

# Ratios of internal doses deposited in different organs to the whole body when such organ is adopted as source of $^{18}\text{F}$ -fluorodeoxyglucose, a Monte Carlo Geant4 study on a male medical internal radiation dose phantom

## ABSTRACT

In the present study, the last stable version of Monte Carlo Geant4 code known as Geant4.10.3 has been used for measuring internal dose ratios to the whole body for about 40 organs. This, by performing a Monte Carlo model of  $^{18}\text{F}$ -fluorodeoxyglucose ( $^{18}\text{F}$ -FDG) inside different organs of medical internal radiation dose male phantom, mimics a human male adult of 70 kg. A dedicated Geant4 user code has been developed in the top of one offered by Geant4 Monte Carlo toolkit and so-called human phantom. Several Monte Carlo simulations have been carried out, and in each of them, we have taken up such organ as source of  $^{18}\text{F}$ -FDG with a small amount of radioactivity, evenly distributed across its volume, and we measure ratios of absorbed doses deposited in organs to the whole body. The results have shown that there are radiation dose contributions from surrounding organs and their gravities are so variable; some organs have near-local character; thus, almost all radiations are locally deposited, which generally do not affect surrounding ones mainly including adrenals, thyroid, clavicles, thymus, testes, bladder, pancreas, scapula and upper spine; whereas, it is not the case for many other organs in which radiation doses are deposited outside of their parent volumes. In addition, absorbed doses in some organs that have high-tissue weighting factors, namely colon, lungs, stomach, bladder, thyroid, and liver are seriously affected by radioactivity of surrounding muscle organs, the gravity of such affectation is mainly growth when a patient is identified as having hyperglycemia or undergoing a hard physical activity.

**Keywords:** Geant4, internal dosimetry, medical internal radiation dose phantom, Monte Carlo

## INTRODUCTION

Today, nuclear medical imaging techniques that employ radiopharmaceuticals such as positron emission tomography (PET) scan and gamma camera are widely used around the world in many hospitals as in medical centers, and their use continues to increase sharply. Historically, when they first appeared, they brought out an interesting donation in diagnosis as in therapy of cancer. Since these techniques use radiopharmaceutical products which contain radioactive materials, the radiation protection area is a subject of many scientific researchers around the world which mainly attempt to study how to protect patient from biologic effect of ionizing radiations and at the same time obtaining a good diagnostic image quality.

During a nuclear fluorodeoxyglucose PET/computed tomography (FDG PET/CT) scan, the patient is irradiated by two distinct sources of radiations: external and internal. The

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dose absorbed by patient from an external radiation source comes from the CT scanner. This last is coupled to the PET scanner to well-located regions where there are probably considerable hyperfixations of the radiopharmaceutical, this by producing a fusion image in which metabolic image is superimposed on anatomical one. Whereas, the internal dose results from the intravenous injection of patient by a given radiopharmaceutical product. Through this article, we will focus on this internal contribution of radiation absorbed dose.

The accurate knowledge of doses absorbed by organs of patient injected by such radiopharmaceutical product is essential to avoid harmful effects of immediate ionizing radiation such as burns, fibrosis and cataract, and long-term effects such as cancers and leukemias. Today, these absorbed doses cannot be perfectly known; but instead, they can only be well estimated because there are many factors which limit their knowledge including heterogeneity character of the radioactivity distributed into tissue level and misunderstanding of cumulating radioactivity in a particular organ. The International Commission on Radiological Protection (ICRP) models which are based on the biokinetic data of different radiopharmaceuticals allow one to estimate radiation dose absorbed by each organ and also for effective dose received by a whole body; this is according to the radioactive activity injected and also depends on the patient's age range (adult, 15-year-old child, 10-year-old child, 5-year-old child, and 1-year-old child). For many years, some commercial and also free software have been developed to facilitate the calculation of patient dosimetric data, thereby following the ICRP models, namely MIRDOSE,<sup>[1]</sup> RADAR,<sup>[2]</sup> OLINDA/EXM,<sup>[3]</sup> DOSEFX,<sup>[4]</sup> and recently RadioPharmaDose.<sup>[5]</sup> However, the calculation of patient dosimetric data performed by these software does not take into account many factors such as the weight of the patient, his state of health, and other morphological and physiological factors.

To properly estimate internal dose absorbed by different structures assembling the body of a patient administered by a radiopharmaceutical, three different levels of structure must be taken into account, namely the organ, the tissue, and the cell. In this article, we focus on the level of the organ because we are interested in the field of radiation protection, while the other two levels are the subjects of metabolic radiotherapy. Since the knowing of the absorbed dose received by a particular patient is so more complicated task, that demand to invest anatomical information offered by CT scan and metabolic one retrieved from PET scan, we just focus on exploiting

anatomical information offered by a medical internal radiation dose (MIRD) male phantom mimicking a human male adult of about 70 Kg. In this research paper, we use Monte Carlo Geant4 code which is a powerful tool for medical physics applications as it is well showed by many valuable works in radiotherapy,<sup>[6-8]</sup> brachytherapy,<sup>[9]</sup> and nuclear medicine.<sup>[10]</sup>

## MATERIALS AND METHODS

The last known version of Geant4 is a software (version 10.3, developed by the Geant4 Collaboration, toolkit, Geant 4) has been used to perform this work. A Geant4-based user code has been developed in the top of a Geant4 example called human phantom; this aims to calculate internal doses deposited in thirty eight organs constituting the male MIRD phantom as shown in Figure 1.

Regarding the physics of the problem, positron is used as primary particle for mimicking FDG-F18 radiopharmaceutical product; the Geant4 physics model named emstandard\_opt2 has been used in this work because it is recommended for modeling the transport of photons and charged particles for medical physics purpose. Going more into program details, thirty-eight Monte Carlo subsimulations have been carried out in Ubuntu 14 Linux operating system installed on a Lenovo Workstation that have 12 CPU cores running at speed of 3 GHz. In each of Monte Carlo simulation considered in this work, we adopt such organ as a source of <sup>18</sup>F-FDG, and then, we calculate ratio of internal dose deposited in each organ to the whole body. To ensure a uniform distribution of positrons across such organ volume, three-dimensional positron positions are loaded from a prepared data

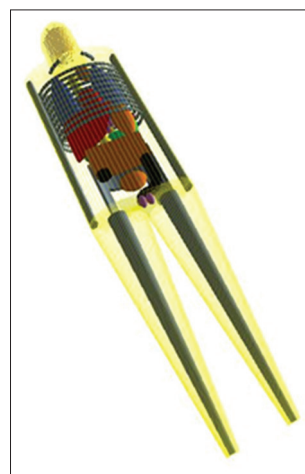


Figure 1: Monte Carlo Geant4 model of male medical internal radiation dose phantom

file having the same name as the target organ with an extension of “.dat” and containing all points that belong to the organ volume. An activity ( $A_0 = 6 \text{ Bq}$ ) has been considered in each of Monte Carlo simulation, which finally leads to simulate about  $6 \times 10^4$  positrons (taken into account that  $\lambda_{F-18} = 1.05241 \times 10^{-4}$  and  $N_{\text{positrons}} = A_0/\lambda_{F-18}$ ). Regarding F-18 decay physics process, positrons are emitted by F-18 with a given kinetic energy, and they are not always at rest during their annihilation with electrons of human tissues. The energetic distribution of positrons has been assumed to fit Rayleigh distribution where the maximum positron energy was fixed to the one corresponding to  $^{18}\text{F}$  decay, numerically, 634 KeV. The Rayleigh distribution shown in Figure 2 has been constructed using the following formula:

$$\text{Energy}_{\text{positron}} (\text{MeV}) = P1 \times \sqrt{-2x \log(1-P2)}$$

Whereas  $P1 = 0.2 \text{ MeV}$  and  $P2$  is a random number between 0 et 1.

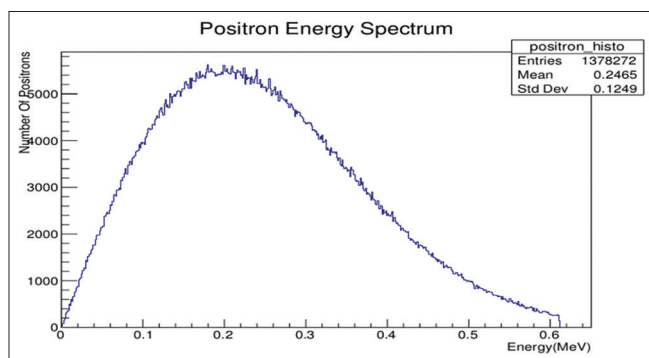


Figure 2: Energy spectrum for  $^{18}\text{F}$  positron emission produced by GNU-Root data analyzing

## RESULTS

Thirty-eight Monte Carlo Geant4 simulations have been considered in this work. The average CPU time spent by these Monte Carlo simulations was about 276 min for an amount of  $^{18}\text{F}$ -FDG of 6 Bq, which is equivalent to take about  $6 \times 10^4$  positrons as primary events. The given results show ratios of absorbed doses in all organs to the whole body (RDWB) in a case in which a particular organ is presented as a source of  $^{18}\text{F}$ -FDG. The results are presented in Tables 1-38. The values those are styled in bold underlined font in Tables 1-38 are corresponding to ones of organs which are taken as sources of FDG-F18.

## DISCUSSION

We start this discussion by analyzing the ratio of internal dose to the whole body locally deposited in such organ chosen as source of  $^{18}\text{F}$ -FDG. With a glance, at the data in Tables 1-38, it can be seen that internal doses are not entirely locally deposited in organs in which the  $^{18}\text{F}$ -FDG came from; however, they are extended to neighboring organs. The gravity of this local dose deposition varies from one organ to another and depends on tissue physics and physiological characteristics on the one side and physics proprieties of radioactive substance on the other side. Indeed, the results have shown that organs in which almost ratios of the radiation doses are locally deposited are in the first place as follows: right adrenal, left adrenal, thyroid, left clavicle, right clavicle, thymus, right testis, bladder, left testis, right scapula, pancreas, left scapula, and upper spine, with values, respectively, of 99.04%, 98.94%, 98.89%, 98.67%, 98.17%, 98.01%, 96.05%, 95.71%, 94.96%, 92.88%, 92.47%, 92.03%, and 90.41%. With regard to radiation emergence, these organs are seemed to be less threatening to surrounding ones as the radiation doses

Table 1: RDWB values when brain is adopted as source of  $^{18}\text{F}$ -fluorodeoxyglucose

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	<b>65.76</b>	Lower large intestine	0.24	Right scapula	0.48
Head	2.15	Male genitalia	1.87	Right testis	0.43
Heart	0.2	Middle lower spine	0.41	Skull	11.62
Left adrenal	0.01	Pancreas	0.17	Small intestine	0.17
Left arm bone	0.28	Pelvis	0.28	Spleen	0.33
Left clavicle	1.28	Rib cage	0.29	Stomach	0.18
Left kidney	0.29	Right adrenal	0.30	Thymus	0.49
Left leg	1.8	Right arm bone	0.23	Thyroid	1.59
Left leg bone	0.65	Right clavicle	0.80	Trunk	0.41
Left lung	0.33	Right kidney	0.23	Upper large intestine	0.18
Left scapula	0.62	Right leg	0.96	Upper spine	2.94
Left testis	0.72	Right leg bone	0.54	Urinary bladder	0.23
Liver	0.18	Right lung	0.37		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 2: RDWB values when head is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	3.78	Lower large intestine	0.27	Right scapula	0.98
Head	<b>22.77</b>	Male genitalia	2.87	Right testis	0.60
Heart	0.62	Middle lower spine	1.54	Skull	7.87
Left adrenal	0.03	Pancreas	0.65	Small intestine	0.28
Left arm bone	0.39	Pelvis	0.31	Spleen	0.44
Left clavicle	3.74	Rib cage	0.68	Stomach	0.28
Left kidney	0.32	Right adrenal	0.63	Thymus	2.47
Left leg	2.09	Right arm bone	0.39	Thyroid	18.50
Left leg bone	0.74	Right clavicle	2.72	Trunk	0.83
Left lung	1.05	Right kidney	0.42	Upper large intestine	0.23
Left scapula	1.17	Right leg	1.03	Upper spine	16.03
Left testis	0.54	Right leg bone	0.56	Urinary bladder	0.8
Liver	0.28	Right lung	1.12		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 3: RDWB values when heart is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.14	Lower large intestine	0.15	Right scapula	0.58
Head	0.25	Male genitalia	0.77	Right testis	0.39
Heart	<b>78.19</b>	Middle lower spine	1.48	Skull	0.18
Left adrenal	0.93	Pancreas	0.99	Small intestine	0.19
Left arm bone	0.24	Pelvis	0.17	Spleen	0.61
Left clavicle	0.47	Rib cage	0.54	Stomach	0.67
Left kidney	0.48	Right adrenal	1.22	Thymus	1.79
Left leg	0.67	Right arm bone	0.25	Thyroid	0.40
Left leg bone	0.26	Right clavicle	0.27	Trunk	0.60
Left lung	1.94	Right kidney	0.46	Upper large intestine	0.21
Left scapula	0.54	Right leg	0.34	Upper spine	0.21
Left testis	0.38	Right leg bone	0.19	Urinary bladder	0.15
Liver	0.99	Right lung	1.68		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 4: RDWB values when left adrenal is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.01	Lower large intestine	0.00	Right scapula	0.00
Head	0.01	Male genitalia	0.01	Right testis	0.01
Heart	0.04	Middle lower SPINE	0.10	Skull	0.01
Left adrenal	<b>98.94</b>	Pancreas	0.12	Small intestine	0.10
Left arm bone	0.01	Pelvis	0.01	Spleen	0.10
Left clavicle	0.02	Rib cage	0.02	Stomach	0.04
Left kidney	0.16	Right adrenal	0.09	Thymus	0.01
Left leg	0.01	Right arm bone	0.01	Thyroid	0.02
Left leg bone	0.01	Right clavicle	0.01	Trunk	0.02
Left lung	0.06	Right kidney	0.04	Upper large intestine	0.01
Left scapula	0.02	Right leg	0.00	Upper spine	0.01
Left testis	0.00	Right leg bone	0.02	Urinary bladder	0.00
Liver	0.03	Right lung	0.03		

RDWB: Ratios of absorbed doses in all organs to the whole body

seem to have nearly a local character. It should emphasize here, that, ratios of absorbed doses in the right and left sides of a given organ are not quite identical; this is due to the fact that the human body members are not perfectly

symmetrical in terms of position, shape, and number. In the second place, we found the following ones: right kidney, left kidney, spleen, lower large intestine, heart, stomach, and upper large intestine, with RDWB values, respectively,

**Table 5: RDWB values when left arm bone is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.41	Lower large intestine	1.18	Right scapula	0.38
Head	0.62	Male genitalia	2.17	Right testis	0.74
Heart	0.65	Middle lower spine	0.76	Skull	0.51
Left adrenal	0.37	Pancreas	1.54	Small intestine	0.79
Left arm bone	<b>66.74</b>	Pelvis	1.01	Spleen	2.38
Left clavicle	0.46	Rib cage	1.07	Stomach	1.47
Left kidney	1.16	Right adrenal	0.34	Thymus	0.87
Left leg	1.85	Right arm bone	0.13	Thyroid	0.10
Left leg bone	0.80	Right clavicle	0.15	Trunk	1.08
Left lung	1.80	Right kidney	0.61	Upper large intestine	0.51
Left scapula	2.72	Right leg	1.16	Upper spine	0.43
Left testis	1.13	Right leg bone	0.73	Urinary bladder	0.41
Liver	0.40	Right lung	0.37		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 6: RDWB values when left clavicle is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.05	Lower large intestine	0.01	Right scapula	0.01
Head	0.08	Male genitalia	0.05	Right testis	0.03
Heart	0.02	Middle lower spine	0.03	Skull	0.06
Left adrenal	0.01	Pancreas	0.01	Small intestine	0.00
Left arm bone	0.02	Pelvis	0.00	Spleen	0.01
Left clavicle	<b>98.67</b>	Rib cage	0.04	Stomach	0.01
Left kidney	0.00	Right adrenal	0.00	Thymus	0.13
Left leg	0.07	Right arm bone	0.01	Thyroid	0.24
Left leg bone	0.03	Right clavicle	0.07	Trunk	0.04
Left lung	0.09	Right kidney	0.00	Upper large intestine	0.00
Left scapula	0.05	Right leg	0.03	Upper spine	0.06
Left testis	0.02	Right leg bone	0.02	Urinary bladder	0.00
Liver	0.01	Right lung	0.02		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 7: RDWB values when left kidney is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.08	Lower large intestine	0.18	Right scapula	0.08
Head	0.12	Male genitalia	0.37	Right testis	0.11
Heart	0.19	Middle lower spine	0.85	Skull	0.08
Left adrenal	2.89	Pancreas	1.26	Small intestine	0.42
Left arm bone	0.18	Pelvis	0.21	Spleen	2.20
Left clavicle	0.04	Rib cage	0.14	Stomach	0.7
Left kidney	<b>86.25</b>	Right adrenal	0.50	Thymus	0.03
Left leg	0.30	Right arm bone	0.06	Thyroid	0.08
Left leg bone	0.10	Right clavicle	0.07	Trunk	0.29
Left lung	0.23	Right kidney	0.50	Upper large intestine	0.40
Left scapula	0.11	Right leg	0.13	Upper spine	0.11
Left testis	0.06	Right leg bone	0.09	Urinary bladder	0.15
Liver	0.28	Right lung	0.13		

RDWB: Ratios of absorbed doses in all organs to the whole body

of 88.54%, 86.25%, 83.64%, 78.49%, 78.19%, 74.39%, and 73.63%. The remained organs classified in the third place are presented with values between 70% and 30%, beginning

with male genitalia (value of 68.56%) and ending with ribcage (38.57%). Finally, muscle organs seem to have an opposed situation; thus, quasi total absorbed doses are

**Table 8: RDWB values when left leg is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.67	Lower large intestine	2.16	Right scapula	0.70
Head	1.22	Male genitalia	9.89	Right testis	6.43
Heart	0.57	Middle lower spine	0.73	Skull	0.88
Left adrenal	1.59	Pancreas	0.78	Small intestine	0.74
Left arm bone	0.66	Pelvis	1.82	Spleen	0.61
Left clavicle	1.37	Rib cage	0.45	Stomach	0.42
Left kidney	1.16	Right adrenal	1.81	Thymus	0.39
Left leg	<b>27.31</b>	Right arm bone	0.75	Thyroid	0.10
Left leg bone	11.17	Right clavicle	0.95	Trunk	1.23
Left lung	0.74	Right kidney	1.03	Upper large intestine	0.62
Left scapula	0.74	Right leg	4.07	Upper spine	0.52
Left testis	8.34	Right leg bone	2.86	Urinary bladder	3.44
Liver	0.49	Right lung	0.57		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 9: RDWB values when left leg bone is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.44	Lower large intestine	0.99	Right scapula	0.62
Head	0.77	Male genitalia	4.65	Right testis	2.27
Heart	0.26	Middle lower spine	0.42	Skull	0.53
Left adrenal	1.03	Pancreas	0.16	Small intestine	0.45
Left arm bone	0.31	Pelvis	1.06	Spleen	0.28
Left clavicle	0.13	Rib cage	0.305	Stomach	0.38
Left kidney	0.59	Right adrenal	0.01	Thymus	0.32
Left leg	8.13	Right arm bone	0.44	Thyroid	0.35
Left leg bone	<b>63.24</b>	Right clavicle	0.97	Trunk	0.70
Left lung	0.29	Right kidney	0.54	Upper large intestine	0.39
Left scapula	0.40	Right leg	2.03	Upper spine	0.50
Left testis	2.96	Right leg bone	1.45	Urinary bladder	1.04
Liver	0.27	Right lung	0.29		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 10: RDWB values when left lung is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.23	Lower large intestine	0.19	Right scapula	0.51
Head	0.40	Male genitalia	1.02	Right testis	0.45
Heart	2.92	Middle lower spine	1.46	Skull	0.34
Left adrenal	1.78	Pancreas	1.49	Small intestine	0.22
Left arm bone	0.82	Pelvis	0.21	Spleen	1.45
Left clavicle	1.73	Rib cage	1.00	Stomach	1.20
Left kidney	0.72	Right adrenal	1.46	Thymus	2.22
Left leg	0.96	Right arm bone	0.17	Thyroid	0.79
Left leg bone	0.38	Right clavicle	0.38	Trunk	0.81
Left lung	<b>68.12</b>	Right kidney	0.39	Upper large intestine	0.20
Left scapula	2.87	Right leg	0.45	Upper spine	0.57
Left testis	0.35	Right leg bone	0.26	Urinary bladder	0.23
Liver	0.49	Right lung	0.77		

RDWB: Ratios of absorbed doses in all organs to the whole body

deposited outside volumes in which they were created. Indeed, results have shown that trunk has only value of 4.22%, left leg 27.31%, right leg 25.39%, and head 22.77%.

We continue this discussion by addressing internal dose contributions brought by surrounding organs in raising irradiation of the organ in question; organs with contributions



**Table 11: RDWB values when left scapula is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.13	Lower large intestine	0.06	Right scapula	0.11
Head	0.20	Male genitalia	0.47	Right testis	0.31
Heart	0.24	Middle lower spine	0.25	Skull	0.16
Left adrenal	0.41	Pancreas	0.13	Small intestine	0.05
Left arm bone	0.50	Pelvis	0.05	Spleen	0.19
Left clavicle	0.40	Rib cage	0.67	Stomach	0.12
Left kidney	0.10	Right adrenal	0.14	Thymus	0.24
Left leg	0.38	Right arm bone	0.05	Thyroid	0.09
Left leg bone	0.14	Right clavicle	0.10	Trunk	0.23
Left lung	1.01	Right kidney	0.04	Upper large intestine	0.04
Left scapula	<b>92.03</b>	Right leg	0.17	Upper spine	0.28
Left testis	0.20	Right leg bone	0.11	Urinary bladder	0.06
Liver	0.07	Right lung	0.12		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 12: RDWB values when left testis is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.02	Lower large intestine	0.09	Right scapula	0.00
Head	0.02	Male genitalia	1.77	Right testis	2.43
Heart	0.01	Middle lower spine	0.02	Skull	0.02
Left adrenal	0.04	Pancreas	0.01	Small intestine	0.02
Left arm bone	0.01	Pelvis	0.03	Spleen	0.02
Left clavicle	0.01	Rib cage	0.01	Stomach	0.01
Left kidney	0.03	Right adrenal	0.03	Thymus	0.00
Left leg	0.07	Right arm bone	0.01	Thyroid	0.00
Left leg bone	0.04	Right clavicle	0.01	Trunk	0.03
Left lung	0.01	Right kidney	0.03	Upper large intestine	0.02
Left scapula	0.02	Right leg	0.04	Upper spine	0.01
Left testis	<b>94.96</b>	Right leg bone	0.03	Urinary bladder	0.11
Liver	0.01	Right lung	0.01		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 13: RDWB values when liver is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.22	Lower large intestine	0.48	Right scapula	0.88
Head	0.44	Male genitalia	2.00	Right testis	0.37
Heart	2.64	Middle lower spine	1.94	Skull	0.32
Left adrenal	2.27	Pancreas	4.21	Small intestine	1.50
Left arm bone	0.32	Pelvis	0.71	Spleen	1.08
Left clavicle	0.06	Rib cage	0.98	Stomach	2.21
Left kidney	1.71	Right adrenal	5.51	Thymus	0.70
Left leg	1.52	Right arm bone	1.12	Thyroid	0.16
Left leg bone	0.62	Right clavicle	0.36	Trunk	1.23
Left lung	0.94	Right kidney	4.32	Upper large intestine	2.15
Left scapula	0.48	Right leg	0.81	Upper spine	0.42
Left testis	0.64	Right leg bone	0.46	Urinary bladder	0.40
Liver	<b>51.43</b>	Right lung	2.39		

RDWB: Ratios of absorbed doses in all organs to the whole body

greater or equal than 2% have been considered in this discussion. We start this part of the discussion by taking into consideration organs that have the largest tissue weighting factors and we finish by ones having the smallest ones.

Indeed, the colon, lungs, and stomach are among the most radiosensitive organs with a value of 0.12, this, according to ICRP 103 (ICRP 2007). Regarding first organ, total absorbed dose seems to be relatively influenced by latent radioactivities

**Table 14: RDWB values when lower large intestine is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.16	Lower large intestine	<b>78.49</b>	Right scapula	0.14
Head	0.25	Male genitalia	2.73	Right testis	2.20
Heart	0.06	Middle lower spine	0.23	Skull	0.19
Left adrenal	0.47	Pancreas	0.19	Small intestine	1.82
Left arm bone	0.38	Pelvis	1.47	Spleen	0.22
Left clavicle	0.10	Rib cage	0.09	Stomach	0.35
Left kidney	0.34	Right adrenal	0.01	Thymus	0.08
Left leg	0.87	Right arm bone	0.12	Thyroid	0.10
Left leg bone	0.43	Right clavicle	0.09	Trunk	0.63
Left lung	0.10	Right kidney	0.23	Upper large intestine	0.83
Left scapula	0.16	Right leg	0.67	Upper spine	0.17
Left testis	1.27	Right leg bone	0.51	Urinary bladder	3.56
Liver	0.16	Right lung	0.11		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 15: RDWB values when male genitalia is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.07	Lower large intestine	1.27	Right scapula	0.06
Head	0.13	Male genitalia	<b>68.56</b>	Right testis	11.64
Heart	0.04	Middle lower spine	0.08	Skull	0.09
Left adrenal	0.10	Pancreas	0.05	Small intestine	0.15
Left arm bone	0.07	Pelvis	0.29	Spleen	0.06
Left clavicle	0.06	Rib cage	0.05	Stomach	0.06
Left kidney	0.09	Right adrenal	0.06	Thymus	0.08
Left leg	0.85	Right arm bone	0.07	Thyroid	0.08
Left leg bone	0.46	Right clavicle	0.01	Trunk	0.21
Left lung	0.04	Right kidney	0.10	Upper large intestine	0.13
Left scapula	0.06	Right leg	0.63	Upper spine	0.09
Left testis	12.49	Right leg bone	0.40	Urinary bladder	1.20
Liver	0.05	Right lung	0.07		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 16: RDWB values when middle lower spine is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.33	Lower large intestine	0.46	Right scapula	0.88
Head	0.70	Male genitalia	1.76	Right testis	0.61
Heart	2.12	Middle lower spine	<b>51.94</b>	Skull	0.41
Left adrenal	4.48	Pancreas	2.70	Small intestine	1.54
Left arm bone	0.43	Pelvis	0.78	Spleen	1.37
Left clavicle	0.63	Rib cage	0.94	Stomach	1.28
Left kidney	3.53	Right adrenal	2.81	Thymus	1.26
Left leg	1.40	Right arm bone	0.39	Thyroid	0.73
Left leg bone	0.51	Right clavicle	0.48	Trunk	1.15
Left lung	1.73	Right kidney	3.61	Upper large intestine	1.13
Left scapula	0.97	Right leg	0.71	Upper spine	1.99
Left testis	0.32	Right leg bone	0.40	Urinary bladder	0.44
Liver	1.40	Right lung	1.71		

RDWB: Ratios of absorbed doses in all organs to the whole body

on trunk (9.89%), pelvis (9.77%), legs organs (8.33%), middle lower spine (4.43%), and finally, on liver (4.13%). The gravity of such influence can be elevated when a patient is identified as having hyperglycemia or in case of strenuous physical

activity because, physiologically, the radiotracer seems to be more cumulated in muscle parts of human body. As of lungs, the things are so different; the right lung is irradiated (about 2.39%) of radiations leaved liver and the two lungs



**Table 17: RDWB values when pancreas is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.03	Lower large intestine	0.06	Right scapula	0.06
Head	0.05	Male genitalia	0.15	Right testis	0.10
Heart	0.31	Middle lower spine	0.46	Skull	0.03
Left adrenal	0.78	Pancreas	<b>92.47</b>	Small intestine	0.16
Left arm bone	0.08	Pelvis	0.07	Spleen	0.65
Left clavicle	0.08	Rib cage	0.09	Stomach	0.79
Left kidney	0.58	Right adrenal	0.61	Thymus	0.06
Left leg	0.14	Right arm bone	0.06	Thyroid	0.02
Left leg bone	0.06	Right clavicle	0.01	Trunk	0.18
Left lung	0.18	Right kidney	0.41	Upper large intestine	0.19
Left scapula	0.10	Right leg	0.08	Upper spine	0.04
Left testis	0.06	Right leg bone	0.04	Urinary bladder	0.04
Liver	0.55	Right lung	0.15		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 18: RDWB values when pelvis is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.25	Lower large intestine	3.70	Right scapula	0.32
Head	0.44	Male genitalia	1.99	Right testis	1.26
Heart	0.24	Middle lower spine	0.97	Skull	0.29
Left adrenal	0.32	Pancreas	0.56	Small intestine	3.54
Left arm bone	0.64	Pelvis	<b>66.86</b>	Spleen	0.52
Left clavicle	0.26	Rib cage	0.23	Stomach	0.56
Left kidney	0.95	Right adrenal	0.28	Thymus	0.11
Left leg	1.70	Right arm bone	0.66	Thyroid	0.28
Left leg bone	0.96	Right clavicle	0.26	Trunk	1.46
Left lung	0.23	Right kidney	1.15	Upper large intestine	2.53
Left scapula	0.28	Right leg	1.11	Upper spine	0.33
Left testis	1.45	Right leg bone	0.79	Urinary bladder	1.70
Liver	0.51	Right lung	0.33		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 19: RDWB values when rib cage is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.47	Lower large intestine	0.39	Right scapula	4.40
Head	0.92	Male genitalia	1.76	Right testis	0.73
Heart	2.55	Middle lower spine	2.30	Skull	0.60
Left adrenal	3.52	Pancreas	1.63	Small intestine	0.45
Left arm bone	1.13	Pelvis	0.32	Spleen	1.95
Left clavicle	3.31	Rib cage	<b>38.57</b>	Stomach	1.62
Left kidney	1.32	Right adrenal	3.32	Thymus	2.76
Left leg	1.76	Right arm bone	1.29	Thyroid	1.70
Left leg bone	0.63	Right clavicle	2.58	Trunk	1.38
Left lung	2.93	Right kidney	1.31	Upper large intestine	0.52
Left scapula	3.90	Right leg	0.86	Upper spine	1.33
Left testis	0.36	Right leg bone	0.52	Urinary bladder	0.15
Liver	1.72	Right lung	3.04		

RDWB: Ratios of absorbed doses in all organs to the whole body

together are irradiated of 5.97% of radiations leaved rib cage; there is also a radiation contribution from trunk to lungs by a value of 2.6% averagely. Respecting stomach, there are smallest contributions of liver (2.21%) and trunk (3.01%).

Generally, it is found that the organs of high sensibility to radiations are affected by radiation state of some surrounding organs. Continually, always talking about tissue weighting factors, bladder, liver, and thyroid come to the second place,

**Table 20: RDWB values when right adrenal is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.01	Lower large intestine	0.00	Right scapula	0.01
Head	0.01	Male genitalia	0.01	Right testis	0.01
Heart	0.03	Middle lower spine	0.09	Skull	0.01
Left adrenal	0.09	Pancreas	0.05	Small intestine	0.01
Left arm bone	0.00	Pelvis	0.01	Spleen	0.02
Left clavicle	0.00	Rib cage	0.02	Stomach	0.02
Left kidney	0.04	Right adrenal	<b>99.04</b>	Thymus	0.01
Left leg	0.04	Right arm bone	0.01	Thyroid	0.01
Left leg bone	0.01	Right clavicle	0.01	Trunk	0.02
Left lung	0.02	Right kidney	0.18	Upper large intestine	0.01
Left scapula	0.01	Right leg	0.01	Upper spine	0.01
Left testis	0.01	Right leg bone	0.01	Urinary bladder	0.00
Liver	0.07	Right lung	0.05		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 21: RDWB values when right arm bone is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.37	Lower large intestine	0.40	Right scapula	2.11
Head	0.54	Male genitalia	2.17	Right testis	1.33
Heart	0.65	Middle lower spine	0.72	Skull	0.36
Left adrenal	0.42	Pancreas	0.46	Small intestine	0.75
Left arm bone	0.36	Pelvis	1.02	Spleen	0.40
Left clavicle	0.49	Rib cage	0.99	Stomach	0.27
Left kidney	0.35	Right adrenal	1.17	Thymus	0.50
Left leg	2.18	Right arm bone	<b>69.08</b>	Thyroid	0.02
Left leg bone	0.94	Right clavicle	0.84	Trunk	1.13
Left lung	0.43	Right kidney	1.32	Upper large intestine	1.23
Left scapula	0.33	Right leg	1.06	Upper spine	0.45
Left testis	0.41	Right leg bone	0.58	Urinary bladder	0.44
Liver	1.86	Right lung	1.87		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 22: RDWB values when right clavicle is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.05	Lower large intestine	0.02	Right scapula	0.05
Head	0.08	Male genitalia	0.12	Right testis	0.05
Heart	0.03	Middle lower spine	0.04	Skull	0.06
Left adrenal	0.01	Pancreas	0.02	Small intestine	0.02
Left arm bone	0.03	Pelvis	0.02	Spleen	0.04
Left clavicle	0.04	Rib cage	0.05	Stomach	0.01
Left kidney	0.07	Right adrenal	0.06	Thymus	0.12
Left leg	0.09	Right arm bone	0.03	Thyroid	0.25
Left leg bone	0.03	Right clavicle	<b>98.17</b>	Trunk	0.06
Left lung	0.03	Right kidney	0.05	Upper large intestine	0.02
Left scapula	0.02	Right leg	0.04	Upper spine	0.05
Left testis	0.03	Right leg bone	0.03	Urinary bladder	0.03
Liver	0.02	Right lung	0.09		

RDWB: Ratios of absorbed doses in all organs to the whole body

with a value of 0.08. The bladder seems to be damaged by radiation leaving trunk of about 5.74% of total internal dose received by whole body when the trunk is taken as source of

<sup>18</sup>F-FDG. There is also a contribution from legs with a value of 5.61% and colon with an average value of 2%. The liver seems to be damaged by radiation leaving trunk of about

**Table 23: RDWB values when right kidney is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.05	Lower large intestine	0.10	Right scapula	0.12
Head	0.09	Male genitalia	0.28	Right testis	0.12
Heart	0.19	Middle lower spine	0.87	Skull	0.06
Left adrenal	0.50	Pancreas	0.43	Small intestine	0.42
Left arm bone	0.06	Pelvis	0.21	Spleen	0.20
Left clavicle	0.05	Rib cage	0.15	Stomach	0.27
Left kidney	0.50	Right adrenal	3.29	Thymus	0.06
Left leg	0.28	Right arm bone	0.19	Thyroid	0.08
Left leg bone	0.11	Right clavicle	0.07	Trunk	0.28
Left lung	0.12	Right kidney	<b>88.54</b>	Upper large intestine	0.44
Left scapula	0.06	Right leg	0.17	Upper spine	0.09
Left testis	0.08	Right leg bone	0.08	Urinary bladder	0.13
Liver	1.02	Right lung	0.26		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 24: RDWB values when right leg is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.68	Lower large intestine	3.29	Right scapula	0.63
Head	1.18	Male genitalia	11.37	Right testis	7.13
Heart	0.39	Middle lower spine	0.73	Skull	0.88
Left adrenal	1.59	Pancreas	0.64	Small intestine	0.90
Left arm bone	0.83	Pelvis	1.73	Spleen	0.56
Left clavicle	1.11	Rib cage	0.44	Stomach	0.47
Left kidney	1.08	Right adrenal	0.49	Thymus	0.32
Left leg	6.05	Right arm bone	0.43	Thyroid	1.24
Left leg bone	3.26	Right clavicle	0.68	Trunk	1.19
Left lung	0.55	Right kidney	0.93	Upper large intestine	0.62
Left scapula	0.90	Right leg	<b>25.39</b>	Upper spine	0.57
Left testis	7.56	Right leg bone	11.07	Urinary bladder	2.17
Liver	0.37	Right lung	0.58		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 25: RDWB values when right leg bone is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.44	Lower large intestine	1.53	Right scapula	0.62
Head	0.71	Male genitalia	4.26	Right testis	2.68
Heart	0.23	Middle lower spine	0.40	Skull	0.54
Left adrenal	2.22	Pancreas	0.20	Small intestine	0.44
Left arm bone	0.58	Pelvis	1.16	Spleen	0.43
Left clavicle	0.27	Rib cage	0.29	Stomach	0.28
Left kidney	0.46	Right adrenal	0.66	Thymus	0.20
Left leg	3.42	Right arm bone	0.24	Thyroid	0.21
Left leg bone	1.72	Right clavicle	0.00	Trunk	0.70
Left lung	0.28	Right kidney	0.59	Upper large intestine	0.32
Left scapula	0.49	Right leg	6.71	Upper spine	0.28
Left testis	2.71	Right leg bone	<b>61.91</b>	Urinary bladder	1.17
Liver	0.28	Right lung	0.35		

RDWB: Ratios of absorbed doses in all organs to the whole body

2.59% of total internal dose received by whole body when the trunk is taken as source of <sup>18</sup>F-FDG. With regard to the thyroid, there is a contribution from head of 18.50%, skull

of 2.58%, and finally, trunk of 2.55% of total dose received by whole body. The other organs with less significance in terms of tissue-weighting factors are not discussed here.

**Table 26: RDWB values when right lung is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.25	Lower large intestine	0.17	Right scapula	3.09
Head	0.46	Male genitalia	1.10	Right testis	0.26
Heart	2.48	Middle lower spine	1.41	Skull	0.33
Left adrenal	0.93	Pancreas	0.66	Small intestine	0.21
Left arm bone	0.19	Pelvis	0.21	Spleen	0.46
Left clavicle	0.62	Rib cage	0.99	Stomach	0.40
Left kidney	0.38	Right adrenal	2.63	Thymus	1.24
Left leg	0.96	Right arm bone	0.87	Thyroid	0.52
Left leg bone	0.38	Right clavicle	2.36	Trunk	0.79
Left lung	0.78	Right kidney	0.86	Upper large intestine	0.24
Left scapula	0.48	Right leg	0.50	Upper spine	0.53
Left testis	0.46	Right leg bone	0.28	Urinary bladder	0.21
Liver	1.48	Right lung	<b>69.86</b>		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 27: RDWB values when right scapula is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.10	Lower large intestine	0.05	Right scapula	<b>92.88</b>
Head	0.23	Male genitalia	0.37	Right testis	0.15
Heart	0.25	Middle lower spine	0.25	Skull	0.14
Left adrenal	0.02	Pancreas	0.08	Small intestine	0.04
Left arm bone	0.07	Pelvis	0.04	Spleen	0.05
Left clavicle	0.08	Rib cage	0.64	Stomach	0.06
Left kidney	0.08	Right adrenal	0.27	Thymus	0.25
Left leg	0.34	Right arm bone	0.45	Thyroid	0.27
Left leg bone	0.13	Right clavicle	0.23	Trunk	0.22
Left lung	0.12	Right kidney	0.08	Upper large intestine	0.04
Left scapula	0.07	Right leg	0.17	Upper spine	0.31
Left testis	0.20	Right leg bone	0.10	Urinary bladder	0.03
Liver	0.13	Right lung	1.01		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 28: RDWB values when right testis is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.01	Lower large intestine	0.01	Right scapula	0.01
Head	0.01	Male genitalia	1.48	Right testis	<b>96.05</b>
Heart	0.01	Middle lower spine	0.01	Skull	0.01
Left adrenal	0.01	Pancreas	0.00	Small intestine	0.02
Left arm bone	0.01	Pelvis	0.04	Spleen	0.00
Left clavicle	0.00	Rib cage	0.01	Stomach	0.01
Left kidney	0.01	Right adrenal	0.00	Thymus	0.00
Left leg	0.07	Right arm bone	0.01	Thyroid	0.00
Left leg bone	0.04	Right clavicle	0.01	Trunk	0.03
Left lung	0.01	Right kidney	0.01	Upper large intestine	0.01
Left scapula	0.02	Right leg	0.06	Upper spine	0.01
Left testis	1.76	Right leg bone	0.04	Urinary bladder	0.11
Liver	0.00	Right lung	0.01		

RDWB: Ratios of absorbed doses in all organs to the whole body

## CONCLUSION

Through this Monte Carlo Geant4 study, we have shown that the total absorbed dose of <sup>18</sup>F-FDG deposited in

such organ depends on radiation dose contributions of surrounding organs; gravity of such dependence seems to vary from strong to weak. On the other hand, we have found that organs of high sensibility to radiations,

**Table 29: RDWB values when skull is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	10.46	Lower large intestine	0.25	Right scapula	0.61
Head	3.73	Male genitalia	1.99	Right testis	0.55
Heart	0.25	Middle lower spine	0.56	Skull	<b>59.33</b>
Left adrenal	0.09	Pancreas	0.22	Small intestine	0.18
Left arm bone	0.24	Pelvis	0.32	Spleen	0.20
Left clavicle	1.80	Rib cage	0.29	Stomach	0.19
Left kidney	0.29	Right adrenal	0.43	Thymus	0.42
Left leg	1.72	Right arm bone	0.21	Thyroid	2.58
Left leg bone	0.63	Right clavicle	1.84	Trunk	0.42
Left lung	0.38	Right kidney	0.17	Upper large intestine	0.14
Left scapula	0.60	Right leg	0.85	Upper spine	5.96
Left testis	0.79	Right leg bone	0.50	Urinary bladder	0.15
Liver	0.21	Right lung	0.47		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 30: RDWB values when small intestine is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.18	Lower large intestine	3.07	Right scapula	0.38
Head	0.37	Male genitalia	1.77	Right testis	0.75
Heart	0.32	Middle lower spine	1.64	Skull	0.26
Left adrenal	0.80	Pancreas	1.00	Small intestine	<b>60.21</b>
Left arm bone	0.50	Pelvis	2.75	Spleen	0.94
Left clavicle	0.05	Rib cage	0.24	Stomach	1.45
Left kidney	1.70	Right adrenal	0.36	Thymus	0.11
Left leg	1.26	Right arm bone	0.48	Thyroid	0.32
Left leg bone	0.52	Right clavicle	0.26	Trunk	1.21
Left lung	0.28	Right kidney	1.93	Upper large intestine	9.34
Left scapula	0.32	Right leg	0.74	Upper spine	0.21
Left testis	0.49	Right leg bone	0.44	Urinary bladder	1.79
Liver	1.22	Right lung	0.33		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 31: RDWB values when spleen is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.06	Lower large intestine	0.18	Right scapula	0.14
Head	0.14	Male genitalia	0.30	Right testis	0.10
Heart	0.35	Middle lower spine	0.46	Skull	0.07
Left adrenal	1.53	Pancreas	3.37	Small intestine	0.27
Left arm bone	0.44	Pelvis	0.14	Spleen	<b>83.64</b>
Left clavicle	0.30	Rib cage	0.27	Stomach	1.59
Left kidney	2.74	Right adrenal	0.22	Thymus	0.11
Left leg	0.36	Right arm bone	0.06	Thyroid	0.03
Left leg bone	0.14	Right clavicle	0.06	Trunk	0.34
Left lung	0.77	Right kidney	0.31	Upper large intestine	0.25
Left scapula	0.24	Right leg	0.21	Upper spine	0.10
Left testis	0.17	Right leg bone	0.11	Urinary bladder	0.05
Liver	0.23	Right lung	0.15		

RDWB: Ratios of absorbed doses in all organs to the whole body

namely colon, lungs, stomach, bladder, thyroid, and liver are relatively affected by radioactivity cumulating in some surrounding organs including those of muscles, which can lead ultimately to elevate absorbed doses to the

cited organs in case of hyperglycemia patient or in case of patient who undergoes strenuous physical activity in which abnormal hyperfixations will be appeared in muscle tissues.

**Table 32: RDWB values when stomach is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.14	Lower large intestine	0.51	Right scapula	0.16
Head	0.21	Male genitalia	0.82	Right testis	0.34
Heart	0.83	Middle lower spine	0.69	Skull	0.18
Left adrenal	0.84	Pancreas	5.65	Small intestine	0.84
Left arm bone	0.53	Pelvis	0.31	Spleen	2.83
Left clavicle	0.11	Rib cage	0.40	Stomach	<b>74.39</b>
Left kidney	1.54	Right adrenal	0.64	Thymus	0.17
Left leg	0.77	Right arm bone	0.12	Thyroid	0.35
Left leg bone	0.29	Right clavicle	0.18	Trunk	0.60
Left lung	0.96	Right kidney	0.58	Upper large intestine	1.11
Left scapula	0.33	Right leg	0.40	Upper spine	0.14
Left testis	0.29	Right leg bone	0.23	Urinary bladder	0.27
Liver	0.95	Right lung	0.27		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 33: RDWB values when thymus is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.03	Lower large intestine	0.01	Right scapula	0.04
Head	0.05	Male genitalia	0.17	Right testis	0.05
Heart	0.14	Middle lower spine	0.06	Skull	0.03
Left adrenal	0.01	Pancreas	0.03	Small intestine	0.01
Left arm bone	0.03	Pelvis	0.00	Spleen	0.02
Left clavicle	0.25	Rib cage	0.07	Stomach	0.02
Left kidney	0.01	Right adrenal	0.01	Thymus	<b>98.01</b>
Left leg	0.04	Right arm bone	0.02	Thyroid	0.16
Left leg bone	0.02	Right clavicle	0.13	Trunk	0.06
Left lung	0.16	Right kidney	0.02	Upper large intestine	0.01
Left scapula	0.07	Right leg	0.02	Upper spine	0.05
Left testis	0.07	Right leg bone	0.01	Urinary bladder	0.00
Liver	0.02	Right lung	0.09		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 34: RDWB values when thyroid is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.04	Lower large intestine	0.00	Right scapula	0.02
Head	0.19	Male genitalia	0.02	Right testis	0.01
Heart	0.02	Middle lower spine	0.02	Skull	0.00
Left adrenal	0.00	Pancreas	0.01	Small intestine	0.00
Left arm bone	0.01	Pelvis	0.00	Spleen	0.00
Left clavicle	0.12	Rib cage	0.01	Stomach	0.01
Left kidney	0.00	Right adrenal	0.01	Thymus	0.09
Left leg	0.03	Right arm bone	0.01	Thyroid	<b>98.89</b>
Left leg bone	0.01	Right clavicle	0.19	Trunk	0.02
Left lung	0.02	Right kidney	0.00	Upper large intestine	0.00
Left scapula	0.02	Right leg	0.02	Upper spine	0.09
Left testis	0.01	Right leg bone	0.01	Urinary bladder	0.00
Liver	0.01	Right lung	0.02		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 35: RDWB values when trunk is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.63	Lower large intestine	3.24	Right scapula	1.74
Head	1.10	Male genitalia	4.22	Right testis	2.81

Contd...



**Table 35: Contd...**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Heart	4.39	Middle lower spine	3.85	Skull	0.83
Left adrenal	3.93	Pancreas	6.13	Small intestine	3.56
Left arm bone	1.26	Pelvis	2.88	Spleen	2.51
Left clavicle	2.03	Rib cage	1.40	Stomach	3.01
Left kidney	2.75	Right adrenal	2.10	Thymus	4.05
Left leg	2.70	Right arm bone	1.12	Thyroid	2.55
Left leg bone	1.21	Right clavicle	2.48	Trunk	<b>4.22</b>
Left lung	2.67	Right kidney	2.77	Upper large intestine	3.09
Left scapula	1.91	Right leg	1.54	Upper spine	1.45
Left testis	1.92	Right leg bone	0.99	Urinary bladder	5.74
Liver	2.59	Right lung	2.60		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 36: RDWB values when upper large intestine is adopted as source of <sup>18</sup>F-FDG**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.14	Lower large intestine	1.27	Right scapula	0.17
Head	0.23	Male genitalia	1.19	Right testis	0.45
Heart	0.24	Middle lower spine	0.88	Skull	0.17
Left adrenal	0.26	Pancreas	1.00	Small intestine	7.09
Left arm bone	0.28	Pelvis	1.38	Spleen	0.68
Left clavicle	0.09	Rib cage	0.16	Stomach	1.42
Left kidney	1.15	Right adrenal	0.09	Thymus	0.09
Left leg	0.86	Right arm bone	0.39	Thyroid	0.30
Left leg bone	0.34	Right clavicle	0.04	Trunk	0.73
Left lung	0.22	Right kidney	1.21	Upper large intestine	<b>73.63</b>
Left scapula	0.22	Right leg	0.43	Upper spine	0.14
Left testis	0.71	Right leg bone	0.26	Urinary bladder	0.64
Liver	1.16	Right lung	0.24		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 37: RDWB values when upper spine is adopted as source <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.59	Lower large intestine	0.05	Right scapula	0.22
Head	1.50	Male genitalia	0.41	Right testis	0.16
Heart	0.12	Middle lower spine	0.63	Skull	1.20
Left adrenal	0.01	Pancreas	0.07	Small intestine	0.04
Left arm bone	0.06	Pelvis	0.07	Spleen	0.07
Left clavicle	0.49	Rib cage	0.13	Stomach	0.04
Left kidney	0.11	Right adrenal	0.11	Thymus	0.33
Left leg	0.33	Right arm bone	0.07	Thyroid	1.06
Left leg bone	0.13	Right clavicle	0.35	Trunk	0.16
Left lung	0.20	Right kidney	0.05	Upper large intestine	0.04
Left scapula	0.21	Right leg	0.16	Upper spine	<b>90.41</b>
Left testis	0.08	Right leg bone	0.09	Urinary bladder	0.01
Liver	0.05	Right lung	0.20		

RDWB: Ratios of absorbed doses in all organs to the whole body

**Table 38: RDWB values when urinary bladder is adopted as source of <sup>18</sup>F-fluorodeoxyglucose**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Brain	0.02	Lower large intestine	0.65	Right scapula	0.06
Head	0.05	Male genitalia	0.52	Right testis	0.39
Heart	0.02	Middle lower spine	0.05	Skull	0.04

Contd...

**Table 38: Contd...**

Organ	RDWB (%)	Organ	RDWB (%)	Organ	RDWB (%)
Left adrenal	0.01	Pancreas	0.02	Small intestine	0.20
Left arm bone	0.06	Pelvis	0.23	Spleen	0.03
Left clavicle	0.02	Rib cage	0.03	Stomach	0.04
Left kidney	0.05	Right adrenal	0.05	Thymus	0.02
Left leg	0.23	Right arm bone	0.04	Thyroid	0.06
Left leg bone	0.11	Right clavicle	0.03	Trunk	0.19
Left lung	0.04	Right kidney	0.08	Upper large intestine	0.17
Left scapula	0.07	Right leg	0.11	Upper spine	0.02
Left testis	0.43	Right leg bone	0.09	Urinary bladder	<b>95.71</b>
Liver	0.04	Right lung	0.02		

RDWB: Ratios of absorbed doses in all organs to the whole body

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### Conflicts of interest

There are no conflicts of interest.

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