Comparison of quantification and image degrading factors for different iodine isotopes (I-123, I-124 and I-131)

Erwann Rault

Supervisor(s): Ignace Lemahieu, Stefaan Vandenberghe

Abstract—**The purpose of this study was to compare quantification and image degrading factors for different iodine isotopes currently used in nuclear medicine: I-123 and I-131 for SPECT imaging and I-124 for PET imaging.**

The imaging characteristics of each isotope were investigated by simulated data. A planar source composed of a circular background with low activity and several hot spots was used to study the contrast recovery and the noise. The resolution was also determined. Moreover, the effect of an attenuating medium on those characteristics was investigated.

Results have shown that the amount of downscatter from high energy peaks into the main energy window, depends on the collimator (SPECT) and increases with the attenuating medium (SPECT and PET). This downscatter decreases the image quality and reduces the accuracy of quantification. However, correction for downscatter significantly improves quantification. I-124 offers the best results, both for contrast recovery and resolution.

Keywords—**I-123, I-131, I-124, contrast recovery, resolution.**

I. Introduction

RADIOACTIVE isotopes are used in nuclear medicine to check some functions of the organism. As they behave chemically exactly the same as non-radioactive ones, they have the same uptake in the body. Iodine is used by the thyroid to produce hormones. If a person is injected some radioactive iodine, it will be possible, by localizing the emission of positrons with a PET (Positron Emission Tomography) scanner or gammas by a SPECT (Single Photon Emission Computed Tomography) scanner, to see whether or not the thyroid is functioning correctly. By injecting a $\beta-$ emitter, it is also possible to kill the cells (mainly cancer cells) which are more likely to uptake those isotopes.

I-123 has a main emission peak at 159 keV. This energy is generally imaged on a SPECT system with a LEHR (Low Energy High Resolution) collimator, optimized for the Tc-99 (140 keV), or with a ME (Medium Energy) collimator, optimized for energies up to 300 keV. However, this radionuclide also emits other peaks of a higher energy. Those, which are of a higher energy than the energy for which the collimator has been designed for, will lead to a lot of penetration and scatter in the collimator and, consequently, will lower the image quality and the quantification.

Due to its emission of positrons, I-124 can be used in PET imaging. PET systems are using an electronic collimation based on interaction time instead of a physical collimator. PET systems are based on the emission of a positron. It will, by the annihilation with an electron, create opposed 511 keV photons which are going to be detected by the scanner. However, the emission spectrum of the I-124 is very complex [1] and the emission of a positron (only 23% of decays) is, in 50% of the emissions, immediately followed by the emission of a gamma of 602 keV which is likely to create some false detections.

I-131 emits electrons that can be used for treatment, but it also emits some photons that can be detected by SPECT detectors. Their main emission energy peak is 364 keV and requires the use of a HEAP (High Energy All Purpose) collimator (thick septa). The spectrum of emission of I-131 is also very complex. Some peaks of emission, above 364 keV, are responsible for penetration and scatter in the collimator [2].

The aim of this study was, for each isotope, to evaluate the image quality and quantify the impact of high energy peaks.

E. Rault is with the Electronics and Information Systems department, Ghent University (UGent), Gent, Belgium, E-mail: Erwann.Rault@UGent.be

II. Materials and Methods

A. Simulations and Reconstruction

Those studies have been performed on two systems, the Philips Axis (SPECT) [3] for I-123 and I-131 and the Philips Allegro (PET) [4] for I-124. Two types of collimators have been compared for I-123, as it is mainly imaged with a LEHR (Low Energy High Resolution) collimator or a ME (Medium Energy) collimator. I-131 has been studied with a HEAP (High Energy All Purpose) collimator.

The GATE (GEANT4 Application for Tomographic Emission) [5] package has been used for the simulations. It is a Monte Carlo simulation toolkit already well validated, and its use of the GEANT4 libraries offers a good accuracy. It allows selection of all different isotopes.

The simulated data were reconstructed with the MLEM algorithm. The number of iterations was chosen to allow the better contrast with a reasonable level of noise.

B. Spectrum analysis

This study aims to point out the proportion of high energy contamination for each of the isotopes involved in this research. Those characteristics will help explaining the imaging possibilities of those isotopes. A point source, placed 15 cm from the collimator, has been simulated to study the spectrum of each isotope and to find out the peaks which influence the image.

C. Resolution study

The PSF (Point Spread Functions) of those isotopes have been drawn by simulation. A point source of 0.1 mm diameter has been acquired with the different systems and the sinograms have been made. As the point source was placed in the center of the scanner, the PSF established are the sum of the angles of the sinograms.

D. Contrast Recovery Curves

A 2D source, composed of a circular background of 17 cm and hotspots from 8 mm to 20 mm on a radius of 7 cm, has been designed to study the contrast evolution with the size of the hotspots. The contrast between the hotspots and the background was set to 4:1.

III. Results

A. Spectrum analysis

Results show that, for I-123, the efficiency is better for the ME collimator when only photons from the photopeak are considered. I-123 with a LEHR collimator (thinner septa) suffers a lot from high energy contamination. The use of a ME collimator decreases this effect.

The phantom increases the importance of high energy contamination. The water phantom is then responsible for a loss of image quality and a bias of the quantification.

B. Resolution study

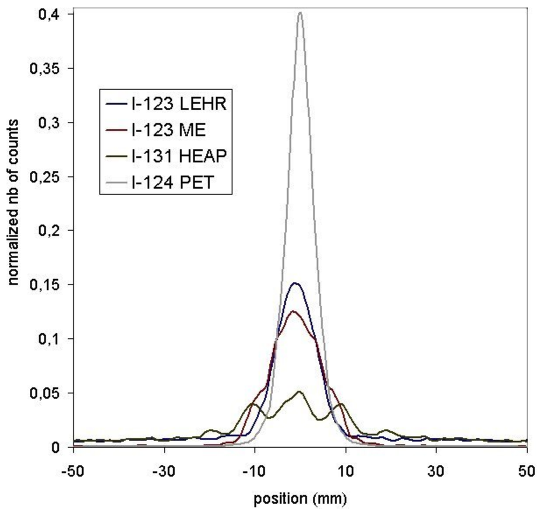

Fig. 1. Point Spread Functions from the different isotopes, without phantom.

The curves presented on Figure 1 show a significantly better resolution for I-124. Between I-123 with a LEHR or a ME collimator, the results are very similar. However, it is possible to see, on the curve of the ME collimator, the impact of the collimator which lower the spatial resolution. In what concerns the I-131, the septas of the collimator are clearly visible on the PSF. They degrade a lot the spatial resolution.

C. Contrast Recovery Curves

On Figure 2, it is shown that the best contrast recovery has been found for I-124. This can be partially explained by the spatial resolution which is higher with this system. In the main time the proportion of scatter is of the same importance than with I-123 with a ME collimator or I-131.

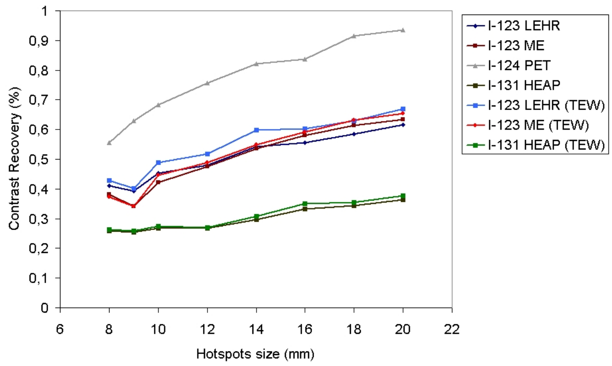

Fig. 2. Contrast Recovery Curves for the different isotopes with or without TEW correction and without a water phantom

Between the LEHR collimator and the ME collimator, for imaging I-123, the results are roughly similar. It seems however that the ME collimator offers better results when no correction is applied on the data. The LEHR collimator offers better results when the TEW correction is applied to the data.

I-131 offers the worst results of contrast recovery. This is certainly due to the poor resolution that can be achieved by the HEAP collimator as the contrast recovery is closely related to the spatial resolution.

IV. Conclusion

Even small high energy peaks (0.1% of the emission) in the emission spectrum of I-123 deliver a significant amount of contamination in the main energy window. However, using the TEW correction can belp lowering their effects. The use of a LEHR collimator seems interesting when good resolution is needed while a ME collimator reduces the contribution of high energy contamination.

I-124 offers the best image quality. In this case, the main image degrading factor is the photon of 602 keV emitted after some positron emission.

Due to its relatively high energy imaging peak, the use of a HEAP collimator is required to image I-131. The image quality that can be achieved with this collimator is lower than the one that has been achieved with the I-123 or the I-124, even if the high energy contamination is less important than in the case of I-123 with a LEHR collimator.

References

[1] Allan C. G. Mitchell, Jose O. Juliano, Charles B. Creager, and C. W. Kocher, “Disintegration of I124 and I123,” *Phys. Rev.*, vol. 113, pp. 628–633, 1959.

[2] D. Autret, A. Bitar, L. Ferrer, A. Lisbona, and M. Bardies, “Monte Carlo modeling of gamma cameras for I-131 imaging in targeted radiotherapy,” *CANCER BIOTHERAPY AND RADIOPHARMACEUTICALS*, vol. 20, no. 1, pp. 77–84, Feb. 2005, non lu.

[3] Steven Staelens, Daniel Strul, Giovanni Santin, Stefaan Vandenberghe, Michel Koole, Yves D’Asseler, Ignace Lemahieu, and Rik Van de Walle, “Monte carlo simulations of a scintillation camera using gate: validation and application modelling.,” *Phys Med Biol*, vol. 48, no. 18, pp. 3021–3042, Sep 2003.

[4] Suleman Surti and Joel S Karp, “Imaging characteristics of a 3-dimensional gso whole-body pet camera.,” *J Nucl Med*, vol. 45, no. 6, pp. 1040–1049, Jun 2004.

[5] S. Jan, G. Santin, D. Strul, and S. Staelens et al., “GATE: a simulation toolkit for PET and SPECT.,” *Phys Med Biol*, vol. 49, no. 19, pp. 4543–4561, Oct 2004.