Preliminary results of 3D dose calculations with MCNP-4B code from a SPECT image

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INTRODUCTION

The fast development in medical image processing have made possible the use of more accurate procedures for calculating patient dose distributions, in which spatial and temporal activity distributions are quantified. In these sense it is important a better estimation of absorbed doses in tumors and healthy tissues for a correct understanding of the tumor response and toxicity in healthy tissues. Such approaches need more realistic representation of the human body than the simple geometric approaches used traditionally.

The simulation of radiation transport by Monte Carlo techniques has become an important basic tool for dose calculations. Several software packages adapt the standard geometrical phantoms, allowing placement of a single or multiple tumors in various localization’s to estimate dose contributions from these tumors to normal organs, but do not at present use patient images. It is unacceptable to use geometrical phantoms to perform dose calculations for individual patient therapy. The developed methodology calculates the doses distribution from medical image from patients.

The doses calculations were performed using Monte Carlo MCNP-4B code1. The medical image was generated in Interfile format using IMAGAMMA, a medical image processing system2.

MATERIALS AND METHODS

The developed method requires the following input:

1. Medical image in Interfile format with known cumulated activity distribution
2. Input Interface Program between Nuclear Medical Image and MCNP-4B Monte Carlo code.
3. Output Interface Program between MCNP-4B Monte Carlo code and Nuclear Medical Image.

Medical image and input interface program

The medical image with the known activity distribution was carried out using the IMAGAMMA med-
ical image processing system. In this system the data is in Interfile format version 3.3. The IMAGAMMA system gives the medical image as tomography slices of known activity distribution with voxel size $6 \times 6 \times 6$ mm (fig. 1). The medical image, that in this case is a spherical phantom, were translated into 3D $64 \times 64 \times 64$ matrix using the developed interface software. These input interface program restrict the calculations to the volume of interest. The program was written in BORLAND DELPHI (fig. 2). It becomes the MCNP output file with the 3D doses distribution to Interfile format for clinical use.

### 3D doses calculations at voxel level with MCNP-4B

Photon and electron transport simulations were performed by MCNP-4B code. The MCNP input file uses the repeated structures option for voxel dosimetry. Each voxel was $6 \times 6 \times 6$ mm. The file consisted of 64 slices, and each slice consisted of one array of $64 \times 64$ slices. The provided option of MCNP code for energy deposition tally was used for dose estimates. Electron transport calculations included the production and subsequent transport of bremsstrahlung photons in the cubical arrays. The calculations were performed in a CELERON 1.2 GHz for 5 million histories and the computer time required to run was approximately 24 hours.

### Output Interface Software

The output interface program creates two files: the doses distribution for each slice in matrix form and binary medical image which is read for IMAGAMA system (fig. 3).

The created software’s are compatible with the Windows system. The interaction with the user is given by the windows.

### RESULTS

The medical image generated from spherical phantom was used to compare the mean dose obtained at voxel level according to the MIRD Pamphlet No. 17 with the MCNP-4B code. The voxel S value for these calculations was generated from a method based on 3D convolution using 3D-Discrete Fourier Transform (3D-DFT) for $^{90}$Y. The dose calculation with Monte Carlo code MCNP-4B was performed with relative error less than 5%.

Very good agreement was seen between these two methods: MCNP-4B and the dose calculation based on voxel S values generated by 3D-DFT convolution.
method. The differences was lower by 1%, see table 1.

**DISCUSSION**

The MCNP-4B code can be used to develop a treatment planning system to provide patient-specific dose distribution at voxel level that represent mini regions with normal and tumor tissues. To be used in clinical practice the code must run in a reasonable amount of time and should use a data interchange image format commonly used in Nuclear Medicine as Interfile format. This methodology allows apply the internal dosimetry from SPECT image and not from the mathematical phantom as it was used in the previous work\(^5\)\(^-\)\(^7\).

The disadvantage in the estimate S-values in each voxel with the Monte Carlo code is the very expensive CPU time required. It is necessary to improve these computational times. The solutions in these sense is the parallel architectures implementation. However, calculations made by paralleling processing could be solution in these sense.

The new methodology to 3D dose calculations using the Monte Carlo MCNP-4B has been applied to phantom image in Interfile format only to show the capabilities of MCNP-4B to calculate 3D doses distributions in a voxel level, but will applied for cancer patients image.

The developed software provides the 3D patient specific doses distribution in the Interfile format to the medical physicist which represents a significant advance over dose information given by the standard geometric phantoms used in nuclear medicine. The developed package has been concluded; therefore the validation will be performed in the future publication, after that be tested with the various cases of patients.

**ACKNOWLEDGMENTS**

The authors are grateful to Dr. Helio Yoriyaz (Instituto de Pesquisas Energéticas e Nucleares, SP, Brasil) for many suggestions in the use of the MCNP-4B code.

**REFERENCES**