Al-Azhar Bulletin of Science: Section B, Vol. 32, No. 2, (December) 2021, pp. 23-31
http://doi.10.21608/absb.2021.93331.1133

Al-Azhar Bulletin of Science: Section B

MONTE CARLO METHOD ESTIMATES FOR INTERNAL DOSIMETRY OF WELL DIFFERENTIATED THYROID CANCER PATIENTS

Maged M. E. El-din [a,*], Eman Massoud [b], Ahmed Y. El-Agamawi [c], Amr M. Kany [d], Mohamed R. Ezz El-din [a].

[a] Radiation Protection Department, Egyptian Nuclear and Radiological Regulatory Authority, Cairo, Egypt.
[b] Jeddah International College, Jeddah, Saudi Arabia.
[c] Faculty of medicine Al-Azhar University, Cairo, Egypt.
[d] Faculty of science Al-Azhar University, Cairo, Egypt.
* Corresponding Author: magedmohamed78@gmail.com

Received: 05 Sep 2021; Revised: 09 Oct 2021; Accepted: 17 Oct 2021; Published: 01 Dec 2021

ABSTRACT

During radiotheranostic procedures, radioiodine-131(^{131}I)activities deliver high internal gamma (ɣ) doses to the patient's organs. Thus, studying the internaldoses of patients is highly required to predict the stochastic or deterministiceffect of gamma radiation that may occur to patients.The objective ofthis study is to calculatethe internal doses for 11 critical organs or body tissues insideWell Differentiated Thyroid Cancer (WDTC) patients' bodiesafter receiving diagnostic and therapeutic ^{131}I activitiesorally during 6days post administration.Internal effective doses delivered tocritical organs are estimated mathematically using Monte Carlo simulation model in which the actual geometry, volume, mass of organs and the source localization wasdesigned based onthe patients' CT images and Oak Ridge National Laboratory (ORNL) phantom.Thus, an average sized human phantom was constructed using MCNP5in whichtwo ^{131}I sources were distributed in the abdominal and the thyroid gland sections.No significant radiation effect is expected during diagnostic procedures for the investigated organs including the thyroid itself. However,some deterministic effects or induction of thyroid cancer might be observedfor patients undergoing postoperative radiotherapy with largeprescribed activities.

Keywords: Radioiodine-131; Internal Dosimetry; Monte Carlo; Well Differentiated Thyroid Cancer.

1. INTRODUCTION

Thyroid cancer is the ninth most common malignant cancer globally with higher risk of occurrence in males than females. Inwhich, radio-iodine (^{131}I) is mostly used in post-operative therapy due to its ability to emit beta (β) radiation. However, Well Differentiated Thyroid Cancer (WDTC) patients are exposed to high levels of gamma (γ)irradiation during radiotheranostic procedures, thus estimating the internal doses are of high priority in order to put limitation of the dose delivered to the patients and prescribe safe^{131}I activities. As the thyroid gland is the target organ for ^{131}I in the form of sodium iodide (NaI) solution, the thyroid gland and its surrounding organs such as brain, lung, heart wall, cervical vertebra and salivary glands are of higher risk than other organs [1-3].

Beta radiation effects to internal organs is assumed to be negligible since beta rays penetrate about 3 mm in human soft tissue thus, most body organs acquire radiation doses from gamma radiation, and exposure to gamma radiation will only be considered [1].

The activity concentration distribution of ^{131}I derived from SPECT/CT images of WDTC patients shows that the administrated activity is mainly distributed within the abdominal section during the first day post-administration. Most of the administrated activity is excreted throw the bladder and the remaining ^{131}I activity slowly migrates to its target organ in the thyroid gland. After 24h post administration, all the remaining activity is concentrated in the thyroid gland tissues with few traces of ^{131}Istill present in the abdomen [4-8].

MCNP5 is a general-purpose radiation particle transport code for modeling the interaction of radiation with materials with powerful three-dimensional geometry and source modeling capabilities that can be applied in medical physics to predict internal absorbed dose in several organs. The use of MCNP with knowledge of patient anatomy will result in a significant improvement in the accuracy of dose calculations [2,15].

Similar published literatures have used Monte Carlo method to calculate the absorbed dose and the absorbed dose per administrated activities for internal organs and body tissues for thyroid cancer patient such as Oktajianto H, Setiawati E, 2016 [2], and Azghadi EH., Motavalli LR, Hakimabad HM., 2014 [9].

The present study simulates WDTC male patient using Monte Carlo method where all ^{131}I administrated activity is localized either in abdominal section (stomach) or in the neck section (thyroid gland). No metastasis is considered in this simulation in order to avoid excessive ^{131}I uptake values by randomly distributed metastasis that causes variable radiation exposure to other sections or spots [10]. The mathematically internal dose rates, absorbed doses and effective doses are calculated inside WDTC patient by MCNP5 software code.

2. MATERIAL AND METHODS

2.1. Human phantom geometries and material composition

The MCNP codes can provide means to simulate gamma radiation delivered to WDTC patients and predict the internal dose rate for each body's organ. The penetration of beta (β) rays to other organs is assumed to be negligible since they mainly deposit inside their containing organs [1,2].

MCNP computer code package (based on Monte Carlo method) is used to design and simulate a three-dimensional average sized Egyptian male patient (175 cm length- 55 cm width- 81 kg weight) with no metastatic distribution in body organs. The human phantom body includes 24 organs and components to resemble CT image of real adult male patient [9,17,18], as shown in fig. 1 and 2.

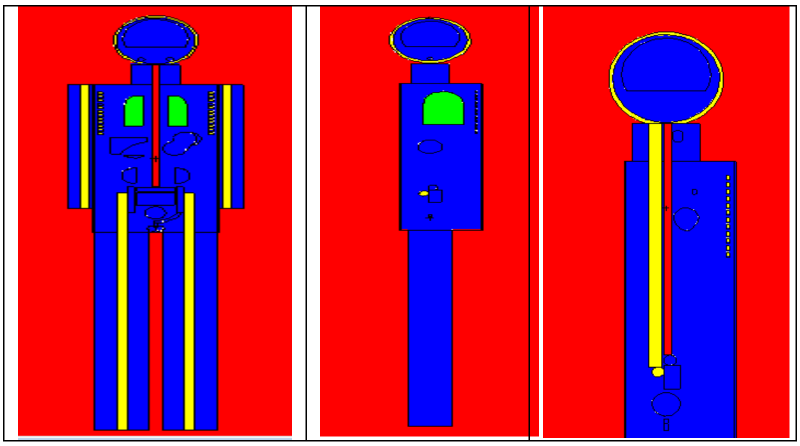
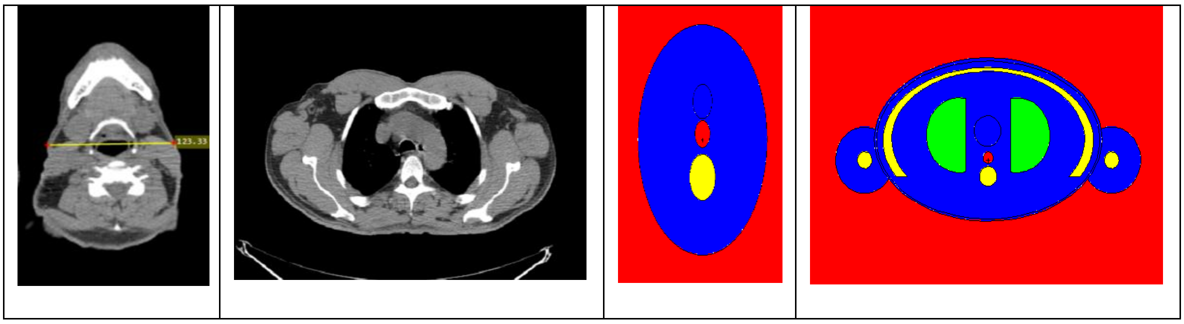


Fig. 1. Side and front view of the MCNP model on XZ and YZ dimensions



(a) (b)

Fig. 2. Cross sectional view on XY dimensions at neck and abdominal levels for: (a) the CT image (b) the MCNP model

The human phantom atomic body composition is based on ORNL phantom details with same material data card and material density of 1.04 and 1.4 g/cm^3 for soft tissues and bone tissue respectively while the lungs and the digestive canal containing air of densities 0.296 and 0.0013 g/cm^3 respectively [9,11].

2.2. Internal dose calculations

Since the total or subtotal thyroidectomized WDTC patients have very low uptake values, thus, low thyroid uptake values for ^{131}I activities are used from 0-5% in this simulation model. Point sources of ^{131}I are fixed inside the patient's abdomen with initial activities from 37 to 74 GBq to resemble the activities that are commonly given to WDTC patients in post-operative radiotherapy.

At start of simulation, all administrated activity of iodine was set inside the abdominal section that was completely eliminated from the abdomen during the first 24 hours post administration. According to the selected iodine uptake values, 30% of the administrated activity migrates to the thyroid gland that is excreted gradually during the next 6 days. Since WDTC patients are instructed to drink liquids and void their bladder all the time, no activity concentrations were set in the phantom's bladder, and all internal gamma radiation exposure to the body organs are caused by activities distributed inside the abdominal cavity and the thyroid gland [1, 11,12].

The average dose rate (resulting from ^{131}I sources inside both the thyroid and abdomen) is estimated for each organ of interest. Then, the cumulative internal absorbed dose is calculated during 6days post administration by constructing time-dose curve and integrating the dose rate under the curve at each organ.

Once the absorbed is obtained, the absorbed dose per administrated activity and equivalent dose are easily calculated using the radiation weighing factor. Since the radiation weighing factor of gamma rays is 1 then the equivalent doses to organs is equal to the absorbed dose that can be assessed to determine the deterministic and stochastic effects based on the International Commission on Radiological Protection (ICRP)118 limits, 2012 [13].

Afterwards, the effective dose to each organ is calculated using the tissue weighing factor according to the equation: $D_e = w_t \times D_{st}$, where, D_e is the effective dose (Sv), D_{st} is the absorbed dose (Gy) and $w_t$is the tissue weighing factor of various organs (table 1) [14].

2.3. Tally specification

The point detector technique and F5 tally are used to calculate the flux and the dose rate at different locations that represent organs surface inside the WDTC patient. In MCNP model, gamma-photon to flux dose conversion factor ANSI are used to calculate the dose rate using dose energy cards (DEn) and dose function cards (DFn). In order to calculate the

Table 1. Tissue weighting factors according to ICRP Publication 128 [14]

Tissue	Tissue weighting factor w_T	Σw_T
Bone-marrow (red), Colon, Lung, Stomach, Breast, Remainder tissues*	0.12	0.72
Gonads	0.08	0.08
Bladder, Oesophagus, Liver, Thyroid	0.04	0.16
Bone surface, Brain, Salivary glands, Skin	0.01	0.04
Total		1.00
* Remainder tissues: Adrenals, Extra thoracic (ET) region, Gall bladder, Heart, Kidneys, Lymphatic nodes, Muscle, Oral mucosa, Pancreas, Prostate, Small intestine, Spleen, Thymus, Uterus/cervix		

gamma tallies, gamma rays of 10^8 photons are used to simulate the transport of gamma photons and accumulate the gamma tallies [15].

3. RESULTS AND DISCUSSION

3.1. Internal dose rate for each organ of interest

The average dose rate around each organ is plotted against time during 6 days post oral administration in which ^{131}I sources are located in abdomen and the thyroid sections, as shown in fig. 3.

3.2. Internal absorbed and equivalent doses for each organ of interest

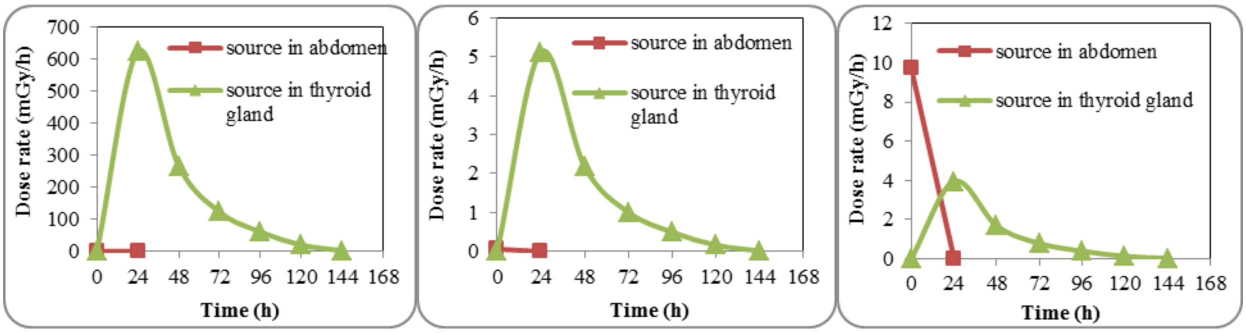
By integrating the area under the dose rate time curves in fig. 3, the absorbed dose delivered to each organ from the activities inside the thyroid gland isobtained. With the same manner, the absorbed dose from the activities inside the abdomen is obtained. The total accumulated absorbed doses are calculated for each organ by summing both the dose acquired by iodine sources in the abdomen and the thyroid gland, as shown in table 2.

From table 2, organs such askidneys and stomach walls gained most of its absorbed dose from the ^{131}I source in the abdomen during the first day post oral administration. On the contrary, organs such as salivary glands, vertebra, brain and thyroid gland were exposed to gamma radiation resulting from the thyroid gland much greater than the abdomen.

It can be observed that, the activities inside the thyroid gland deliver a greater radiation exposure to its surrounding organs than the activities in the abdomen do. However, the effect of the activities resulting from the abdomen during the first day post oral administration should be taken into consideration for estimating the internal absorbed doses delivered to organs as well.

In comparing with records in ICRP 128, 2014 [14] and results in Azghadi EH., Motavalli LR, Hakimabad HM. [9], Oktajianto H, Setiawati E, 2016 [2], the obtained total absorbed doses per administrated activity in the present study were greatly compatible using the same thyroid uptake values.

Few differences with the comparative studies [2,9] may be noticed as two sources were implanted in different locations in our present study (thyroid and abdomen) based on SPECT/CT imaging of patients [4-8] while one source was set in the thyroid gland only in the comparative literatures. Also, the difference may be due to differences in geometry and design of organs.



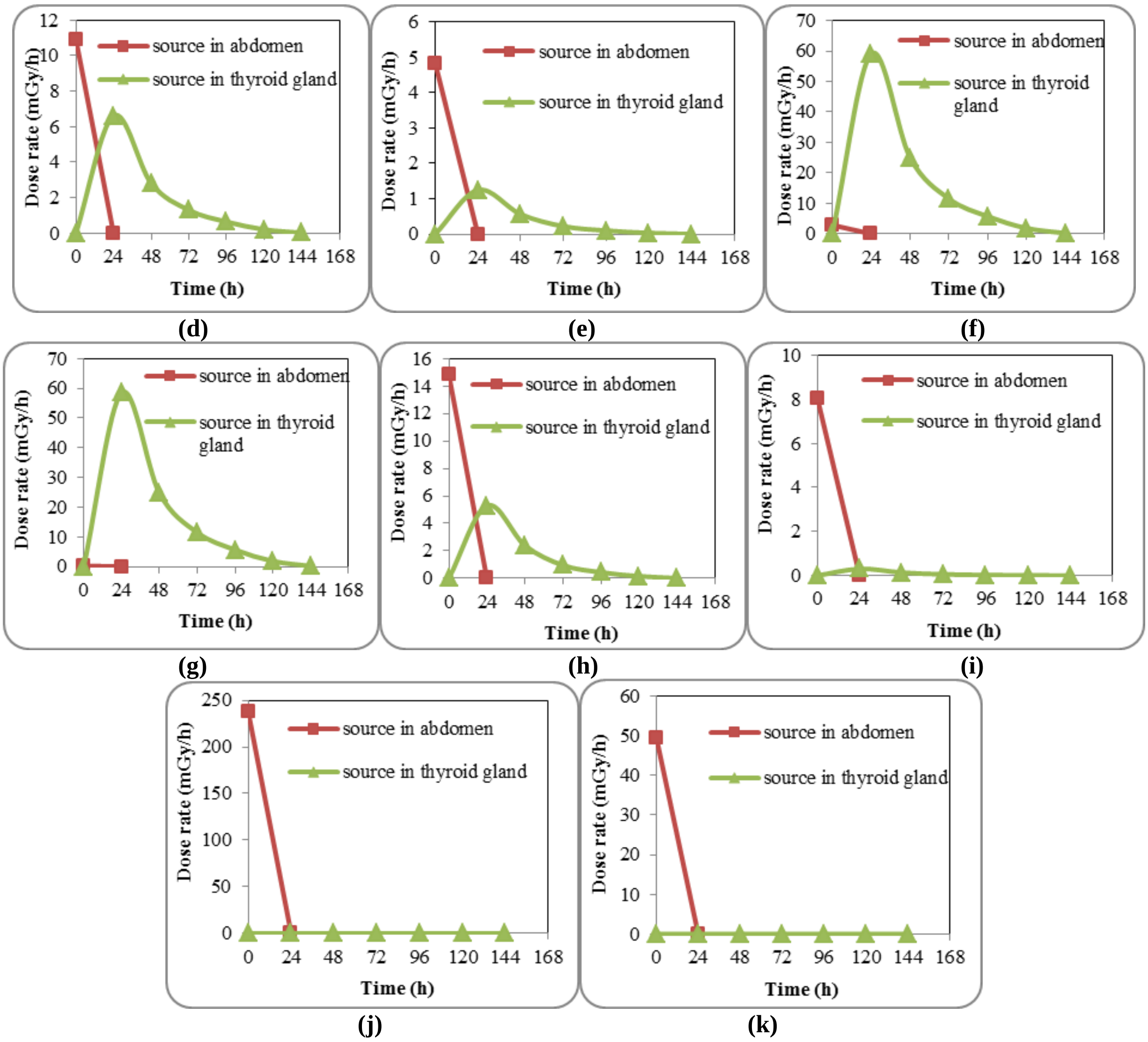


Fig. 3. Internal absorbed dose rate for:(a) Thyroid gland, (b) Brain, (c) Lungs, (d) Heart wall, (e) Thymus, (f) Salivary glands, (g) Cervical vertebra, (h) Dorsal vertebra, (i) Lumbar vertebra, (j) Stomach wall (k) Kidneys

Table 2 Internal average absorbed dose using activitiesfrom 37 to 74GBq

Organ		Absorbed dose (mGy)		
		From thyroid	**From abdomen**	**Total**
Brain		154.078 ± 51.359	0.731 ± 0.244	154.809 ± 51.603
Salivary glands		1774.983 ± 591.661	34.619 ± 11.54	1809.602 ± 603.201
Thyroid		20740.905 ± 6913.635	3824.802 ±1274.934	24565.6875 ±8188.5625
Lungs		118.532 ± 39.511	116.46 ± 38.82	234.992 ± 78.331
Thymus		37.462 ± 12.487	58.05 ± 19.5	95.513 ± 31.838
Heart wall		198.886 ± 66.295	131.078 ± 43.693	329.965 ± 109.988
Vertebra	**Cervical**	1756.817 ± 585.605	3.174± 1.058	1759.99 ± 586.663
	Dorsal	158.691 ± 52.897	177.912 ±9.304	336.603 ± 112.201
	Lumbar	9.081 ± 3.027	96.3 ± 32.1	105.381 ± 35.127
	Total vertebra	1924.589 ± 641.53	277.386 ± 92.462	2201.975 ± 733.992
Kidneys		1.748 ± 0.583	593.127 ± 197.709	594.875 ± 198.293
Stomach wall		3.458 ± 1.153	2849.4 ± 949.8	2852.858 ± 950.953

The gamma exposure resulting from the activities inside the abdomen alone may be considered the lowest potential exposure to internal organs in which thyroid gland uptake values are at minimum degree where no activity distribution is in the thyroid gland.

The total absorbed doses for eachorgan in table 2 are plotted against the administrated activities in fig. 4.

The obtained results from fig. 4 show that, no significant excess of inducing cancer risk or any deterministic effects for WDTC patients using diagnostic activities with radioiodine.

It is observed that the thyroid, stomach walls, salivary glands, kidneys and the vertebra are the most exposed organs at risk during radiotherapy procedures. Meanwhile the brain, heart walls, lungs and thymus were exposed to gamma radiation less than 0.5Gy.

Table 3. Internal average absorbed dose per administrated activity in our studyin comparing with ICRP 128values[14] and other published studies [2,9]

Organ		Average absorbed dose per administrated activity (mGy/MBq)					
		Present Study			ICRP 128 [14]	Hoseinan-Azghadi et al [9]	Hammam Oktajianto and EviSetiawati[2]
		From thyroid	From abdomen	Total			
Brain		$2.776 \pm 0.925*10^{-2}$	$0.013 \pm 0.004*10^{-2}$	$2.789 \pm 0.93*10^{-2}$	$2.1*10^{-2}$	$3.9*10^{-2}$	$5.4*10^{-2}$
Salivary glands		0.32 ± 0.107	$0.624 \pm 0.208*10^{-2}$	0.32604 ± 0.109	0.27	0.142	----
Thyroid		3.737 ± 1.246	0.689 ± 0.23	4.426 ± 1.475	2.9	2.072	----
Lungs		$1.941 \pm 0.647*10^{-2}$	$2.102 \pm 0.701*10^{-2}$	$4.043 \pm 1.348*10^{-2}$	$5.3 *10^{-2}$	$3.4*10^{-2}$	$4.864*10^{-2}$
Thymus		$0.675 \pm 0.225*10^{-2}$	$1.046 \pm 0.349*10^{-2}$	$1.72 \pm 0.573*10^{-2}$	$2.4*10^{-2}$	$1.15*10^{-2}$	----
Heart wall		$3.704 \pm 1.235*10^{-2}$	$2.362 \pm 0.787*10^{-2}$	$6.067 \pm 2.022*10^{-2}$	$6.2*10^{-2}$	$12.3*10^{-2}$	----
Vertebra	Cervical	$31.654 \pm 10.551*10^{-2}$	$0.0571 \pm 0.019*10^{-2}$	$31.711 \pm 10.57*10^{-2}$	----	$24.7*10^{-2}$	$37.84*10^{-2}$
	Dorsal	$2.752 \pm 0.917*10^{-2}$	$3.206 \pm 1.0687*10^{-2}$	$5.958 \pm 1.986*10^{-2}$	----	----	----
	Lumbar	$0.153 \pm 0.0511*10^{-2}$	$1.734 \pm 0.578*10^{-2}$	$1.887 \pm 0.629*10^{-2}$	----	----	----
	Totalvertebra	$33.997 \pm 11.332*10^{-2}$	$4.998 \pm 1.666*10^{-2}$	$41.281 \pm 13.76*10^{-2}$	----	----	----
Kidneys		$3.1 \pm 1.033*10^{-4}$	$10.687 \pm 3.562*10^{-2}$	$10.718 \pm 3.573*10^{-2}$	$2.7*10^{-2}$	----	----
Stomach wall		$6.23 \pm 2.0767*10^{-4}$	$5.134 \pm 1.711*10^{-1}$	$5.14 \pm 1.713*10^{-1}$	$8.7*10^{-1}$	----	----

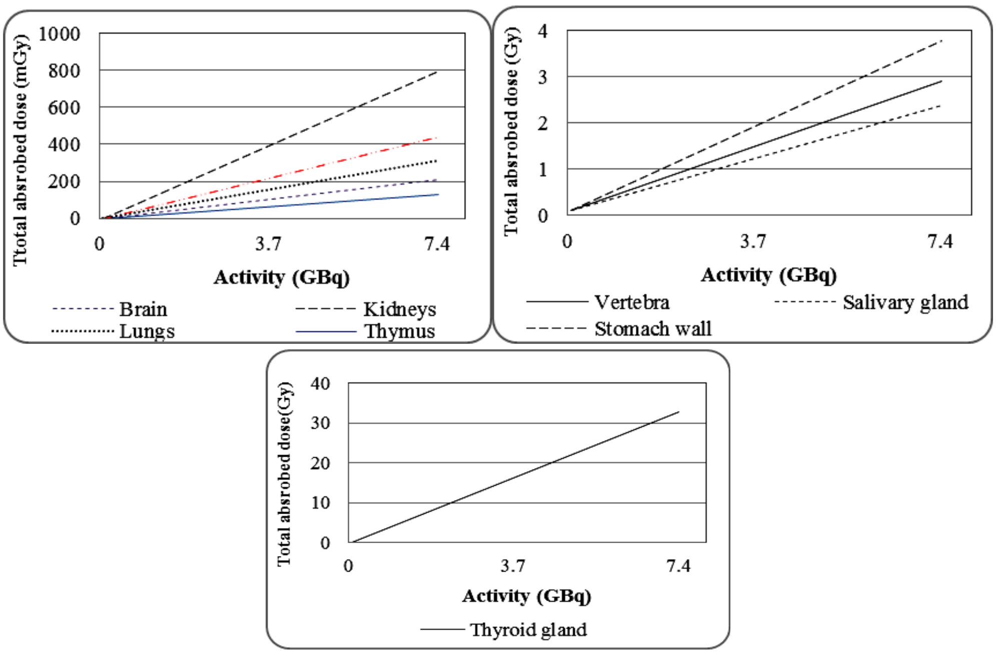
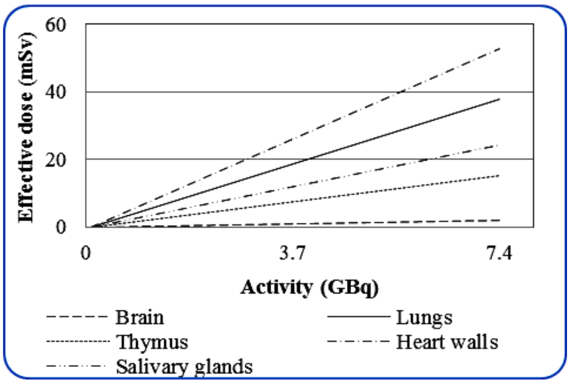


Fig. 4. Total absorbed dose of critical organs against administrated activityfor:(a) Brain,lungs, heart walls, thymus and kidneys(b) Salivary glands, stomach walls, and cervical vertebra(c) Thyroid gland

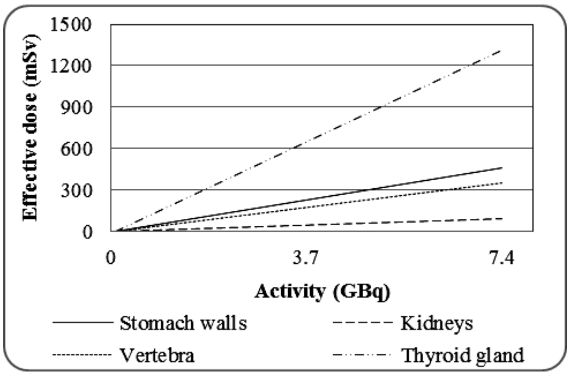
Based on ICRP pub.118, 2012 [13], and NCS report, 2016 [16], radiation effects such as mental cognitive defects, cardiovascular diseases, acute pneumonitis, renal failure, mucosa lining loss won't probably be seen. Also, cancer incidences in the brain, thymus, salivary glands, and lungs are less likely predicted. However, the bone marrow threshold value is reached (0.5 Gy) in which hematopoietic disturbances may occur to patients. Also, the risk of thyroid cancer incidence is significant; however, high absorbed doses are mainly prescribed to kill all cells in thyroid tissue during radiotherapy procedures.

3.3. Internal effective dose during whole body diagnosis and radiotherapy procedures

The average effective doses are calculated by multiplying the average absorbed doses by the tissue weighing factor of each organ in table 1.



(a)



(b)

Fig. 5 Effective dose to critical organs against administrated activityfor(a) the brain, the lungs, the heart walls, the thymus and salivary glands (b) the kidneys, the stomach walls, and vertebra, and the thyroid gland

The results obtained in fig. 4and 5 show that, the thyroid gland and the stomach walls are the most exposed organs to the gamma radiation that can be referred to self-irradiation from its contained activities. Also, the vertebra is highly exposed to gamma radiation due to its location behind the thyroid gland.

Meanwhile, the least organs that exposed to gamma radiation are the brain and the salivary gland due to the skull tissue density and its atomic composition that attenuate the radiation by higher factor than other soft tissue organs such as thymus, lung and heart wall [2].

CONCLUSION

Not only the ^{131}I activity distributed in the thyroid gland can deliver high radiation doses to patient's organs, but also, the time interval in which ^{131}I activities remain in the abdomen should be taken into account during 1st day post-administration for internal dosimetry of organs as the activity distributed in abdomen delivers significant effective doses to patient's organs. The thyroid gland, stomach walls and vertebra are the most organs at risk either by self-irradiation from its contained activities in case of thyroid and stomach walls or from its location near the thyroid gland(in case of vertebra).Radio-iodine therapeutic activities may cause some radiation effect such as hematopoietic disturbance and thyroid cancer incidence while other radiation effects such as mental cognitive defects, cardiovascular diseases or cancer incidences in brain, salivary glands lungs or thymus may not be probably observed. Thus, it's recommended to use long term treatment plan with therapeutic activities lower than 55.5 GBq(as possible) to avoid further effects of gamma radiation exposure. Meanwhile, no evidence that, diagnostic activities may cause any deterministic or stochastic radiation effect to body organs was found during the investigation.

REFERNCES

[1] Emad El-din MM, Massoud E, El-Agamawi AY, Kany AM, Ezz El-din MR. Radiation dosimetry

for thyroid cancer patients and validation using 3D printing phantoms. Int. J. Nuclear Energy Science and Technology (IJNEST), 2020: 14 (4): 339-345.

[2] Oktajianto H, Setiawati E. Monte carlo simulation in internal radiotherapy of thyroid cancer.International Journal of Engineering Technologies and Management Research. September 2016; 3: 16-24.

[3] Feng PJH, Ouyang W, Wu J, Chen P, Wang J, Sun Y, Xian J, Huang L.Radiation dose rates of differentiated thyroid cancer patients after 131 I therapy. Radiation and Environmental Biophysics. 2018; 57:169–172.

[4] Mekkawy NM, Mohamed M. The role of ^{131}I SPECT-CT as a diagnostic tool in management of patients with differentiated thyroid cancer.Egyptian J. Nucl. Med. 2017; 15(2): 73,74.

[5] Palaniswamy SS, Subramanyam P. Unusual sites of metastatic and benign I-131 uptake in patients with differentiated thyroid carcinoma.Indian Journal of Endocrinology and Metabolism. 2018; 22(6): 741-749.

[6] Semirgin SU. Usefulness of SPECT/CT imaging in the management of patients with differentiated thyroid carcinoma.Erciyes Med J. 2020; 42(1): 51-52.

[7] Spanu A, Nuvoli S, Marongiu A, Gelo I, Mele L,Piras B,Madeddu G.Neck lymph node metastasis detection in patients with differentiated thyroid carcinoma (DTC) in long-term follow-up: a 131I-SPECT/CT stud.BMC Cancer. 2020; 20(239): 5-7.

[8] Huang CC, Lin YH, Kittipayak S, Hwua YS, Wang SY, Pan LK. Biokinetic model of radioiodine I-131 in nine thyroid cancer patients subjected to in-vivo gamma camera scanning: A simplified five compartmental model.PLoSONE. 2020; 15(5) : 5-10. https://doi.org/10.1371 /journal.pone.0232480.

[9]Azghadi EH., Motavalli LR,Hakimabad HM.Internal dosimetry estimates using voxelized reference phantoms for thyroid agents. Journal of Radiation Research. 2014; 55: 407-422.

[10] Beşli LU, Demir M.Radiation dosimetry in thyroid cancer patients. Radiation Dosimetry in Thyroid Cancer Journal; 2016; 230-232.

[11]Krstic D., Nikezic D.Input files with ORNL-mathematical phantoms of the human body for MCNP-4B" In: Computer Physics Communications. 2007; 176:33-37.

[12]Özdal A, Erselcan T, Özdemir Ö, Özgüven Y, Silov G, Erdoğan Z. Evaluation of the physical and biological dosimetry methods in iodine-131-treated patients.World Journal of Nuclear Medicine journal. December 2018; 17(4): 4-6. http://www.wjnm.org.

[13] International Commission on Radiological Protection (ICRP) Annals. ICRP Statement on Tissue Reactions and Early and Late Effects of Radiation in Normal Tissues and Organs-Threshold Doses for Tissue Reactions in a Radiation Protection Context. ICRP Publication 118, Oxford, Pergamon Press. 2012; 41: 300-305.

[14]International Commission on Radiological Protection (ICRP) Annals. Radiation dose to patients from radiopharmaceuticals: a compendium of current information related to frequently used substances.ICRP Publication 128, Oxford, Pergamon Press. 2014:30, 247-280, 300-304.

[15] Emad El-din MM, Mahmoud RMM, Eid I, Ezz El-din MR, Rizk RA. Radiation dose rate assessment around patients in PET/CT units. Int. J. Nuclear Energy Science and Technology. 2018; 12 (1): 36.

[16] Netherlands Commission on Radiation Dosimetry Subcommittee Radiation Doses & Risk Estimation forMedical Diagnostics and Research (NCS). Human Exposure to Ionizing Radiation for Clinical and Research Purposes: Radiation Dose & Risk Estimates. NCS reports. 2016: 9-14.http://radiationdosimetry.org

[17] Asl RG, Sabbaghi1 R, Ahangari1 HT, Hejazi1 P, Foroutan M. Prediction of Absorbed Dose to normal organs with endocrine tumors for I-131 by use of ^{99m}TC Single Photon Emission Computed Tomography/ Computed Tomography and Geant4 application for tomographic emission simulation. Medknow Indian Journal of Nuclear Medicine. 2021: 36, 3, 273-276.

[18] Andersson M,Mattsson S.Improved patient dosimetry at radioiodine therapy by combining the ICRP compartment model and the EANM pre-therapeutic standard procedure for benign thyroid diseases. Frontiers in Endocrinology. 2021: 12, 1-6. http://frontiersin.org

قياس الجرعات الاشعاعية الداخلية لمرضى سرطان الغدة الدرقية باستخدام كود المحاكاة مونت كارلو

ماجد محمد عماد الدين (1) ، أيمان مسعود أحمد (2) ، أحمد يسرى العجماوى (3) ، عمرو محمد أسماعيل كانى (4)، محمد رضا عز الدين (1)

[1] قسم الوقاية الإشعاعية، هيئة الرقابة النووية والإشعاعية، القاهره ، مصر
[2] جامعه جده الدولية ، جده، السعودية
[3] كلية الطب، قسم علاج الاورام ، جامعه الازهر الشريف ، القاهره ، مصر
[4] كلية العلوم ، قسم الفيزياء ، جامعه الأزهر الشريف ، القاهره ، مصر

الملخص:

إن الأعضاء الداخلية لمرضى سرطان الغدة الدرقية تكون معرضه لجرعات إشعاعية مرتفعه خلال عمليات التشخيص والعلاج الاشعاعى باستخدام نظير ماده اليود-131وهو مايستدعى دراسة وتقييم تلك الجرعات الداخلية لتحديد مستوى التأثيرات الإشعاعية العشوائية والحتمية المحتملة للمرضى.ولذلك فإن الهدف من الدراسة هو قياس الجرعات الإشعاعية الداخلية المكتسبة والفعالة لأحد عشر عضوا داخلياً لأجسام مرضى سرطان الغدة الدرقية المتمايز لمده 6 أيام من استخدام جرعات إشعاعية تشخيصية وعلاجية من نظير ماده اليود-131.باستخدام نموذج المحاكاة مونت كارلو تم حساب الجرعة الإشعاعية الفعالة للأعضاء الداخلية حيث تم تصميم النموذج الحسابي لأجسام المرضى مع الأخذ فى الاعتبار عوامل مثل كتله وحجم ومكان الاعضاء الداخلية بناءً على بيانات صور الاشعه المقطعية للمرضى والنموذج الحسابى ORNL حيث تم تثبيت الانشطه الاشعاعية لنظير ماده اليود-131 داخل الغده الدرقية وداخل المعده.توصلت نتائج الدراسه الى انه وبالرغم من عدم إحتماليه ظهور اى اعراض جانبيه ناتجه عن التعرض للاشعاع خلال عملية التشخيص الاشعاعى، فإنه قد تظهر بعض الاعراض الحتميه أثناء عمليات العلاج الإشعاعى باستخدام الانشطه الاشعاعية لماده اليود-131.