ANTROPOMETRIC-ANTROPOMORFIC 3D VOXEL MODEL REPRESENTATIVE OF A THORAX'S RABBIT FOR DOSIMETRIC PROPOSALS

Tarcisio Passos R. Campos
João Paulo Lopes de Andrade
Igor Temponi Costa
Curso de Pós Graduação em Ciências e Técnicas Nucleares - CCTN/UFMG,
Av. Antônio Carlos, 6627, CEP: 31270901, Belo Horizonte, MG, Brasil,
campos@nuclear.ufmg.br

ABSTRACT *Animal models has been used in experimentation with ionizing radiation. The evaluation of the energy absorbed per unit tissue mass in vivo transported by nuclear particles is task to be performed before experimentation. Estocastic or deterministic methodology can be applied, however the dosimetric protocols applied in radiotherapy center can not be applied directly due to the inherent small geometry and chemical composition distinct from human. The present article addresses a method that predict the dose distribution into the rabbit thorax based on the solution of the transport phenomena in a voxel model. Herein, the construction of the three-dimensional voxel model anthropomorphic - anthropometric to the rabbit is presented. The model is assembling from a set of computer tomography of the rabbit. The computational phantom of the thorax starts at the digitalization of the CT images, tissue definition, and color image representation of each tissue and organ. The chemical composition and mass density of each tissue is evaluated as similar date presented by ICRU. To treat the images, a code namely SISCODES, developed in house, was used. The perspective for the model is to be used in dosimetric studies on radiotherapy in vivo experiments.*

Keywords: dosimetry, radiotherapy implants, radiological response.

1. Introduction

Ionizing radiation technology are very much applied in the medical field to the diagnostic of many diseases, as well as for treating innumerous diseases, in particular the cancer. Therefore this technology has a relevant social matter. In order to improve the knowledge in nuclear transport particle in biological tissues, as well as radioprotection, dosimetry and radiation oncology protocols, experimental dosimetry of the radiation on in vivo models should be done. Such experiments has the proposal of investigate new or alternative ways of irradiating the human being, testing the parameters involved on the technique, such as absorbed dose (Energy per unit mass), dose rate, fractionation, hyper fractionation, radioprotection and radioresistence effects, etc. However, to study dosimetry on a vivo animal, there are the needs to predict dose in advance. However, there is not a suitable technique to predict dose in animals, and the water phantom applied to calibrate equipments in hospital, does not match the delicate geometry of the small animal, such as rabbit. Such facts justify the proposal of assembling a three-dimensional voxel model with anatomic and anthropomorphic representation of the tissues and organs of the rabbit.

2. Materials and Methods

The voxel phantom represent a computational model based on the anatomy of the thorax of the rabbit. The process of generating the model starts from a tomography of the thorax of the rabbit, in which each tomographic section was digitalized, identified, scaling and concatenated until producing a 3D gray level model. Later, the tissue in each voxel was identified one by one, receiving an identification color. The mass density and chemical composition of each tissue was evaluated based on the ICRU-44 and ICRU-63 (ICRU, 1992). A computational program supports the procedure of image color processing. It has a architecture of client/server operating Internet protocols, developed on the research group NRI-*Núcleo de Radiações Ionizantes* of the nuclear engineering department of the UFMG, namely SISCODES – Sistema Computacional para Cálculo Dosimétrico utilizando Código Estocástico (Trindade, 2004). This computational software provides the tools of developing voxel model for dosimetric proposals.

Herein, its evaluates the sum of the kinetics energy of each nuclear charged particle, considered as secondary particle, released after interaction of neutron particle (photon or neutron) with the tissue or organ, per unity of tissue mass, defined as KERMA, considering the atomic composition of each tissue in studies. (Faw, 1999) The calculus is present in plots: KERMA (cGy) per unit of fluency (particle/cm^2) versus the monoenergetic photon or neutron incident. To check the procedure of KERMA evaluation, the comparison with the KERMA provided by NIST is performed.

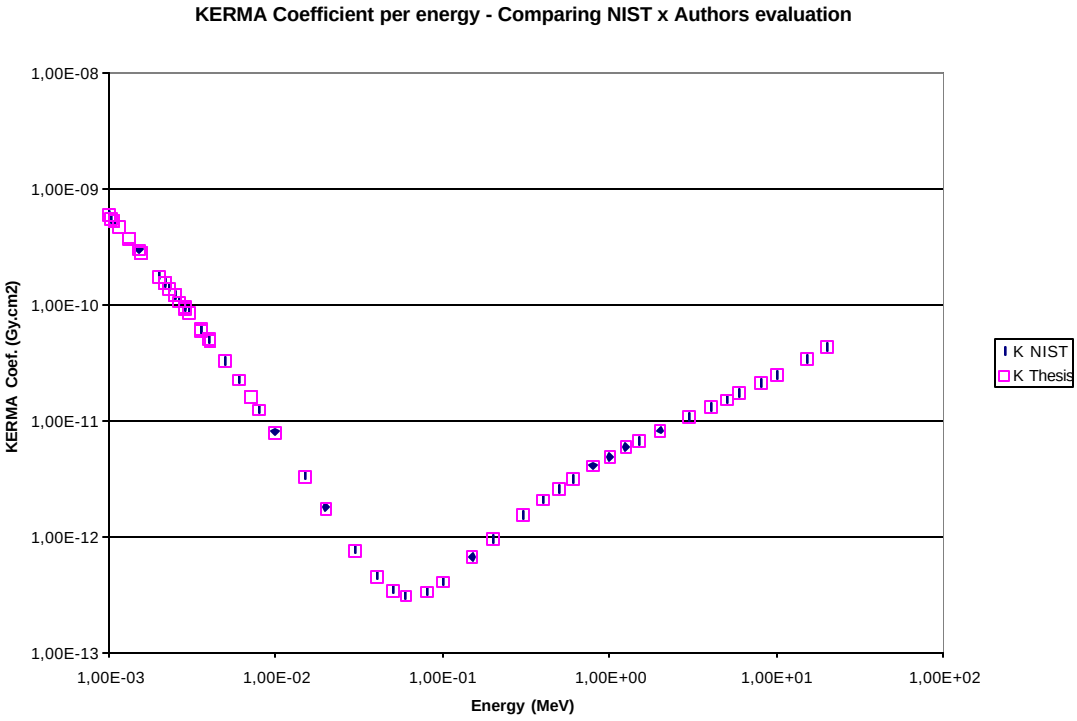

Figure 1 – Plot of the KERMA evaluated by the authors and the KERMA evaluated by NIST

3. Results

Figure 1 presents the comparison results of the KERMA calculation and NIST results. Figure 2 presents the values of neutrons KERMA for the rabbit's tissues depicted in Tab.1. Figure 3 presents the KERMA of photons for the same tissues and organs. The results and its analysis are restricting to the rabbit tissues. The imprecision of the evaluation is a combination of various experimental varables. It is related to the imprecision of the elementary composition of the in vivo tissues, the density of the rabbit's tissue, the accuracy of the nuclear microscopic cross-sections with photons and neutrons of various energies, and also the inaccuracy of the calculations.

The computational matrix of voxels was introduced in the MCNP5 nuclear code and its respective materials (organs and tissues) and its properties. Fig.4 illustrates the sections of the model generated by the graphic interface of the SISCODES software. Figure 4 presents six images of a computer tomography showing the transversal sections of the rabbit, and to the side, the same ones in matrix of voxels of tissue, in which each color represents one distinct tissue. As example, skin is identified by light rose, adipose tissue in light yellow, muscle in orange, skeleton-cartilage in light blue, skeleton-bone in green, dark blue is the lung, red the liver and blue the spinal marrow. The region in lighter blue, between each side of the lung, corresponds to the mediastinal mass.

Table 1 – Tissue and organs used on the 3D rabbit model

Tissue	**Elemental composition (percentage by mass)**										
	H	C	N	O	Na	S	Cl	K	P	Ca	Mg
Adipose tissue (adult)	11.4	59.8	0.7	27.8	0.1	0.1	0.1	-	-	-	-
External air	-	-	75.5	23.2	-	-	-	-	-	-	-
Heart (adult healthy)	10.4	13.9	2.9	71.8	0.1	0.2	0.2	0.3	0.2	-	-
Liver (adult healthy)	10.2	13.9	3.0	71.6	0.2	0.3	0.2	0.3	0.3	-	-
Lung (adult healthy)	10.3	10.5	3.1	74.9	0.2	0.3	0.3	0.2	0.2	-	-
Mediastinal space	10.4	13.9	2.9	71.8	0.1	0.2	0.2	0.3	0.2	-	-
Muscle (adult)	10.2	14.3	3.4	71.0	0.1	0.3	0.1	0.4	0.2	-	-
Spinal marrow (adult)	10.7	14.6	2.2	71.2	0.2	0.2	0.3	0.3	0.4	-	-
Skeleton-cartilage (adult)	9.6	9.9	2.2	74.4	0.5	0.9	0.3	-	2.2	-	-
Skeleton-bone (adult)	3.4	15.5	4.2	43.5	0.1	0.3	-	-	10.3	22.5	0.2
Skin (adult)	10.0	20.4	4.2	64.5	0.2	0.2	0.3	0.1	0.1	-	-

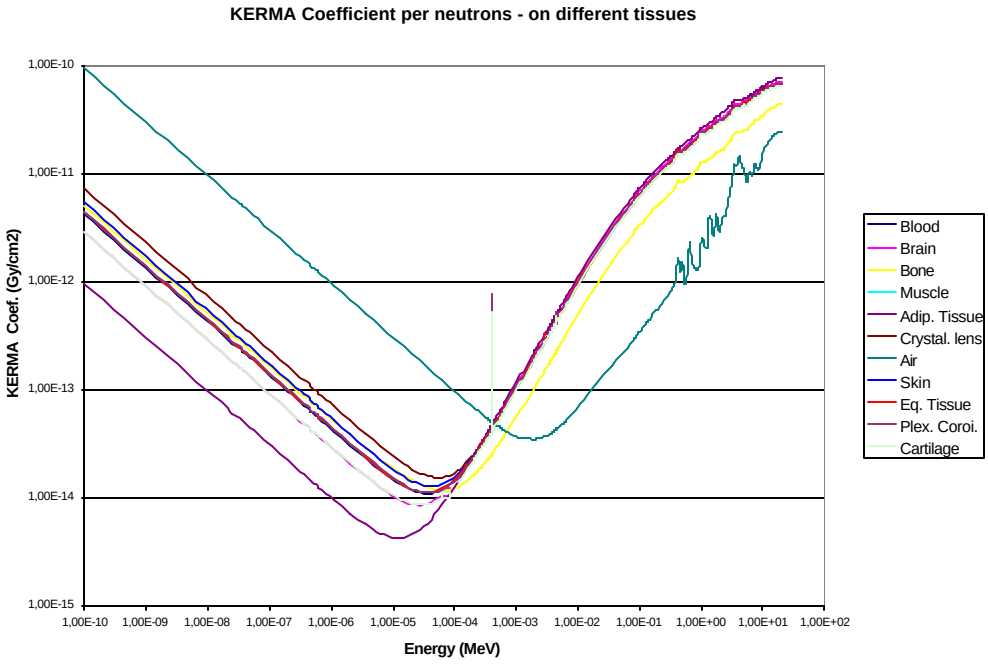

Figure 2 – Conversion Coefficients of KERMA (cGy) per unit of fluency (particle/cm^2) versus energy of the neutron incident.

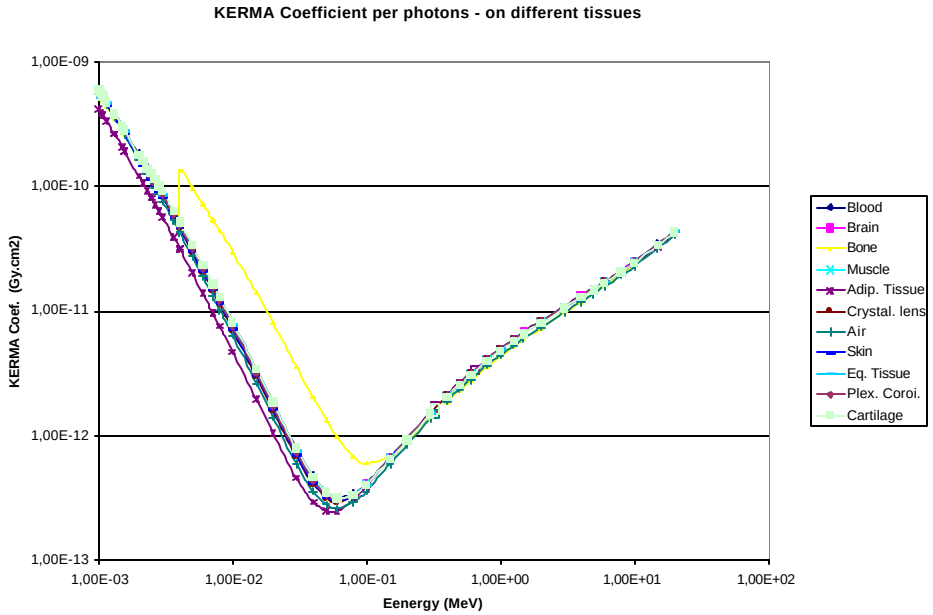

Figure 3 – Conversion Coefficients of KERMA (cGy) per unit of fluency (particle/cm^2) versus energy of the photons incident.

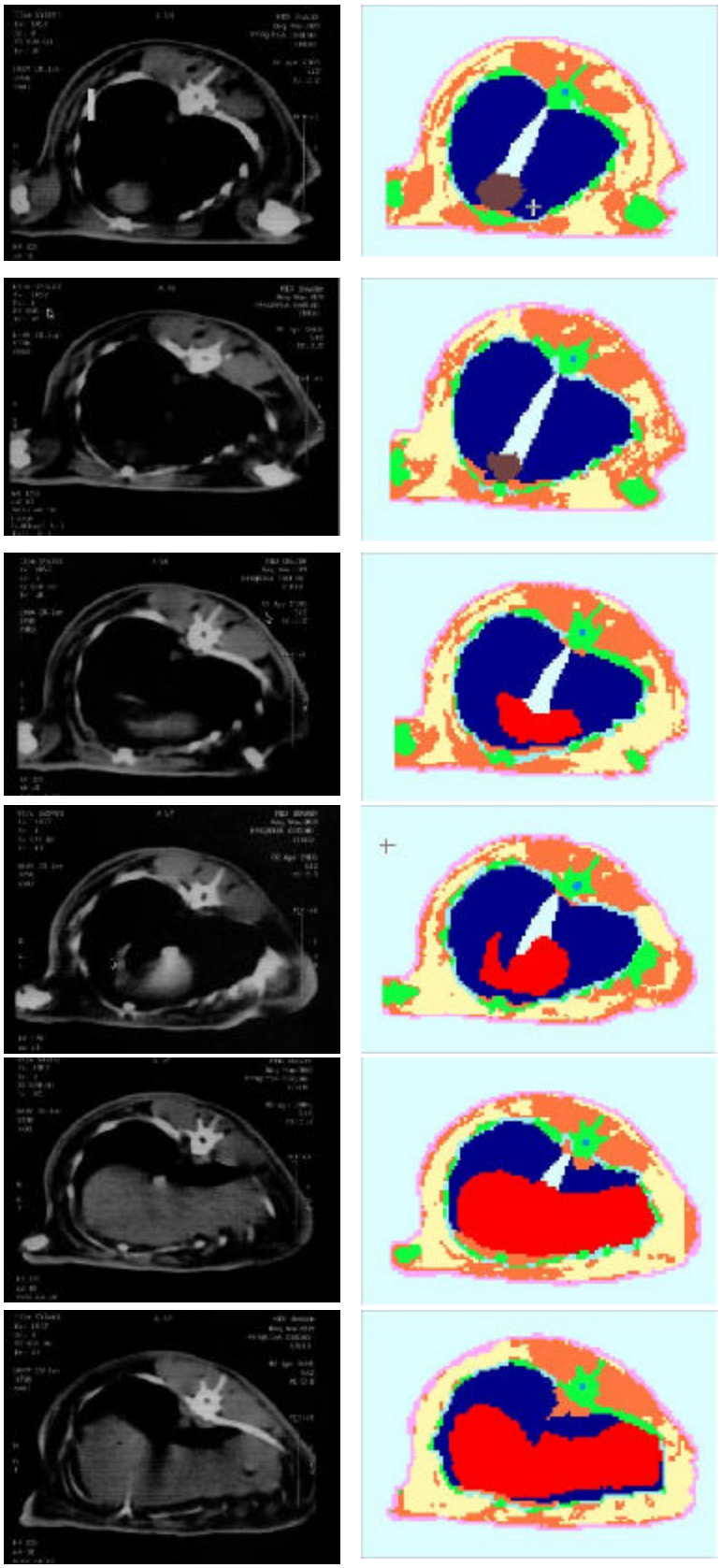

Figure 4 – Image view of six distinct sections of the tomographic image (left); and its respective image obtained at the 3D color voxel model (right).

5. Conclusion

The model has been prepared with a set of tissues and organs defined in Tab.1. The chemical composition of each tissue was assumed be equivalent to human body. This assumption has not been tested or verified. The voxel dimension was 1x1x3 mm size, which presents an adequate special resolution. The mathematical model was developed with 23 sections. It will be used in the dosimetric studies allowing evaluation of absorbed dose in radiotherapy, calibration of instruments and linear accelerators, and optimization of image quality. It will be used in study of internal dosimetry, implant of new radioactive sealed sources, as well as simulations in radiotherapy planning in bi and three dimensional protocols, optimizing radiation therapy.

6. Acknowledgements

The authors especially thank the support of FAPEMIG-950/01, and for the institutions FUNDEP-infrastructure, CNPq-bolsaPQ- that direct and indirectly collaborated to the construction of experimental setup. We thank the grants of "Iniciação Científica" by FAPEMIG and CNPq to the joint co-authors of the work. We alert for the systematically low priority established and the no direct support from CNPq to this research. The authors thank Prof. Leo Heller and Profª Ana Figueiredo Gontijo for having approved the changes in the Civil Project of the PCA1 allowing the construction of the ditch that led to the irradiation room.

7. References

Briesmeister, J.F. MCNP – A General Monte Carlo N - Particle Transport Code System. Version 4A, Los Alamos National Laboratory, 1993.

ICRU-46, 1992, Photon, Electron, Proton and Neutron Interaction Data for Body Tissues. Report 46, International Commission on Radiation Units and Measurements, Bethesda.

ICRU-63, 2000, Nuclear Data for Neutron and Proton Radiotherapy and for Radiation Protection. Report 63, International Commission on Radiation Units and Measurements, Bethesda.

Diário Oficial da União, Brasil, Diretrizes Básicas de Radioproteção: Resolução CNEN – 012/88, 1988.

Faw, R. E. & Shultis, J. K., 1999, Radiological Assessment – Sources and doses. American Nuclear Society, Illinois, USA.

TRINDADE, B., Desenvolvimento de um sistema Computacional para Cálculo Dosimétrico utilizando Código Estocástico, SISCODES, dissertação de mestrado, programa de pós-graduação em Ciências e Técnicas Nucleares, dez.2004.

8. Responsibility notice

The author is the only responsible for the printed material included in this article.