ASSESSMENT OF ARRAY SCINTILLATION DETECTOR FOR FOLLICLE THYROID 2-D IMAGE ACQUISITION USING MONTE CARLO SIMULATION

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ABSTRACT

This work presents an innovative study to find out the adequate scintillation inorganic detector array to be used coupled to a specific light photo sensor, a charge coupled device (CCD), through a fiber optic plate. The goal is to choose the type of detector that fits a 2-dimensional imaging acquisition of a cell thyroid tissue application with high resolution and detection efficiency in order to map a follicle image using gamma radiation emission. A point or volumetric source - detector simulation by using a MCNP4B general code, considering different source energies, detector materials and geometry including pixel sizes and reflector types was performed. In this study, simulations were performed for 7 x 7 and 127 x 127 arrays using CsI(Tl) and BGO scintillation crystals with pixel size ranging from 1 x 1 cm² to 10 x 10 μm² and radiation thickness ranging from 1mm to 10 mm. The effect of all these parameters was investigated to find the best source-detector system that result in an image with the best contrast details. The results showed that it is possible to design a specific imaging system that allows searching for in-vitro studies, specifically in radiobiology applied to endocrine physiology.

1. INTRODUCTION

The image acquisition applied to nuclear medicine and radiobiology is a valuable research method for determination of thyroid anatomy to seek disorders associated to follicular cells. Most of the equipments used to acquire these images are normally composed by a collimator, an array of scintillation detectors and a photo sensor device [1]. On the other hand, the optical and the electron microscopes also allow the observation of in-vitro samples of tissues with good precision and high resolution. Both techniques can be useful to microstructures imaging and in the analyses of less than 2 mm diameter specimens of tissue.

The Monte Carlo (MC) simulation has been used in radiation detection, applied nuclear physics, radiation dosimetry and medical applications since the improvement of data processing compatible with personnel computers (PC) [2]. The MC is a fast, reliable and not
expensive tool that allows searching for useful parameters related to the systems used in nuclear medicine, specifically in radiobiology on endocrine physiology studies. This work presents an innovative study to find out the adequate scintillation inorganic detector array coupled to a fiber optic plate and a specific light photo sensor, a charge coupled device (CCD). The goal is to choose the type of detector that fits the application suggested here with good spatial resolution and good detection efficiency in order to map a follicle image using gamma radiation emission [3]. The diameter of the follicles varies considerably even within a single thyroid gland in about 200 μm to 900 μm [4]. A source - detector simulations were performed by using a MCNP4B – A General Monte Carlo N-Particle Transport Code considering different source energies, detector materials and geometries including pixel sizes and reflector types. The follicles were simulated as ring isotropic gamma radiation sources.

2. MATERIALS AND METHODS

The methodology used herein is based on the conventional procedure of histological exam (in-vitro) of samples of material of the thyroid gland, where the sample of the material to be analyzed is positioned over a glass sheet to be later observed through microscope. The basic material composition of the thyroid is protein. In the case of the extraction of material from a gland that was submitted to thyroid uptake exam, a percentage of iodine absorbed by the organ, natural originated from the composition alimentary or radioactive (artificial) will be retained temporarily in the periphery of the follicle [4].

The sequence of steps simulated herein described was performed considering first a low resolution with a 7 x 7 cm array detector, 1 x 1 cm pixel size afterward to high resolution with a 1270 x 1270 μm array detector, 10 x 10 μm pixel size, so that the system could be capable of identifying and observing clearly a 2 – dimensional image of the cellular area of the thyroid gland or two adjacent thyroid follicle. The source – detector geometry was chosen in order to obtain the greater efficiency of detector. Thus, a reasonable choice of the distance source-detector used was 0.0001 cm.

2.1. Proposed simulated system overview

The system modeled for simulation is shown in figure 1. This structure allows the use of simple codes using MCNP4B tool. The main purpose is to simulate the interaction of photons provided from a point or volumetric source with an array of selected types of scintillation detectors. In this first step the simulation was performed for CsI(Tl) and BGO detector with an MgO reflector material.

The system proposed for simulation is based on a commercial CCD detector with array of 1024 x 1024 pixels each pixel with 13.5 μm x 13.5 μm that could be directly coupled to the detector via a 1:1 fiber optic taper.
2.1.1. Modeling of the radiation source

A photon radiation point source with energy ranging from 60 keV to 364 keV was simulated to verify the behavior of the code and the interaction of radiation with the detector and reflector materials. The detector is an array of 7 x 7 pixels and was modeled for BGO and CsI (TI) detectors with a 1 cm$^2$, 1 mm$^2$ and 100 μm$^2$ pixelsizes and 1cm thickness. The volumetric source was modeled as four rings to simulate the proximity of follicles each one with 200 μm, 300μm, 400 μm and 50 μm external diameter and circular crown of about 10 μm. This type of source was applied to simulations with array dimensions of 1270 x 1270 pixels and effective pixel size of 10 x 10 μm. All the sources are isotropic emission.

![Diagram of detector setup](image)

Figure 1. A top view of schematic diagram of simulated system proposed. The gray areas represent the 7 x 7 array of detectors with a specific radiation thickness.

2.2. Monte Carlo simulation using MCNP4B code

The primary goal of the repeated-structures capability of MCNP4B is to make it possible to describe only the cells and surfaces of any structure that appears more than once in geometry, as a result, the amount of input data and computer memory is reduced [2]. This feature was used in all the run simulations. Figure 2 shows a typical repeated structure that represents the model of simulated array detector used in this work.

For photon transport, the code takes into account photoelectric absorption, with the possibility of K- and L-shell fluorescent emission or Auger electron, coherent and incoherent scattering and pair production. The database of cross-sections is particular to each material type and energy of the incident particle and to the kind of interaction it undergoes and also includes geometry and material specifications [5].

INAC 2007, Santos, SP, Brazil.
Figure 2. A model of 7x7 array used to simulate the source-detector system. The arbitrary numbers in each pixel correspond to a single cell detector and its respective reflector/separator.

3. RESULTS

3.1 Simulation using point source

The results of simulation for point source are shown in figure 3 and table 1. Figure 3 shows the histograms for 159 keV photons distribution in a 7 x 7 array with 1 x 1 cm pixel size for CsI (TI) and BGO detector. Point source is positioned on the transversal axis to element 1 and distant 0.5 cm from detector.

Table 1 shows the photons distribution in 7 x 7 array for BGO detector and MgO reflector/separator with the thickness of 20 percent of the pixel size for a point source positioned 0.016 cm from element number 1. The pixel size of detector is 1 x 1 mm with 1 cm thickness.

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Table 1. Number of photons interacting in a 7 x 7 array for BGO detector with MgO reflector/separator for a point source positioned 0.016 cm from element 1.

<table>
<thead>
<tr>
<th>Energy (keV)</th>
<th>60</th>
<th>140</th>
<th>159</th>
<th>364</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average value</td>
<td>11318</td>
<td>69010</td>
<td>63114</td>
<td>21494</td>
</tr>
<tr>
<td>Neighborhood</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak max.</td>
<td>26083</td>
<td>255119</td>
<td>210280</td>
<td>52164</td>
</tr>
<tr>
<td>Ratio</td>
<td>2.3</td>
<td>3.7</td>
<td>3.3</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Figure 3. A comparison of 159 keV photons interaction in the neighborhood of element 1 for CsI(Tl) (a) and BGO (b)detectors.
3.2 Simulation using volumetric source

Figure 4 shows the results of simulation for volumetric source radiation. A 2D image was obtained for 159 keV photons interaction in a 127 x 127 array of BGO detector.

![Figure 4. A simulation of four follicles for 159 keV photons interaction for BGO array detector.](image)

3. CONCLUSIONS

The use of Monte Carlo method using MCNP4B tool is a relatively practical and inexpensive manner to simulate complex array detector structures. In this study, simulations were performed to optimize the length and the type of material of detector array and reflector in order to evaluate the possibility of developing an imaging system coupled to CCD through fiber optic taper, with a 10 μm spatial resolution.

The preliminary simulations with a point source showed that the detector materials with higher density has a greater detection efficiency, otherwise, as the detector dimensions decrease the count efficiency diminishes as well.

As can be seen in figure 4, due to the image contrast obtained from the simulations, it is possible to evaluate each follicle with a sharp definition by using radiation emission. Therefore, there is a possibility of developing the complete system proposed to investigate micro-structures, as it is performed by an optical microscope. The images obtained from the other simulations with different detectors were similar to that one showed in figure 4. As a result of this work we plan to investigate other possibilities of geometry sources, detector and reflector dimensions to improve the image resolution and counting efficiency.
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REFERENCES