OPTIMIZATION OF THYROID MEASUREMENTS WITH MONTE CARLO SIMULATION IN IN-VIVO MONITORING

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ABSTRACT

In case of *in-vivo* measurement of low activity in the human body, the non-standard geometry and the limited measurement times considerably increase the measurement uncertainty. Thyroid measurements are also influenced by various parameters such as the age of the individual, the shape of thyroid, the position of the thyroid inside the human body, the detector distance from the body surface, the distribution of the activity within the organ. After efficiency calibration of the thyroid counter with physical phantoms, efficiency calibration was performed by numerical methods to optimize the measurements. In order to take into account uncertainties introduced by these factors in the estimation of dose attributed to different radioactive isotopes of iodine, numerical simulations based on Monte Carlo photon transport techniques were performed, detector response and corresponding detection efficiencies were calculated.

INTRODUCTION

In vivo monitoring is a measurement method that enables estimation of occupational or accidental intake of radionuclides. During the monitoring the incorporated radionuclides and quantity of the retained activity in the whole body or in a specific organ can be identified. After the measurement of the retained activity, the intake and then the equivalent or effective dose due to incorporated radionuclides can be deduced [1], [2].

To determine the relationship between the measurement quantity (count-rate in a photoelectric peak) and the retained activity, physical calibration phantoms, representing the whole body or a specific organ are needed. The approximate shape of these phantoms are sufficient to obtain reliable calibration factors but in some cases, the available phantoms are not suitable.

In case of a nuclear reactor accident, one of the major elements of atmospheric releases are radio-iodine isotopes that are naturally retained in thyroid, following inhalation or ingestion.

The calibration of the thyroid monitoring devices is usually carried out with an adult thyroid phantom which is not representative for the age dependent thyroid size of children. The prior calibration with child-specific phantoms the uncertainties in the thyroid dose assessment could be reduced. Several factors influence the calibration results in a particular the detection system such as the measurement geometry, the body and even the anatomical characteristics of the thyroid .

Monte Carlo simulation was performed for a spectrometer and simple physical phantoms of the thyroid in our laboratory to investigate the effect of the main parameters. This poster summarizes the results of the Monte Carlo simulation and comparisons with the implemented physical calibration of the efficiency.

METHODS

During the study, the uncertainties of the efficiency calibration of the thyroid monitoring system were analysed with the measurement and simulation according to several assumptions:

1) The phantom geometry (1 hole or 2 hole) was set as it mimics the adult anatomy.
2) The neck to detector distance was set at various distances (d=3.5, 7.5, 15.5 cm without collimator and d= 19.5, 23.5, 31.5 cm with collimator) in front of the phantom.
3) The thyroid mass and size varied depending on age, in the phantoms varied from 4.7 to 20 g.
4) The thyroid distance from the body surface (s=1.2-3.4 cm).

Table 1: Thyroid phantoms parameters and their perturbed values

	Default	Perturbation
Neck to distance (d) [cm]	3.5 19.5	7.5, 15.5 (without collimator) 23.5, 31.5 (with collimator)
Thyroid mass (a) [Age]	20 g (Adult [>18y])	4.7 g (Child [3-5y]) 10 g (Teenager [11-15y])
Thyroid distance from the surface (s) [cm]	1.6 1.2 1.2	2.8, 3.4 (adult) 2 (teenager) 2 (child)

MEASUREMENT

EQUIPMENT

Thyroid activity could be measured by lead shielded NaI(Tl) scintillation detector, standing on a vertically adjustable stand allows the optimal set of the equipment. A second collimator can be placed which is a lead truncated cone shape with a 4,5 cm inner diameter and 11 cm outer diameter window entrance. The Figure 1 illustrates the thyroid counting system.

Figure 1: Thyroid counting system

PHATOMS

For the efficiency calibration the ANSI thyroid phantom available at the laboratory was used. This phantom is made of plexi-glass cylinder with a diameter of 150 mm and a height of 146 mm. It has one cavity (20 ml) modelling the thyroid of an adult with 3 calibration sources with different ^{131}I activities.

The SURO phantom with three different sizes (adult, teen and child) was also used in this project. These phantoms contained in three pairs of holes with different wall thickness. The activities to be measured were filed in two vials and each vial contained ^{133}Ba in gel form. The Figure 2 shows the used phantoms.

Figure 2: Thyroid phantoms: ANSI (left); SURO (right).

MODEL

DETECTOR

The Monte Carlo simulation was performed by MCNP version 6 to obtain pulse height spectra from the NaI(Tl) spectrometer for various phantoms. The spectrometer with crystal size of 40 mm diameter was modelled (as realistically as possible based on the information provided by the manufacturer). The crystal is covered by aluminium alloyed Mg-Si and it is mounted inside a lead collimator.

PHANTOMS

Figure 3. represent two physical phantoms for the simulation and the detector geometry. The ANSI phantom was created by PMMA and the SURO phantom was styrene.

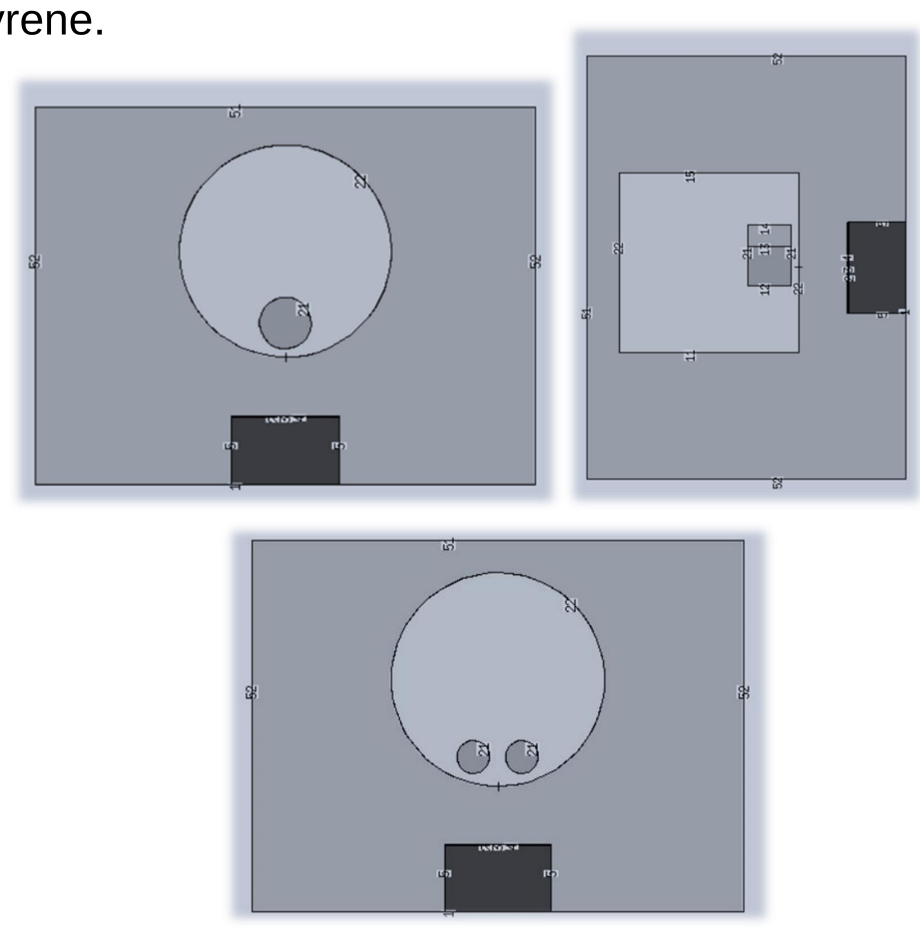

Figure 3: The thyroid geometry and detector model with MC simulation.

RESULTS

DETECTION EFFICIENCY OF THE DIFFERENT PHANTOMS AT 364 keV

	Measurement		Simulation
Phantom geometry	Efficiency [cps/Bq]	Ratio with default	Ratio with default
ANSI (1 hole, adult)	0.70	100%	100%
SURO (2 hole, adult)	0.98	141%	98%

DETECTION EFFICIENCY OF THE NECK TO DETECTOR DISTANCE AT 364 keV

	Measurement		Simulation
Neck to detector distance (d) [cm]	Efficiency [cps/Bq]	Ratio with default	Ratio with default
3.5	4.90	100%	100%
7.5	2.40	50%	43%
15.5	0.85	17%	15%
19.5	0.70	100%	100%
23.5	0.54	77%	72%
31.5	0.34	45%	43%

DETECTION EFFICIENCY OF THE THYROID VOLUME (AGE) AT 364 keV

	Measurement		Simulation
Thyroid mass (a) [Age]	Efficiency [cps/Bq]	Ratio with default	Ratio with default
Adult [>18]	0.98	100%	100%
Teenager [11-15]	1.07	109%	112%
Child [3-5]	1.01	103%	119%

DETECTION EFFICIENCY OF THE THYROID DISTANCE FROM THE SURFACE AT 364 keV

		Measurement		Simulation
Thyroid distance from the surface (s) [cm]		Efficiency [cps/Bq]	Ratio with default	Ratio with default
Adult [>18]	1.6	0.98	100%	100%
	2.8	0.70	72%	72%
	3.4	0.50	51%	62%
Teen [11-15]	1.2	1.07	100%	100%
	2	0.98	92%	79%
Child [3-5]	1.2	1.01	100%	100%
	2	0.73	72%	71%

CONCLUSION

It can be stated that the adequate thyroid measurement result are influenced by various parameters e.g. the shape of thyroid, position of the thyroid inside the human body, the distance between the detector and the body surface. The computed uncertainties due to various parameters should be taken into account while estimating the activity of iodine isotopes in the thyroid. All these factors affect the accuracy of the dose estimation as well.

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