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Erkek Çocuklarda I-131 Radyoizotopunun Vücut Dozunun Yaşa Göre Değişimi

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Öz

Anahtar kelimeler
Monte Carlo
Nükleer Tıp
Radyasyon
Doz

Nükleer tıpta kritik organların aldığı doz, vücut içine yerleştirilen radyoizotoplar nedeniyle önem kazanmaktadır. Tıbbi uygulamalar, genel popülasyonun radyasyona maruz kalmasının ana nedenleri arasındadır. Bu uygulamalarda, Bilgisayarlı Tomografi (BT) taramaları birincil kaynak olurken, nükleer tıp ise ikinci en büyük kaynaktır. Nükleer tıp prosedürlerinin kullanımına ilişkin olarak verilmesi gereken bilinçli kararlar, soğurulan radyasyon dozunun ve ilişkili risklerin daha iyi anlaşılmasını gerektirir. Bu çalışmada Monte Carlo merkezli NCINM (Nükleer Tıp için Ulusal Kanser Enstitüsü Dozimetri Sistemi) kodu yardımıyla 0, 1, 5, 10 ve 15 yaşındaki erkek çocukların tiroit bezine iyot radyoizotopu, I-131 yerleştirildiğinde tiroit bezi, timüs ve lenf bezlerinin absorbe edilen dozunun değişimi araştırılmıştır.

Change in Body Dose of I-131 Radioisotope in Boys by Age

Abstract

Keywords
Monte Carlo
Nuclear Medicine
Radiation
Dose

In nuclear medicine, the dose received by the critical organs becomes important due to the radioisotopes placed inside the body. Medical applications are among the main causes of radiation exposure to the general population. In these applications, Computed Tomography (CT) scans are the primary source, while nuclear medicine is the second largest. The informed decisions that must be made regarding the use of nuclear medicine procedures require a better understanding of the absorbed radiation dose and the associated risks. In this study, when iodine radioisotope I-131 inserted into the thyroid gland of boys aged 0, 1, 5, 10 and 15, change of the absorbed dose of the thyroid gland, thymus and lymph nodes was investigated by the Monte Carlo based NCINM (National Cancer Institute Dosimetry System for Nuclear Medicine) code.

1. Introduction

In nuclear medicine applications, imaging of organs, evaluation of organ functions and treatment of damaged organs, albeit limited, can be provided by means of radioactive substances that are given to the patient's body and emit low-dose radiation (Smith 1984). In nuclear medicine procedures, in which radioactive nuclei with short half-lives are generally preferred, gamma rays emitted from the radioactive nucleus are collected with the help of a gamma camera and transferred to the computer to obtain visual information about the desired region.

In nuclear medicine, which is mostly for diagnostic imaging, it is an important issue to determine which organs the radiation emitted by the radiopharmaceutical applied to the patient will affect and the total radiation risk for the patient (Toohey *et al*. 2000). Because it is desired that the radiation dose to be given to the suspected organ should not cause damage to other healthy tissues and organs. Since this information cannot be determined by clinical measurements in practice, it is calculated using computer-generated body-like models. These models may be mathematical models developed in the 1970s, in which organ and tissue volumes are represented by simple geometric shapes, or they may be tomographic models developed in the late 1990s and based on real body images.

The Monte Carlo technique was first used in the design of atomic weapons in the 1940s and has been accepted as a successful tool for applications where the interactions of radiation with material are studied (Andreo 1991). The method is widely used today where physical measurements are either very difficult or impossible, and it is a modeling technique that tries to describe an event or experiment numerically using various statistical techniques in general. In modeling the interactions of radiation with the material medium, this method determines the properties of the particles carrying the radiation energy, such as energy, position, flight direction and flight distance, using random numbers and appropriate probability distributions. Thus, the physical interaction types that the particles moving in the medium will undergo, the amount of energy to be lost in each interaction, the scattering. angles etc. tries to guess. As a result, the amount of radiation dose to be released in predefined volumes is calculated.

Radioactive iodine therapy is a method that has been successfully applied for almost 50 years in the treatment of goiter diseases, which are defined as hyperthyroidism and cause high thyroid gland hormone levels in the blood. Radioactive iodine, which is given orally as a capsule or liquid, is absorbed from the digestive system, and collected in the thyroid gland cells, and the radiation it emits stops the growth and activity of thyroid cells. The function of the overactive thyroid gland returns to normal or unwanted thyroid tissues are destroyed. While radioactive iodine is excreted from the body mostly through the urine, some of it is excreted with saliva, sweat, and feces. The ones that are not excreted also disappear after a while, and there is no more radioisotope in your body between 10 days and 1 month. Residence time in the body is shorter at low doses and longer at higher doses. Radioactive iodine treatment is usually given on an outpatient basis to patients with hyperthyroidism, and hospitalization is required in some special cases. In some kinds of cancers of the thyroid gland, radioactive iodine therapy is also used for the destruction of thyroid gland residues left behind after thyroid gland surgery and for the treatment of the spread of thyroid cancers in the body. The dose of radioactive iodine varies according to the kind of thyroid cancer.

In this study, Monte Carlo simulation studies were performed by placing I-131 radioisotope in the thyroid in a newborn, 1-, 5-, 10-, and 15-years old boy phantom. The doses received by the thyroid gland, thymus, and lymph nodes were calculated via the NCINM code.

2. Material and Method

The absorbed radiation dose of any tissue of the organ cannot be directly measured or calculated without exposure. Some of the physical quantities related with radiation, such as air kerma or fluency, are converted to the absorbed organ dose using radiation dose coefficients (ICRP 1987, ICRP 1996, ICRP 2000). In calculations of the dose coefficients, computational phantoms are often combined with a Monte Carlo based computer simulation code. In the earliest forms of the phantoms, the contours of the body and organs were defined by mathematical equations or shapes (Eckerman *et al.* 1996). Although, these phantoms offered flexibility for modification, were far from anatomically realistic. The next generation of voxel (volume element) or tomographic phantom was created from medical images, mostly CT or MR images, and provide very realistic anatomical similarity (Xu 2014). However, due to the limitations of voxels, changing phantom and organ sizes, shapes, and positions is time-consuming. The latest generation of phantoms is known as hybrid phantoms that combine the advantages of both stylized and voxel phantoms and are both flexible and anatomically realistic (Xu 2014).

NCINM code is based on the widely accepted MIRD formalism (Loevinger *et al.* 1991). This code was developed in three steps:

- First, calculations of a comprehensive library of specific absorbed fractions (SAFs) for multiple combinations of source and target sites in a set of computational phantoms (both pediatric and adult) combined with a MCNP code.
- Second, derivation of a S values library from SAFs and nuclear decay data from ICRP report (ICRP 2008).
- Finally, a GUI-based user-friendly code was compiled to facilitate the dosimetry process.

The code will give following outputs:

i. Absorbed doses and absorbed doses

   Absorbed doses and absorbed doses per unit administered activity are calculated for all target regions in terms of mGy and mGy/MBq, respectively. Absorbed does per unit administered activity to target region r_T, which is also called absorbed dose coefficients, $\frac{D(r_T)}{A_o}$, is calculated using:

   $$\frac{D(r_T)}{A_0} = \sum_{r_s} \frac{\tilde{A}(r_s)}{A_0} S(r_T \leftarrow r_s)$$

   where first term is the cumulated activity per unit administered activity in source tissue r_s and second term is the S value for regions r_s (source) and r_T (target).

ii. Two effective doses

   Effective doses is calculated based on ICRP 60 (ICRP 1991) and 103 (ICRP 2007) in terms of S_v.

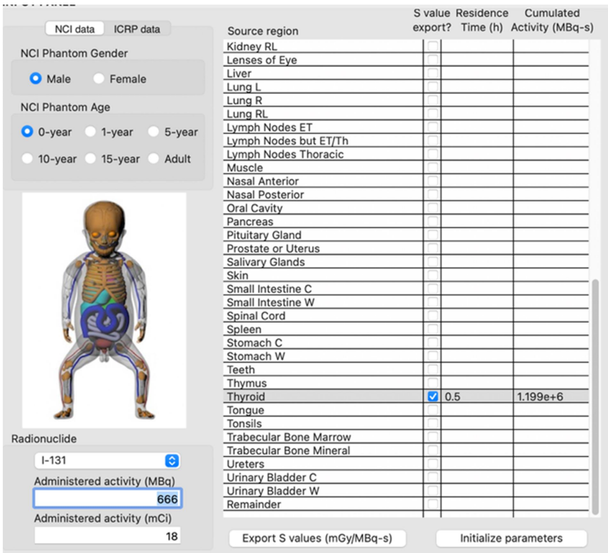
iii. Target region mass

iv. S values (mGy/MBq.s)

   S values are calculated for selected regions r_s (source) and r_T (target), selected phantom, and also selected radionuclide. Besides S values are displayed on screen and could be taken as a file in text format.

3. Results

In this study, NCINM code developed by NCI was used. With the help of this Monte Carlo-based code, the I-131 radioisotope with an activity of 666 MBq or 18 mCi was placed in the thyroid gland of a boy phantom of different ages for half an hour. This selected activity is in the selected range for Hyperthyroid treatment. The doses taken by the thyroid gland, thymus, and lymph nodes were calculated and compared with each other. In Fig. 1, the input window of the code where the parameters are entered is given. The phantom selected in this window belongs to a newborn boy.



NCI Phantom Gender
● Male ○ Female

NCI Phantom Age
● 0-year ○ 1-year ○ 5-year
○ 10-year ○ 15-year ○ Adult

Radionuclide: I-131

Administered activity (MBq): 666

Administered activity (mCi): 18

Source region	S value export?	Residence Time (h)	Cumulated Activity (MBq-s)
Kidney RL	☐		
Lenses of Eye	☐		
Liver	☐		
Lung L	☐		
Lung R	☐		
Lung RL	☐		
Lymph Nodes ET	☐		
Lymph Nodes but ET/Th	☐		
Lymph Nodes Thoracic	☐		
Muscle	☐		
Nasal Anterior	☐		
Nasal Posterior	☐		
Oral Cavity	☐		
Pancreas	☐		
Pituitary Gland	☐		
Prostate or Uterus	☐		
Salivary Glands	☐		
Skin	☐		
Small Intestine C	☐		
Small Intestine W	☐		
Spinal Cord	☐		
Spleen	☐		
Stomach C	☐		
Stomach W	☐		
Teeth	☐		
Thymus	☐		
Thyroid	☑	0.5	1.199e+6
Tongue	☐		
Tonsils	☐		
Trabecular Bone Marrow	☐		
Trabecular Bone Mineral	☐		
Ureters	☐		
Urinary Bladder C	☐		
Urinary Bladder W	☐		
Remainder	☐		

Figure 1. NCINM code input window.

In Fig. 2, phantoms of boys at different ages (1, 5, 10, 15) are shown. As can be seen in this figure, the internal organs, bone and tissue structure have a more realistic appearance compared to the older phantoms.

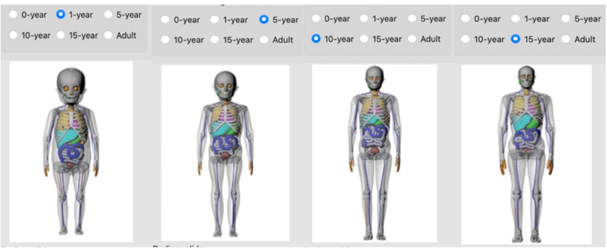


Figure 2. Phantom of a boy aged 1, 5, 10 and 15.

In Fig. 3, the doses taken by the thyroid gland are given according to age. The same graph is given for the Thymus in Fig. 4 and the lymph node in Fig. 5.

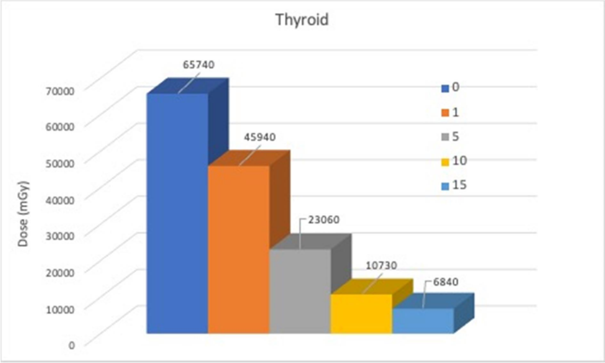


Figure 3. The change in the dose of the thyroid gland according to the age.

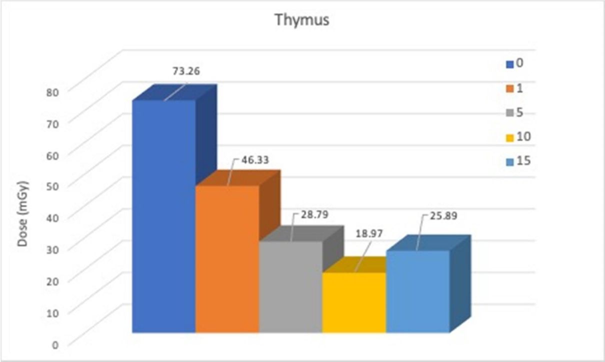


Figure 4. The change in the dose of the thymus according to the age.

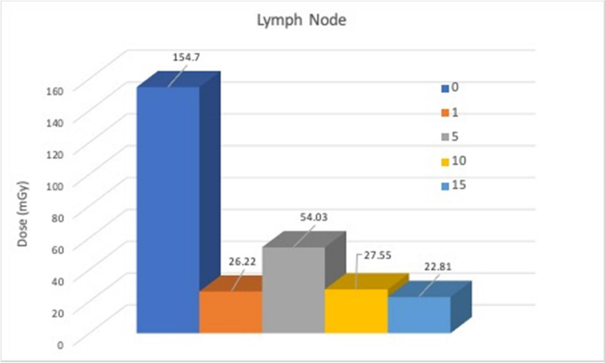


Figure 5. The change in the dose of the lymph node according to the age.

4. Conclusion

Using the reference pediatric computational phantoms available in the NCINM code, we calculated the doses received by the thyroid gland, thymus, and lymph nodes via Monte Carlo-based NCINM code. Organ dose coefficients were calculated for the I-131 radioisotope with the activity of 666 MBq (equal to 18 mCi) placed in the thyroid gland for half an hour for 5 different male phantoms (newborn, 1-, 5-, 10- and 15-years old). The results showed that the absorbed doses of critical organs were inversely proportional to age and became highly significant at younger ages. As expected, the x-ray exposed region geometry plays an important role in the age-related dependence of organ doses, followed by effective dose. The data obtained will be useful to other users using pediatric reference phantoms for MCNPX based dose calculation to compare the calculation process.

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