Original Article

Comparison of Image Quality of Different Radionuclides Technetium-99m, Samarium-153, and Iodine-123

Abstract

Introduction: The choice of the radionuclide has a key role in nuclear medicine which appearing the lowest scatter fraction. In addition, the presence of penetrated and scattered photons from collimator in single-photon emission computed tomography images degrades resolution and contrast. Thus, image quality depends on sensitivity and resolution of the collimator–detector system. The goal of this study was to compare the image quality that can be achieved by three radionuclides: technetium-99 m (Tc-99 m), iodine-123 (I-123), and samarium-153 (Sm-153). **Materials and Methods:** Tc-99 m and Sm-153 were imaged with low-energy high resolution (LEHR) collimator, while I-123 was imaged with medium-energy (ME) collimator. We modeled the Siemens Symbia Medical system using Monte Carlo simulation code SIMIND. The imaging characteristics of each radionuclide were investigated by simulated data: point spread function, sensitivity (Cps/MBq) and geometric, penetration and scattering distribution. **Results:** Tc-99 m and Sm-153 give best and results with LEHR collimator for spatial resolution (full width at half maximum [FWHM] = 3.19 mm; full width at tenth maximum [FWTM] = 6.73 mm) and (FWHM = 3.22 mm; FWTM = 7.39 mm), respectively. Whereas, I-123 provided with ME collimator a lower resolution (FWHM = 4.89 mm; FWTM = 9.89 mm). The sensitivity recorded by Tc-99 m, Sm-153, and I-153 were (31.21 Cps/MBq), (10.16 Cps/MBq), and (51.22 Cps/MBq), respectively. **Conclusion:** Tc-99 m and Sm-153 give the best and generally similar imaging properties with LEHR. For I-123, the ME collimator helps lowering the influence of high-energy gamma rays.

Keywords: *Geometric, imaging, penetration, resolution, scattering, sensitivity, SIMIND*

Youssef Bouzekraoui, Farida Bentayeb, Hicham Asmi, Faustino Bonutti[1]

Department of Physics, LPHE, Modeling and Simulations, Faculty of Science, Mohammed V University, Rabat, Morocco, [1]Department of Medical Physics, Academic Hospital of Udine, Udine, Italy

Introduction

In nuclear medicine, the radionuclides technetium-99 m (Tc-99 m) and iodine-123 (I-123) are most commonly used in single-photon emission computed tomography imaging. While, Samarium-153 (Sm-153) emits gamma radiation at 103 keV and has a physical half-life of 46.7 h, which is well suited for scintigraphic imaging.[1] Whereas, Sm-153 possesses both therapeutic beta and diagnostic gamma radiations, making it an alternative radionuclide to Y-90 in liver cancer treatment.[2] The Sm-153 imaging was useful in gastrointestinal scintigraphy.[3] In addition, Sm-153 has been used in various scintigraphic studies.[4,5] Sm-153 has average, and maximum beta particle ranges in water of 0.5 mm and 3.0 mm, respectively. It is undeniable that the image quality strongly depends on the types of detected photons in the photopeak window. This photon retching the detector were classified as: the geometric component (passed without any interaction inside the collimator), the penetration component (passed through septa without attenuation), or the scatter component (scattered in the septa). In addition, photons that are absorbed in the collimator septa produce an X-ray component by the photoelectric effect.[6] Only the first component provides the correct information. The penetration and scattering effects in collimator degrade contrast, resolution, and quantification. As well as, image quality and quantification accuracy are affected by these factors.[7] Gamma camera cannot classify the detected photons into geometric, penetrated, or scattered photons. To solve this difficulty, we used Monte Carlo simulation technique to assess the geometric, penetration, and scatter contribution inside the photopeak window.[8] Whereas there are few studies

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Address for correspondence:
Dr. Youssef Bouzekraoui, Department of Physics, LPHE, Modeling and Simulations, Faculty of Science, Mohammed V University, Rabat, Morocco.
E-mail: youssef0fsr@gmail.com

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related with the assessment of geometric, penetration, and scatter components.[9-12]

The aim of this study was to evaluate the image quality for each radionuclide. We model the Siemens Symbia medical system Gamma Camera, using Monte Carlo SIMIND code.[13-17] Moreover, evaluate the geometric, scattered, and septal penetration components. We also evaluate the resolution and sensitivity (Cps/MBq).

Materials and Methods

Images were acquired on a Siemens Medical System Symbia using both a medium-energy (ME), low-energy high resolution (LEHR), and ME collimators [Table 1]. I-123 was imaged with ME collimator, whereas Tc-99 m and Sm-153 were imaged with LEHR [Table 2]. Therefore, a point source has been placed at 12 cm from the detector surface and located in horizontal cylindrical water phantom of dimension 16 cm × 22 cm × 22 cm. We have modeled the detector with a radius equal to 25 cm having 2.54 cm NaI (Tl) crystal thickness. We made the intrinsic spatial resolution of 0.34 cm and energy resolution of 8.80% at 140 keV. We have used, the SIMIND Monte Carlo code developed by Michael Ljungberg.

Images were acquired using a 128 × 128 matrix and a pixel size = 0.34 mm × 0.34 mm. The images created by SIMIND in ImageJ software, National Institutes of Health, and the Laboratory for Optical and Computational Instrumentation (University of Wisconsin).[18]

Table 1: Collimators specifications

Low energy	ME	LEHR
Geometric of hole	Hexagonal	Hexagonal
Length of hole (mm)	4.064	2.405
Septal thickness (mm)	0.114	0.016
Diameter of hole (mm)	0.294	0.111

ME: Medium-energy, LEHR: Low-energy high resolution

Table 2 shows photons energies and intensities of I-123, Tc-99 m, and Sm-153 radionuclides decay. For I-123 and Sm-153, ten peaks have been simulated, and three peaks have also been simulated for Tc-99 m [Table 2]. Simulations were carried out for two separate conditions: in air and with scattering medium (cylinder of water). In this simulation study, the main energy window was centered on the main energy peak of radionuclides for width of 20% of this energy (I-123 [159 keV]: 143–175 keV, Tc-99 m [141 keV]: 131–151 keV, and Sm-153 [103 keV]: 93–113 keV). The point spread function (PSF) was studied for each radionuclide. The full width at half maximum (FWHM) and the full width at tenth maximum (FWTM) were computed from the PSF to quantify the resolution. All imaging parameters have been compared with or without a scattering medium.

Results and Discussion

The detected spectrum of radionuclides without collimator is shown in Figure 1. The energies are shown the energies of the main emission peaks of the isotopes.

The different fractions detected within 20% peak energy window for all radionuclides are shown in Table 3. In

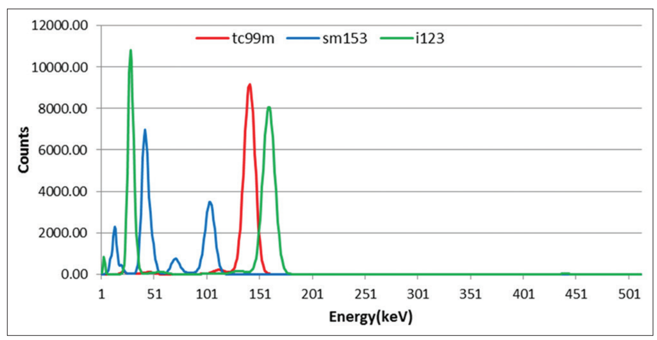

Figure 1: Energy spectra of photons on the detector without the use of collimator

Table 2: Energies and intensities of gamma rays emitted from: The technetium-99m, samarium-153, and iodine-123 sources

Tc-99m		Sm-153		I-123	
Energy (keV)	Abundance (%)	Energy (keV)	Abundance (%)	Energy (keV)	Abundance (%)
20.67	1.12	40.9	16.6	27.2	24.69
21.02	0.18	41.54	30	27.47	45.98
140.51	88.5	47.11	9.45	31.1	13.16
-	-	48.38	2.44	31.76	2.86
-	-	69.67	4.69	−158.97	83.25
-	-	75.42	0.17	346.35	0.13
-	-	83.37	0.19	440.02	0.42
-	-	89.49	0.16	505.33	0.27
-	-	97.43	0.77	528.96	1.28
-	-	103.18	29.19	538.54	0.38

Tc-99m: Technetium-99m, Sm-153: Samarium-153, I-123: Iodine-123 water, the geometric fraction is large for Tc-99 m compared to the two other radionuclides. Whereas, in air this fraction, it is approximately the same for the three radionuclides. Because, these components depend on the energy of photons, object under study and collimator design parameters.

Figure 2 shows images of a point source for different radionuclides in water and air. The fogginess in the images formed by I-123 in water and air caused by scatter and penetration components due to high-energy gamma ray's emissions. The images formed by Sm-153 and TC-99 m show clearly a good quality.

Table 3: Geometric, penetration, and scatter fractions achieved with the isotopes

Phantom	Isotopes	Collimators	Geometric (%)	Penetration	Scatter (%)
Water	Tc-99m	LEHR	90.92	5.99	3.09
	Sm-153	LEHR	85	10.46	4.36
	I-123	ME	88.08	7.4	4.52
Air	Tc-99m	LEHR	90.09	6.61	3.3
	Sm-153	LEHR	89.49	7.13	3.24
	I-123	ME	90.43	6.03	3.54

ME: Medium-energy, LEHR: Low-energy high resolution, Tc-99m: Technetium-99m, Sm-153: Samarium-153, I-123: Iodine-123

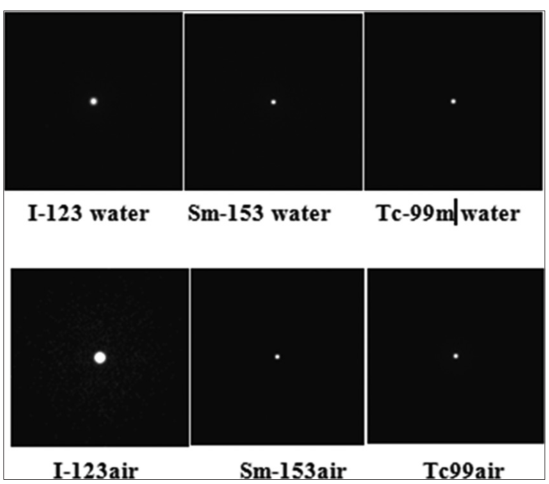

Figure 2: Planar images created at the end of each simulation

Resolution and sensitivity (Cps/MBq) study

The PSF obtained for all of the isotopes, in air and water, are shown in Figure 3. Tc-99 m and Sm-153 offer a better resolution than the I-123 in both cases. The curve of I-123 with the ME collimator shows the effects of the septa which lowers the resolution.

Images quality depends on resolution and also by sensitivity of the detector collimator system. Figure 4 shows the comparison of sensitivity for three radionuclides.

Figure 4 shows that for each isotope the water phantom decreases the sensitivity. For I-123, the ME produced the high sensitivity compared with LEHR for two other radionuclides.

Quantification of the resolution

FWHM and FWTM were calculated from profiles through the source images.

FWHM and FWTM are shown in Table 4; it shows that, for each isotope, the water phantom increases FWTM, while FWHM remains roughly the same. FWHM was better for the LEHR then for the ME collimator. In addition, FWHM was similar for both Tc-99 m and Sm-153.

Conclusion

The effect of penetrated and scattered photons has been studied both qualitatively and quantitatively for Sm-153 and Tc-99 m and I-123. Since the results of the simulation show that the Sm-153 and Tc-99 m produced, generally, the best and similar imaging characteristics with LEHR collimator. However, the sensitivity obtained, with air and water phantom, was more than that of the other one. For I-123 imaging, the use of an ME collimator is important when the resolution is not required.

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Nil.

Conflicts of interest

There are no conflicts of interest.

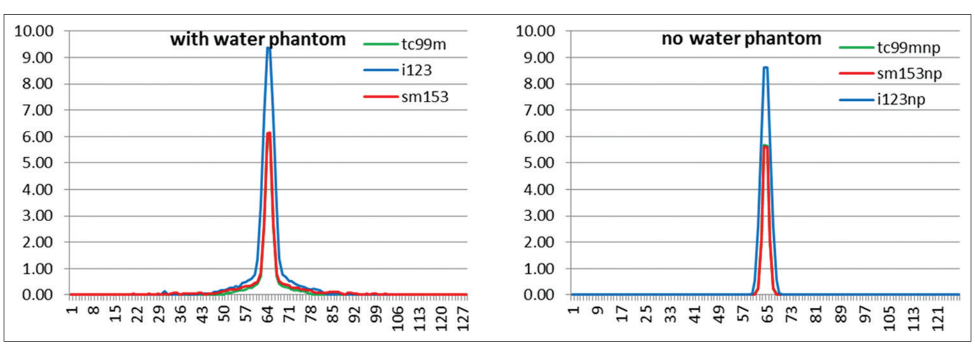

Figure 3: Point spread function for technetium-99 m, Samarium-153, and Iodine-123

Table 4: Full width at half maximum, full width at tenth maximum, and sensitivity data for the different radionuclides point source

Phantom	Isotopes	FWHM (mm)	FWTM (mm)	Sensitivity (cps/MBq)
Water	Tc-99m	3.19	6.73	31.21
	Sm-153	3.22	7.39	10.16
	I-123	4.89	9.89	51.22
Air	Tc-99m	3.01	5.41	104.9
	Sm-153	3	5.39	34.48
	I-123	4.62	7.78	162.7

FWHM: Full width at half maximum, FWTM: Full width at tenth maximum, Tc-99m: Technetium-99m, Sm-153: Samarium-153, I-123: Iodine-123

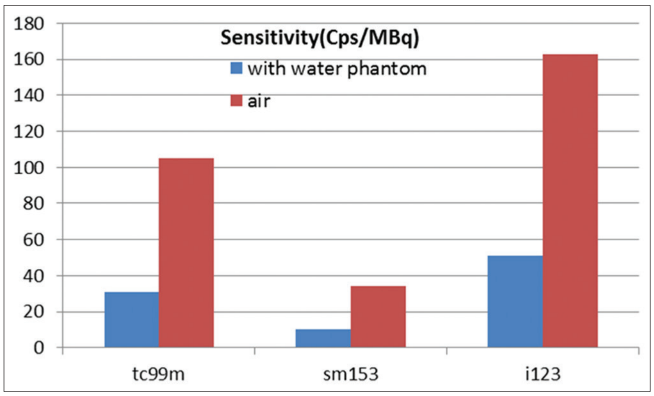

Figure 4: Sensitivity at the end of simulation

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