Uncertainty in SPECT Sensitivity Factor For Lu-177 Radiopharmaceutical Dosimetry

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Introduction

With the increase in facilities implementing radiopharmaceutical therapy (RPT) dosimetry, there is a critical need to understand the uncertainties involved in the calculation of dose. Uncertainties arise at every step of the dosimetry process, which includes source activity calibration, dose calibrator measurements, and methods for camera calibration and SPECT reconstruction. This project evaluated the uncertainty at 3 imaging centers in the determination of the sensitivity factor for SPECT/CT and is part of a larger project to quantify uncertainty in our dosimetry process overall.

Methods and Materials

Uncertainty in SPECT sensitivity factor due to (1) different dose calibrators, (2) phantom preparation, (3) camera stability, and (4) method of regions of interest (ROI) contouring on the SPECT images for determining counts was evaluated.

50mCi of Lu-177 was split evenly between two bottles: Phantom 1 ("baseline") and Phantom 2. Both were inserted into a Graves phantom and scanned with a Siemens Intevo Bold SPECT/CT camera at 8 timepoints over the course of a week.

Activity measurements were made on two Capintec CRC-55tW dose calibrators: one which had been calibrated for Lu-177 and another using the same dial settings to evaluate the influence of dose calibrator differences.

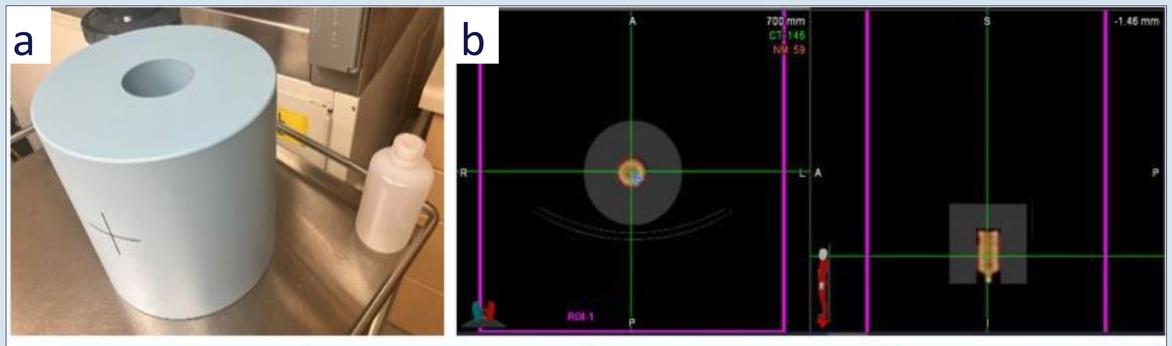
Regions of Interest (ROI) to obtain total counts were drawn using 5 different methods:

- SPECT FOV ("standard")
- Entire Graves phantom
- Bottle only
- Bottle + 3 mm
- Bottle as a cylinder (ignoring narrowing at the neck)

Sensitivity factors were calculated using Equation (1) and were compared for the two phantom datasets, the date/time of scan, and ROI contouring method.

Eq. 1

$$Sensitivity\ Factor = \frac{total\ counts}{acquisition\ time\ x\ activity}$$



c

Clinical Site	1	2	3
SPECT/CT Make/Model	Siemens Intevo Bold	Siemens Symbia Intevo 6	Siemens Symbia Intevo
Dose Calibrator	Capintec CRC55tW	Capintec CRC55tR	Capintec CRC55tW
Sensitivity Factor (cps/MBq)	9.518	10.829	7.507

Figure 1 (a) Graves Phantom; (b) SPECT/CT of Graves phantom filled with Lu-177 with magenta contour showing volume of interest to calculate total counts; (c) Make and model of SPECT/CT and dose calibrators at 3 different centers with corresponding sensitivity factors.

a

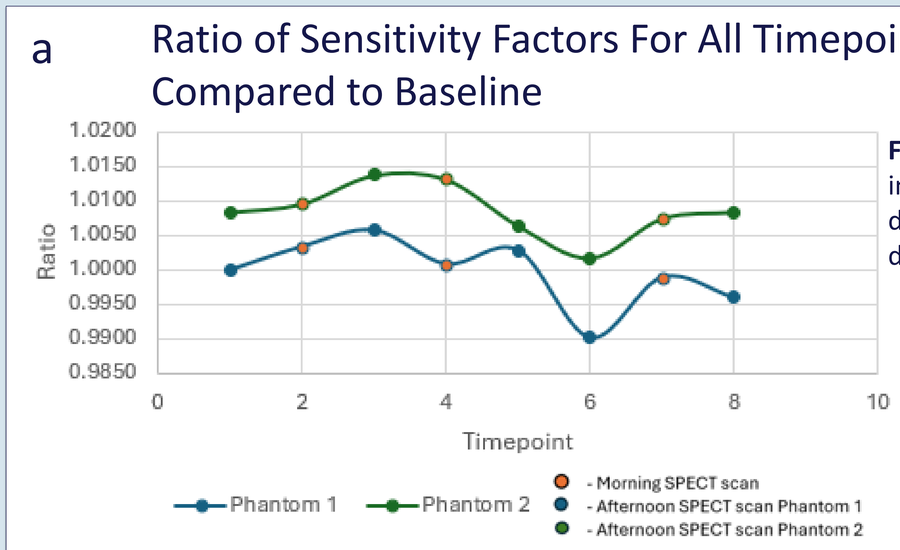


Figure 2 (a) Variability in sensitivity factor vs day of scan and time of day

b

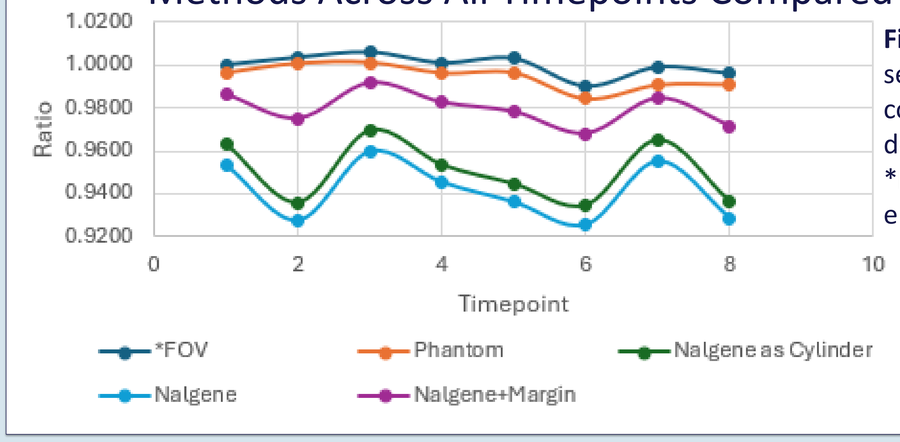


Figure 2 (b) Variability in sensitivity factor vs contouring method for determining total counts. *FOV ROI encompassing entire SPECT FOV.

Results

(1) Dose Calibrators: Two Capintec CRC-55tW dose calibrators were available for use, one of which had been calibrated for Lu-177 measurements with a reference dose activity. Measurement of the vials and syringes in both dose calibrators using the same dial settings showed a systematic 2% higher measurement in the non-calibrated dose calibrator.

(2) *Phantom Preparation:* Following the "standard" protocol for sensitivity factor determination, the ratios across all time points were (Figure 2a)

- Phantom 1: 0.990-1.006
- Phantom 2: 1.002-1.014

Sensitivity factors determined using the second phantom were consistently higher (0.62-1.24%) than those determined using the first.

(3) Camera Stability: Figure 2 shows which data points correspond to morning (orange dots) vs afternoon (blue dots) scans and shows that the date/time of the scan does not produce substantial differences in sensitivity factors when using the whole FOV as the ROI, especially compared to other contouring methods (Figure 2b).

(4) ROI Contouring Method: Across the 5 different methods for ROI contouring, the ratios ranged from 0.926-1.006, highlighting the need to standardize ROI contouring (Figure 2).

Discussion

Proper setup of the dose calibrator is a crucial first step towards accurate determination of a SPECT camera's sensitivity factor, and therefore, dosimetry calculations. Even with using the same dose calibrator make/model, differences of 2% can occur. Further work is needed to verify across multiple dose calibrators with a NIST-traceable source.

Even with a well-established, standardized process for filling and imaging a simple phantom geometry, there can still be differences in measurements. This further emphasizes the need to keep protocols for determining sensitivity factors as simple and robust as possible.

There does not appear to be a preferred time of day to determine the sensitivity factor on our SPECT cameras (i.e., AM before the detectors have warmed-up or PM after continual use throughout the day).

Using the whole SPECT FOV for determining the total counts used to calculate the sensitivity factor seems the most robust to fluctuations in the camera's sensitivity throughout the day and any other setup uncertainties.

Conclusion

With the implementation of RPT dosimetry, standardization is critical to maintaining uncertainty at an acceptable level until more broad uncertainty guidelines are available. The entire sensitivity factor determination process, which involves equipment, activity measurements, and imaging and contouring procedures is linked and must be calibrated together. Any deviations from the standardized process will influence determination of dose.

No conflicts of interest to disclose.