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Effects of physical parameters of tumors on the early lung cancer recognition by MCNP code

D. Rezaei-Ochbolagh [a], M. Moradi, S. Salmannezhad
a. Department of Physics, University of Mohaghegh Ardabili, P.O. Box 179, Ardabil, I. R. of Iran

Abstract: Applications of the Monte Carlo method in medical physics cover almost all topics, including radiation protection, diagnostic radiology, radiotherapy and nuclear medicine. MCNP is a general-purpose Monte Carlo N-Particle code that can be used for neutron, photon, electron, or coupled neutron/photon/electron transport. In this work, the MCNP4C code was used for simulating lung and trachea. In order to recognize growing tumor, a tumor with determined properties was defined in lung that activated by doping of ^{99m}Tc. We observed count rate has downfallen because of tumor presence. This means that photons that emitted from ^{99m}Tc have been absorbed by tumor. In other words, this method can recognize existence of grown tumor in lung. This method shows when a tumor is growing 7cm depth in lung, it can be detected by point detector.

Keywords: Lung Cancer, MCNP4C, Monte Carlo simulation, Recognition radiology.

Introduction

Cigarette smoking increases the internal intake of ^{210}Po and ^{210}Pb, which are contained in cigarette tobacco in relatively high concentrations. Polonium-210 and ^{210}Pb that are inhaled and deposited in the lung tissues will contribute to an increase in the internal radiation dose and in the number of lung cancer incidences observed among smokers (Khater, 2004).

Lung cancer is one of the most common types of cancer, with more than 175,000 deaths per year in United States (Gurcan *et al*., 2002). Lung cancer is the leading cause of cancer-related death in the world, with non-small cell lung cancer (NSCLC) accounting for nearly 80% of cases (Gioizno, 2002). PET, Positron Emission Tomography, with (^{18}F) 2-fluoro-2-deoxy-D-glucose (FDG) is a well-established functional imaging technique for diagnostic imaging, especially for cancer (Higashi *et al*., 2003; Rohren *et al*., 2004).

Lung examination through computed tomography (CT) is an effective examination method which has been scientifically accepted as the gold standard for the lung cancer. Thorax perfusion CT is a new method giving opportunity to functional evaluation of lung cancer. Functional radiological imaging plays an extremely significant role in diagnosis, treatment and follow-up periods of the lung cancer. It is very important to evaluate the metabolism and microcirculation of the tumor using functional methods (Miles and Griffith, 2003). New imaging method, perfusion CT, has advanced our ability to detect, characterize, and quantify pulmonary pathology (Ovale *et al.,* 2007).

Because of using Monte Carlo simulation by MCNP code, our work is different from other reports using simple phantoms such as the spheres into a water-filled cylinder, which was placed in a body phantom (Bangel *et at.,* 1997). With our method, there are more regions throughout the lungs that might have greater variability in counts. In this work, ability of MCNP code has been investigated to diagnose lung cancer. By considering biological properties of human lung, input file of MCNP code was accomplished. A tumor with determined properties was defined in lung. It was assumed the lung contained ^{99m}TC to recognize tumor.

Materials and method

We employed the Monte Carlo code system MCNP for the simulation. MCNP is a general purpose Monte Carlo N-Particle code that is used to calculate coupled neutral / charged particle code. This code uses a three-dimensional heterogeneous geometry and transports photons and electrons in the energy range from 1KeV to 100MeV. Low energy phenomena, such as characteristic x-ray and Auger electrons, are also accurately modeled. MCNP requires the source for a particular problem to be specified in a user defined input file. The source includes distributions of the position, energy and angle of starting particles. In this study we used of 4c version that was released in 1999 (Mostaar *et al.,* 2003).

The right and left lungs region were approximated with ellipsoid equations 1 and 2

* **Corresponding author:** Tel.:+984515514703; fax: +984515514701. E-mail address: ddrezaey@yahoo.com (D.Rezaei-Ochbolagh.)

respectively. It was assumed that the lungs have composed ORNL-UF phantom model lung tissue with a density of 0.26 g/cm^3 (Akkurt & Eckerman., 2007).

$0.3043(X-2)^2+4(Y+4.8)^2+(Z+10)2-64=0$ (Eq.1)

$0.2674(X-2)^2+3.515(Y-4.8)^2+(Z+10)^2-56.25=0$ (Eq.2)

By considering above points, MCNP input file was accomplished. Fig. 1 has been extracted from output file of MCNP code. As seen in Fig. 1, a spherical region that defined by Eq. 3, was embedded between left and right lungs as heart region. It was assumed a grown tumor that indicated by Eq. 4, located in left lung.

$(X-1)^2+(Y-0.4)^2+(Z+9)^2=4.84$ (Eq.3)

$(X-2)^2+(Y+6)^2+(Z+10)^2=0.01$ (Eq.4)

According to Fig. 1, 11 point detectors were set outside of left lung for detection gamma-ray that emitted from distributed ^{99m}Tc source inside of lung. By comparing detectors counts, it is possible to distinguish tumor as an undesirable body in lung.

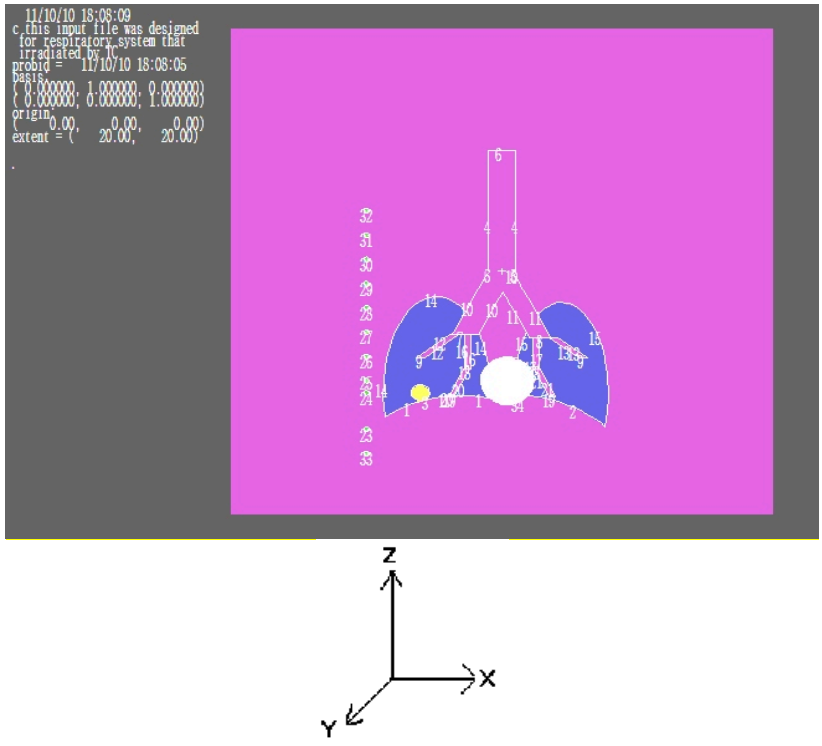

Fig. 1 Lung configuration assembly that extracted from output file of MCNP code.

Results and discussion

At first we assumed a sphere with radius of 0.1 cm and with density of 1 g/cm^3 has been located at depth of 5cm from surface of lung as a tumor. Also, it was assumed the activity of ^{99m}Tc (Gamma-Ray energy=140 KeV) that distributed in lungs, is 5mCi (185 MBq). Its effective dose is about 1.5 mSv. Then point detectors that situated at z=-5, -4,-3…+5 count emitted photons from lung. This simulation was repeated for different densities (from 1 to 5g/cm^3) of tumors. Results have been extracted from output file of MCNP code and shown in Fig. 2. As seen in Fig. 2, by increasing tumor density, detector sensitivity has been decreased. This means that photons that emitted from ^{99m}Tc have been absorbed by tumor and absorbed photon counts depend on tumor density.

The tumor can probably grow anywhere of lung (Berbeco *et al*., 2005). So, its distance from lung surface has different value. In order to verify the ability of this method to recognize depth of located tumor, we have repeated calculations for different depths. We have assumed the tumor has 0.1cm radius and 2g/cm^3 density. Results that obtained from output files of MCNP code, have been plotted in Fig. 3. According to Fig. 3, it is impossible to recognize tumors that situated at 10 cm and more by this method.

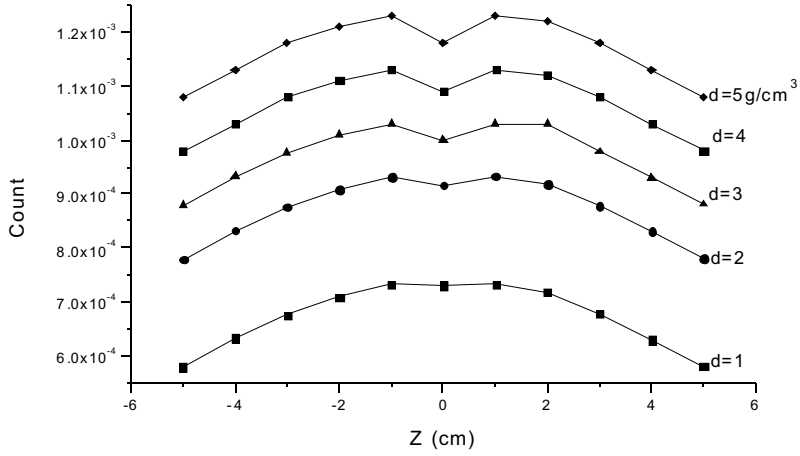

Fig.2 variations of detector counts with distance from tumor location (z=0). Those variations have been investigated for tumor densities of 1, 2, 3, 4, and 5 g/cm3. Detector counts decrease by increasing density. It is assumed the tumor that located at depth of 5 cm, has 0.1cm radius.

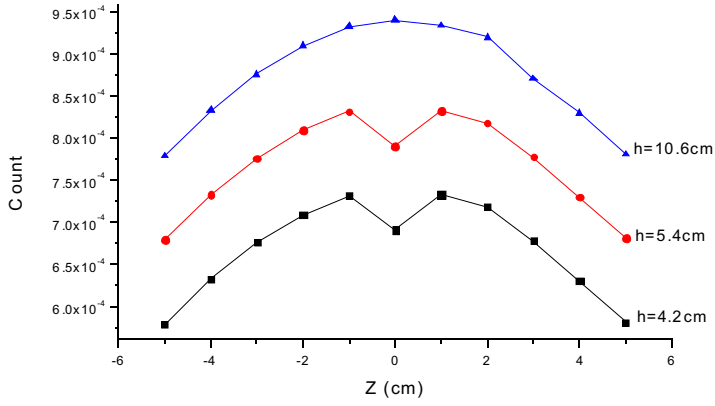

Fig.3 variations of detector counts with distance from tumor location (Z=0). Those variations have been investigated for tumor depths of 4.2, 5.4, and 10.6 cm. It was assumed the tumor has 0.1cm radius and 2g/cm^3 density.

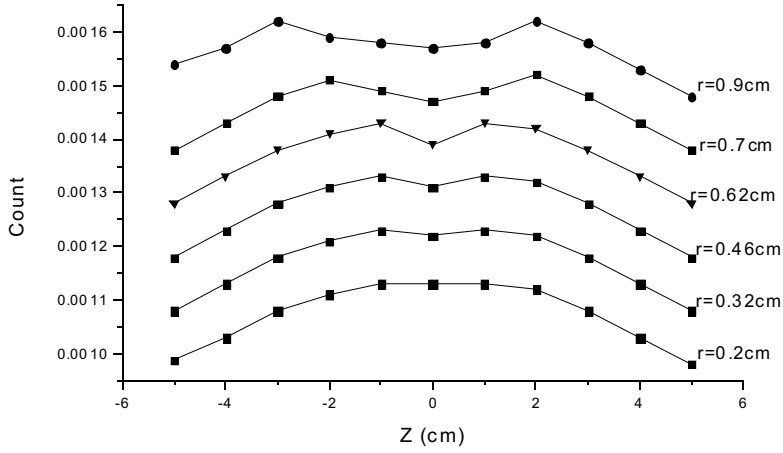

Fig.4 Variation of count rate with distance from tumor existence location when ρ=1g/cm^3 and depth of tumor = 5 cm. The results are shown for different radii from 0.2 to 0.9 cm.

The tumor is growing with lapse of time. Therefore, its size lumps and its radius increases. In this section, we consider a tumor with radius of 0.2 cm and density of 1g/cm^3, is growing at depth of 5 cm. By using Monte Carlo simulation and geometry of this situation, input file of MCNP code was created. The obtained data from output file of MCNP code are arranged and plotted in Fig. 4. As seen in Fig. 4, when the radius is 2 cm, it is difficult to recognize existence of tumor. By growing the tumor, absorbed photons counts are increased and it is possible to distinguish tumor appearance.

Conclusion

A new method for recognizing tumor in lung with MCNP4C Monte Carlo method has been presented. The method has been the basis of applied to simulated tumor in lung, which shows that it can automatically recognize lung cancer using MCNP4C early.

Although we could not determine how the stability of this method experimentally but the data approximately show ability of this method to detect tumor appearance.

This method shows when a tumor is growing 7 cm depth in lung, it can be detected by point detector. In order to recognize growing tumor, the lung must be activated by doping of ^{99m}Tc. Fig. 5 shows detector counts that obtained with and without tumor in lung. As seen in this Fig. 5 count rate has downfallen at z = 0 because of tumor presence. This means that photons that emitted from ^{99m}Tc have been absorbed by tumor. In other words, this method can recognize existence of grown tumor in lung.

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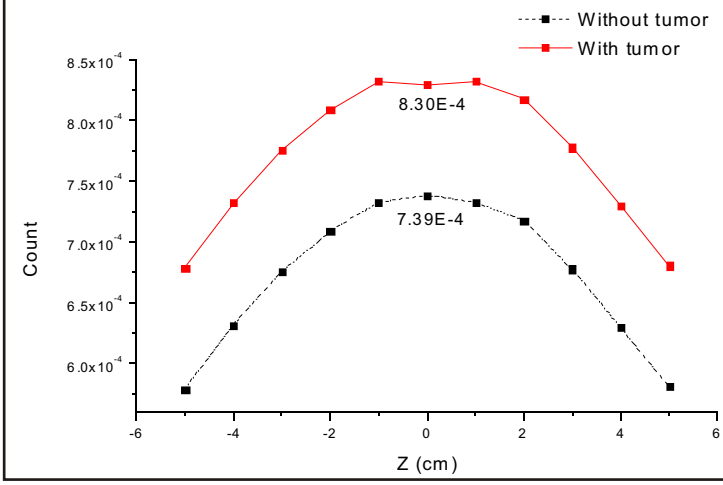

Fig.5. Variations of detector counts with distance for lung with (Solid) and without (Dash) tumor. Tumor that has 1g/cm^3 density and 0.1cm radius is located at z=0 and 7cm depth.