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Original Article

Study of absorbed dose in important organs during helical CT chest scan using MCNP code and MIRD phantom

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ABSTRACT

Purpose: Study of absorbed dose in the heart, breast, stomach, lungs, thyroid, kidney, and liver during CT scan of the chest at different tube voltages using Medical Internal Radiation Dose (MIRD) phantom and MCNP code at values of tube voltage 80 kVp, 100 kVp, and 120 kVp.
Method: The graphical interface, CT-DOSE CALC, was based on Visual Basic language and linked to a Monte Carlo code in order to simulate the movement of radiation source in both types of computed tomography imaging (axial/helical scan). The modified ORNL MIRD phantom was used to evaluate the average deposited energy and absorbed dose in important organs and tissues. Also the absorbed dose in heart, skin, and the ratio between the absorbed dose in skin and the absorbed dose in heart were calculated.
Results: The absorbed doses in heart muscle were 9.11, 21.86, 36.99 mGy, in breasts were 2.03, 3.90, 6.22 mGy, and for thyroid were 0.78, 1.66, 2.79 mGy at 80, 100, 120 kVp respectively.
Conclusion: As a result of CT chest scan, it is always necessary to set accuracy to obtain acceptable images for medical diagnosis and to reduce patient dose to minimum.

1. Introduction

Radiation dose from computed tomography (CT) has become a public concern. With the increasing use of CT, the radiation exposure from CT scans has become the primary contributor to the public medical exposure. According to National Council on Radiation Protection and Measurements (NCRP) report No. 160, CT scans contributed half of the total patient medical exposure [1]. Effective dose resulting from the computerized imaging devices extends within the range of 1–12 mSv. The effective dose at tomography of the abdomen and pelvis is about 10 mSv and it is higher than the amount of 400–500 times the dose caused by conventional imaging of the chest, estimated at 0.02–0.04 mSv. On the other hand, the dangers arising from this radiation have random effect that does not appear immediately, but may appear in later years or even generations later [2].

Table 1 gives a comparison between the effective dose resulting from the computed tomography and each of the traditional imaging of the chest and the number of years of exposure to natural background radiation which produces the same effective dose resulting from computed tomography [2].

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Table 1
A comparison between the effective dose resulting from the computed tomography and each of the traditional imaging of the chest and the number of years of exposure to natural background radiation which produces the same effective dose resulting from computed tomography.

Imaging protocol	Effective dose (mSv)	Number of the chest's images in the traditional imaging	Number of years of exposure to natural background radiation
Head scan	2.3	115	1 year
Chest scan	8	400	3.6 year
Abdomen and pelvis scan	10	500	4.5 year

1.1. MCNP code

MCNP is comprised of about 425 subroutines written in Fortran 90 and C. MCNP has been made as system independent as possible to enhance its portability, and has been written to comply with the ANSI Fortran 90 standard.

MCNP is a general-purpose Monte Carlo N–Particle code (MCNP) that can be used for neutron, photon, electron, or coupled neutron/photon/electron transport, including the capability to calculate given values for critical systems. For photons, the code accounts for incoherent and coherent scattering, the possibility of fluorescent emission after photoelectric absorption, absorption in pair production with local emission of annihilation radiation, and bremsstrahlung [3].

Table 2
Elemental composition of the tissues for all phantoms except the newborn [6].

Element	Percent by weight		
	Lung	Skeleton	Soft tissue
H	10.134	7.337	10.454
C	10.238	25.475	22.663
N	2.866	3.057	2.490
O	75.752	47.893	63.525
F	0	0.025	0
Na	0.184	0.236	0.112
Mg	0.007	0.112	0.013
Si	0.006	0.002	0.030
P	0.080	5.095	0.134
S	0.225	0.173	0.204
Cl	0.266	0.143	0.133
K	0.194	0.153	0.208
Ca	0.009	10.190	0.024
Fe	0.037	0.008	0.005
Zn	0.001	0.005	0.003
Rb	0.001	0.002	0.001
Sr	0	0.003	0
Zr	0	0	0.001
Pb	0	0.001	0
Density	0.296 g/cm^3	1.4 g/cm^3	1.04 g/cm^3

1.2. Visual basic

Visual Basic is a tool that allows you to develop Windows (Graphic User Interface - GUI) applications. The applications have a familiar appearance to the user.

Visual Basic is event-driven, meaning code remains idle until called upon to respond to some event (button pressing, menu selection, ...). Visual Basic is governed by an event processor [4].

1.3. Computational phantom

The computational phantom, designed to represent human anatomy, started with a simple geometry of cylinders and spheres of homogeneous composition. The first

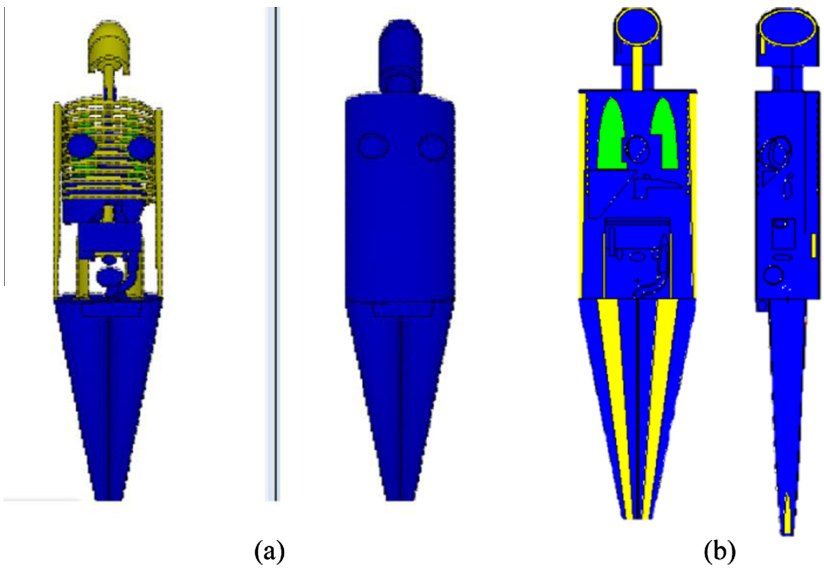

Fig. 1. The mathematical Phantom adopted in this research using MCNP5-beta code, (a) three-dimension drawing, (b) two-dimensional drawing.

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