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NEW APPROACH IN ESTIMATION OF PATIENT EFFECTIVE DOSE FROM ^{131}I

NOVI PRISTUP U PROCENI EFEKTIVNE DOZE KOJU PACIJENT PRIMI OD ^{131}I

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Ključne reči
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Key words
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Apstrakt

Tokom oralne primene terpijske kapsule $Na^{131}I$ razumno je pretpostaviti da je vreme od 15 minuta pre njenog razlaganja dovoljno dugačko da izazove dodatnu ekspoziciju. Dozu je nemoguće odrediti neposrednim merenjem pa se preporučuju računske tehnike. Glavni cilj naših istraživanja bio je da se izračuna efektivna doza i rizici nastali kao posledica prisustva kapsule u stomaku pre njenog razlaganja. Za modelovanje transporta gama zračenja i beta čestica emitovanih iz radionuklida ^{131}I koristili smo Monte Karlo paket MCNP4b. Izračunali smo apsorbovanu energiju po jedinici transformacije u stomaku i okolnim organima. U cilju procene efektivne doze koristili smo odgovarajuće tkivne težinske faktore.

INTRODUCTION

Capsules containing $Na^{131}I$ are indicated for the therapy of some thyroid carcinomas such as functioning metastatical papillary or follicular carcinoma of the thyroid; and for the treatment of hyperthyroidism (diffuse toxic goiter and single or multiple toxic nodular goiter). They are also used for the treatment of recurrent hyperthyroidism after surgery. The recommended activities for $Na^{131}I$ capsules for the therapy delivered to the average patient (70 kg) are between 3.7 GBq and 7.4 GBq for ablation of normal thyroid tissue and for subsequent treatments and between 148 MBq and 370 MBq for hyperthyroidism. For the purpose of this paper the nominal dose of 3.7 GBq has been chosen [(1)] The administration of $Na^{131}I$ capsules or solutions is oral. In the case of solution, absorption in gastrointestinal tract starts immediately. On the other hand dissolving of capsules cause that radioactivity of ^{131}I retained in stomach for 15 minutes before the absorption starts. In this time interval a large amount of radioactivity needlessly expose a part of stomach and several surrounding organs. Comparing the treatment of patients by solution this is the additional risk. If this risk is well known it is possible to justify the application of capsules in comparison to solution of $Na^{131}I$ for therapy.

MATERIALS AND METHODS

The calculations were performed using a few various anthropomorphic phantoms[(2,3,4)]. The novel MIRD anthropomorphic models are very suitable for presented calculation because they are representative for broad population and easy to use in Monte Carlo calculation. These models were developed for calculations of doses absorbed in specific organs when the source is in some other organ. Mathematical description is very simple and easy to use for all important organs in humane body.[(5)] In this paper we gave our results only for the new MIRD model and wall defined by equation 1.[(5)]

$$\left(\frac{x-x_0}{a}\right)^2+\left(\frac{y-y_0}{b}\right)^2+\left(\frac{z-z_0}{c}\right)^2\le 1 \qquad \left(\frac{x-x_0}{a-d}\right)^2+\left(\frac{y-y_0}{b-d}\right)^2+\left(\frac{z-z_0}{c-d}\right)^2\ge 1 \qquad (1)$$

The phantom consists of three major sections:

(a) an elliptical cylinder representing the trunk and arms;

(b) two truncated circular cones representing the legs and feet; and

(c) a circular cylinder on which sits an elliptical cylinder capped by half an ellipsoid representing the neck and head.

The other organs are modelled by appropriate geometrical figures. The stomach wall is represented by the volume between two concentric ellipsoids and the contents by the volume within the inner ellipsoid.

Three phantom tissue types are recognized as skeletal, lung, and all other tissue (soft tissue). The densities of those tissues are: 1.4 gcm^{-3}; 1.04 gcm^{-3} and 0.296 gcm^{-3} respectively. The exact composition of each tissue type is given in ICRP 70, ICRP 89 and ICRU 46 [6,7,8] The soft tissue composition used in this paper is presented as

10.6 % H + 11.5 % C + 2.2 % N + 75.1 % O + 0.1 % Na + 0.1 % P + 0.1 % S + 0.2 % Cl + 0.1 % K

We used the radiation transport code MCNP4b, a general Monte Carlo N-Particle transport code (MCNP), developed at the Los Alamos National Laboratory (9). In the case of ^{131}I beta particles and gamma rays transport should be taken into account[10]. Proper tally specification is very important in MCNP calculations. In the case of dose distribution calculation in different organs for gamma rays the tallies *F8 and F6 are applicable and therefore used. And for beta rays only *F8 tally can be used. These tallies give the absorbed energy in organs in units MeV/g per disintegration. In the case of calculation of local dose distribution in stomach wall beside F6 and *F8 tallies, just for gamma rays F2 tally has been used. Because this tally represents flux averaged over a surface, flux-dose rate conversion coefficients have been used [11].

RESULTS

Effective dose and cancer risk

These calculations have been performed by MCNP4b package for the point source iodine-131 in soft tissue. For beta dose *F8 tally and for gamma dose both *F8 and F2 tallies have been used. Due to the sphere symmetry estimated uncertainties are less than 0.01 %, and they are negligible (insignificant). According to these results large doses are obtained at distances of several millimetres and very large are obtained at the distances less than one millimetre. Taking into account capsule wall shielding, these values are lower but could still achieve significant values. These results indicate that the concept of average organ or tissue dose is not applicable in situation like these. Space dose fractionation has to be taken into account. By application of MCNP4b software the absorbed energy in the most exposed organs as a consequence of ^{131}I capsule staying in stomach has been calculated. For the capsule activity of 3.7 GBq its 15 minutes remaining in stomach, the dose equivalent (radiation weighting factor equal unity) in different organs are calculated. The relative uncertainty was not higher than 5%. Using calculated imparted energies per transformation as well as radiation quality factors we have calculated dose equivalent rates in different organs as a base for effective dose estimation.

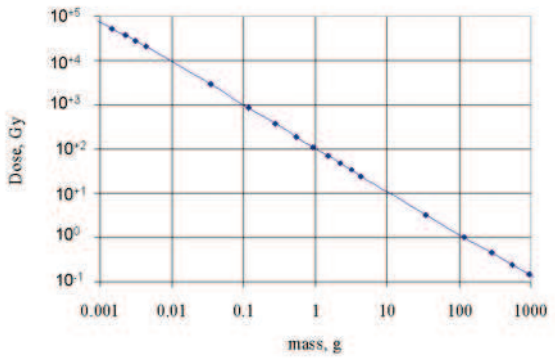
Considering the number of histories obtained uncertainties of Monte Carlo calculations of energy imparted in organs (MeV per disintegration) are acceptable. By means of tissue weighting factors [12] and dose equivalent in different organs the effective dose has been calculated and presented in table 1

Table1. Calculated values of effective dose in different organs.

Organ	Tissue weighting factor	*E* [Sv]
Bladder	0.05	4.98E-04
Bone surface	0.01	5.56E-09
Colon	0.12	9.41E-04
Liver	0.05	5.75E-06
Lungs	0.12	3.03E-06
Ovary, gonads	0.20	4.81E-04
Skin	0.01	1.33E-06
Stomach	0.12	7.43E-02

It is evident that a middle dose is less than 1 Gy for an organ like stomach (130 g), about 10 Gy in an organ like thyroid (10 g) and higher than 100 Gy in the most exposed part of stomach (less than 1 g). If the mass of soft tissue is ten times smaller than the average dose is approximately ten times higher.

Fig.1. The average doses in function of sphere mass for point source activity 3.7 GBq



Risk estimation

Effective dose at the whole body level is 76.2 mSv. As expected, this value is relatively small. The additional risk of cancer death with the value of 0.6e-3 is negligible. The same situation comes from the calculation of Summary of the Lifetime Mortality in the Whole Population from Specific Fatal Cancers after Exposure at Low Radiation Dose and Dose Rates[12]. The risk coefficients and calculated risk are presented in table 2.

Table 2. The risk coefficients and calculated risks for different organs.

Organ	Risk coefficient ($10^{-2}Sv^{-1}$)	Risk
Bladder	0.30	2.99E-05
Bone surface	0.05	2.78E-10
Colon	0.80	2.27E-05
Liver	0.15	1.73E-07
Lungs	0.85	2.014-07
Ovary,gonads	0.10	2.40E-06
Skin	0.02	2.65E-08
Stomach	1.10	6.81E-03
Kidney	0.5	1.35E-06
Total risk		6.917E-03

DISCUSION AND CONCLUSION

The investigations and calculations were started with assumption (hypothesis) that effective doses in belly (stomach) have to be locally high considering the entered high activities. Application of solution has some advantages as the absorption in stomach wall as nearly momentarily but has a lot of disadvantages. Capsules containing $Na^{131}I$ are widely used as they are more comfortable for administration and there is less possibility for local contamination of patient and medical staff. Recommended dosages for the therapy of average patient (70 kg) are in the range from 148 MBq to 7.4 GBq, depending of disease which has to be treated. As the administration of $Na^{131}I$ capsules is oral they retain in stomach for at least 15 minutes before absorption starts. During that time a large amount of radioactivity needlessly expose a part of stomach and several surrounding organs. This statement was the main reason for our prediction about the necessity of additional risk estimation. Obtained results indicate that

In such case the traditional concept of risk is not applicable, so it become necessary to create the very new concept which is able to cover higher risks under presented circumstances. We strongly recommend the estimation of additional risks for each type of the procedure as a part of QA programs for $Na^{131}I$ capsules application.

These results do not point out to higher risk to patient because of the 15 minutes capsule staying in stomach. But because of high activity of capsule local doses and dose rates could be very large and the presented model for risk calculation could not be appropriate. Therefore it is necessary to know dose distance relation in stomach wall.

The investigations and calculations were started with assumpted values of local doses of several grays in stomach wall could not be ignored even they are not, generally, significant from the stand point of current radiation protection rules.

Abstract

During the oral application of $Na^{131}I$ therapeutic capsule it is reasonable to presume that 15 minutes in stomach is long enough to make additional exposure. As it is not possible to determine it by direct measurements there is a strong recommendation to estimate the dose by calculation. The main goal of our investigation was calculation of effective dose and risk as a result of ^{131}I capsules remaining in stomach before the absorption starts. Monte Carlo code MCNP4b was used to model the transport of gamma and beta particles emitted by radionuclide ^{131}I treated as a point source at the bottom of the stomach. Absorbed energy per unit transformation in stomach and surrounding organs has been calculated. The dose equivalents in these organs have been calculated in aim to determine the effective doses using appropriate tissue weighting factor values.

REFERENCES

1. Rosario P, Reis J, Barroso A: Efficacy of low and high 131I doses for thyroid remnant ablation in patients with differentiated thyroid carcinoma based on post-operative cervical uptake, Nuclear Medicine Communications. 2004; .25, 11: 1077-1081,
2. Snyder W, Ford MR, Warner G: Estimates of Specific Absorbed Fractions for Photon Sources Uniformly Distributed in Various Organs of a Heterogeneous Phantom, Pamphlet No. 5, revised, Society of Nuclear Medicine, New York, 1978.
3. Zubal I: Computerized 3-dimensional segmented human anatomy. Med. Phys. 1994; 21: 299–302,
4. Segears W, Lalush D, Tsui B: Modeling respiratory mechanics in the MCAT and spleen-based MCAT phantoms, IEEE Trans. Nucl. Sci, 2001; 48: 89–97, .
5. Eckerman K, Cristy M, .Ryman J: The ORNL Mathematical Phantom Series, Oak Ridge National Laboratory Report; 1996. Available at: http://homer.hsr.ornl.gov/VLab/VLabPhan.html
6. International Commission on Radiological Protection: Basic Anatomical & Physiological Data for use in Radiological Protection: The Skeleton, ICRP Publication 70, Annals of the ICRP 25; 1996.
7. International Commission on radiological Protection: Basic Anatomical and Physiological Data for Use in Radiological Protection: Reference Values, ICRP Publication 89 Annals of the ICRP 32, 2002: 3-4: 1-277,
8. International Commission on Radiation Units and Measurements. Photon, Electron, Proton and Neutron Interaction Data for Body Tissues, ICRU Report 46: Bethesda, MD; 1992.
9. Briesmeister J: " MCNP—A General Monte Carlo N-Particle Transport Code,Version 4B", Report LA-12625-M. Los Alamos, NM; 1997.
10. Chul SYF, Ekström LP, Firestone RB. The Lund/LBNL Nuclear Data Search, Version 2.0; 1999. Available at: http://nucleardata.nuclear.lu.se/NuclearData/toi/index.asp.
11. International Commission on Radiological Protection. Conversion Coefficients for use in Radiological Protection against External Radiation, ICRP Publication 74. Annals of the ICRP 26; 1997.
12. International Commission on Radiological Protection. Report of the Task Group on Reference Man ICRP Publication 23; Pergamon Press Oxford; 1975.

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