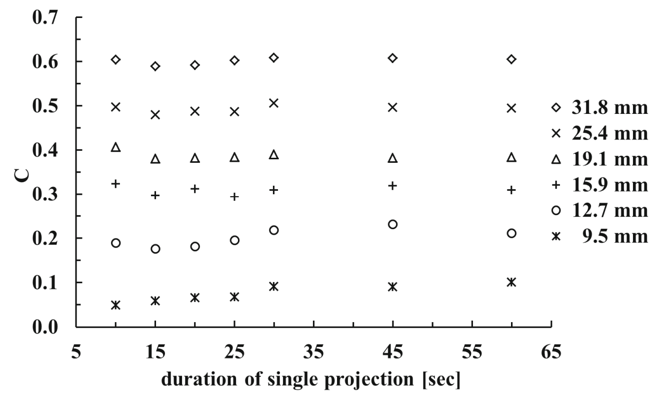

Figure 1 The averaged image contrast for 6 cold spheres for different duration of a single projection, 128 projections and 128 x 128 matrix size and AC.

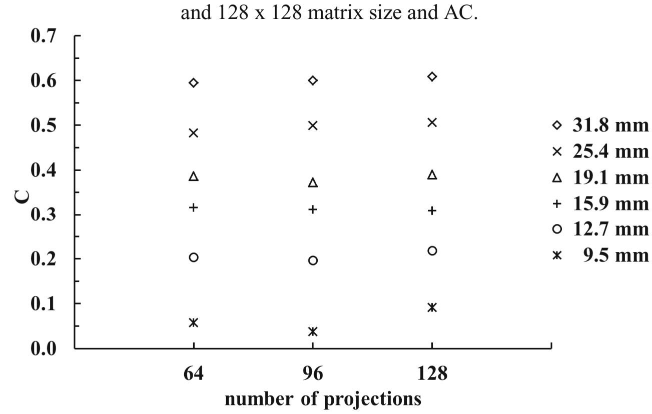

Figure 2 The averaged image contrast for 6 cold spheres for different number of projections, 128 projections and 128 x 128 matrix size and AC.

Durations of scans for the settings with 30 sec per projection, 128 x 128 matrix size and following number of projections: 128, 96 and 64 projections were as follows: 32 min, 24 min and 16 min, respectively.

Average values of *COV* were less than 0.50 % for all the acquired combinations of acquisition parameters with AC and without AC, with exception of images acquired with 30 sec per projection, 128 projections, matrix size 64 x 64 with AC and without AC. In these cases average *COV* values were 1.901 ±0.001 % and 1.980 ±0.009 %, respectively.

Table 2 Averaged spheres contrast for two acquisition parameters settings spheres: (30 sec per projection, 128 projections, 64 x 64 matrix size with AC) and reference scan (30 sec per projection, 128 projections, 128 x 128 matrix size with AC) – the difference between images significant according to the established criterion.

sphere diameter [mm]	64 x 64	128 x 128	*p* value
31.8	0.552 ±0.004	0.609 ±0.008	**< 0.050**
25.4	0.416 ±0.003	0.506 ±0.008	**< 0.050**
19.1	0.276 ±0.003	0.390 ±0.007	**< 0.050**
15.9	0.149 ±0.002	0.309 ±0.009	**< 0.050**
12.7	0.111 ±0.002	0.218 ±0.008	**< 0.050**
9.5	0.050 ±0.002	0.091 ±0.006	**< 0.050**

Table 3 Averaged spheres contrast for two acquisition parameters settings spheres: 30 sec per projection, 64 projections, 128 x 128 matrix size with AC) and reference scan (30 sec per projection, 128 projections, 128 x 128 matrix size with AC) – the difference between images insignificant according to established criterion.

sphere diameter [mm]	64 projections	128 projections	*p* value
31.8	0.595 ±0.012	0.609 ±0.008	0.1266
25.4	0.482 ±0.013	0.506 ±0.008	**< 0.050**
19.1	0.387 ±0.009	0.390 ±0.007	0.8273
15.9	0.316 ±0.008	0.309 ±0.009	0.2752
12.7	0.204 ±0.009	0.218 ±0.008	0.1266
9.5	0.057 ±0.006	0.091 ±0.006	0.2752

V. DISCUSSION

The study was devoted to finding optimal acquisition parameters of the test of an overall SPECT/CT system performance, on the one hand being in accordance with the recommendations requirements and on the other hand giving the opportunity to spare less time for its execution.

An image indistinguishable in quality from the reference scan acquired in accordance with the regulations but made in the shortest time (decrease from 32 min. to 16 min., respectively), was obtained for the following settings: 30 sec per projection, 64 projections and 128x128 matrix.

Taking into account IAEA recommendations in details (phantom filled with 400 MBq of ^{99m}Tc) and activity used in the study (740 MBq) saving time could be even two times greater.

Reduction of the duration of a single projection, and especially the size of the matrix, or lack of AC, significantly deteriorated image quality. On the other hand, an increase of the duration of a single projection over 30 sec did not bring a significant improvement of image quality, but increased the duration of the test.

VI. CONCLUSIONS

The methodology of optimization of acquisition parameters for an overall SPECT/CT system performance test has been presented for Symbia T16 TruePoint SPECT/CT system in terms of duration of a single acquisition and quality of the acquired images.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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