IOPscience iopscience.iop.org

Home Search Collections Journals About Contact us My IOPscience

Organ and effective dose conversion coefficients for a sitting female hybrid computational phantom exposed to monoenergetic protons in idealized irradiation geometries

This content has been downloaded from IOPscience. Please scroll down to see the full text.

2014 Phys. Med. Biol. 59 7957

(http://iopscience.iop.org/0031-9155/59/24/7957)

View the table of contents for this issue, or go to the journal homepage for more

Download details:

IP Address: 143.107.255.190
This content was downloaded on 15/07/2015 at 11:53

Please note that terms and conditions apply.

IOP Publishing | Institute of Physics and Engineering in Medicine Physics in Medicine & Biology

Phys. Med. Biol. **59** (2014) 7957–8003 doi:10.1088/0031-9155/59/24/7957

# Organ and effective dose conversion coefficients for a sitting female hybrid computational phantom exposed to monoenergetic protons in idealized irradiation geometries

**M C Alves[1], W S Santos[2], Choonsik Lee[3], Wesley E Bolch[4], John G Hunt[5] and A B Carvalho Júnior[1]**

[1] Departamento de Física, Universidade Federal de Sergipe, Campus Prof. José Aloísio de Campos, 49.100-000, São Cristóvão–SE, Brazil
[2] Instituto de Pesquisas Energéticas e Nuclears, Comissão Nacional de Energia Nuclear (IPEN-CNEN/SP) São Paulo, Brazil
[3] Division of Cancer Epidemiology and Genetics, National Cancer Institute, National Institute of Health, Bethesda, MD 20852, USA
[4] Department of Nuclear and Radiological Engineering, University of Florida, Gainesville, FL 32611–8300, USA
[5] Dosimetry Division, Instituto de Radioproteção e Dosimetria, Rio de janeiro, RJ 22783-127, Brazil

E-mail: alves.materia@gmail.com

Received 28 July 2014, revised 23 September 2014
Accepted for publication 24 October 2014
Published 26 November 2014

**Abstract**

The conversion coefficients (CCs) relate protection quantities, mean absorbed dose ($D_T$) and effective dose ($E$), with physical radiation field quantities, such as fluence ($\Phi$). The calculation of CCs through Monte Carlo simulations is useful for estimating the dose in individuals exposed to radiation. The aim of this work was the calculation of conversion coefficients for absorbed and effective doses per fluence ($D_T/\Phi$ and $E/\Phi$) using a sitting and standing female hybrid phantom (UFH/NCI) exposure to monoenergetic protons with energy ranging from 2 MeV to 10 GeV. The radiation transport code MCNPX was used to develop exposure scenarios implementing the female UFH/NCI phantom in sitting and standing postures. Whole-body irradiations were performed using the recommended irradiation geometries by ICRP publication 116 (AP, PA, RLAT, LLAT, ROT and ISO). In most organs, the conversion coefficients $D_T/\Phi$ were similar for both postures. However, relative differences were significant for organs located in the abdominal region, such as ovaries, uterus and urinary bladder, especially

 © 2014 Institute of Physics and Engineering in Medicine Printed in the UK & the USA 

in the AP, RLAT and LLAT geometries. Anatomical differences caused by changing the posture of the female UFH/NCI phantom led an attenuation of incident protons with energies below 150 MeV by the thigh of the phantom in the sitting posture, for the front-to-back irradiation, and by the arms and hands of the phantom in the standing posture, for the lateral irradiation.

Keywords: protons, computational dosimetry, conversion coefficients

(Some figures may appear in colour only in the online journal)

## 1. Introduction

Background radiation is mainly formed by cosmic radiation, in which nearly 90% are energetic protons (Townsend 2001). Secondary radiations such as protons, neutrons, pion and muons are produced when cosmic radiation penetrates the atmosphere causing nuclear reactions with its constituents (Reitz 1993). Estimating the dose due occupational exposures to this type of radiation is important, including workers such as aircraft crew, who are normally exposed to a significant amount of proton beams.

Due to the difficulty in estimating the absorbed dose in an individual through experimental techniques, computational human phantom coupled to Monte Carlo radiation transport code can simulate exposure scenarios to estimate the absorbed dose in organ or tissue. The simulation technique provides dose conversion coefficients, which converts measured quantity (e.g. air kerma) to absorbed dose (ICRP 2010). Monte Carlo method is a widespread technique that uses probability density functions and random numbers in order to determine energy, position, direction and path-length of individual particles as well the type of physical interaction that occurs when radiation interacts with matter (Bozkurt and Xu 2004). Computational human phantoms are computational representations of the human anatomy (Kramer *et al* 2004). To date, two classes of computational phantoms have been used in computational dosimetry: Constructive Solid Geometry (CSG) and Boundary Representation (BREP) phantoms. Examples of CSG are the mathematical and voxel phantoms (Xu 2010). In mathematical phantoms, anatomical structures are represented by mathematical equations such as planes, cylinders, spheres and cones. Voxel phantoms are constructed from medical images (computed tomography or magnetic resonance imaging) of real patients or from the sectional color photographs of cadaver. Although voxel phantoms provide more realistic anatomical representation for dosimetry calculations, there are some limitations such as the dependence of organs contour with images segmentation and the individual anatomy reflecting the tomographic data. To overcome these limitations and with the advance of computer graphics, BREP phantoms were introduced more recently which take advantage of the realistic anatomy of voxel phantoms and the flexibility of mathematical phantoms for adjusting organ contours and volumes. Hybrid phantoms, which belongs to the BREP class of phantoms, are developed basically from medical images, like voxel phantom, but three steps is performed: polygonization of voxel phantom, modelling internal organ structure via polygon mesh and NURBS (non-uniform rational B-spline) surface to match reference organ volumes and phantom voxelization (Piegl 1991, Lee 2007).

Several researchers used voxel phantoms for the calculation of dose conversion coefficients for protons (Bozkurt and Xu 2004, Zhang 2008, Sato 2009). However, no studies using computational phantoms in sitting posture have been reported. Dosimetric calculations suggest that for external exposures, specifically the posture may influence the absorbed doses in

organs significantly. Thus, use phantoms with variable stature in standing or sitting, depending on the scenario of irradiation, is another step to make the simulation of increasingly specific exposure, e.g. airplane crew. The problem, strictly speaking, is that the results can only be applied to a person who has the same posture of the phantom, while for a person with different posture, values can be wrong. To better represent these posture differences, this study presents adult anthropomorphic phantoms, in both standing and sitting developed for the calculation of absorbed doses in radiosensitive organs and tissues of the human body. The aims of the current study were calculate absorbed and effective dose conversion coefficients using a standing and a sitting adult female hybrid simulator exposure to monoenergetic protons in antero-posterior (AP), postero-anterior (PA), right-lateral (RLAT), left-lateral (LLAT), rotational (ROT) and isotropic (ISO) geometries. The conversion factors from different postures were compared to each other.

## 2. Materials and methods

### *2.1. Monte Carlo code*

In this work, simulations were performed using the MCNPX code (Version 2.7), a general purpose Monte Carlo transport code developed from the Los Alamos National Laboratory (LANL) (Pelowitz 2011). The code can handle the 3D geometry transport and interaction of neutrons, protons, electrons, photons, heavy charged particles and others in a wide range of energies (Briesmeister 2000). MCNPX was used for simulating proton interactions and secondary particles (photons, electrons, neutrons, other protons) generated when protons interact with matter. In order to model the interactions of thermal neutrons with the molecules in the body, the S(α,β) function describing the scattering law for light water molecules at 300 K temperature was employed for all materials of organs and tissues. This model was considered necessary in all simulations since a typical proton interaction will produce neutrons which tend to be down-scattered to thermal energies (Briesmeister 1997).

### *2.2. Hybrid computational phantom*

The Hybrid Adult Female computational human phantom developed at the University of Florida and the National Cancer Institute (Lee 2010) (figure 1) was implemented in MCNPX code in two postures: standing and sitting. The legs including skeletal structures of the original hybrid phantom in NURBS-format were deformed to represent the same phantom in sitting posture. Multiple control points included in the surface of legs and skeletons were adjusted using a 3D modeling software, Rhinoceros. Modification to other body parts except legs was not attempted.

### *2.3. Exposure scenarios*

Exposure scenarios were developed for the two phantoms in different postures independently. In both postures, the phantom, surrounded by vacuum, was irradiated by monoenergetic protons with the energies from 2 MeV to 10 GeV in six irradiation geometries: antero-posterior (AP), postero-anterior (PA), right-lateral (RLAT), left-lateral (LLAT), rotational (ROT) and isotropic (ISO), which are defined in the ICRP Publication 116 [3]. In each simulation $10^8$ particle histories were considered in order to keep the relative error under 10% in all organs of interest. Values of energy deposited by all particles transported

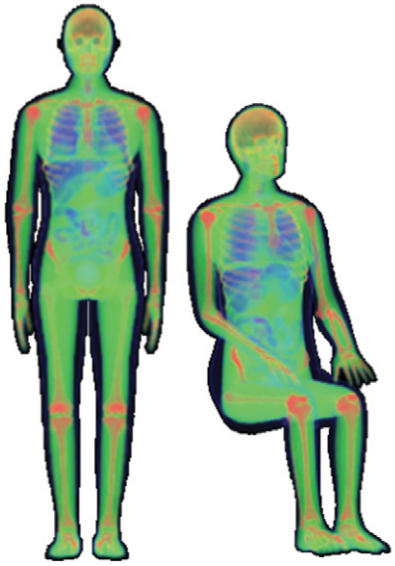

**Figure 1.** 3D renderings of the UFH/NCI adult female hybrid phantoms in the standing (left) and sitting (right) postures.

in the simulations were normalized by incident proton fluence to derive organ dose conversion coefficients (pGy cm$^2$). The organ dose conversion coefficients ($D_T/\Phi$) and effective dose conversion coefficients (E/$\Phi$) of the standing and sitting UFH/NCI adult female phantoms were calculated and compared to each other. The F6 tally command of MCNPX was used to calculate absorbed dose in organs and tissues for protons and secondary particles generated. To obtain the equivalent-dose conversion coefficients, the organ-dose conversion coefficients were multiplied by 2, which is the radiation weighting factor of protons, as recommended in ICRP Publication 103 (2007). Red bone marrow (RBM) and bone surface are not explicitly defined in the hybrid phantoms since these tissues are presented in sophisticated spongiosa and medullary cavity structures. Therefore, the absorbed dose in RBM was determined by averaging the absorbed dose in each spongiosa multiplied with the mass ratios of red bone marrow contained in each region (ICRP 2010). The absorbed dose in bone surface was obtained from the absorbed dose in each spongiosa and medullary cavity, which contain endosteum tissue, multiplied with the mass ratios of endosteum contained in each region (ICRP 2010).

## 3. Results and discussion

Initially, results of fluence-to-absorbed dose conversion coefficients of the UFH/NCI female phantom in the standing posture were compared with the ICRP female phantom in AP, PA, RLAT and ISO irradiation geometries (ICRP 2007, 2010). The comparison of fluence-to-absorbed dose conversion coefficients for four representative organs (breast, red bone marrow, skin and uterus) are presented in attached tables A.1–A.4. As presented in tables A.1–A.4, high relative differences were observed between conversion coefficients of the UFH/NCI and the ICRP phantom in energies lower than 100 MeV. In skin, for example, conversion coefficients of ICRP female phantom are until 45% higher than

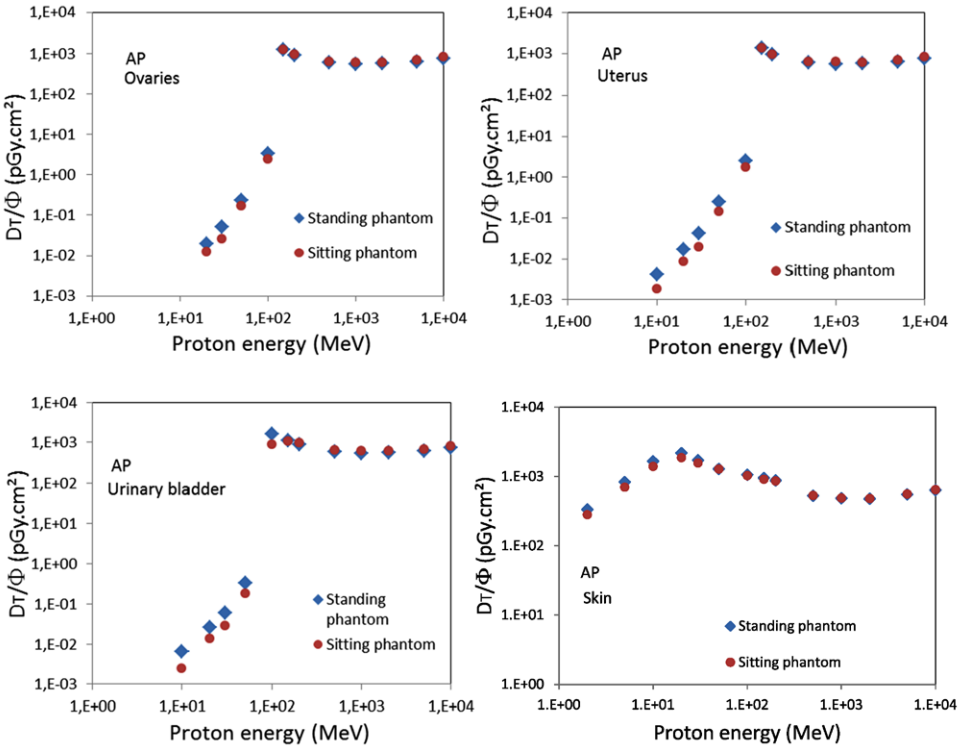


**Figure 2.** Fluence-to-absorbed dose conversion coefficients ($D_T/\Phi$) for ovaries, uterus, urinary bladder and skin in AP geometry.

in UFH/NCI phantom from 2 to 10 MeV of proton energy and these differences occurred due to the difference in voxel size between ICRP and UFH/NCI phantoms, which in the former is 1.775 × 1.775 × 4.84 $mm^3$ while in the later is 3 × 3 × 3 $mm^3$. In Breast, below 30 MeV, conversion coefficients were much higher in the ICRP reference phantom since in the UFH/NCI there is a layer of adipose tissue around the breasts that reduces proton energy. Although, it was observed high differences in absorbed dose conversion coefficients between the ICRP reference female and the UFH/NCI female phantom, the magnitude of conversion coefficients of both phantoms is the same, especially at energies higher than 100 MeV. The difference observed in conversion coefficients is due to structural differences between the ICRP and the UFH/NCI female phantom.

The calculated fluence-to-absorbed dose conversion coefficients in units of pGy $cm^2$, are given in attached tables B.1–B.6 for the 27 organs of the standing and sitting UFH/NCI female phantom. As presented in tables B.1–B.6, statistical uncertainties for most organs irradiated in antero-posterior (AP), postero-anterior (PA), right lateral (RLAT), left lateral (LLAT), rotational (ROT) and isotropic (ISO) geometry are less than 10% considering $10^8$ particle histories in each simulation. For smallest and/or deeper organs (such as ovaries, adrenals, thymus, pancreas and kidneys), the statistical uncertainties are beyond 10% since fewer number of particles interacts in these organs. Minor statistical uncertainties were observed in organs that are uniformly distributed in the body, such as skin, RBM, bone surface and muscle for almost all proton energies studied.

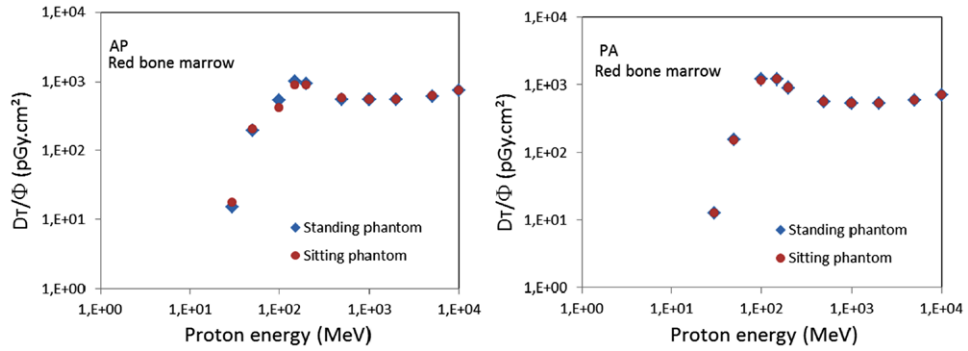


**Figure 3.** Fluence-to-absorbed dose conversion coefficients ($D_T/\Phi$) for red bone marrow in AP and PA geometry.

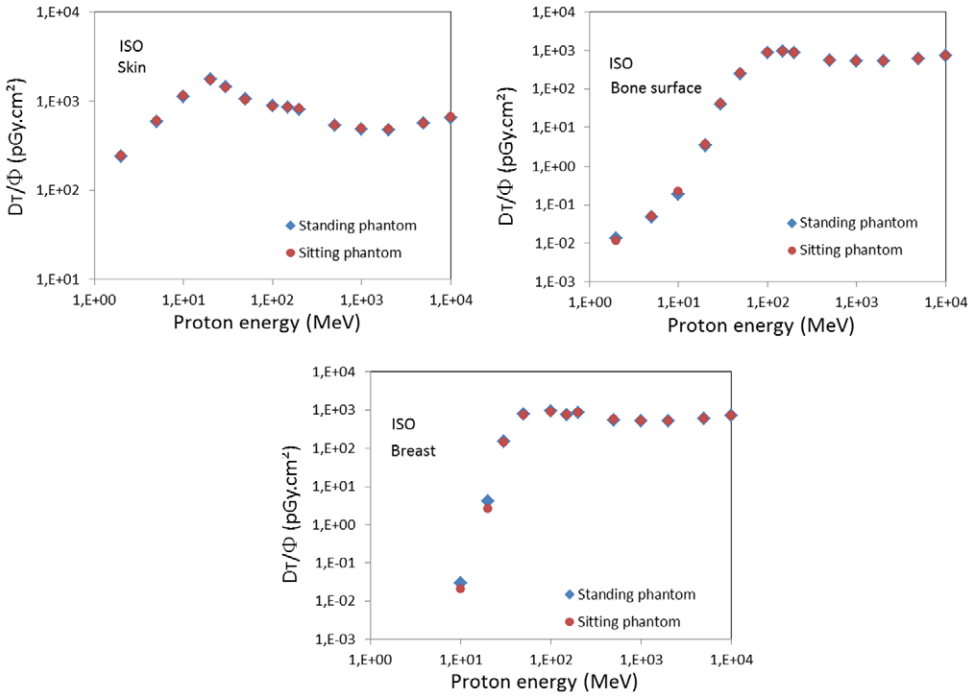


**Figure 4.** Fluence-to-absorbed dose conversion coefficients ($D_T/\Phi$) for skin, bone surface and breast in ISO geometry.

Tables B.1–B.6 also presents the comparison of fluence-to-absorbed dose conversion coefficients of all relevant organs in both postures for AP, PA, RLAT, LLAT, ROT and ISO geometry. Relative differences (RD) between standing and sitting UFH/NCI simulator were calculated using the following equation (1):

$$\mathrm{RD}(\%) = \left( \frac{\mathrm{CC(sitting)} - \mathrm{CC(standing)}}{\mathrm{CC(standing)}} \right) \tag{1}$$

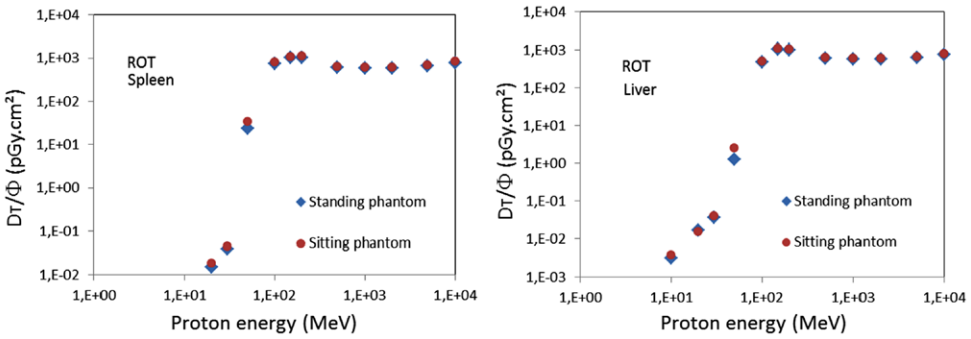


**Figure 5.** Fluence-to-absorbed dose conversion coefficients ($D_T/\Phi$) for spleen and liver in ROT geometry.

As seen in tables B.1–B.6, less than 5% or no relevant differences in conversion coefficients occur for some organs and tissue such as extrathoracic region, oral mucosa, salivary glands and tonsils in all geometry and almost all energies studied. No significant differences between conversion coefficients in standing and sitting postures for these organs occurred because the change in posture did not affect the energy which is deposited.

However in organs located in pelvic and lower abdominal region (ovaries, uterus, bladder, colon and small intestine) differences in conversion coefficients were observed for AP geometry as can be seen in figure 2. In ovaries, uterus and bladder the conversion coefficients until 150 MeV of proton energy are between 25 and 50% higher in the standing phantom and above this energy the conversion coefficients for the sitting phantom are around 10% higher. Anatomical differences caused by changing the posture of the phantom lead an attenuation of incident protons with energies below 150 MeV by the thigh of the phantom in the sitting posture. In colon and small intestine, the phantom thigh, arms and hands located in front of the body also contribute to reducing the energy of incident protons with low energy (below 50 MeV), but the differences in conversion coefficients are around 20%. In skin (figure 2), bone surface and muscle the conversion coefficients of the phantom in standing posture were also higher than in sitting posture. Differences occur because protons have an interaction area with these tissues higher in the standing phantom, so the energy deposited was also higher in this posture. Between 10 and 30 MeV the conversion coefficients for bone surface in the sitting phantom were higher. It occurred because the arms and hands are placed in front of the phantom perpendicular to the beam and therefore protons lose energy in these structures in sitting phantom more than in standing phantom at very low energy, contributing to dose in bone surface.

In PA geometry, however, the thigh of the phantom did not attenuates the incident beam in organs located in pelvic and lower abdominal region, so differences in conversion coefficients was not observed, except for ovaries, uterus and urinary bladder which presented differences between 10 and 30% below 100 MeV of proton energy. Differences in conversion coefficients in skin, muscle and bone surface in PA geometry were similar to the AP geometry, the standing phantom presented conversion coefficients higher than the sitting phantom. As presented in figure 3, in all energies simulated, red bone marrow did not present differences in conversion coefficients because in PA geometry the change in posture did not affect bones that have a higher concentration of red marrow, like sacrum, pelvis and spine. Minor structure differences contribute to conversion coefficients of thyroid in the standing phantom be 47% greater than in the sitting phantom at 100 MeV of protons energy.

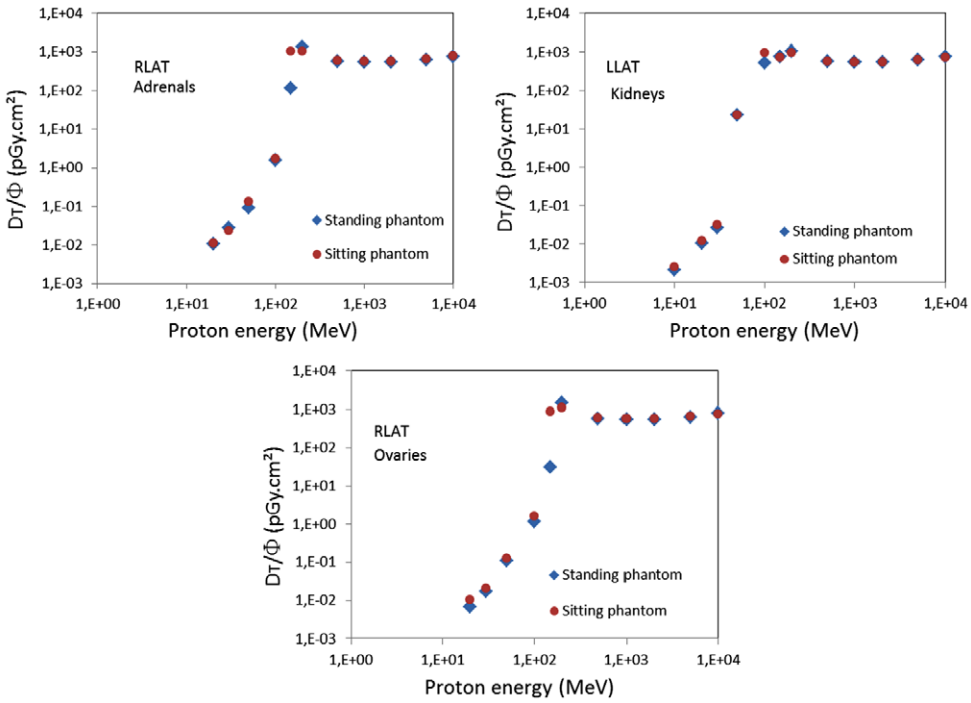


**Figure 6.** Fluence-to-absorbed dose conversion coefficients ($D_T/\Phi$) for adrenals and ovaries in RLAT geometry and kidneys in LLAT geometry.

In isotropic geometry the phantoms are irradiated in all directions with the same probability. This explains there were no significant differences in conversion coefficients in skin and bone surface, since protons can hit these tissues equally in both posture. However, some organ dose conversion coefficients presented significant differences in this irradiation geometry as presented in figure 4. In breast, for example, the conversion coefficient in the standing phantom was higher than in sitting phantom from 20 to 100 MeV, because the thigh of the phantom in the sitting posture attenuates the beam in bottom to head direction. Similarly, in liver, spleen, colon and uterus the phantom thigh leads to differences in conversion coefficients, but in these organs the conversion coefficients in standing phantom were lower because in the standing posture the legs and thigh attenuates the beam in upward direction and the arms attenuates the beam in lateral irradiation, resulting in less dose in these organs in low energy region. Also in ovaries, small intestine and urinary bladder were observed differences in organ dose conversion coefficients, however in the sitting phantom the values were higher until 100 MeV. Differences around 10% in conversion coefficients were observed in other organs and tissues.

In rotational geometry the results of comparison of conversion coefficients in both postures were similar to the isotropic geometry. In liver, spleen (figure 5) and kidneys the arms and hands in the lateral of the body attenuates the beam in the standing phantom while in the sitting posture the arms are in front the phantom, so this structure did not attenuate the beam in these organs. However, some organs and tissues that presented differences in organ dose conversion coefficients in ISO geometry because of the attenuation of the beam by the

**Table 1.** Effective dose per unit fluence (pSv·cm$^2$) under AP, PA, RLAT, LLAT, ROT and ISO geometry on UFH/NCI from monoenergetic protons.

| AP | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|
| Proton energy (MeV) | $E/\Phi$ (pSv·cm$^2$) | Relative error | $E/\Phi$ (pSv·cm$^2$) | Relative error | Relative difference (RD) |
| 2 | 5.63 | 0.01% | 6.68 | 0.01% | −15.7% |
| 5 | 14.05 | 0.01% | 16.67 | 0.01% | −15.7% |
| 10 | 28.03 | 0.01% | 33.27 | 0.01% | −15.8% |
| 20 | 39.80 | 0.02% | 45.93 | 0.18% | −13.4% |
| 30 | 91.57 | 0.07% | 94.07 | 0.15% | −2.7% |
| 50 | 736.98 | 0.07% | 737.03 | 0.11% | 0.0% |
| 100 | 1930.89 | 0.03% | 2038.50 | 0.04% | −5.3% |
| 150 | 2315.52 | 0.04% | 2354.52 | 0.04% | −1.7% |
| 200 | 1807.87 | 0.04% | 1805.96 | 0.04% | 0.1% |
| 500 | 1166.69 | 0.05% | 1137.24 | 0.05% | 2.6% |
| 1000 | 1103.56 | 0.06% | 1078.06 | 0.07% | 2.4% |
| 2000 | 1099.60 | 0.08% | 1078.92 | 0.09% | 1.9% |
| 5000 | 1244.36 | 0.09% | 1218.53 | 0.11% | 2.1% |
| 10 000 | 1478.12 | 0.09% | 1449.75 | 0.12% | 2.0% |
| PA | Sitting phantom | | Standing phantom | | |
| Proton energy (MeV) | $E/\Phi$ (pSv·cm$^2$) | Relative error | $E/\Phi$ (pSv·cm$^2$) | Relative error | Relative difference (RD) |
| 2 | 5.64 | 0.01% | 6.69 | 0.01% | −15.7% |
| 5 | 14.08 | 0.01% | 16.70 | 0.01% | −15.7% |
| 10 | 28.08 | 0.01% | 33.31 | 0.01% | −15.7% |
| 20 | 36.15 | 0.01% | 43.45 | 0.01% | −16.8% |
| 30 | 31.83 | 0.02% | 38.37 | 0.02% | −17.1% |
| 50 | 79.02 | 0.04% | 85.96 | 0.04% | −8.1% |
| 100 | 1041.48 | 0.04% | 1069.36 | 0.05% | −2.6% |
| 150 | 2657.92 | 0.05% | 2673.21 | 0.05% | −0.6% |
| 200 | 1941.82 | 0.04% | 1948.71 | 0.04% | −0.4% |
| 500 | 1177.86 | 0.05% | 1184.05 | 0.05% | −0.5% |
| 1000 | 1116.53 | 0.06% | 1122.66 | 0.07% | −0.5% |
| 2000 | 1116.68 | 0.07% | 1118.76 | 0.09% | −0.2% |
| 5000 | 1253.82 | 0.08% | 1255.28 | 0.10% | −0.1% |
| 10 000 | 1498.64 | 0.10% | 1499.97 | 0.11% | −0.1% |
| RLAT | Sitting phantom | | Standing phantom | | |
| Proton energy (MeV) | $E/\Phi$ (pSv·cm$^2$) | Relative error | $E/\Phi$ (pSv·cm$^2$) | Relative error | Relative difference (RD) |
| 2 | 4.61 | 0.02% | 3.99 | 0.01% | 15.4% |
| 5 | 11.50 | 0.02% | 9.96 | 0.01% | 15.4% |
| 10 | 22.94 | 0.02% | 19.88 | 0.01% | 15.4% |
| 20 | 32.47 | 0.04% | 29.70 | 0.07% | 9.3% |
| 30 | 55.06 | 0.10% | 55.08 | 0.21% | 0.0% |
| 50 | 215.36 | 0.10% | 220.21 | 0.18% | −2.2% |

(*Continued*)

**Table 1.** (*Continued*)

| | | | | | |
|---|---|---|---|---|---|
| 100 | 830.43 | 0.08% | 1052.08 | 0.07% | –21.1% |
| 150 | 1671.55 | 0.07% | 1657.79 | 0.04% | 0.8% |
| 200 | 2020.41 | 0.07% | 2083.33 | 0.05% | –3.0% |
| 500 | 1154.42 | 0.07% | 1145.19 | 0.05% | 0.8% |
| 1000 | 1097.74 | 0.08% | 1086.54 | 0.06% | 1.0% |
| 2000 | 1102.17 | 0.10% | 1090.47 | 0.07% | 1.1% |
| 5000 | 1258.36 | 0.10% | 1248.29 | 0.08% | 0.8% |
| 10 000 | 1505.91 | 0.11% | 1493.28 | 0.09% | 0.8% |
| LLAT | Sitting phantom | | Standing phantom | | |
| Proton energy (MeV) | $E/\Phi$ (pSv·cm$^2$) | Relative error | $E/\Phi$ (pSv·cm$^2$) | Relative error | Relative difference (RD) |
| 2 | 4.61 | 0.02% | 3.99 | 0.01% | 15.4% |
| 5 | 11.50 | 0.02% | 9.96 | 0.01% | 15.4% |
| 10 | 22.94 | 0.02% | 19.87 | 0.01% | 15.4% |
| 20 | 32.85 | 0.04% | 29.39 | 0.09% | 11.7% |
| 30 | 56.42 | 0.10% | 53.92 | 0.22% | 4.6% |
| 50 | 228.29 | 0.10% | 214.28 | 0.19% | 6.5% |
| 100 | 1003.76 | 0.08% | 818.21 | 0.07% | 22.7% |
| 150 | 1866.91 | 0.07% | 1512.14 | 0.04% | 23.5% |
| 200 | 2031.56 | 0.06% | 2120.64 | 0.05% | –4.2% |
| 500 | 1152.96 | 0.07% | 1146.85 | 0.05% | 0.5% |
| 1000 | 1094.24 | 0.08% | 1090.54 | 0.06% | 0.3% |
| 2000 | 1096.98 | 0.10% | 1094.02 | 0.07% | 0.3% |
| 5000 | 1249.95 | 0.10% | 1257.07 | 0.08% | –0.6% |
| 10 000 | 1493.46 | 0.11% | 1504.42 | 0.09% | –0.7% |
| ROT | Sitting phantom | | Standing phantom | | |
| Proton energy (MeV) | $E/\Phi$ (pSv·cm$^2$) | Relative error | $E/\Phi$ (pSv·cm$^2$) | Relative error | Relative difference (RD) |
| 2 | 6.09 | 0.03% | 6.23 | 0.02% | –2.2% |
| 5 | 15.07 | 0.03% | 15.40 | 0.03% | –2.2% |
| 10 | 29.27 | 0.03% | 29.84 | 0.06% | –1.9% |
| 20 | 44.09 | 0.05% | 44.62 | 0.30% | –1.2% |
| 30 | 75.89 | 0.15% | 76.48 | 0.42% | –0.8% |
| 50 | 342.47 | 0.19% | 344.59 | 0.31% | –0.6% |
| 100 | 1345.91 | 0.10% | 1373.67 | 0.11% | –2.0% |
| 150 | 2259.85 | 0.11% | 2213.63 | 0.10% | 2.1% |
| 200 | 2100.67 | 0.09% | 2001.42 | 0.09% | 5.0% |
| 500 | 1243.43 | 0.11% | 1187.04 | 0.11% | 4.8% |
| 1000 | 1177.59 | 0.14% | 1123.13 | 0.14% | 4.8% |
| 2000 | 1179.77 | 0.17% | 1126.02 | 0.17% | 4.8% |
| 5000 | 1331.60 | 0.18% | 1275.28 | 0.20% | 4.4% |
| 10 000 | 1591.02 | 0.20% | 1521.78 | 0.21% | 4.5% |

(*Continued*)

**Table 1.** (*Continued*)

| ISO | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|
| Proton energy (MeV) | $E/\Phi$ (pSv·cm$^2$) | Relative error | $E/\Phi$ (pSv·cm$^2$) | Relative error | Relative difference (RD) |
| 2 | 4.87 | 0.02% | 4.79 | 0.02% | 1.6% |
| 5 | 12.00 | 0.02% | 11.83 | 0.03% | 1.5% |
| 10 | 23.06 | 0.02% | 22.83 | 0.05% | 1.0% |
| 20 | 37.07 | 0.04% | 37.84 | 0.21% | –2.0% |
| 30 | 72.48 | 0.10% | 75.86 | 0.34% | -4.5% |
| 50 | 278.73 | 0.13% | 289.50 | 0.26% | –3.7% |
| 100 | 983.70 | 0.08% | 1032.77 | 0.11% | –4.8% |
| 150 | 1761.77 | 0.08% | 1773.59 | 0.08% | –0.7% |
| 200 | 1848.62 | 0.06% | 1849.09 | 0.08% | 0.0% |
| 500 | 1159.04 | 0.07% | 1154.32 | 0.08% | 0.4% |
| 1000 | 1100.59 | 0.09% | 1094.25 | 0.10% | 0.6% |
| 2000 | 1105.76 | 0.11% | 1097.23 | 0.13% | 0.8% |
| 5000 | 1269.48 | 0.14% | 1262.52 | 0.14% | 0.6% |
| 10 000 | 1519.14 | 0.14% | 1505.09 | 0.15% | 0.9% |

phantom thigh in bottom to head direction, such as breast, in ROT geometry these differences in conversion coefficients were not observed.

In RLAT and LLAT geometry the thigh of the phantom did not contribute directly to differences in conversion coefficients in organs located in pelvic and lower abdominal region, but the absorbed-dose conversion coefficients are affected by the arms and hands of the phantom that in the standing posture are in the lateral region of the body and in the sitting posture are in front the phantom. In adrenals, kidneys and ovaries (see figure 6), for example, the absorbed-dose conversion coefficients were higher for the sitting posture until 150 MeV of protons energy as can be seen in tables B.3–B.4, since the phantom arms attenuate the proton beam, resulting in lower dose in these organs. However, at 200 MeV of protons energy, the organ-dose conversion coefficient was higher in the standing posture. The differences observed in skin-dose conversion coefficients are due to the different areas of interaction between the protons and the tissue in both postures, so the conversion coefficient were higher in the sitting phantom because in this posture the area of interaction is larger, since the arms and hands are in front the phantom and contribute to the dose in skin. Some organs, such as brain, breast, extrathoracic region, oral mucosa, salivary glands, thymus, thyroid and tonsils, presented differences less than 10% in conversion coefficients because the change in posture did not affect the dose deposition.

Table 1 lists the results for fluence-to-effective dose conversion coefficients in both postures for AP, PA, LLAT, RLAT, ROT and ISO geometry, in units of pSv cm$^2$, and the statistical error percentages propagated from organ absorbed doses. Fluence-to-effective dose conversion coefficients were calculated from organ-dose conversion coefficients calculated only for the female phantom. The reason for doing this methodology was to examine the influence in conversion coefficients due to the change in the phantom posture, but as recommended in ICRP 2010, the effective dose must be calculated using the Sex-average equivalent doses obtained from the average of equivalent dose of male and female phantoms. In AP geometry, 15% differences in fluence-to-effective dose conversion coefficients were observed between 2 to 20 MeV. This occur because the major contribution to effective

dose at low energies is the skin dose and the fluence-to-skin dose in standing phantom is higher than in sitting phantom between 2 to 20 MeV. As the proton energy increase there's no differences in conversion coefficients in all geometry. Results from comparison of fluence-to-effective dose conversion coefficients in PA geometry are very similar to the AP geometry. In isotropic and rotational irradiation geometry less than 5% differences between conversion coefficients of both postures were observed in all energy simulated. In RLAT and LLAT geometries the fluence-to-effective dose conversion coefficients were around 15% between 2 and 20 MeV and at 100 and 150 MeV, but in the remaining energies there are no significant differences. In this case the conversion coefficients in the sitting phantom were higher because the skin dose conversion coefficients, which between 2 and 20 MeV of proton energy contribute more to the effective dose than other tissues, were higher in the sitting phantom.

## 4. Conclusions

Comprehensive sets of organ and effective dose conversion coefficients for external proton beams in idealized irradiation geometries were calculated from two UFH/NCI adult female phantoms in standing and sitting postures. The values depend significantly on the morphology and the irradiation geometry, especially at lower energies (below 150 MeV). Change the posture lead to differences in energy deposition in organ and tissue. In antero-posterior geometry the major cause to differences in conversion coefficients is the position of the thigh of the computational phantom, for example, ovaries, uterus and urinary bladder presented conversion coefficients 50% higher in the standing phantom at 30 MeV. In lateral geometries the main contributor to differences in organ-dose conversion coefficients are the position of arms and hands, for example, in organs located in abdominal region such as adrenals, kidneys and pancreas the sitting phantom presented conversion coefficients more than 50% higher at 100 and 150 MeV. In rotational and isotropic geometry the thigh, arms and hands contribute to differences in organ-dose, but the phantoms are irradiated in many directions, so the contribution to differences in conversion coefficients is smaller than in AP, PA, RLAT and LLAT geometries. Since the absence of a set of conversion coefficients for proton source using sitting phantom in literature, this study contributed to filling this lack in addition to providing results more consistent for real exposure scenarios.

**Table A.1.** Absorbed dose per unit fluence (pGy cm$^2$) under AP geometry from monoenergetic protons for ICRP reference female phantom and UFH/NCI female phantom in standing posture.

| AP | Energy (MeV) | $D_T/\Phi$ (pGy cm²) (reference female phantom) | $D_T/\Phi$ (pGv cm²) (UF/NCI female phantom) | Relative difference (%) | | Energy (MeV) | $D_T/\Phi$ (pGy cm²) (reference female phantom) | $D_T/\Phi$ (pGv cm²) (UF/NCI female phantom) | Relative difference (%) |
|---|---|---|---|---|---|---|---|---|---|
| Skin | 2 | 604 | 334 | −45% | Red bone marrow | 2 | | | |
| | 5 | 1510 | 834 | −45% | | 5 | | | |
| | 10 | 3020 | 1663 | −45% | | 10 | 0.007 | 0.005 | −19% |
| | 20 | 2320 | 2182 | −6% | | 20 | 0.05 | 3.4 | 6267% |
| | 30 | 1720 | 1721 | 0% | | 30 | 0.6 | 15.2 | 2424% |
| | 50 | 1260 | 1288 | 2% | | 50 | 236 | 196 | −17% |
| | 100 | 1030 | 1061 | 3% | | 100 | 795 | 540 | −32% |
| | 150 | 1020 | 953 | −7% | | 150 | 1370 | 1013 | −26% |
| | 200 | 853 | 877 | 3% | | 200 | 924 | 939 | 2% |
| | 500 | 537 | 530 | −1% | | 500 | 589 | 557 | −5% |
| | 1000 | 488 | 487 | 0% | | 1000 | 571 | 558 | −2% |
| | 2000 | 486 | 478 | −2% | | 2000 | 591 | 554 | −6% |
| | 5000 | 517 | 552 | 7% | | 5000 | 641 | 616 | −4% |
| | 10 000 | 590 | 637 | 8% | | 10 000 | 773 | 740 | −4% |

| AP | Energy (MeV) | $D_T/\Phi$ (pGy cm²) (reference female phantom) | $D_T/\Phi$ (pGv cm²) (UF/NCI female phantom) | Relative difference (%) | | Energy (MeV) | $D_T/\Phi$ (pGy cm²) (reference female phantom) | $D_T/\Phi$ (pGv cm²) (UF/NCI female phantom) | Relative difference (%) |
|---|---|---|---|---|---|---|---|---|---|
| Breast | 2 | | | | Uterus | 2 | | | |
| | 5 | | | | | 5 | | | |
| | 10 | 1.25 | 0.01 | −99% | | 10 | | | |
| | 20 | 1200 | 0.49 | −100% | | 20 | 0.04 | 0.02 | −60% |
| | 30 | 2140 | 214 | −90% | | 30 | 0.1 | 0.04 | −59% |
| | 50 | 2650 | 2054 | −22% | | 50 | 0.5 | 0.2 | −47% |
| | 100 | 1360 | 1444 | 6% | | 100 | 1330 | 2.5 | −100% |
| | 150 | 985 | 994 | 1% | | 150 | 1280 | 1404 | 10% |
| | 200 | 807 | 812 | 1% | | 200 | 928 | 953 | 3% |
| | 500 | 528 | 525 | −1% | | 500 | 616 | 603 | −2% |
| | 1000 | 471 | 481 | 2% | | 1000 | 595 | 571 | −4% |
| | 2000 | 465 | 475 | 2% | | 2000 | 625 | 573 | −8% |
| | 5000 | 486 | 560 | 15% | | 5000 | 659 | 631 | −4% |
| | 10 000 | 523 | 646 | 23% | | 10 000 | 807 | 762 | −6% |

**Table A.2.** Absorbed dose per unit fluence (pGy cm$^2$) under PA geometry from monoenergetic protons for ICRP reference female phantom and UFH/NCI female phantom in standing posture.

| PA | Energy (MeV) | $D_T/\Phi$ (pGy cm²) (reference female phantom) | $D_T/\Phi$ (pGv cm²) (UF/NCI female phantom) | Relative diference (%) | | Energy (MeV) | $D_T/\Phi$ (pGy cm²) (reference female phantom) | $D_T/\Phi$ (pGv cm²) (UF/NCI female phantom) | Relative diference (%) |
|---|---|---|---|---|---|---|---|---|---|
| Skin | 2 | 605 | 334 | –45% | Red bone marrow | 2 | | | |
| | 5 | 1510 | 835 | –45% | | 5 | | | |
| | 10 | 3020 | 1665 | –45% | | 10 | 0.005 | 0.005 | 13% |
| | 20 | 2150 | 2138 | –1% | | 20 | 0.03 | 0.6 | 1575% |
| | 30 | 1590 | 1655 | 4% | | 30 | 0.1 | 12.7 | 10096% |
| | 50 | 1200 | 1239 | 3% | | 50 | 104 | 154 | 48% |
| | 100 | 1040 | 1057 | 2% | | 100 | 1200 | 1186 | –1% |
| | 150 | 1030 | 950 | –8% | | 150 | 1260 | 1213 | –4% |
| | 200 | 854 | 881 | 3% | | 200 | 904 | 906 | 0% |
| | 500 | 542 | 530 | –2% | | 500 | 597 | 573 | –4% |
| | 1000 | 500 | 487 | –3% | | 1000 | 590 | 544 | –8% |
| | 2000 | 500 | 477 | –5% | | 2000 | 611 | 541 | –11% |
| | 5000 | 559 | 552 | –1% | | 5000 | 676 | 598 | –11% |
| | 10000 | 634 | 638 | 1% | | 10000 | 801 | 719 | –10% |

| PA | Energy (MeV) | $D_T/\Phi$ (pGy cm²) (reference female phantom) | $D_T/\Phi$ (pGv cm²) (UF/NCI female phantom) | Relative diference (%) | | Energy (MeV) | $D_T/\Phi$ (pGy cm²) (reference female phantom) | $D_T/\Phi$ (pGv cm²) (UF/NCI female phantom) | Relative diference (%) |
|---|---|---|---|---|---|---|---|---|---|
| Breast | 2 | | | | Uterus | 2 | | | |
| | 5 | | | | | 5 | | | |
| | 10 | 0.0011 | 0.0018 | 66% | | 10 | 0.005 | 0.004 | –13% |
| | 20 | 0.014 | 0.007 | –49% | | 20 | 0.03 | 0.02 | –41% |
| | 30 | 0.036 | 0.017 | –53% | | 30 | 0.1 | 0.04 | –42% |
| | 50 | 0.20 | 0.11 | –48% | | 50 | 0.4 | 0.2 | –41% |
| | 100 | 1.99 | 1.4 | –30% | | 100 | 285 | 2.3 | –99% |
| | 150 | 1650 | 960 | –42% | | 150 | 1380 | 1617 | 17% |
| | 200 | 1010 | 1146 | 13% | | 200 | 954 | 972 | 2% |
| | 500 | 646 | 616 | –5% | | 500 | 625 | 598 | –4% |
| | 1000 | 620 | 581 | –6% | | 1000 | 618 | 570 | –8% |
| | 2000 | 630 | 568 | –10% | | 2000 | 656 | 570 | –13% |
| | 5000 | 722 | 649 | –10% | | 5000 | 734 | 637 | –13% |
| | 10000 | 866 | 764 | –12% | | 10000 | 874 | 763 | –13% |

**Table A.3.** Absorbed dose per unit fluence (pGy cm$^2$) under RLAT geometry from monoenergetic protons for ICRP reference female phantom and UFH/NCI female phantom in standing posture.

| RLAT | Energy (MeV) | $D_T/\Phi$ (pGy cm²) (reference female phantom) | $D_T/\Phi$ (pGv cm²) (UF/NCI female phantom) | Relative diference (%) | RLAT | Energy (MeV) | $D_T/\Phi$ (pGy cm²) (reference female phantom) | $D_T/\Phi$ (pGv cm²) (UF/NCI female phantom) | Relative diference (%) |
|---|---|---|---|---|---|---|---|---|---|
| Skin | 2 | 307 | 200 | −35% | Red bone marrow | 2 | | | |
| | 5 | 768 | 498 | −35% | | 5 | | | |
| | 10 | 1530 | 993 | −35% | | 10 | 0.001 | 0.003 | 223% |
| | 20 | 1190 | 1321 | 11% | | 20 | 0.02 | 0.4 | 2030% |
| | 30 | 941 | 1070 | 14% | | 30 | 0.1 | 9.3 | 8481% |
| | 50 | 763 | 835 | 9% | | 50 | 143 | 93.3 | −35% |
| | 100 | 895 | 856 | −4% | | 100 | 322 | 379 | 18% |
| | 150 | 891 | 841 | −6% | | 150 | 775 | 783 | 1% |
| | 200 | 781 | 770 | −1% | | 200 | 1010 | 970 | −4% |
| | 500 | 540 | 523 | −3% | | 500 | 597 | 569 | −5% |
| | 1000 | 500 | 481 | −4% | | 1000 | 594 | 545 | −8% |
| | 2000 | 504 | 475 | −6% | | 2000 | 622 | 545 | −12% |
| | 5000 | 557 | 559 | 0% | | 5000 | 695 | 617 | −11% |
| | 10 000 | 643 | 649 | 1% | | 10 000 | 832 | 745 | −10% |

| RLAT | Energy (MeV) | $D_T/\Phi$ (pGy cm²) (reference female phantom) | $D_T/\Phi$ (pGv cm²) (UF/NCI female phantom) | Relative diference (%) | RLAT | Energy (MeV) | $D_T/\Phi$ (pGy cm²) (reference female phantom) | $D_T/\Phi$ (pGv cm²) (UF/NCI female phantom) | Relative diference (%) |
|---|---|---|---|---|---|---|---|---|---|
| Breast | 2 | | | | Uterus | 2 | | | |
| | 5 | | | | | 5 | | | |
| | 10 | 0.017 | 0.00 | −82% | | 10 | | | |
| | 20 | 202 | 0.19 | −100% | | 20 | 0.007 | 0.007 | 5% |
| | 30 | 429 | 77.6 | −82% | | 30 | 0.023 | 0.018 | −23% |
| | 50 | 762 | 536 | −30% | | 50 | 0.10 | 0.11 | 17% |
| | 100 | 930 | 850 | −9% | | 100 | 0.96 | 1.3 | 39% |
| | 150 | 984 | 923 | −6% | | 150 | 84.7 | 117 | 38% |
| | 200 | 968 | 978 | 1% | | 200 | 1280 | 1352 | 6% |
| | 500 | 575 | 554 | −4% | | 500 | 618 | 585 | −5% |
| | 1000 | 556 | 513 | −8% | | 1000 | 653 | 563 | −14% |
| | 2000 | 563 | 509 | −10% | | 2000 | 659 | 565 | −14% |
| | 5000 | 591 | 590 | 0% | | 5000 | 783 | 644 | −18% |
| | 10 000 | 698 | 691 | −1% | | 10 000 | 936 | 774 | −17% |

**Table A.4.** Absorbed dose per unit fluence (pGy $cm^2$) under ISO geometry from monoenergetic protons for ICRP reference female phantom and UFH/NCI female phantom in standing posture.

| ISO | Energy (MeV) | $D_T/\Phi$ (pGy cm²) (reference female phantom) | $D_T/\Phi$ (pGv cm²) (UF/NCI female phantom) | Relative diference (%) | | Energy (MeV) | $D_T/\Phi$ (pGy cm²) (reference female phantom) | $D_T/\Phi$ (pGv cm²) (UF/NCI female phantom) | Relative diference (%) |
|---|---|---|---|---|---|---|---|---|---|
| Skin | 2 | 385 | 239 | −38% | Red bone marrow | 2 | | | |
| | 5 | 944 | 589 | −38% | | 5 | | | |
| | 10 | 1780 | 1132 | −36% | | 10 | 0.083 | 0.058 | −30% |
| | 20 | 1870 | 1765 | −6% | | 20 | 0.34 | 1.12 | 232% |
| | 30 | 1420 | 1451 | 2% | | 30 | 7.4 | 15.0 | 101% |
| | 50 | 1030 | 1063 | 3% | | 50 | 109 | 116 | 7% |
| | 100 | 867 | 892 | 3% | | 100 | 497 | 492 | −1% |
| | 150 | 880 | 859 | −2% | | 150 | 966 | 877 | −9% |
| | 200 | 818 | 809 | −1% | | 200 | 917 | 916 | 0% |
| | 500 | 538 | 529 | −2% | | 500 | 589 | 576 | −2% |
| | 1000 | 492 | 486 | −1% | | 1000 | 578 | 548 | −5% |
| | 2000 | 498 | 479 | −4% | | 2000 | 617 | 548 | −11% |
| | 5000 | 567 | 561 | −1% | | 5000 | 712 | 622 | −13% |
| | 10000 | 672 | 651 | −3% | | 10000 | 893 | 750 | −16% |

| ISO | Energy (MeV) | $D_T/\Phi$ (pGy cm²) (reference female phantom) | $D_T/\Phi$ (pGv cm²) (UF/NCI female phantom) | Relative diference (%) | | Energy (MeV) | $D_T/\Phi$ (pGy cm²) (reference female phantom) | $D_T/\Phi$ (pGv cm²) (UF/NCI female phantom) | Relative diference (%) |
|---|---|---|---|---|---|---|---|---|---|
| Breast | 2 | | | | Uterus | 2 | | | |
| | 5 | | | | | 5 | | | |
| | 10 | 40.5 | 0.03 | −100% | | 10 | | | |
| | 20 | 311 | 4.1 | −99% | | 20 | 0.02 | 0.01 | −34% |
| | 30 | 629 | 154 | −76% | | 30 | 0.04 | 0.02 | −40% |
| | 50 | 996 | 785 | −21% | | 50 | 0.17 | 0.16 | −6% |
| | 100 | 858 | 960 | 12% | | 100 | 131 | 22.8 | −83% |
| | 150 | 831 | 754 | −9% | | 150 | 848 | 939 | 11% |
| | 200 | 913 | 871 | −5% | | 200 | 1010 | 1000 | −1% |
| | 500 | 574 | 556 | −3% | | 500 | 598 | 599 | 0% |
| | 1000 | 538 | 518 | −4% | | 1000 | 598 | 570 | −5% |
| | 2000 | 550 | 514 | −7% | | 2000 | 661 | 577 | −13% |
| | 5000 | 632 | 601 | −5% | | 5000 | 785 | 662 | −16% |
| | 10000 | 758 | 705 | −7% | | 10000 | 1020 | 791 | −22% |

**Table B.1.** Absorbed dose per unit fluence (pGy cm$^2$) under AP geometry from monoenergetic protons for UFH/NCI in standing and sitting posture.

| AP | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Adrenals | 2 | | | | | | Brain | | | | | | Breast | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | 0.002 59 | 5.3% | 0.002 60 | 5.9% | -0.6% | | 0.0105 | 3.6% | 0.0101 | 3.9% | 3.3% |
| | 20 | 0.0106 | 9.5% | 0.0117 | 11.0% | -10.1% | | 0.0126 | 2.5% | 0.0128 | 2.8% | -1.7% | | 0.49 | 1.8% | 0.49 | 2.0% | 0.1% |
| | 30 | 0.025 | 7.4% | 0.023 | 7.9% | 7.8% | | 0.0339 | 1.8% | 0.0337 | 2.3% | 0.5% | | 214.36 | 0.1% | 213.84 | 0.1% | 0.2% |
| | 50 | 0.16 | 11.4% | 0.15 | 9.1% | 8.2% | | 64.56 | 0.2% | 64.36 | 0.2% | 0.3% | | 2056.17 | 0.1% | 2054.03 | 0.1% | 0.1% |
| | 100 | 1.80 | 6.0% | 1.69 | 6.9% | 5.9% | | 767.70 | 0.1% | 767.65 | 0.1% | 0.0% | | 1445.58 | 0.1% | 1444.46 | 0.1% | 0.1% |
| | 150 | 88.63 | 1.1% | 88.34 | 1.2% | 0.3% | | 1387.21 | 0.1% | 1387.34 | 0.1% | 0.0% | | 994.70 | 0.1% | 993.68 | 0.1% | 0.1% |
| | 200 | 1083.29 | 0.3% | 1077.82 | 0.3% | 0.5% | | 925.90 | 0.1% | 925.99 | 0.1% | 0.0% | | 813.62 | 0.1% | 812.10 | 0.1% | 0.2% |
| | 500 | 613.98 | 0.4% | 604.68 | 0.4% | 1.5% | | 561.04 | 0.1% | 561.18 | 0.1% | 0.0% | | 527.89 | 0.1% | 524.61 | 0.1% | 0.6% |
| | 1000 | 592.94 | 0.5% | 590.82 | 0.6% | 0.4% | | 525.06 | 0.1% | 525.23 | 0.1% | 0.0% | | 485.71 | 0.1% | 480.65 | 0.1% | 1.1% |
| | 2000 | 596.59 | 0.6% | 589.47 | 0.7% | 1.2% | | 526.91 | 0.1% | 526.50 | 0.1% | 0.1% | | 480.64 | 0.1% | 474.93 | 0.2% | 1.2% |
| | 5000 | 656.07 | 0.6% | 657.23 | 0.8% | -0.2% | | 600.19 | 0.1% | 600.44 | 0.1% | 0.0% | | 563.54 | 0.2% | 560.29 | 0.2% | 0.6% |
| | 10 000 | 791.91 | 0.8% | 786.87 | 0.7% | 0.6% | | 715.38 | 0.1% | 715.92 | 0.2% | -0.1% | | 650.79 | 0.2% | 645.57 | 0.2% | 0.8% |

| AP | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Colon | 2 | | | | | | Oesophagus | | | | | | Gall bladder | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | 0.0040 | 4.2% | 0.0048 | 4.3% | −16% | | | | | | | | | | | | |
| | 20 | 0.019 | 2.1% | 0.024 | 2.1% | −23% | | 0.016 | 5.4% | 0.015 | 6.3% | 2.9% | | 0.02 | 6.8% | 0.01 | 7.8% | 17.1% |
| | 30 | 0.05 | 1.5% | 0.06 | 1.6% | −17% | | 0.035 | 3.9% | 0.035 | 4.1% | 0.3% | | 0.04 | 5.0% | 0.04 | 5.4% | 0.1% |
| | 50 | 0.25 | 1.7% | 0.28 | 1.8% | −11% | | 0.21 | 5.3% | 0.20 | 4.8% | 8.2% | | 0.23 | 11.0% | 0.24 | 11.9% | −4.4% |
| | 100 | 1216.17 | 0.1% | 1255.07 | 0.1% | −3% | | 459.06 | 0.3% | 465.09 | 0.4% | −1.3% | | 2.40 | 5.0% | 2.21 | 5.1% | 8.7% |
| | 150 | 1244.23 | 0.1% | 1252.03 | 0.1% | −1% | | 1872.54 | 0.2% | 1873.66 | 0.2% | −0.1% | | 1456.03 | 0.2% | 1452.82 | 0.3% | 0.2% |
| | 200 | 915.73 | 0.1% | 902.36 | 0.1% | 1% | | 968.75 | 0.2% | 966.93 | 0.2% | 0.2% | | 957.45 | 0.2% | 959.98 | 0.3% | −0.3% |
| | 500 | 604.98 | 0.1% | 578.06 | 0.1% | 5% | | 597.53 | 0.2% | 595.49 | 0.2% | 0.3% | | 610.71 | 0.3% | 603.94 | 0.4% | 1.1% |
| | 1000 | 573.46 | 0.1% | 546.00 | 0.1% | 5% | | 567.09 | 0.3% | 567.02 | 0.3% | 0.0% | | 579.11 | 0.5% | 572.95 | 0.5% | 1.1% |
| | 2000 | 571.12 | 0.1% | 548.15 | 0.2% | 4% | | 567.44 | 0.4% | 566.37 | 0.4% | 0.2% | | 573.69 | 0.6% | 568.27 | 0.7% | 1.0% |
| | 5000 | 639.91 | 0.1% | 615.64 | 0.2% | 4% | | 637.09 | 0.4% | 635.95 | 0.5% | 0.2% | | 641.90 | 0.7% | 642.06 | 0.9% | 0.0% |
| | 10 000 | 761.28 | 0.2% | 734.86 | 0.2% | 4% | | 762.09 | 0.5% | 763.36 | 0.6% | -0.2% | | 769.96 | 0.8% | 770.18 | 0.9% | 0.0% |

(*Continued*)

**Table B.1.** (*Continued*)

| AP | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Heart | 2 | | | | | | Kidneys | | | | | | Liver | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | 0.00 | 5.1% | 0.005 | 5.8% | 6% | | 0.002 | 8.1% | 0.003 | 8.3% | −26% | | 0.004 26 | 4.0% | 0.004 29 | 4.4% | −1% |
| | 20 | 0.02 | 2.5% | 0.02 | 2.8% | 1% | | 0.009 | 3.9% | 0.012 | 4.1% | −21% | | 0.019 | 1.9% | 0.020 | 2.1% | −3% |
| | 30 | 0.05 | 1.8% | 0.05 | 2.5% | −2% | | 0.021 | 3.1% | 0.025 | 3.2% | −15% | | 0.045 | 1.4% | 0.046 | 1.6% | −1% |
| | 50 | 0.26 | 1.8% | 0.26 | 2.0% | 1% | | 0.13 | 3.0% | 0.13 | 2.9% | −2% | | 0.24 | 1.1% | 0.23 | 1.3% | 1% |
| | 100 | 1058.34 | 0.1% | 1059.92 | 0.1% | 0% | | 1.51 | 1.7% | 1.58 | 1.9% | −4% | | 830.74 | 0.1% | 832.56 | 0.1% | −0.2% |
| | 150 | 1316.50 | 0.1% | 1317.15 | 0.1% | 0% | | 326.95 | 0.2% | 326.81 | 0.2% | 0.0% | | 1305.66 | 0.1% | 1308.05 | 0.1% | −0.2% |
| | 200 | 912.78 | 0.1% | 913.38 | 0.1% | 0% | | 1102.25 | 0.1% | 1101.36 | 0.1% | 0.1% | | 940.98 | 0.1% | 942.16 | 0.1% | −0.1% |
| | 500 | 580.71 | 0.1% | 579.46 | 0.1% | 0% | | 609.91 | 0.1% | 598.44 | 0.1% | 2% | | 590.59 | 0.1% | 585.84 | 0.1% | 1% |
| | 1000 | 549.60 | 0.1% | 547.63 | 0.2% | 0% | | 591.61 | 0.1% | 580.32 | 0.2% | 2% | | 560.63 | 0.1% | 555.63 | 0.1% | 1% |
| | 2000 | 550.25 | 0.2% | 547.52 | 0.2% | 0% | | 586.48 | 0.2% | 578.07 | 0.2% | 1% | | 561.14 | 0.1% | 556.60 | 0.1% | 1% |
| | 5000 | 615.80 | 0.2% | 614.33 | 0.2% | 0% | | 659.69 | 0.2% | 654.72 | 0.2% | 1% | | 627.39 | 0.1% | 624.51 | 0.1% | 0.5% |
| | 10 000 | 736.15 | 0.2% | 733.52 | 0.2% | 0% | | 790.77 | 0.2% | 786.39 | 0.2% | 1% | | 749.88 | 0.1% | 747.74 | 0.1% | 0.3% |

| AP | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Lungs | 10 | 0.0041 | 3.0% | 0.0044 | 3.3% | −6% | Extrathoracic region | | | | | | Oral mucosa | | | | | |
| | 20 | 0.018 | 1.4% | 0.019 | 1.7% | −5% | | 35.51 | 1.0% | 35.63 | 1.1% | −0.3% | | 0.023 | 5.0% | 0.026 | 5.5% | −12% |
| | 30 | 0.045 | 1.1% | 0.046 | 1.3% | −2% | | 123.29 | 0.7% | 124.55 | 0.8% | −1% | | 0.35 | 7.2% | 0.38 | 7.8% | −8% |
| | 50 | 1.174 | 0.9% | 1.171 | 1.0% | 0.3% | | 1073.81 | 0.3% | 1075.57 | 0.3% | −0.2% | | 3.64 | 2.8% | 3.78 | 3.1% | −4% |
| | 100 | 1443.99 | 0.1% | 1444.28 | 0.1% | 0.0% | | 1475.68 | 0.2% | 1481.39 | 0.2% | −0.4% | | 1722.13 | 0.2% | 1717.11 | 0.2% | 0.3% |
| | 150 | 1129.41 | 0.1% | 1128.38 | 0.1% | 0.1% | | 1011.36 | 0.2% | 1013.54 | 0.2% | −0.2% | | 1147.26 | 0.2% | 1140.50 | 0.2% | 1% |
| | 200 | 896.39 | 0.1% | 895.27 | 0.1% | 0.1% | | 822.11 | 0.2% | 825.94 | 0.2% | −0.5% | | 871.01 | 0.2% | 869.70 | 0.2% | 0.2% |
| | 500 | 573.04 | 0.1% | 570.65 | 0.1% | 0.4% | | 540.97 | 0.3% | 543.31 | 0.3% | −0.4% | | 547.85 | 0.2% | 545.01 | 0.3% | 1% |
| | 1000 | 539.40 | 0.1% | 535.46 | 0.1% | 1% | | 507.58 | 0.4% | 511.90 | 0.4% | −1% | | 512.83 | 0.3% | 510.99 | 0.4% | 0.4% |
| | 2000 | 543.73 | 0.1% | 542.31 | 0.1% | 0.3% | | 504.62 | 0.5% | 507.01 | 0.5% | −0.5% | | 514.03 | 0.4% | 513.00 | 0.4% | 0.2% |
| | 5000 | 616.68 | 0.1% | 613.31 | 0.1% | 1% | | 578.42 | 0.5% | 578.14 | 0.6% | 0.0% | | 589.23 | 0.4% | 587.37 | 0.5% | 0.3% |
| | 10 000 | 735.94 | 0.1% | 732.22 | 0.1% | 1% | | 685.57 | 0.6% | 676.27 | 0.6% | 1% | | 701.50 | 0.5% | 697.44 | 0.5% | 1% |

(*Continued*)

**Table B.1.** (*Continued*)

| AP | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Ovaries | 2 | | | | | | Pancreas | | | | | | Salivary glands | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | 0.003 | 9.4% | 0.004 | 10.1% | −28% | | | | | | |
| | 20 | 0.01 | 10.4% | 0.02 | 9.6% | −35% | | 0.013 | 4.6% | 0.015 | 5.2% | −14% | | 0.30 | 7.0% | 0.31 | 7.7% | −1% |
| | 30 | 0.03 | 8.6% | 0.05 | 6.5% | −50% | | 0.031 | 3.5% | 0.035 | 3.7% | −9% | | 1.57 | 3.7% | 1.62 | 4.2% | −3% |
| | 50 | 0.17 | 12.7% | 0.23 | 5.2% | −24% | | 0.18 | 4.0% | 0.19 | 4.4% | −7% | | 79.91 | 0.7% | 80.34 | 0.7% | −1% |
| | 100 | 2.41 | 5.8% | 3.38 | 5.0% | −29% | | 1.99 | 2.1% | 1.95 | 2.3% | 2% | | 1454.47 | 0.2% | 1465.13 | 0.2% | −1% |
| | 150 | 1272.11 | 0.3% | 1235.52 | 0.3% | 3% | | 2146.10 | 0.1% | 2144.82 | 0.1% | 0.1% | | 1149.54 | 0.2% | 1145.55 | 0.2% | 0.3% |
| | 200 | 947.03 | 0.3% | 924.87 | 0.4% | 2% | | 1004.37 | 0.1% | 1002.45 | 0.1% | 0.2% | | 870.72 | 0.2% | 868.36 | 0.2% | 0.3% |
| | 500 | 642.59 | 0.4% | 594.70 | 0.5% | 8% | | 611.43 | 0.2% | 603.38 | 0.2% | 1% | | 549.56 | 0.2% | 546.71 | 0.2% | 1% |
| | 1000 | 613.59 | 0.5% | 559.08 | 0.6% | 10% | | 583.24 | 0.2% | 573.96 | 0.2% | 2% | | 511.68 | 0.3% | 509.71 | 0.3% | 0.4% |
| | 2000 | 601.91 | 0.7% | 567.06 | 0.8% | 6% | | 583.07 | 0.2% | 581.26 | 0.3% | 0.3% | | 512.57 | 0.3% | 509.63 | 0.4% | 1% |
| | 5000 | 684.07 | 0.8% | 637.32 | 0.9% | 7% | | 650.53 | 0.3% | 647.35 | 0.3% | 0.5% | | 584.92 | 0.3% | 581.72 | 0.4% | 1% |
| | 10 000 | 809.22 | 0.8% | 755.79 | 0.9% | 7% | | 778.82 | 0.3% | 779.67 | 0.3% | –0.1% | | 688.68 | 0.4% | 688.68 | 0.5% | 0.0% |
| AP | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Small intestine | 2 | | | | | | Skin | 281.44 | 0.0% | 334.04 | 0.0% | −16% | Spleen | | | | | |
| | 5 | | | | | | | 702.41 | 0.0% | 833.72 | 0.0% | −16% | | | | | | |
| | 10 | 0.004 | 3.8% | 0.005 | 4.1% | −21% | | 1400.56 | 0.0% | 1662.70 | 0.0% | −16% | | | | | | |
| | 20 | 0.016 | 2.0% | 0.021 | 2.0% | −24% | | 1873.61 | 0.0% | 2182.44 | 0.0% | −14% | | 0.01 | 5.0% | 0.02 | 5.0% | −24% |
| | 30 | 0.04 | 1.4% | 0.05 | 1.5% | −20% | | 1569.44 | 0.0% | 1720.57 | 0.0% | −9% | | 0.034 | 3.8% | 0.034 | 3.4% | 0.0% |
| | 50 | 0.23 | 1.4% | 0.25 | 1.5% | −9% | | 1286.04 | 0.0% | 1288.47 | 0.0% | –0.2% | | 0.17 | 3.5% | 0.18 | 4.3% | −1% |
| | 100 | 974.47 | 0.1% | 985.47 | 0.1% | −1% | | 1031.61 | 0.0% | 1060.75 | 0.0% | −3% | | 11.45 | 1.1% | 11.44 | 1.3% | 0.1% |
| | 150 | 1333.17 | 0.1% | 1325.42 | 0.1% | 1% | | 913.36 | 0.0% | 952.76 | 0.0% | −4% | | 1482.50 | 0.2% | 1484.02 | 0.2% | –0.1% |
| | 200 | 935.61 | 0.1% | 925.30 | 0.1% | 1% | | 864.06 | 0.0% | 877.50 | 0.0% | −2% | | 989.12 | 0.2% | 989.60 | 0.2% | 0.0% |
| | 500 | 611.69 | 0.1% | 587.12 | 0.1% | 4% | | 533.73 | 0.0% | 529.55 | 0.0% | 1% | | 597.40 | 0.2% | 589.11 | 0.2% | 1% |
| | 1000 | 580.18 | 0.1% | 553.90 | 0.1% | 5% | | 491.16 | 0.0% | 486.63 | 0.0% | 1% | | 568.01 | 0.2% | 561.15 | 0.3% | 1% |
| | 2000 | 577.34 | 0.1% | 555.93 | 0.1% | 4% | | 482.14 | 0.0% | 477.56 | 0.0% | 1% | | 567.73 | 0.3% | 562.83 | 0.3% | 1% |
| | 5000 | 640.98 | 0.1% | 623.11 | 0.1% | 3% | | 560.58 | 0.0% | 551.67 | 0.1% | 2% | | 635.60 | 0.3% | 633.03 | 0.3% | 0.4% |
| | 10 000 | 764.73 | 0.1% | 744.90 | 0.2% | 3% | | 647.44 | 0.1% | 637.06 | 0.1% | 2% | | 761.35 | 0.3% | 757.04 | 0.4% | 1% |

(*Continued*)

**Table B.1.** (*Continued*)

| AP | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Stomach | 2 | | | | | | Thymus | | | | | | Thyroid | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | 0.0048 | 6.4% | 0.0052 | 7.0% | −7% | | | | | | | | | | | | |
| | 20 | 0.021 | 3.3% | 0.023 | 3.4% | −6% | | 0.023 | 7.0% | 0.025 | 7.6% | −8% | | 0.035 | 5.6% | 0.031 | 7.0% | 13% |
| | 30 | 0.048 | 2.4% | 0.050 | 2.6% | −5% | | 0.065 | 11.8% | 0.055 | 5.6% | 17% | | | | | | |
| | 50 | 0.26 | 2.6% | 0.25 | 3.0% | 3% | | 0.33 | 6.5% | 0.35 | 6.5% | −6% | | 1700.04 | 0.3% | 1718.94 | 0.3% | −1% |
| | 100 | 1319.71 | 0.1% | 1319.18 | 0.1% | 0.0% | | 2211.28 | 0.2% | 2199.42 | 0.3% | 1% | | 1459.46 | 0.2% | 1476.29 | 0.3% | −1% |
| | 150 | 1268.75 | 0.1% | 1265.63 | 0.1% | 0.2% | | 1102.79 | 0.2% | 1097.10 | 0.3% | 1% | | 996.49 | 0.2% | 1007.24 | 0.3% | −1% |
| | 200 | 913.36 | 0.1% | 910.94 | 0.1% | 0.3% | | 868.33 | 0.2% | 861.70 | 0.3% | 1% | | 817.13 | 0.3% | 824.11 | 0.3% | −1% |
| | 500 | 589.29 | 0.1% | 583.03 | 0.2% | 1% | | 567.18 | 0.3% | 563.38 | 0.4% | 1% | | 542.36 | 0.3% | 545.97 | 0.4% | −1% |
| | 1000 | 556.25 | 0.2% | 550.34 | 0.2% | 1% | | 538.44 | 0.4% | 530.43 | 0.5% | 2% | | 511.30 | 0.5% | 514.95 | 0.5% | −1% |
| | 2000 | 556.34 | 0.2% | 550.02 | 0.2% | 1% | | 535.20 | 0.5% | 526.97 | 0.6% | 2% | | 507.45 | 0.6% | 510.08 | 0.7% | −1% |
| | 5000 | 621.98 | 0.2% | 616.00 | 0.3% | 1% | | 596.38 | 0.6% | 594.51 | 0.7% | 0.3% | | 576.03 | 0.7% | 579.86 | 0.8% | −1% |
| | 10 000 | 743.63 | 0.3% | 738.53 | 0.3% | 1% | | 710.85 | 0.7% | 705.51 | 0.7% | 1% | | 673.32 | 0.7% | 683.63 | 1.1% | −2% |

| AP | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Tonsil | 2 | | | | | | Urinary bladder | | | | | | Uterus | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | 0.002 | 10.5% | 0.006 | 8.1% | −62% | | | | | | |
| | 20 | | | | | | | 0.01 | 7.4% | 0.03 | 4.0% | −48% | | 0.01 | 7.1% | 0.02 | 5.4% | −49% |
| | 30 | | | | | | | 0.03 | 3.7% | 0.06 | 2.9% | −52% | | 0.02 | 5.2% | 0.04 | 3.9% | −54% |
| | 50 | 0.17 | 6.9% | 0.18 | 6.8% | −7% | | 0.18 | 5.1% | 0.33 | 4.3% | −44% | | 0.14 | 5.6% | 0.24 | 4.4% | −42% |
| | 100 | 2.44 | 11.9% | 2.33 | 14.3% | 5% | | 893.75 | 0.2% | 1633.68 | 0.2% | −45% | | 1.77 | 2.8% | 2.46 | 2.5% | −28% |
| | 150 | 1384.25 | 0.5% | 1400.91 | 0.6% | −1% | | 1082.96 | 0.2% | 1138.81 | 0.2% | −5% | | 1367.51 | 0.2% | 1403.85 | 0.2% | −3% |
| | 200 | 918.88 | 0.5% | 919.44 | 0.6% | −0.1% | | 959.93 | 0.2% | 883.90 | 0.2% | 9% | | 981.39 | 0.2% | 953.05 | 0.2% | 3% |
| | 500 | 555.01 | 0.7% | 559.80 | 0.8% | −1% | | 631.71 | 0.2% | 574.73 | 0.2% | 10% | | 651.47 | 0.2% | 603.16 | 0.2% | 8% |
| | 1000 | 522.46 | 0.9% | 523.41 | 1.1% | −0.2% | | 606.87 | 0.2% | 543.93 | 0.3% | 12% | | 627.76 | 0.2% | 571.10 | 0.3% | 10% |
| | 2000 | 530.04 | 1.2% | 535.11 | 1.4% | −1% | | 604.38 | 0.3% | 547.63 | 0.4% | 10% | | 620.00 | 0.3% | 572.68 | 0.3% | 8% |
| | 5000 | 603.61 | 1.9% | 604.19 | 2.3% | −0.1% | | 685.71 | 0.3% | 611.69 | 0.5% | 12% | | 703.40 | 0.3% | 631.41 | 0.4% | 11% |
| | 10 000 | 711.66 | 1.8% | 719.75 | 2.1% | −1% | | 814.36 | 0.5% | 732.08 | 0.6% | 11% | | 826.83 | 0.3% | 761.53 | 0.5% | 9% |

(*Continued*)

**Table B.1.** (*Continued*)

| AP | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Muscle | 2 | 0.000 93 | 2.4% | 0.000 88 | 2.8% | 5% | | | | | | | | | | |
| | 5 | 0.015 | 0.9% | 0.014 | 1.0% | 7% | | | | | | | | | | |
| | 10 | 0.101 | 0.5% | 0.096 | 0.5% | 5% | 0.010 | 3.4% | 0.008 | 3.8% | 19% | 0.004 | 3.3% | 0.005 | 3.2% | −20% |
| | 20 | 24.14 | 0.0% | 27.27 | 0.0% | −11% | 7.84 | 0.2% | 7.24 | 0.3% | 8% | 3.83 | 0.2% | 3.43 | 0.3% | 12% |
| | 30 | 77.69 | 0.0% | 88.31 | 0.0% | −12% | 36.42 | 0.1% | 31.83 | 0.2% | 14% | 17.45 | 0.1% | 15.22 | 0.2% | 15% |
| | 50 | 279.01 | 0.0% | 337.99 | 0.0% | −17% | 195.16 | 0.1% | 200.94 | 0.1% | −3% | 205.92 | 0.1% | 196.48 | 0.1% | 5% |
| | 100 | 745.12 | 0.0% | 1057.79 | 0.0% | −30% | 959.47 | 0.0% | 1065.22 | 0.0% | −10% | 421.36 | 0.0% | 540.36 | 0.0% | −22% |
| | 150 | 912.54 | 0.0% | 1148.22 | 0.0% | −21% | 944.05 | 0.0% | 1050.58 | 0.0% | −10% | 884.54 | 0.0% | 1013.00 | 0.0% | −13% |
| | 200 | 857.63 | 0.0% | 911.61 | 0.0% | −6% | 831.42 | 0.0% | 874.98 | 0.0% | −5% | 896.00 | 0.0% | 939.37 | 0.0% | −5% |
| | 500 | 559.81 | 0.0% | 566.01 | 0.0% | −1% | 552.13 | 0.0% | 536.85 | 0.0% | 3% | 578.17 | 0.0% | 556.66 | 0.0% | 4% |
| | 1000 | 528.06 | 0.0% | 532.64 | 0.0% | −1% | 523.33 | 0.0% | 530.41 | 0.0% | −1% | 554.65 | 0.0% | 557.76 | 0.1% | −1% |
| | 2000 | 530.33 | 0.0% | 531.96 | 0.0% | −0.3% | 520.76 | 0.1% | 525.41 | 0.1% | −1% | 552.45 | 0.1% | 553.72 | 0.1% | −0.2% |
| | 5000 | 610.20 | 0.0% | 603.00 | 0.0% | 1% | 588.89 | 0.1% | 586.96 | 0.1% | 0.3% | 620.74 | 0.1% | 615.59 | 0.1% | 1% |
| | 10 000 | 727.32 | 0.0% | 715.10 | 0.0% | 2% | 706.48 | 0.1% | 702.56 | 0.1% | 1% | 747.49 | 0.1% | 740.28 | 0.1% | 1% |

Bone surface

Red bone marrow

**Table B.2.** Absorbed dose per unit fluence (pGy cm$^2$) under PA geometry from monoenergetic protons for UFH/NCI in standing and sitting posture.

| PA | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Adrenals | 2 | | | | | | Brain | | | | | | Breast | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | 0.0035 | 4.8% | 0.0034 | 5.4% | 3% | | 0.0017 | 7.0% | 0.0018 | 7.1% | −8% |
| | 20 | 0.026 | 6.7% | 0.024 | 7.8% | 9% | | 0.0154 | 2.3% | 0.0155 | 2.6% | −1% | | 0.0072 | 3.4% | 0.0071 | 3.6% | 2% |
| | 30 | 0.064 | 4.7% | 0.060 | 5.4% | 7% | | 0.044 | 1.6% | 0.043 | 1.8% | 2% | | 0.0167 | 2.5% | 0.0171 | 2.9% | −3% |
| | 50 | 0.33 | 9.1% | 0.28 | 8.2% | 20% | | 75.46 | 0.1% | 75.48 | 0.2% | 0.0% | | 0.106 | 2.5% | 0.105 | 2.8% | 1% |
| | 100 | 2820.12 | 0.3% | 2818.92 | 0.3% | 0.0% | | 1133.12 | 0.1% | 1134.15 | 0.1% | −0.1% | | 1.39 | 1.4% | 1.39 | 1.5% | 0.3% |
| | 150 | 1133.84 | 0.3% | 1132.88 | 0.3% | 0.1% | | 1271.32 | 0.1% | 1271.46 | 0.1% | 0.0% | | 960.86 | 0.1% | 959.94 | 0.1% | 0.1% |
| | 200 | 889.58 | 0.3% | 887.28 | 0.3% | 0.3% | | 898.51 | 0.1% | 899.00 | 0.1% | −0.1% | | 1146.57 | 0.1% | 1145.81 | 0.1% | 0.1% |
| | 500 | 581.26 | 0.4% | 577.48 | 0.4% | 1% | | 555.03 | 0.1% | 555.24 | 0.1% | 0.0% | | 615.62 | 0.1% | 616.04 | 0.1% | −0.1% |
| | 1000 | 547.28 | 0.5% | 548.31 | 0.6% | −0.2% | | 519.26 | 0.1% | 519.70 | 0.1% | −0.1% | | 580.13 | 0.1% | 580.83 | 0.1% | −0.1% |
| | 2000 | 548.01 | 0.6% | 547.22 | 0.7% | 0.1% | | 520.34 | 0.1% | 520.22 | 0.1% | 0.0% | | 570.41 | 0.1% | 567.98 | 0.2% | 0.4% |
| | 5000 | 603.95 | 0.7% | 605.65 | 0.8% | −0.3% | | 593.21 | 0.1% | 593.72 | 0.1% | −0.1% | | 649.98 | 0.1% | 649.02 | 0.2% | 0.1% |
| | 10 000 | 720.31 | 1.0% | 733.27 | 1.0% | −2% | | 705.10 | 0.1% | 706.74 | 0.2% | −0.2% | | 765.26 | 0.2% | 763.79 | 0.2% | 0.2% |

| PA | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Colon | 2 | | | | | | Oesophagus | | | | | | Gall bladder | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | 0.003 30 | 4.4% | 0.003 34 | 5.0% | −1% | | | | | | | | | | | | |
| | 20 | 0.013 | 2.2% | 0.014 | 2.4% | −8% | | 0.018 | 5.0% | 0.019 | 5.7% | −6% | | 0.0157 | 6.6% | 0.0156 | 8.2% | 1% |
| | 30 | 0.032 | 1.8% | 0.033 | 1.8% | −3% | | 0.05 | 3.4% | 0.04 | 3.9% | 4% | | 0.04 | 8.7% | 0.03 | 6.1% | 18% |
| | 50 | 0.17 | 2.1% | 0.19 | 2.4% | −7% | | 0.25 | 4.4% | 0.27 | 5.8% | −8% | | | | | | |
| | 100 | 80.47 | 0.3% | 80.34 | 0.3% | 0.2% | | 100.33 | 0.7% | 102.18 | 0.8% | −2% | | 2.37 | 5.2% | 2.49 | 5.8% | −5% |
| | 150 | 1241.28 | 0.1% | 1240.91 | 0.1% | 0.0% | | 1291.43 | 0.1% | 1287.23 | 0.2% | 0.3% | | 1665.85 | 0.2% | 1662.78 | 0.3% | 0.2% |
| | 200 | 1004.88 | 0.1% | 1004.81 | 0.1% | 0.0% | | 933.52 | 0.2% | 933.30 | 0.2% | 0.0% | | 973.63 | 0.2% | 971.21 | 0.3% | 0.2% |
| | 500 | 600.76 | 0.1% | 602.50 | 0.1% | −0.3% | | 593.44 | 0.2% | 590.25 | 0.2% | 1% | | 605.25 | 0.3% | 605.62 | 0.4% | −0.1% |
| | 1000 | 573.41 | 0.1% | 576.38 | 0.1% | −1% | | 557.02 | 0.3% | 555.70 | 0.3% | 0.2% | | 574.42 | 0.5% | 573.13 | 0.5% | 0.2% |
| | 2000 | 575.41 | 0.1% | 576.75 | 0.1% | −0.2% | | 557.13 | 0.4% | 557.96 | 0.4% | −0.1% | | 579.56 | 0.6% | 573.35 | 0.7% | 1% |
| | 5000 | 644.78 | 0.1% | 643.60 | 0.2% | 0.2% | | 618.16 | 0.4% | 623.74 | 0.5% | −1% | | 637.27 | 0.7% | 644.86 | 1.0% | −1% |
| | 10 000 | 773.77 | 0.2% | 773.10 | 0.2% | 0.1% | | 743.25 | 0.5% | 742.29 | 0.6% | 0.1% | | 763.70 | 0.7% | 766.14 | 1.0% | −0.3% |

**Table B.2.** (*Continued*)

| PA | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | $D_T/\Phi$ (pGy cm²) | relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Heart | 2 | | | | | | Kidneys | | | | | Liver | | | | |
| | 5 | | | | | | | | | | | | | | | |
| | 10 | 0.0031 | 6.4% | 0.0029 | 7.0% | 8% | 0.007 | 4.7% | 0.008 | 5.2% | −4% | 0.0037 | 4.2% | 0.0038 | 4.7% | −1% |
| | 20 | 0.013 | 3.1% | 0.012 | 3.6% | 5% | 0.032 | 2.3% | 0.035 | 2.6% | −7% | 0.017 | 2.0% | 0.018 | 2.3% | −6% |
| | 30 | 0.0315 | 2.4% | 0.0325 | 3.2% | −3% | 0.078 | 1.6% | 0.084 | 2.2% | −7% | 0.039 | 1.5% | 0.039 | 1.7% | 0.2% |
| | 50 | 0.17 | 2.4% | 0.18 | 2.8% | −6% | 464.55 | 0.1% | 464.53 | 0.2% | 0.0% | 0.20 | 1.2% | 0.21 | 1.3% | −2% |
| | 100 | 54.11 | 0.4% | 54.05 | 0.4% | 0.1% | 1691.84 | 0.1% | 1692.59 | 0.1% | 0.0% | 483.72 | 0.1% | 484.81 | 0.1% | −0.2% |
| | 150 | 1362.87 | 0.1% | 1368.38 | 0.1% | −0.4% | 1035.80 | 0.1% | 1035.95 | 0.1% | 0.0% | 1294.39 | 0.1% | 1297.95 | 0.1% | −0.3% |
| | 200 | 996.63 | 0.1% | 994.73 | 0.1% | 0.2% | 837.54 | 0.1% | 838.63 | 0.1% | −0.1% | 972.34 | 0.1% | 975.19 | 0.1% | −0.3% |
| | 500 | 596.04 | 0.1% | 596.44 | 0.1% | −0.1% | 548.37 | 0.1% | 549.83 | 0.1% | −0.3% | 593.22 | 0.1% | 595.56 | 0.1% | −0.4% |
| | 1000 | 567.51 | 0.1% | 568.85 | 0.2% | −0.2% | 518.98 | 0.2% | 520.68 | 0.2% | −0.3% | 566.29 | 0.1% | 569.38 | 0.1% | −1% |
| | 2000 | 568.05 | 0.2% | 569.18 | 0.2% | −0.2% | 520.53 | 0.2% | 522.54 | 0.2% | −0.4% | 567.20 | 0.1% | 568.66 | 0.1% | −0.3% |
| | 5000 | 636.43 | 0.2% | 637.12 | 0.2% | −0.1% | 589.67 | 0.2% | 591.25 | 0.2% | −0.3% | 634.30 | 0.1% | 634.53 | 0.1% | 0.0% |
| | 10 000 | 764.09 | 0.2% | 763.19 | 0.2% | 0.1% | 696.73 | 0.2% | 696.84 | 0.3% | 0.0% | 760.11 | 0.1% | 760.19 | 0.1% | 0.0% |

| PA | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Lungs | 2 | | | | | | Extrathoracic region | | | | | Oral mucosa | | | | |
| | 5 | | | | | | | | | | | | | | | |
| | 10 | 0.00404 | 3.1% | 0.00400 | 3.5% | 1% | | | | | | | | | | |
| | 20 | 0.0186 | 1.5% | 0.0190 | 1.7% | −2% | 0.0112 | 8.0% | 0.0108 | 8.7% | 3% | 0.0112 | 7.4% | 0.0106 | 9.1% | 6% |
| | 30 | 0.04 | 1.1% | 0.05 | 1.3% | −2% | 0.033 | 5.9% | 0.027 | 6.4% | 22% | 0.029 | 6.7% | 0.031 | 6.1% | −6% |
| | 50 | 1.41 | 0.8% | 1.40 | 0.9% | 1% | 0.18 | 6.9% | 0.17 | 8.4% | 6% | 0.20 | 6.2% | 0.21 | 6.2% | −3% |
| | 100 | 1576.45 | 0.1% | 1576.37 | 0.1% | 0.0% | 149.32 | 0.6% | 149.15 | 0.6% | 0.1% | 516.44 | 0.3% | 515.70 | 0.3% | 0.1% |
| | 150 | 1179.35 | 0.1% | 1179.22 | 0.1% | 0.0% | 1317.09 | 0.2% | 1325.08 | 0.2% | −1% | 1323.95 | 0.2% | 1317.42 | 0.2% | 0.5% |
| | 200 | 890.28 | 0.1% | 890.02 | 0.1% | 0.0% | 952.15 | 0.2% | 955.91 | 0.2% | −0.4% | 927.55 | 0.2% | 923.51 | 0.2% | 0.4% |
| | 500 | 577.59 | 0.1% | 577.83 | 0.1% | 0.0% | 577.05 | 0.3% | 577.26 | 0.3% | 0.0% | 589.56 | 0.2% | 587.92 | 0.3% | 0.3% |
| | 1000 | 540.27 | 0.1% | 539.73 | 0.1% | 0.1% | 543.95 | 0.4% | 545.58 | 0.4% | −0.3% | 548.78 | 0.3% | 549.63 | 0.3% | −0.2% |
| | 2000 | 546.08 | 0.1% | 545.70 | 0.1% | 0.1% | 541.50 | 0.4% | 545.74 | 0.5% | −1% | 547.47 | 0.4% | 548.12 | 0.4% | −0.1% |
| | 5000 | 616.37 | 0.1% | 615.56 | 0.1% | 0.1% | 613.94 | 0.6% | 614.08 | 0.5% | 0.0% | 614.39 | 0.4% | 612.91 | 0.5% | 0.2% |
| | 10 000 | 736.20 | 0.1% | 735.83 | 0.1% | 0.1% | 734.12 | 0.6% | 733.44 | 0.6% | 0.1% | 732.80 | 0.5% | 728.70 | 0.5% | 1% |

(*Continued*)

**Table B.2.** (*Continued*)

| PA | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) |
| Ovaries | 2 | | | | | | Pancreas | | | | | | Salivary glands | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | 0.004 | 8.5% | 0.005 | 9.0% | −14% | | | | | | |
| | 20 | | | | | | | 0.019 | 4.1% | 0.020 | 4.4% | −4% | | 0.014 | 5.2% | 0.013 | 6.2% | 2% |
| | 30 | 0.04 | 12.4% | 0.03 | 8.0% | 22% | | 0.046 | 3.0% | 0.045 | 3.2% | 3% | | 0.04 | 7.8% | 0.05 | 9.3% | −9% |
| | 50 | 0.19 | 15.2% | 0.15 | 5.8% | 32% | | 0.24 | 2.7% | 0.25 | 3.0% | −5% | | 6.95 | 1.7% | 7.04 | 2.0% | −1% |
| | 100 | 1.91 | 6.8% | 2.21 | 7.2% | −13% | | 537.35 | 0.2% | 536.90 | 0.2% | 0.1% | | 1804.25 | 0.2% | 1782.43 | 0.2% | 1% |
| | 150 | 2254.46 | 0.3% | 2253.25 | 0.3% | 0.1% | | 1268.89 | 0.1% | 1269.51 | 0.1% | 0.0% | | 1146.00 | 0.2% | 1143.06 | 0.2% | 0.3% |
| | 200 | 999.95 | 0.3% | 1005.86 | 0.4% | −1% | | 926.40 | 0.1% | 924.86 | 0.1% | 0.2% | | 879.82 | 0.2% | 878.25 | 0.2% | 0.2% |
| | 500 | 590.22 | 0.4% | 601.43 | 0.5% | −2% | | 596.42 | 0.2% | 597.87 | 0.2% | −0.2% | | 572.34 | 0.2% | 571.86 | 0.2% | 0.1% |
| | 1000 | 571.21 | 0.6% | 575.97 | 0.6% | −1% | | 563.64 | 0.2% | 565.54 | 0.2% | −0.3% | | 536.62 | 0.3% | 534.62 | 0.3% | 0.4% |
| | 2000 | 574.37 | 0.7% | 569.31 | 0.7% | 1% | | 564.52 | 0.3% | 566.64 | 0.3% | −0.4% | | 529.77 | 0.3% | 529.54 | 0.4% | 0.0% |
| | 5000 | 643.88 | 0.7% | 643.25 | 0.8% | 0.1% | | 628.16 | 0.3% | 626.78 | 0.3% | 0.2% | | 595.64 | 0.3% | 593.37 | 0.4% | 0.4% |
| | 10 000 | 772.54 | 0.8% | 774.52 | 0.8% | −0.3% | | 752.18 | 0.3% | 753.91 | 0.4% | −0.2% | | 702.65 | 0.4% | 696.88 | 0.4% | 1% |

| PA | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) |
| Small intestine | 2 | | | | | | Skin | 281.96 | 0.0% | 334.49 | 0.0% | −16% | Spleen | | | | | |
| | 5 | | | | | | | 703.74 | 0.0% | 834.90 | 0.0% | −16% | | | | | | |
| | 10 | 0.003 | 4.0% | 0.004 | 4.4% | −8% | | 1403.46 | 0.0% | 1665.28 | 0.0% | −16% | | 0.0059 | 7.5% | 0.0064 | 8.1% | −8% |
| | 20 | 0.014 | 2.0% | 0.016 | 2.1% | −12% | | 1778.25 | 0.0% | 2137.78 | 0.0% | −17% | | 0.027 | 3.5% | 0.026 | 4.0% | 3% |
| | 30 | 0.03 | 1.7% | 0.04 | 1.7% | −4% | | 1347.49 | 0.0% | 1655.32 | 0.0% | −19% | | 0.064 | 2.9% | 0.066 | 3.2% | −3% |
| | 50 | 0.18 | 1.6% | 0.19 | 1.6% | −2% | | 980.37 | 0.0% | 1238.67 | 0.0% | −21% | | 6.04 | 1.2% | 6.04 | 1.3% | 0.0% |
| | 100 | 202.78 | 0.1% | 203.46 | 0.2% | −0.3% | | 837.30 | 0.0% | 1057.32 | 0.0% | −21% | | 1880.15 | 0.2% | 1885.22 | 0.2% | −0.3% |
| | 150 | 1461.53 | 0.1% | 1461.60 | 0.1% | 0.0% | | 792.44 | 0.0% | 950.04 | 0.0% | −17% | | 1086.11 | 0.2% | 1091.27 | 0.2% | −0.5% |
| | 200 | 993.36 | 0.1% | 993.98 | 0.1% | −0.1% | | 835.93 | 0.0% | 881.10 | 0.0% | −5% | | 860.55 | 0.2% | 863.94 | 0.2% | −0.4% |
| | 500 | 600.67 | 0.1% | 603.25 | 0.1% | −0.4% | | 529.03 | 0.0% | 529.58 | 0.0% | −0.1% | | 561.75 | 0.2% | 565.41 | 0.2% | −1% |
| | 1000 | 573.70 | 0.1% | 576.94 | 0.1% | −1% | | 487.22 | 0.0% | 486.55 | 0.0% | 0.1% | | 531.61 | 0.2% | 537.75 | 0.3% | −1% |
| | 2000 | 574.74 | 0.1% | 578.51 | 0.1% | −1% | | 480.22 | 0.0% | 477.46 | 0.0% | 1% | | 530.28 | 0.3% | 533.47 | 0.3% | −1% |
| | 5000 | 644.67 | 0.1% | 644.90 | 0.1% | 0.0% | | 561.38 | 0.0% | 552.00 | 0.1% | 2% | | 597.62 | 0.3% | 599.65 | 0.3% | −0.3% |
| | 10 000 | 773.04 | 0.1% | 773.83 | 0.2% | −0.1% | | 652.73 | 0.1% | 637.76 | 0.1% | 2% | | 711.18 | 0.3% | 714.92 | 0.4% | −1% |

(*Continued*)

**Table B.2.** (*Continued*)

| PA | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Stomach | 2 | | | | | | Thymus | | | | | | Thyroid | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | 0.0034 | 7.0% | 0.0034 | 8.3% | –0.5% | | | | | | | | | | | | |
| | 20 | 0.0139 | 3.5% | 0.0136 | 4.0% | 2% | | 0.014 | 8.6% | 0.012 | 9.6% | 16% | | 0.013 | 8.6% | 0.011 | 10.4% | 14% |
| | 30 | 0.034 | 2.7% | 0.032 | 3.3% | 6% | | 0.030 | 6.2% | 0.032 | 7.2% | –6% | | 0.028 | 5.9% | 0.029 | 7.2% | –3% |
| | 50 | 0.20 | 3.5% | 0.19 | 3.3% | 5% | | 0.20 | 8.0% | 0.18 | 12.3% | 7% | | 0.18 | 6.0% | 0.20 | 12.4% | –10% |
| | 100 | 66.09 | 0.5% | 65.70 | 0.5% | 1% | | 2.11 | 4.7% | 1.95 | 4.9% | 8% | | 2.96 | 4.7% | 5.61 | 4.8% | –47% |
| | 150 | 1546.17 | 0.1% | 1542.17 | 0.1% | 0.3% | | 1936.88 | 0.2% | 1895.69 | 0.3% | 2% | | 1439.51 | 0.2% | 1455.22 | 0.3% | –1% |
| | 200 | 977.87 | 0.1% | 977.94 | 0.1% | 0.0% | | 988.52 | 0.2% | 979.45 | 0.3% | 1% | | 941.73 | 0.3% | 951.60 | 0.3% | –1% |
| | 500 | 601.14 | 0.1% | 604.00 | 0.2% | –0.5% | | 585.90 | 0.3% | 579.22 | 0.4% | 1% | | 581.53 | 0.3% | 590.87 | 0.4% | –2% |
| | 1000 | 572.05 | 0.2% | 576.26 | 0.2% | –1% | | 553.65 | 0.4% | 546.90 | 0.5% | 1% | | 546.05 | 0.5% | 554.84 | 0.5% | –2% |
| | 2000 | 572.72 | 0.2% | 575.48 | 0.2% | –0.5% | | 558.16 | 0.5% | 549.57 | 0.6% | 2% | | 547.15 | 0.6% | 556.64 | 0.7% | –2% |
| | 5000 | 638.08 | 0.2% | 640.70 | 0.3% | –0.4% | | 625.78 | 0.6% | 617.15 | 0.7% | 1% | | 616.95 | 0.6% | 623.31 | 0.7% | –1% |
| | 10 000 | 764.81 | 0.3% | 767.23 | 0.3% | –0.3% | | 751.77 | 0.7% | 736.00 | 0.7% | 2% | | 736.75 | 0.7% | 735.88 | 0.7% | 0.1% |
| PA | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Tonsil | 2 | | | | | | Urinary bladder | | | | | | Uterus | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | 0.0029 | 10.1% | 0.0032 | 10.5% | –11% | | 0.0032 | 10.9% | 0.0044 | 11.8% | –29% |
| | 20 | | | | | | | 0.012 | 5.1% | 0.013 | 5.4% | –4% | | 0.014 | 5.2% | 0.018 | 5.6% | –25% |
| | 30 | 0.05 | 9.7% | 0.04 | 11.1% | 39% | | 0.030 | 5.2% | 0.032 | 3.8% | –6% | | 0.034 | 4.2% | 0.041 | 4.6% | –17% |
| | 50 | 0.26 | 13.9% | 0.25 | 10.0% | 3% | | 0.13 | 2.6% | 0.15 | 4.4% | –17% | | 0.19 | 4.0% | 0.21 | 4.6% | –12% |
| | 100 | 2722.10 | 0.5% | 2718.93 | 0.6% | 0.1% | | 1.66 | 3.3% | 1.97 | 3.5% | –16% | | 2.01 | 2.4% | 2.27 | 2.5% | –11% |
| | 150 | 1162.74 | 0.5% | 1159.65 | 0.6% | 0.3% | | 1301.48 | 0.2% | 1303.18 | 0.2% | –0.1% | | 1613.82 | 0.1% | 1616.93 | 0.2% | –0.2% |
| | 200 | 895.99 | 0.5% | 892.53 | 0.6% | 0.4% | | 1034.36 | 0.1% | 1037.32 | 0.2% | –0.3% | | 969.09 | 0.2% | 971.68 | 0.2% | –0.3% |
| | 500 | 581.39 | 0.7% | 576.58 | 0.8% | 1% | | 589.80 | 0.2% | 599.03 | 0.2% | –2% | | 592.80 | 0.2% | 597.55 | 0.2% | –1% |
| | 1000 | 546.37 | 0.9% | 548.37 | 1.1% | –0.4% | | 566.24 | 0.3% | 576.33 | 0.3% | –2% | | 562.11 | 0.3% | 570.23 | 0.3% | –1% |
| | 2000 | 546.09 | 1.2% | 543.66 | 1.4% | 0.4% | | 570.90 | 0.3% | 574.35 | 0.3% | –1% | | 564.06 | 0.3% | 570.13 | 0.3% | –1% |
| | 5000 | 609.73 | 1.4% | 607.83 | 1.5% | 0.3% | | 646.48 | 0.4% | 646.73 | 0.4% | 0.0% | | 630.28 | 0.3% | 637.33 | 0.4% | –1% |
| | 10 000 | 747.55 | 3.0% | 746.91 | 3.6% | 0.1% | | 773.25 | 0.4% | 781.35 | 0.5% | –1% | | 754.36 | 0.4% | 763.38 | 0.4% | –1% |

(*Continued*)

**Table B.2.** (*Continued*)

| PA | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Muscle | 2 | 0.0007 | 2.8% | 0.0008 | 2.9% | −12% | | | | | | | | | | |
| | 5 | 0.011 | 1.0% | 0.013 | 1.1% | −13% | | | | | | | | | | |
| | 10 | 0.08 | 0.5% | 0.09 | 0.6% | −12% | 0.007 | 3.9% | 0.005 | 3.0% | 40% | 0.0051 | 2.2% | 0.0052 | 2.5% | −1% |
| | 20 | 21.02 | 0.0% | 27.78 | 0.0% | −24% | 2.17 | 0.4% | 1.22 | 0.6% | 78% | 0.551 | 0.9% | 0.551 | 1.0% | 0.0% |
| | 30 | 64.49 | 0.0% | 84.10 | 0.0% | −23% | 29.17 | 0.1% | 29.82 | 0.2% | −2% | 12.69 | 0.2% | 12.74 | 0.2% | −0.4% |
| | 50 | 365.44 | 0.0% | 448.33 | 0.0% | −18% | 248.35 | 0.1% | 257.08 | 0.1% | −3% | 153.26 | 0.1% | 153.56 | 0.1% | −0.2% |
| | 100 | 918.54 | 0.0% | 1154.38 | 0.0% | −20% | 842.75 | 0.0% | 1345.76 | 0.0% | −37% | 1148.33 | 0.0% | 1186.22 | 0.0% | −3% |
| | 150 | 966.00 | 0.0% | 1117.08 | 0.0% | −14% | 907.85 | 0.0% | 1166.97 | 0.0% | −22% | 1191.90 | 0.0% | 1212.62 | 0.0% | −2% |
| | 200 | 868.92 | 0.0% | 895.40 | 0.0% | −3% | 724.67 | 0.0% | 883.99 | 0.0% | −18% | 903.30 | 0.0% | 905.98 | 0.0% | −0.3% |
| | 500 | 561.40 | 0.0% | 561.21 | 0.0% | 0.0% | 541.03 | 0.0% | 557.06 | 0.0% | −3% | 567.18 | 0.0% | 573.13 | 0.0% | −1% |
| | 1000 | 528.77 | 0.0% | 527.64 | 0.0% | 0.2% | 510.65 | 0.0% | 525.86 | 0.0% | −3% | 538.39 | 0.0% | 544.02 | 0.1% | −1% |
| | 2000 | 529.76 | 0.0% | 527.28 | 0.0% | 0.5% | 512.52 | 0.1% | 521.26 | 0.1% | −2% | 535.90 | 0.1% | 540.89 | 0.1% | −1% |
| | 5000 | 607.54 | 0.0% | 598.62 | 0.0% | 1% | 585.11 | 0.1% | 580.60 | 0.1% | 1% | 594.17 | 0.1% | 598.29 | 0.1% | −1% |
| | 10 000 | 722.01 | 0.0% | 709.26 | 0.0% | 2% | 705.15 | 0.1% | 695.22 | 0.1% | 1% | 714.09 | 0.1% | 719.04 | 0.1% | −1% |

Bone surface

Red bone marrow

**Table B.3.** Absorbed dose per unit fluence (pGy cm$^2$) under RLAT geometry from monoenergetic protons for UFH/NCI in standing and sitting posture.

| RLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Adrenals | 2 | | | | | | Brain | | | | | | Breast | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | 0.0036 | 5.5% | 0.0032 | 4.3% | 10% | | 0.0034 | 7.3% | 0.0031 | 6.2% | 9% |
| | 20 | | | | | | | 0.0160 | 2.7% | 0.0157 | 2.1% | 2% | | 0.21 | 3.3% | 0.19 | 2.6% | 6% |
| | 30 | 0.021 | 10.3% | 0.022 | 7.1% | –4% | | 0.05 | 1.9% | 0.04 | 1.4% | 6% | | 77.44 | 0.2% | 77.63 | 0.2% | –0.3% |
| | 50 | 0.14 | 14.0% | 0.10 | 6.0% | 36% | | 136.90 | 0.1% | 137.07 | 0.1% | –0.1% | | 536.21 | 0.1% | 535.82 | 0.1% | 0.1% |
| | 100 | 55.06 | 1.6% | 8.39 | 3.4% | 556% | | 1301.25 | 0.1% | 1303.03 | 0.1% | 0% | | 853.01 | 0.2% | 850.27 | 0.1% | 0% |
| | 150 | 1515.14 | 0.4% | 643.90 | 0.5% | 135% | | 1189.02 | 0.1% | 1190.55 | 0.1% | –0.1% | | 926.10 | 0.2% | 922.94 | 0.1% | 0.3% |
| | 200 | 1006.19 | 0.4% | 1324.72 | 0.3% | –24% | | 883.62 | 0.1% | 885.19 | 0.1% | –0.2% | | 981.66 | 0.2% | 978.10 | 0.1% | 0.4% |
| | 500 | 609.42 | 0.5% | 577.55 | 0.4% | 6% | | 560.32 | 0.1% | 560.92 | 0.1% | –0.1% | | 558.26 | 0.2% | 554.17 | 0.1% | 1% |
| | 1000 | 580.58 | 0.6% | 549.92 | 0.5% | 6% | | 524.39 | 0.1% | 524.76 | 0.1% | –0.1% | | 518.48 | 0.2% | 512.97 | 0.1% | 1% |
| | 2000 | 580.86 | 0.7% | 557.52 | 0.5% | 4% | | 522.84 | 0.1% | 524.03 | 0.1% | –0.2% | | 514.36 | 0.2% | 508.53 | 0.2% | 1% |
| | 5000 | 650.96 | 0.8% | 632.39 | 0.6% | 3% | | 592.64 | 0.1% | 593.36 | 0.1% | –0.1% | | 594.30 | 0.2% | 589.76 | 0.2% | 1% |
| | 10 000 | 772.05 | 0.8% | 769.17 | 0.7% | 0.4% | | 704.40 | 0.2% | 705.61 | 0.1% | –0.2% | | 695.09 | 0.2% | 691.34 | 0.2% | 1% |
| RLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Colon | 2 | | | | | | Oesophagus | | | | | | Gall bladder | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | 0.003 | 6.8% | 0.002 | 5.3% | 19% | | | | | | | | | | | | |
| | 20 | 0.011 | 3.2% | 0.010 | 2.6% | 4% | | 0.009 | 9.2% | 0.010 | 6.7% | –10% | | 0.010 | 10.1% | 0.012 | 7.6% | –19% |
| | 30 | 0.03 | 2.3% | 0.02 | 1.9% | 8% | | 0.023 | 6.2% | 0.023 | 5.4% | 0.2% | | 0.026 | 7.1% | 0.028 | 10.2% | –7% |
| | 50 | 0.15 | 2.7% | 0.14 | 1.9% | 7% | | 0.14 | 9.4% | 0.15 | 7.2% | –6% | | 0.12 | 4.2% | 0.13 | 6.2% | –7% |
| | 100 | 293.07 | 0.2% | 286.13 | 0.2% | 2% | | 141.41 | 1.0% | 142.27 | 0.7% | –1% | | 1.70 | 7.5% | 1.68 | 6.0% | 1% |
| | 150 | 805.59 | 0.1% | 1029.15 | 0.1% | –22% | | 1004.81 | 0.3% | 1185.12 | 0.2% | –15% | | 203.40 | 1.1% | 1155.87 | 0.3% | –82% |
| | 200 | 1048.04 | 0.1% | 963.75 | 0.1% | 9% | | 1133.33 | 0.3% | 1159.24 | 0.2% | –2% | | 1121.41 | 0.3% | 1033.26 | 0.3% | 9% |
| | 500 | 585.09 | 0.1% | 586.30 | 0.1% | –0.2% | | 565.87 | 0.3% | 570.28 | 0.2% | –1% | | 567.39 | 0.4% | 595.66 | 0.3% | –5% |
| | 1000 | 559.74 | 0.1% | 559.92 | 0.1% | 0.0% | | 543.95 | 0.4% | 543.08 | 0.3% | 0.2% | | 548.37 | 0.6% | 563.94 | 0.4% | –3% |
| | 2000 | 561.77 | 0.2% | 562.69 | 0.1% | –0.2% | | 549.06 | 0.4% | 548.83 | 0.3% | 0.0% | | 557.48 | 0.8% | 569.35 | 0.6% | –2% |
| | 5000 | 640.91 | 0.2% | 642.33 | 0.1% | –0.2% | | 624.34 | 0.5% | 628.68 | 0.4% | –1% | | 632.99 | 0.9% | 651.09 | 0.7% | –3% |
| | 10 000 | 770.70 | 0.2% | 769.26 | 0.2% | 0.2% | | 752.88 | 0.6% | 757.53 | 0.4% | –1% | | 765.82 | 0.9% | 777.85 | 0.7% | –2% |

(*Continued*)

**Table B.3.** (*Continued*)

| RLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Heart | 2 | | | | | | Kidneys | | | | | | Liver | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | 0.0013 | 10.5% | 0.0014 | 8.2% | −6% | | 0.003 | 10.0% | 0.002 | 7.9% | 19% | | 0.0032 | 5.5% | 0.0032 | 4.1% | 1% |
| | 20 | 0.0075 | 5.2% | 0.0069 | 3.8% | 8% | | 0.012 | 4.4% | 0.011 | 3.7% | 18% | | 0.015 | 2.6% | 0.013 | 2.1% | 9% |
| | 30 | 0.019 | 3.6% | 0.018 | 3.1% | 7% | | 0.032 | 3.2% | 0.027 | 2.8% | 19% | | 0.04 | 1.9% | 0.03 | 1.5% | 5% |
| | 50 | 0.109 | 4.1% | 0.108 | 2.9% | 1% | | 23.41 | 0.5% | 23.44 | 0.4% | −0.2% | | 0.23 | 1.5% | 0.47 | 0.9% | −52% |
| | 100 | 3.74 | 1.4% | 4.42 | 1.0% | −15% | | 992.98 | 0.2% | 527.88 | 0.2% | 88% | | 412.76 | 0.1% | 498.30 | 0.1% | −17% |
| | 150 | 983.01 | 0.2% | 1103.22 | 0.1% | −11% | | 750.04 | 0.2% | 791.07 | 0.1% | −5% | | 1201.77 | 0.1% | 1229.36 | 0.1% | −2% |
| | 200 | 1081.42 | 0.1% | 1051.48 | 0.1% | 3% | | 981.96 | 0.2% | 1092.62 | 0.1% | −10% | | 1008.87 | 0.1% | 981.67 | 0.1% | 3% |
| | 500 | 588.04 | 0.1% | 590.22 | 0.1% | −0.4% | | 586.04 | 0.2% | 579.43 | 0.1% | 1% | | 575.40 | 0.1% | 579.06 | 0.1% | −1% |
| | 1000 | 564.65 | 0.2% | 565.33 | 0.1% | −0.1% | | 559.92 | 0.2% | 552.68 | 0.2% | 1% | | 547.56 | 0.1% | 550.88 | 0.1% | −1% |
| | 2000 | 566.87 | 0.2% | 566.33 | 0.2% | 0.1% | | 557.30 | 0.2% | 555.62 | 0.2% | 0.3% | | 551.88 | 0.1% | 552.39 | 0.1% | −0.1% |
| | 5000 | 647.46 | 0.2% | 645.12 | 0.2% | 0.4% | | 632.27 | 0.2% | 638.32 | 0.2% | −1% | | 626.14 | 0.1% | 627.02 | 0.1% | −0.1% |
| | 10 000 | 775.69 | 0.3% | 772.30 | 0.2% | 0.4% | | 751.30 | 0.3% | 760.17 | 0.2% | −1% | | 750.61 | 0.2% | 750.03 | 0.1% | 0.1% |
| RLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Lungs | 2 | | | | | | Extrathoracic region | | | | | | Oral mucosa | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | 0.002 | 4.9% | 0.002 | 3.7% | 0.0% | | | | | | | | | | | | |
| | 20 | 0.0107 | 2.3% | 0.0105 | 1.8% | 2% | | 26.42 | 1.3% | 26.25 | 1.0% | 1% | | 0.016 | 7.2% | 0.019 | 5.0% | −13% |
| | 30 | 0.0263 | 1.8% | 0.0258 | 1.4% | 2% | | 70.06 | 1.0% | 69.27 | 0.8% | 1% | | 0.064 | 8.3% | 0.057 | 5.7% | 12% |
| | 50 | 0.139 | 1.7% | 0.143 | 1.4% | −3% | | 140.05 | 0.6% | 139.56 | 0.5% | 0.4% | | 23.80 | 1.1% | 24.23 | 0.8% | −2% |
| | 100 | 316.59 | 0.1% | 379.41 | 0.1% | −17% | | 1890.00 | 0.2% | 1887.83 | 0.2% | 0% | | 2121.97 | 0.2% | 2118.58 | 0.2% | 0% |
| | 150 | 900.21 | 0.1% | 896.04 | 0.1% | 0.5% | | 1081.62 | 0.2% | 1082.10 | 0.2% | 0.0% | | 1075.50 | 0.2% | 1073.97 | 0.2% | 0.1% |
| | 200 | 1061.27 | 0.1% | 1057.55 | 0.1% | 0.4% | | 863.72 | 0.2% | 862.15 | 0.2% | 0.2% | | 859.92 | 0.2% | 858.00 | 0.2% | 0.2% |
| | 500 | 567.74 | 0.1% | 566.45 | 0.1% | 0.2% | | 569.54 | 0.3% | 568.27 | 0.2% | 0.2% | | 565.77 | 0.3% | 564.31 | 0.2% | 0.3% |
| | 1000 | 533.00 | 0.1% | 532.07 | 0.1% | 0.2% | | 532.46 | 0.4% | 534.90 | 0.3% | −0.5% | | 533.74 | 0.4% | 532.10 | 0.3% | 0.3% |
| | 2000 | 542.72 | 0.1% | 541.13 | 0.1% | 0.3% | | 529.07 | 0.5% | 531.72 | 0.4% | −0.5% | | 530.95 | 0.4% | 530.82 | 0.3% | 0.0% |
| | 5000 | 628.63 | 0.1% | 626.72 | 0.1% | 0.3% | | 590.42 | 0.6% | 600.88 | 0.5% | −2% | | 593.91 | 0.5% | 594.11 | 0.4% | 0.0% |
| | 10 000 | 754.91 | 0.1% | 753.07 | 0.1% | 0.2% | | 700.71 | 0.6% | 712.83 | 0.6% | −2% | | 703.79 | 0.5% | 704.19 | 0.4% | −0.1% |

(*Continued*)

**Table B.3.** (*Continued*)

| RLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Ovaries | 2 | | | | | | Pancreas | | | | | | Salivary glands | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | | | | |
| | 20 | | | | | | | 0.0065 | 8.1% | 0.0072 | 6.0% | −9% | | 83.06 | 0.5% | 83.39 | 0.4% | −0.4% |
| | 30 | 0.021 | 10.1% | 0.015 | 9.8% | 39% | | 0.018 | 5.7% | 0.017 | 5.0% | 6% | | 393.21 | 0.3% | 396.39 | 0.2% | −1% |
| | 50 | 0.11 | 8.6% | 0.13 | 14.8% | −11% | | 0.11 | 5.8% | 0.10 | 5.0% | 13% | | 984.28 | 0.3% | 1019.59 | 0.2% | −3% |
| | 100 | 1.58 | 8.9% | 1.24 | 7.7% | 27% | | 1.35 | 3.2% | 1.15 | 2.6% | 18% | | 1200.20 | 0.3% | 1222.82 | 0.2% | −2% |
| | 150 | 909.09 | 0.7% | 24.33 | 2.7% | 3637% | | 401.05 | 0.4% | 9.47 | 1.4% | 4137% | | 1145.56 | 0.2% | 1147.60 | 0.2% | −0.2% |
| | 200 | 1140.91 | 0.6% | 1421.47 | 0.5% | −20% | | 1226.48 | 0.3% | 1094.88 | 0.2% | 12% | | 869.20 | 0.2% | 869.55 | 0.2% | 0.0% |
| | 500 | 601.21 | 0.6% | 569.77 | 0.5% | 6% | | 597.90 | 0.3% | 574.55 | 0.2% | 4% | | 563.08 | 0.3% | 564.31 | 0.2% | −0.2% |
| | 1000 | 575.36 | 0.7% | 552.81 | 0.6% | 4% | | 575.82 | 0.3% | 552.29 | 0.2% | 4% | | 524.85 | 0.3% | 525.37 | 0.3% | −0.1% |
| | 2000 | 577.14 | 0.9% | 555.94 | 0.7% | 4% | | 577.84 | 0.3% | 558.96 | 0.3% | 3% | | 521.07 | 0.4% | 521.01 | 0.3% | 0.0% |
| | 5000 | 649.86 | 0.9% | 643.82 | 0.7% | 1% | | 661.59 | 0.4% | 647.39 | 0.3% | 2% | | 588.14 | 0.4% | 588.83 | 0.3% | −0.1% |
| | 10 000 | 782.00 | 1.0% | 778.18 | 0.7% | 0.5% | | 796.22 | 0.4% | 785.22 | 0.3% | 1% | | 692.61 | 0.5% | 693.26 | 0.4% | −0.1% |

| RLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Small intestine | 2 | | | | | | Skin | 230.34 | 0.0% | 199.56 | 0.0% | 15% | Spleen | | | | | |
| | 5 | | | | | | | 574.87 | 0.0% | 498.08 | 0.0% | 15% | | | | | | |
| | 10 | 0.003 | 5.9% | 0.002 | 4.7% | 21% | | 1146.36 | 0.0% | 993.29 | 0.0% | 15% | | | | | | |
| | 20 | 0.011 | 2.9% | 0.009 | 2.3% | 22% | | 1475.62 | 0.0% | 1320.55 | 0.0% | 12% | | 0.0040 | 8.9% | 0.0037 | 6.7% | 8% |
| | 30 | 0.03 | 2.1% | 0.02 | 1.9% | 17% | | 1139.14 | 0.0% | 1070.12 | 0.0% | 6% | | 0.0092 | 6.6% | 0.0092 | 5.3% | −0.1% |
| | 50 | 3.13 | 0.9% | 0.13 | 1.8% | 2389% | | 854.92 | 0.0% | 834.72 | 0.0% | 2% | | 0.063 | 7.3% | 0.061 | 6.2% | 3% |
| | 100 | 348.62 | 0.2% | 158.98 | 0.2% | 119% | | 880.26 | 0.0% | 855.61 | 0.0% | 3% | | 0.93 | 4.1% | 0.82 | 3.2% | 13% |
| | 150 | 1048.39 | 0.1% | 832.08 | 0.1% | 26% | | 882.69 | 0.0% | 840.51 | 0.0% | 5% | | 3.84 | 2.5% | 3.32 | 2.0% | 16% |
| | 200 | 1050.06 | 0.1% | 1118.30 | 0.1% | −6% | | 803.01 | 0.0% | 769.91 | 0.0% | 4% | | 742.41 | 0.2% | 184.28 | 0.3% | 303% |
| | 500 | 597.36 | 0.1% | 584.87 | 0.1% | 2% | | 525.81 | 0.0% | 522.52 | 0.0% | 1% | | 585.71 | 0.2% | 563.15 | 0.2% | 4% |
| | 1000 | 571.65 | 0.1% | 560.77 | 0.1% | 2% | | 484.21 | 0.0% | 480.82 | 0.0% | 1% | | 563.08 | 0.3% | 543.40 | 0.2% | 4% |
| | 2000 | 572.51 | 0.1% | 564.75 | 0.1% | 1% | | 478.32 | 0.1% | 475.30 | 0.0% | 1% | | 567.05 | 0.3% | 554.51 | 0.2% | 2% |
| | 5000 | 646.40 | 0.2% | 644.90 | 0.1% | 0.2% | | 558.94 | 0.1% | 558.60 | 0.0% | 0.1% | | 666.74 | 0.3% | 653.85 | 0.2% | 2% |
| | 10 000 | 774.49 | 0.2% | 773.52 | 0.1% | 0.1% | | 649.76 | 0.1% | 648.98 | 0.0% | 0.1% | | 801.23 | 0.3% | 794.50 | 0.2% | 1% |

(*Continued*)

**Table B.3.** (*Continued*)

| RLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Stomach | 2 | | | | | | Thymus | | | | | | Thyroid | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | | | | |
| | 20 | 0.0050 | 6.7% | 0.0054 | 5.5% | −8% | | | | | | | | 0.02 | 10.2% | 0.01 | 8.2% | 16% |
| | 30 | 0.0134 | 4.8% | 0.0131 | 8.6% | 2% | | 0.024 | 9.6% | 0.023 | 7.0% | 6% | | 0.03 | 7.7% | 0.04 | 5.6% | −7% |
| | 50 | 0.09 | 7.2% | 0.07 | 4.3% | 22% | | 0.16 | 14.7% | 0.13 | 9.0% | 23% | | 122.89 | 1.1% | 123.46 | 0.9% | −0.5% |
| | 100 | 1.03 | 3.1% | 1.05 | 2.5% | −1% | | 1.95 | 7.2% | 1.96 | 5.2% | −1% | | 1128.24 | 0.5% | 1118.33 | 0.4% | 1% |
| | 150 | 43.64 | 0.6% | 114.53 | 0.3% | −62% | | 1709.93 | 0.4% | 1670.19 | 0.3% | 2% | | 1260.99 | 0.4% | 1256.97 | 0.3% | 0.3% |
| | 200 | 904.82 | 0.2% | 1218.21 | 0.1% | −26% | | 971.50 | 0.4% | 966.02 | 0.3% | 1% | | 907.81 | 0.4% | 904.44 | 0.3% | 0.4% |
| | 500 | 587.63 | 0.2% | 595.34 | 0.1% | −1% | | 573.48 | 0.5% | 569.73 | 0.3% | 1% | | 579.58 | 0.5% | 577.63 | 0.3% | 0.3% |
| | 1000 | 566.43 | 0.2% | 575.38 | 0.2% | −2% | | 540.49 | 0.6% | 539.35 | 0.4% | 0.2% | | 548.17 | 0.6% | 543.07 | 0.4% | 1% |
| | 2000 | 573.15 | 0.3% | 577.04 | 0.2% | −1% | | 552.47 | 0.7% | 545.43 | 0.5% | 1% | | 553.31 | 0.7% | 536.09 | 0.5% | 3% |
| | 5000 | 665.59 | 0.3% | 671.12 | 0.2% | −1% | | 622.71 | 0.8% | 617.24 | 0.6% | 1% | | 620.43 | 0.8% | 614.78 | 0.6% | 1% |
| | 10 000 | 802.52 | 0.3% | 803.08 | 0.2% | −0.1% | | 738.34 | 0.8% | 730.94 | 0.6% | 1% | | 732.76 | 0.9% | 729.67 | 0.7% | 0.4% |

| RLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Tonsil | 2 | | | | | | Urinary bladder | | | | | | Uterus | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | | | | |
| | 20 | | | | | | | 0.008 | 7.3% | 0.007 | 5.8% | 25% | | 0.008 | 8.6% | 0.007 | 7.2% | 6% |
| | 30 | 0.04 | 10.8% | 0.05 | 8.5% | −16% | | 0.022 | 5.0% | 0.018 | 7.7% | 24% | | 0.023 | 7.9% | 0.018 | 5.8% | 31% |
| | 50 | | | | | | | 0.12 | 7.7% | 0.11 | 7.4% | 5% | | 0.12 | 7.1% | 0.11 | 5.4% | 11% |
| | 100 | 2193.19 | 0.9% | 2254.17 | 0.6% | −3% | | 1.62 | 4.0% | 1.20 | 3.4% | 34% | | 1.53 | 3.4% | 1.33 | 3.0% | 15% |
| | 150 | 1122.56 | 0.8% | 1122.24 | 0.6% | 0.0% | | 894.40 | 0.3% | 512.39 | 0.3% | 75% | | 740.61 | 0.3% | 117.10 | 0.6% | 532% |
| | 200 | 866.60 | 0.8% | 874.94 | 0.6% | −1% | | 1083.86 | 0.2% | 1272.44 | 0.2% | −15% | | 1109.57 | 0.3% | 1351.54 | 0.2% | −18% |
| | 500 | 571.20 | 1.0% | 570.15 | 0.7% | 0.2% | | 596.09 | 0.2% | 579.40 | 0.2% | 3% | | 596.54 | 0.3% | 584.68 | 0.2% | 2% |
| | 1000 | 553.13 | 1.3% | 533.19 | 0.9% | 4% | | 574.25 | 0.3% | 556.85 | 0.2% | 3% | | 576.80 | 0.3% | 562.91 | 0.3% | 2% |
| | 2000 | 545.50 | 1.5% | 527.08 | 1.1% | 3% | | 574.15 | 0.4% | 560.61 | 0.3% | 2% | | 575.29 | 0.4% | 564.78 | 0.3% | 2% |
| | 5000 | 602.76 | 1.7% | 583.56 | 1.2% | 3% | | 650.12 | 0.4% | 646.46 | 0.3% | 1% | | 648.59 | 0.4% | 644.08 | 0.3% | 1% |
| | 10 000 | 715.86 | 1.7% | 697.81 | 1.7% | 3% | | 784.68 | 0.5% | 780.54 | 0.4% | 1% | | 782.04 | 0.5% | 774.40 | 0.3% | 1% |

(*Continued*)

**Table B.3.** (*Continued*)

| RLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Muscle | 2 | 0.000 74 | 3.3% | 0.000 67 | 2.5% | 12% | Bone surface | | | | | | Red bone marrow | | | | | |
| | 5 | 0.012 | 1.2% | 0.011 | 0.9% | 8% | | | | | | | | | | | | |
| | 10 | 0.08 | 0.6% | 0.07 | 0.5% | 8% | | 0.001 | 3.4% | 0.006 | 3.6% | –82% | | 0.002 | 3.6% | 0.003 | 2.9% | –50% |
| | 20 | 31.10 | 0.0% | 31.12 | 0.0% | –0.1% | | 4.57 | 0.4% | 5.21 | 0.3% | –12% | | 0.35 | 0.7% | 0.38 | 0.5% | –9% |
| | 30 | 88.18 | 0.0% | 88.27 | 0.0% | –0.1% | | 35.03 | 0.2% | 39.39 | 0.1% | –11% | | 9.04 | 0.2% | 9.27 | 0.2% | –2% |
| | 50 | 264.29 | 0.0% | 249.55 | 0.0% | 6% | | 252.86 | 0.1% | 266.43 | 0.1% | –5% | | 98.75 | 0.1% | 93.33 | 0.1% | 6% |
| | 100 | 693.57 | 0.0% | 642.42 | 0.0% | 8% | | 769.26 | 0.1% | 710.14 | 0.0% | 8% | | 449.19 | 0.1% | 378.53 | 0.0% | 19% |
| | 150 | 879.04 | 0.0% | 852.93 | 0.0% | 3% | | 991.60 | 0.0% | 902.27 | 0.0% | 10% | | 992.83 | 0.0% | 782.65 | 0.0% | 27% |
| | 200 | 935.53 | 0.0% | 911.46 | 0.0% | 3% | | 914.45 | 0.0% | 871.71 | 0.0% | 5% | | 1009.03 | 0.0% | 969.77 | 0.0% | 4% |
| | 500 | 560.33 | 0.0% | 556.68 | 0.0% | 1% | | 551.69 | 0.0% | 549.42 | 0.0% | 0.4% | | 572.66 | 0.0% | 569.27 | 0.0% | 1% |
| | 1000 | 528.62 | 0.0% | 525.11 | 0.0% | 1% | | 522.80 | 0.1% | 521.12 | 0.0% | 0.3% | | 547.30 | 0.1% | 545.42 | 0.0% | 0.3% |
| | 2000 | 530.50 | 0.0% | 527.91 | 0.0% | 0.5% | | 520.33 | 0.1% | 519.86 | 0.0% | 0.1% | | 545.43 | 0.1% | 545.40 | 0.1% | 0.0% |
| | 5000 | 611.32 | 0.0% | 611.24 | 0.0% | 0.0% | | 589.04 | 0.1% | 590.83 | 0.1% | –0.3% | | 614.73 | 0.1% | 617.40 | 0.1% | –0.4% |
| | 10 000 | 727.87 | 0.0% | 728.09 | 0.0% | 0.0% | | 706.82 | 0.1% | 709.52 | 0.1% | –0.4% | | 739.46 | 0.1% | 744.87 | 0.1% | –1% |

**Table B.4.** Absorbed dose per unit fluence (pGy cm$^2$) under LLAT geometry from monoenergetic protons for UFH/NCI in standing and sitting posture.

| LLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Adrenals | 2 | | | | | | Brain | | | | | | Breast | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | 0.0039 | 5.2% | 0.0035 | 4.2% | 11% | | 0.003 | 7.4% | 0.003 | 5.7% | 0.0% |
| | 20 | | | | | | | 0.0159 | 2.8% | 0.0157 | 2.0% | 2% | | 0.20 | 3.4% | 0.19 | 2.6% | 6% |
| | 30 | | | | | | | 0.0465 | 1.8% | 0.0460 | 1.4% | 1% | | 78.21 | 0.2% | 78.44 | 0.2% | −0.3% |
| | 50 | 0.13 | 16.2% | 0.09 | 5.8% | 41% | | 136.14 | 0.1% | 136.32 | 0.1% | 0% | | 536.49 | 0.1% | 536.05 | 0.1% | 0.1% |
| | 100 | 1.73 | 6.8% | 1.53 | 6.0% | 13% | | 1310.01 | 0.1% | 1311.84 | 0.1% | 0% | | 853.52 | 0.2% | 850.16 | 0.1% | 0.4% |
| | 150 | 1046.89 | 0.4% | 113.83 | 1.0% | 820% | | 1185.63 | 0.1% | 1187.37 | 0.1% | 0% | | 927.48 | 0.2% | 922.47 | 0.1% | 1% |
| | 200 | 1012.00 | 0.4% | 1353.61 | 0.3% | −25% | | 883.18 | 0.1% | 884.31 | 0.1% | 0% | | 982.38 | 0.2% | 979.41 | 0.1% | 0.3% |
| | 500 | 604.89 | 0.5% | 569.10 | 0.4% | 6% | | 560.15 | 0.1% | 560.57 | 0.1% | 0% | | 558.43 | 0.2% | 554.60 | 0.1% | 1% |
| | 1000 | 581.74 | 0.6% | 550.99 | 0.5% | 6% | | 524.19 | 0.1% | 524.67 | 0.1% | 0% | | 518.75 | 0.2% | 513.89 | 0.1% | 1% |
| | 2000 | 576.62 | 0.7% | 552.97 | 0.6% | 4% | | 522.84 | 0.1% | 523.73 | 0.1% | 0% | | 514.51 | 0.2% | 508.64 | 0.2% | 1% |
| | 5000 | 654.73 | 0.8% | 635.17 | 0.7% | 3% | | 592.52 | 0.1% | 593.50 | 0.1% | 0% | | 594.97 | 0.2% | 589.47 | 0.2% | 1% |
| | 10000 | 771.81 | 0.8% | 767.48 | 0.7% | 1% | | 704.34 | 0.2% | 705.44 | 0.1% | 0% | | 696.05 | 0.2% | 691.57 | 0.2% | 1% |

| LLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Colon | 2 | | | | | | Oesophagus | | | | | | Gall bladder | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | 0.003 | 6.7% | 0.002 | 5.4% | 19% | | | | | | | | | | | | |
| | 20 | 0.011 | 3.0% | 0.009 | 2.5% | 20% | | 0.010 | 10.1% | 0.009 | 6.7% | 10% | | 0.0079 | 10.9% | 0.0064 | 10.4% | 23% |
| | 30 | 0.03 | 2.4% | 0.02 | 1.9% | 15% | | 0.03 | 6.8% | 0.02 | 4.6% | 15% | | 0.0178 | 8.4% | 0.0176 | 6.9% | 1% |
| | 50 | 26.04 | 0.5% | 0.14 | 2.3% | 18 608% | | 0.14 | 9.3% | 0.13 | 6.5% | 12% | | | | | | |
| | 100 | 295.11 | 0.2% | 290.05 | 0.2% | 2% | | 126.79 | 1.0% | 127.60 | 0.8% | −1% | | 1.20 | 8.4% | 1.08 | 6.6% | 11% |
| | 150 | 780.71 | 0.1% | 934.87 | 0.1% | −16% | | 789.86 | 0.4% | 748.40 | 0.3% | 6% | | 22.39 | 3.1% | 367.70 | 0.6% | −94% |
| | 200 | 1053.51 | 0.1% | 984.84 | 0.1% | 7% | | 1033.51 | 0.2% | 1041.68 | 0.2% | −1% | | 1479.00 | 0.4% | 1374.21 | 0.3% | 8% |
| | 500 | 585.86 | 0.1% | 588.40 | 0.1% | –0.4% | | 567.57 | 0.3% | 569.04 | 0.2% | 0% | | 585.21 | 0.4% | 598.10 | 0.3% | −2% |
| | 1000 | 560.50 | 0.1% | 561.27 | 0.1% | –0.1% | | 546.01 | 0.4% | 545.53 | 0.3% | 0% | | 560.67 | 0.6% | 576.09 | 0.4% | −3% |
| | 2000 | 562.02 | 0.2% | 563.05 | 0.1% | –0.2% | | 550.36 | 0.5% | 551.01 | 0.3% | 0% | | 559.96 | 0.7% | 583.05 | 0.6% | −4% |
| | 5000 | 639.97 | 0.2% | 643.11 | 0.1% | –0.5% | | 626.09 | 0.5% | 626.41 | 0.4% | 0% | | 654.70 | 0.8% | 658.15 | 0.7% | −1% |
| | 10000 | 769.90 | 0.2% | 770.06 | 0.2% | 0.0% | | 755.16 | 0.6% | 755.69 | 0.4% | 0% | | 788.82 | 0.8% | 795.11 | 0.7% | −1% |

(*Continued*)

**Table B.4.** (*Continued*)

| LLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Heart | 2 | | | | | | Kidneys | | | | | | Liver | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | 0.003 | 8.9% | 0.002 | 6.8% | 6% | | 0.0024 | 9.6% | 0.0022 | 7.7% | 8% | | 0.001 31 | 8.2% | 0.001 33 | 6.3% | −2% |
| | 20 | 0.010 | 4.3% | 0.011 | 3.3% | −2% | | 0.013 | 4.5% | 0.010 | 3.6% | 25% | | 0.0064 | 3.9% | 0.0059 | 3.0% | 8% |
| | 30 | 0.029 | 3.0% | 0.027 | 2.6% | 5% | | 0.031 | 3.4% | 0.027 | 2.9% | 18% | | 0.016 | 2.9% | 0.014 | 2.2% | 14% |
| | 50 | 0.15 | 3.1% | 0.16 | 2.7% | −6% | | 1.00 | 2.2% | 0.95 | 1.7% | 5% | | 0.091 | 2.4% | 0.086 | 1.8% | 5% |
| | 100 | 321.75 | 0.2% | 391.81 | 0.1% | −18% | | 998.70 | 0.2% | 446.66 | 0.2% | 124% | | 2.30 | 0.8% | 6.20 | 0.5% | −63% |
| | 150 | 1242.44 | 0.1% | 1321.08 | 0.1% | −6% | | 755.69 | 0.2% | 830.34 | 0.1% | −9% | | 354.94 | 0.2% | 392.12 | 0.1% | −9% |
| | 200 | 999.31 | 0.1% | 980.72 | 0.1% | 2% | | 985.06 | 0.2% | 1089.81 | 0.1% | −10% | | 946.71 | 0.1% | 973.84 | 0.1% | −3% |
| | 500 | 580.77 | 0.1% | 583.47 | 0.1% | −0.5% | | 586.04 | 0.2% | 578.29 | 0.1% | 1% | | 586.78 | 0.1% | 588.61 | 0.1% | −0.3% |
| | 1000 | 552.68 | 0.2% | 553.69 | 0.1% | −0.2% | | 559.08 | 0.2% | 552.82 | 0.2% | 1% | | 565.63 | 0.1% | 568.16 | 0.1% | −0.4% |
| | 2000 | 555.89 | 0.2% | 555.85 | 0.2% | 0.0% | | 557.88 | 0.2% | 556.03 | 0.2% | 0.3% | | 570.30 | 0.1% | 570.93 | 0.1% | −0.1% |
| | 5000 | 630.22 | 0.2% | 629.19 | 0.2% | 0.2% | | 630.85 | 0.2% | 639.10 | 0.2% | −1% | | 658.76 | 0.1% | 659.46 | 0.1% | −0.1% |
| | 10000 | 754.52 | 0.3% | 750.92 | 0.2% | 0.5% | | 751.75 | 0.3% | 762.02 | 0.2% | −1% | | 792.24 | 0.1% | 793.16 | 0.1% | −0.1% |
| LLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Lungs | 2 | | | | | | Extrathoracic region | | | | | | Oral mucosa | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | 0.0024 | 4.8% | 0.0023 | 3.7% | 6% | | | | | | | | | | | | |
| | 20 | 0.0104 | 2.6% | 0.0098 | 1.9% | 6% | | 26.40 | 1.3% | 26.50 | 1.0% | −0.4% | | 0.018 | 7.0% | 0.020 | 6.2% | −13% |
| | 30 | 0.03 | 1.7% | 0.02 | 1.5% | 3% | | 61.36 | 1.1% | 61.77 | 0.8% | −1% | | 0.06 | 6.7% | 0.05 | 5.2% | 4% |
| | 50 | 1.44 | 1.1% | 0.13 | 1.5% | 993% | | 134.70 | 0.7% | 133.45 | 0.5% | 1% | | 37.39 | 0.9% | 37.58 | 0.7% | −0.5% |
| | 100 | 228.05 | 0.1% | 230.32 | 0.1% | −1% | | 1868.72 | 0.2% | 1867.72 | 0.2% | 0.1% | | 2088.07 | 0.2% | 2084.69 | 0.2% | 0.2% |
| | 150 | 760.41 | 0.1% | 776.36 | 0.1% | −2% | | 1085.46 | 0.2% | 1084.08 | 0.2% | 0.1% | | 1075.13 | 0.2% | 1071.86 | 0.2% | 0.3% |
| | 200 | 1103.33 | 0.1% | 1091.62 | 0.1% | 1% | | 862.00 | 0.2% | 862.45 | 0.2% | −0.1% | | 858.84 | 0.2% | 857.97 | 0.2% | 0.1% |
| | 500 | 567.12 | 0.1% | 566.31 | 0.1% | 0.1% | | 567.89 | 0.3% | 568.01 | 0.2% | 0.0% | | 565.48 | 0.3% | 564.79 | 0.2% | 0.1% |
| | 1000 | 533.41 | 0.1% | 532.98 | 0.1% | 0.1% | | 533.32 | 0.4% | 536.10 | 0.3% | −1% | | 534.42 | 0.4% | 531.21 | 0.3% | 1% |
| | 2000 | 543.28 | 0.1% | 542.35 | 0.1% | 0.2% | | 528.51 | 0.5% | 531.20 | 0.4% | −1% | | 531.62 | 0.4% | 530.04 | 0.3% | 0.3% |
| | 5000 | 630.34 | 0.1% | 629.31 | 0.1% | 0.2% | | 592.80 | 0.6% | 602.41 | 0.5% | −2% | | 592.63 | 0.5% | 593.70 | 0.4% | −0.2% |
| | 10000 | 756.95 | 0.1% | 755.83 | 0.1% | 0.1% | | 704.39 | 0.6% | 709.14 | 0.5% | −1% | | 703.26 | 0.6% | 705.01 | 0.5% | −0.2% |

(*Continued*)

**Table B.4.** (*Continued*)

| LLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Ovaries | 2 | | | | | | Pancreas | | | | | | Salivary glands | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | | | | |
| | 20 | | | | | | | 0.014 | 6.0% | 0.012 | 4.7% | 19% | | 92.05 | 0.5% | 92.50 | 0.3% | −0.5% |
| | 30 | | | | | | | 0.031 | 4.6% | 0.027 | 4.0% | 14% | | 416.79 | 0.3% | 420.32 | 0.2% | −1% |
| | 50 | | | | | | | 0.17 | 5.0% | 0.13 | 4.0% | 29% | | 985.31 | 0.3% | 1019.31 | 0.2% | −3% |
| | 100 | 1.60 | 8.8% | 1.18 | 7.3% | 35% | | 320.46 | 0.4% | 1.50 | 2.2% | 21 257% | | 1198.53 | 0.3% | 1219.98 | 0.2% | −2% |
| | 150 | 874.88 | 0.7% | 31.75 | 2.3% | 2656% | | 1213.85 | 0.3% | 763.55 | 0.2% | 59% | | 1144.86 | 0.2% | 1144.78 | 0.2% | 0.0% |
| | 200 | 1124.72 | 0.6% | 1486.56 | 0.5% | −24% | | 1020.02 | 0.3% | 1231.93 | 0.2% | −17% | | 868.21 | 0.2% | 869.08 | 0.2% | −0.1% |
| | 500 | 605.98 | 0.6% | 572.69 | 0.5% | 6% | | 586.94 | 0.3% | 564.94 | 0.2% | 4% | | 563.89 | 0.3% | 564.55 | 0.2% | −0.1% |
| | 1000 | 576.44 | 0.7% | 549.53 | 0.6% | 5% | | 561.75 | 0.3% | 541.72 | 0.2% | 4% | | 523.79 | 0.3% | 524.90 | 0.3% | −0.2% |
| | 2000 | 577.38 | 0.9% | 558.31 | 0.7% | 3% | | 565.09 | 0.3% | 549.27 | 0.3% | 3% | | 520.69 | 0.4% | 520.70 | 0.3% | 0.0% |
| | 5000 | 653.94 | 0.9% | 646.54 | 0.7% | 1% | | 639.83 | 0.4% | 629.98 | 0.3% | 2% | | 588.81 | 0.4% | 588.90 | 0.3% | 0.0% |
| | 10000 | 776.33 | 1.0% | 786.18 | 0.8% | −1% | | 763.67 | 0.4% | 762.87 | 0.3% | 0.1% | | 690.35 | 0.5% | 692.39 | 0.4% | −0.3% |

| LLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Small intestine | 2 | | | | | | Skin | 230.33 | 0.0% | 199.55 | 0.0% | 15% | Spleen | | | | | |
| | 5 | | | | | | | 574.86 | 0.0% | 498.07 | 0.0% | 15% | | | | | | |
| | 10 | 0.0026 | 6.1% | 0.0020 | 4.9% | 31% | | 1146.32 | 0.0% | 993.27 | 0.0% | 15% | | 0.005 | 10.0% | 0.004 | 8.1% | 11% |
| | 20 | 0.011 | 3.3% | 0.009 | 2.4% | 17% | | 1474.18 | 0.0% | 1316.62 | 0.0% | 12% | | 0.024 | 4.5% | 0.017 | 4.1% | 42% |
| | 30 | 0.03 | 2.4% | 0.02 | 1.8% | 16% | | 1139.44 | 0.0% | 1063.94 | 0.0% | 7% | | 0.05 | 3.3% | 0.04 | 2.9% | 32% |
| | 50 | 0.14 | 2.1% | 5.82 | 0.5% | −98% | | 865.01 | 0.0% | 840.24 | 0.0% | 3% | | 29.94 | 0.6% | 0.18 | 3.0% | 16 196% |
| | 100 | 221.98 | 0.2% | 221.79 | 0.1% | 0% | | 894.04 | 0.0% | 865.43 | 0.0% | 3% | | 1006.47 | 0.2% | 165.82 | 0.3% | 507% |
| | 150 | 994.95 | 0.1% | 733.17 | 0.1% | 36% | | 885.19 | 0.0% | 843.42 | 0.0% | 5% | | 1192.07 | 0.1% | 1395.43 | 0.1% | −15% |
| | 200 | 1066.95 | 0.1% | 1084.88 | 0.1% | −2% | | 803.42 | 0.0% | 769.64 | 0.0% | 4% | | 885.11 | 0.2% | 916.16 | 0.1% | −3% |
| | 500 | 598.97 | 0.1% | 586.49 | 0.1% | 2% | | 526.50 | 0.0% | 523.07 | 0.0% | 1% | | 559.78 | 0.2% | 553.63 | 0.2% | 1% |
| | 1000 | 574.91 | 0.1% | 562.02 | 0.1% | 2% | | 484.85 | 0.0% | 481.49 | 0.0% | 1% | | 525.01 | 0.3% | 521.83 | 0.2% | 1% |
| | 2000 | 575.92 | 0.1% | 565.67 | 0.1% | 2% | | 478.94 | 0.1% | 475.75 | 0.0% | 1% | | 527.62 | 0.3% | 525.21 | 0.2% | 0.5% |
| | 5000 | 651.59 | 0.2% | 645.85 | 0.1% | 1% | | 559.36 | 0.1% | 558.88 | 0.0% | 0.1% | | 600.63 | 0.3% | 605.77 | 0.3% | −1% |
| | 10000 | 779.74 | 0.2% | 777.18 | 0.1% | 0.3% | | 650.19 | 0.1% | 649.20 | 0.0% | 0.2% | | 715.23 | 0.4% | 721.91 | 0.3% | −1% |

(*Continued*)

**Table B.4.** (*Continued*)

| LLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Stomach | 2 | | | | | | Thymus | | | | | | Thyroid | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | 0.003 | 8.5% | 0.004 | 6.4% | −15% | | | | | | | | | | | | |
| | 20 | 0.016 | 4.3% | 0.017 | 3.2% | −4% | | | | | | | | 0.016 | 10.3% | 0.015 | 7.8% | 10% |
| | 30 | 0.042 | 3.3% | 0.041 | 2.3% | 2% | | 0.028 | 12.7% | 0.029 | 6.8% | −2% | | 0.040 | 7.6% | 0.039 | 5.4% | 1% |
| | 50 | 0.20 | 3.1% | 0.22 | 2.6% | −9% | | 0.15 | 14.9% | 0.14 | 8.8% | 4% | | 186.63 | 0.9% | 185.55 | 0.7% | 1% |
| | 100 | 777.57 | 0.2% | 1193.96 | 0.1% | −35% | | 2.22 | 7.0% | 1.92 | 5.4% | 16% | | 1292.92 | 0.5% | 1281.19 | 0.3% | 1% |
| | 150 | 1278.05 | 0.1% | 1269.12 | 0.1% | 1% | | 1885.76 | 0.4% | 1858.16 | 0.3% | 1% | | 1250.32 | 0.4% | 1244.48 | 0.3% | 0.5% |
| | 200 | 947.20 | 0.1% | 917.82 | 0.1% | 3% | | 987.38 | 0.4% | 978.37 | 0.3% | 1% | | 904.24 | 0.4% | 902.48 | 0.3% | 0.2% |
| | 500 | 577.02 | 0.2% | 583.84 | 0.1% | −1% | | 571.81 | 0.5% | 564.46 | 0.3% | 1% | | 576.37 | 0.5% | 578.58 | 0.3% | −0.4% |
| | 1000 | 546.77 | 0.2% | 552.97 | 0.2% | −1% | | 538.40 | 0.6% | 535.03 | 0.4% | 1% | | 547.15 | 0.6% | 546.21 | 0.4% | 0.2% |
| | 2000 | 550.20 | 0.3% | 553.10 | 0.2% | −1% | | 549.22 | 0.7% | 539.61 | 0.5% | 2% | | 548.69 | 0.7% | 542.55 | 0.5% | 1% |
| | 5000 | 623.32 | 0.3% | 623.55 | 0.2% | 0.0% | | 618.78 | 0.8% | 615.77 | 0.6% | 0.5% | | 614.27 | 0.8% | 617.02 | 0.6% | −0.4% |
| | 10000 | 745.76 | 0.3% | 739.76 | 0.2% | 1% | | 741.03 | 0.9% | 732.49 | 0.6% | 1% | | 732.11 | 1.1% | 732.20 | 0.8% | 0.0% |
| LLAT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Tonsil | 2 | | | | | | Urinary bladder | | | | | | Uterus | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | | | | |
| | 20 | | | | | | | 0.010 | 6.6% | 0.008 | 5.7% | 20% | | 0.009 | 8.1% | 0.007 | 7.3% | 34% |
| | 30 | | | | | | | 0.021 | 5.4% | 0.018 | 4.6% | 16% | | 0.020 | 7.0% | 0.018 | 5.6% | 14% |
| | 50 | | | | | | | 0.12 | 7.3% | 0.10 | 5.9% | 26% | | 0.13 | 7.0% | 0.10 | 5.0% | 24% |
| | 100 | 2273.53 | 0.8% | 2338.20 | 0.6% | −3% | | 1.56 | 4.1% | 1.30 | 3.5% | 20% | | 1.57 | 3.6% | 1.32 | 3.0% | 18% |
| | 150 | 1116.86 | 0.8% | 1117.43 | 0.6% | −0.1% | | 877.48 | 0.3% | 525.73 | 0.3% | 67% | | 718.42 | 0.3% | 106.99 | 0.6% | 571% |
| | 200 | 870.09 | 0.8% | 867.44 | 0.6% | 0.3% | | 1086.49 | 0.2% | 1270.38 | 0.2% | −14% | | 1114.22 | 0.3% | 1357.86 | 0.2% | −18% |
| | 500 | 576.17 | 1.0% | 568.59 | 0.7% | 1% | | 593.96 | 0.2% | 580.12 | 0.2% | 2% | | 598.22 | 0.3% | 582.76 | 0.2% | 3% |
| | 1000 | 552.83 | 1.3% | 538.19 | 0.9% | 3% | | 574.31 | 0.3% | 555.14 | 0.2% | 3% | | 577.37 | 0.3% | 561.03 | 0.3% | 3% |
| | 2000 | 543.20 | 1.5% | 531.12 | 1.1% | 2% | | 574.28 | 0.4% | 560.78 | 0.3% | 2% | | 573.30 | 0.4% | 565.03 | 0.3% | 1% |
| | 5000 | 591.37 | 1.6% | 584.55 | 1.2% | 1% | | 650.68 | 0.4% | 646.63 | 0.3% | 1% | | 648.18 | 0.4% | 644.20 | 0.3% | 1% |
| | 10000 | 710.82 | 1.7% | 701.06 | 1.7% | 1% | | 785.88 | 0.5% | 779.20 | 0.4% | 1% | | 781.91 | 0.5% | 776.44 | 0.3% | 1% |

(*Continued*)

**Table B.4.** (*Continued*)

| LLAT | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) |
| Muscle | 2 | 0.0007 | 3.4% | 0.0006 | 2.6% | 9% | | | | | | | | | | |
| | 5 | 0.011 | 1.2% | 0.010 | 0.9% | 8% | | | | | | | | | | |
| | 10 | 0.08 | 0.6% | 0.07 | 0.5% | 8% | 0.005 | 6.1% | 0.007 | 3.9% | −22% | 0.004 | 4.3% | 0.005 | 3.0% | −14% |
| | 20 | 30.57 | 0.0% | 30.30 | 0.0% | 1% | 6.08 | 0.3% | 6.66 | 0.2% | −9% | 1.17 | 0.4% | 1.14 | 0.3% | 3% |
| | 30 | 87.42 | 0.0% | 85.02 | 0.0% | 3% | 41.10 | 0.2% | 45.28 | 0.1% | −9% | 12.13 | 0.2% | 12.15 | 0.1% | −0.2% |
| | 50 | 260.02 | 0.0% | 244.92 | 0.0% | 6% | 259.85 | 0.1% | 272.61 | 0.1% | −5% | 101.72 | 0.1% | 97.33 | 0.1% | 5% |
| | 100 | 702.61 | 0.0% | 648.19 | 0.0% | 8% | 770.25 | 0.1% | 710.24 | 0.0% | 8% | 450.28 | 0.1% | 375.42 | 0.1% | 20% |
| | 150 | 894.91 | 0.0% | 872.18 | 0.0% | 3% | 990.69 | 0.0% | 900.71 | 0.0% | 10% | 988.75 | 0.0% | 778.57 | 0.0% | 27% |
| | 200 | 934.13 | 0.0% | 908.56 | 0.0% | 3% | 914.96 | 0.0% | 871.38 | 0.0% | 5% | 1010.20 | 0.0% | 970.45 | 0.0% | 4% |
| | 500 | 560.23 | 0.0% | 556.62 | 0.0% | 1% | 551.77 | 0.0% | 549.22 | 0.0% | 0.5% | 573.04 | 0.0% | 569.26 | 0.0% | 1% |
| | 1000 | 528.47 | 0.0% | 524.98 | 0.0% | 1% | 523.09 | 0.1% | 520.91 | 0.0% | 0.4% | 547.61 | 0.1% | 545.43 | 0.0% | 0.4% |
| | 2000 | 530.43 | 0.0% | 527.78 | 0.0% | 1% | 520.51 | 0.1% | 519.74 | 0.0% | 0.1% | 545.79 | 0.1% | 545.45 | 0.1% | 0.1% |
| | 5000 | 610.95 | 0.0% | 610.96 | 0.0% | 0.0% | 589.33 | 0.1% | 590.51 | 0.1% | –0.2% | 615.09 | 0.1% | 617.98 | 0.1% | −0.5% |
| | 10000 | 727.31 | 0.0% | 727.78 | 0.0% | –0.1% | 707.19 | 0.1% | 709.60 | 0.1% | –0.3% | 739.78 | 0.1% | 745.57 | 0.1% | −1% |

Bone surface

Red bone marrow

**Table B.5.** Absorbed dose per unit fluence (pGy cm$^2$) under ROT geometry from monoenergetic protons for UFH/NCI in standing and sitting posture.

| ROT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) |
| Adrenals | 2 | | | | | | Brain | | | | | | Breast | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | 0.0042 | 10.2% | 0.0034 | 10.4% | 25% | | | | | | |
| | 20 | | | | | | | 0.016 | 5.2% | 0.015 | 5.0% | 7% | | 0.85 | 3.0% | 0.88 | 2.7% | −3% |
| | 30 | | | | | | | 0.05 | 3.5% | 0.04 | 3.6% | 9% | | 134.21 | 0.3% | 136.04 | 0.3% | −1% |
| | 50 | 0.19 | 9.2% | 0.17 | 10.5% | 9% | | 89.08 | 0.3% | 82.56 | 0.3% | 8% | | 854.33 | 0.2% | 874.79 | 0.2% | −2% |
| | 100 | 767.31 | 1.2% | 724.82 | 1.2% | 6% | | 1243.05 | 0.2% | 1153.87 | 0.2% | 8% | | 917.64 | 0.3% | 965.46 | 0.2% | −5% |
| | 150 | 1087.97 | 0.8% | 947.16 | 0.8% | 15% | | 1360.83 | 0.2% | 1273.63 | 0.2% | 7% | | 813.72 | 0.2% | 837.40 | 0.2% | −3% |
| | 200 | 1149.37 | 0.7% | 1056.16 | 0.7% | 9% | | 965.56 | 0.2% | 902.03 | 0.2% | 7% | | 992.34 | 0.2% | 1018.84 | 0.2% | −3% |
| | 500 | 656.78 | 0.8% | 599.42 | 0.8% | 10% | | 603.26 | 0.2% | 563.58 | 0.2% | 7% | | 576.24 | 0.2% | 590.65 | 0.2% | −2% |
| | 1000 | 620.61 | 1.1% | 575.92 | 1.1% | 8% | | 564.54 | 0.2% | 526.04 | 0.2% | 7% | | 537.62 | 0.3% | 549.74 | 0.3% | −2% |
| | 2000 | 631.34 | 1.4% | 572.78 | 1.3% | 10% | | 566.97 | 0.3% | 526.75 | 0.3% | 8% | | 533.11 | 0.3% | 541.26 | 0.3% | −2% |
| | 5000 | 698.00 | 1.5% | 641.66 | 1.4% | 9% | | 639.28 | 0.3% | 596.60 | 0.3% | 7% | | 615.14 | 0.3% | 632.71 | 0.3% | −3% |
| | 10000 | 833.63 | 1.5% | 764.01 | 1.4% | 9% | | 758.24 | 0.3% | 708.16 | 0.3% | 7% | | 721.13 | 0.4% | 739.31 | 0.4% | −2% |

| ROT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) |
| Colon | 2 | | | | | | Oesophagus | | | | | | Gall bladder | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | 0.0039 | 9.8% | 0.0035 | 9.9% | 11% | | | | | | | | | | | | |
| | 20 | 0.015 | 5.0% | 0.016 | 4.7% | −5% | | | | | | | | | | | | |
| | 30 | 0.039 | 5.1% | 0.040 | 3.9% | −3% | | 0.0392 | 10.3% | 0.0389 | 10.0% | 1% | | | | | | |
| | 50 | 3.49 | 2.6% | 2.47 | 2.7% | 41% | | 0.193 | 10.4% | 0.182 | 8.3% | 6% | | 0.14 | 8.0% | 0.18 | 12.9% | −21% |
| | 100 | 540.54 | 0.3% | 614.83 | 0.3% | −12% | | 266.98 | 1.1% | 251.61 | 1.1% | 6% | | 2.25 | 11.6% | 2.20 | 10.9% | 3% |
| | 150 | 1102.64 | 0.2% | 1085.14 | 0.2% | 2% | | 1448.81 | 0.4% | 1333.10 | 0.4% | 9% | | 1463.30 | 0.7% | 1370.94 | 0.6% | 7% |
| | 200 | 1074.10 | 0.2% | 1022.12 | 0.2% | 5% | | 1066.11 | 0.4% | 981.65 | 0.4% | 9% | | 1091.69 | 0.6% | 1043.24 | 0.6% | 5% |
| | 500 | 630.66 | 0.2% | 601.17 | 0.2% | 5% | | 638.52 | 0.5% | 591.31 | 0.5% | 8% | | 645.21 | 0.8% | 602.12 | 0.7% | 7% |
| | 1000 | 601.82 | 0.3% | 573.86 | 0.2% | 5% | | 604.25 | 0.7% | 553.51 | 0.6% | 9% | | 612.36 | 1.0% | 575.71 | 1.1% | 6% |
| | 2000 | 599.55 | 0.3% | 574.67 | 0.3% | 4% | | 611.13 | 0.8% | 565.42 | 0.8% | 8% | | 614.99 | 1.4% | 570.88 | 1.3% | 8% |
| | 5000 | 677.25 | 0.3% | 647.33 | 0.3% | 5% | | 681.09 | 0.9% | 633.08 | 0.9% | 8% | | 667.77 | 1.5% | 647.57 | 1.5% | 3% |
| | 10000 | 809.95 | 0.4% | 778.13 | 0.4% | 4% | | 810.83 | 0.9% | 775.99 | 1.6% | 4% | | 813.63 | 1.5% | 771.58 | 1.5% | 5% |

(*Continued*)

**Table B.5.** (*Continued*)

| ROT | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) |
| Heart | 2 | | | | | | | | | | | | | | | |
| | 5 | | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | | |
| | 20 | 0.015 | 6.7% | 0.017 | 6.1% | −7% | 0.019 | 6.9% | 0.018 | 6.4% | 6% | 0.0037 | 9.9% | 0.0030 | 10.0% | 22% |
| | 30 | 0.036 | 5.7% | 0.036 | 4.6% | 0% | 0.049 | 5.8% | 0.046 | 5.5% | 7% | 0.015 | 4.9% | 0.016 | 4.4% | −6% |
| | 50 | 0.18 | 5.4% | 0.19 | 6.4% | −4% | 129.50 | 0.6% | 125.15 | 0.6% | 3% | 0.040 | 3.7% | 0.037 | 3.2% | 8% |
| | 100 | 399.75 | 0.4% | 391.44 | 0.4% | 2% | 964.76 | 0.3% | 779.38 | 0.3% | 24% | 2.50 | 1.5% | 1.28 | 1.8% | 95% |
| | 150 | 1324.11 | 0.2% | 1269.86 | 0.2% | 4% | 975.45 | 0.3% | 950.81 | 0.3% | 3% | 518.48 | 0.2% | 493.61 | 0.2% | 5% |
| | 200 | 1048.80 | 0.2% | 1003.09 | 0.2% | 5% | 1083.90 | 0.2% | 1014.65 | 0.2% | 7% | 1124.59 | 0.2% | 1076.24 | 0.2% | 4% |
| | 500 | 618.27 | 0.3% | 590.76 | 0.3% | 5% | 653.72 | 0.3% | 597.55 | 0.3% | 9% | 1078.55 | 0.2% | 1023.22 | 0.2% | 5% |
| | 1000 | 591.55 | 0.3% | 563.76 | 0.3% | 5% | 621.43 | 0.3% | 568.73 | 0.3% | 9% | 631.63 | 0.2% | 600.33 | 0.2% | 5% |
| | 2000 | 594.01 | 0.4% | 566.19 | 0.4% | 5% | 622.00 | 0.4% | 569.11 | 0.4% | 9% | 604.93 | 0.2% | 572.56 | 0.2% | 6% |
| | 5000 | 662.85 | 0.4% | 636.73 | 0.4% | 4% | 708.29 | 0.4% | 647.98 | 0.4% | 9% | 605.17 | 0.3% | 574.58 | 0.2% | 5% |
| | 10000 | 794.23 | 0.5% | 763.13 | 0.5% | 4% | 841.52 | 0.5% | 767.99 | 0.5% | 10% | 680.59 | 0.2% | 646.38 | 0.2% | 5% |
| | | | | | | | Kidneys | | | | | Liver | | | | |
| ROT | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | |
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) |
| Lungs | 2 | | | | | | | | | | | | | | | |
| | 5 | | | | | | | | | | | | | | | |
| | 10 | 0.0035 | 7.7% | 0.0033 | 7.4% | 5% | 1.81 | 9.1% | 1.90 | 8.4% | −5% | | | | | |
| | 20 | 0.017 | 3.6% | 0.017 | 3.4% | 0% | 20.97 | 3.1% | 21.53 | 2.9% | −3% | | | | | |
| | 30 | 0.041 | 2.7% | 0.040 | 2.8% | 4% | 54.81 | 2.2% | 54.79 | 2.1% | 0% | | | | | |
| | 50 | 5.07 | 1.4% | 4.05 | 1.4% | 25% | 390.53 | 1.0% | 388.54 | 0.9% | 1% | 12.87 | 3.2% | 11.84 | 3.1% | 9% |
| | 100 | 981.45 | 0.2% | 960.47 | 0.2% | 2% | 1440.99 | 0.5% | 1389.09 | 0.5% | 4% | 1895.69 | 0.5% | 1800.30 | 0.4% | 5% |
| | 150 | 1209.63 | 0.1% | 1141.54 | 0.1% | 6% | 1201.25 | 0.5% | 1146.66 | 0.4% | 5% | 1208.32 | 0.4% | 1147.70 | 0.4% | 5% |
| | 200 | 1046.21 | 0.1% | 978.39 | 0.1% | 7% | 916.40 | 0.5% | 875.62 | 0.4% | 5% | 929.46 | 0.5% | 879.42 | 0.4% | 6% |
| | 500 | 625.07 | 0.1% | 586.95 | 0.1% | 6% | 590.41 | 0.6% | 567.83 | 0.6% | 4% | 605.21 | 0.6% | 573.32 | 0.5% | 6% |
| | 1000 | 588.03 | 0.2% | 550.76 | 0.2% | 7% | 557.93 | 0.8% | 532.11 | 0.8% | 5% | 571.07 | 0.7% | 532.21 | 0.7% | 7% |
| | 2000 | 595.00 | 0.2% | 557.87 | 0.2% | 7% | 561.72 | 1.0% | 542.52 | 1.1% | 4% | 560.84 | 0.8% | 536.87 | 0.8% | 4% |
| | 5000 | 677.16 | 0.2% | 636.74 | 0.2% | 6% | 625.77 | 1.1% | 618.24 | 1.1% | 1% | 633.27 | 0.9% | 598.96 | 0.9% | 6% |
| | 10000 | 810.24 | 0.3% | 760.58 | 0.2% | 7% | 738.75 | 1.1% | 718.76 | 1.1% | 3% | 747.89 | 0.9% | 704.93 | 0.9% | 6% |
| | | | | | | | Extrathoracic region | | | | | Oral mucosa | | | | |

(*Continued*)

**Table B.5.** (*Continued*)

| ROT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) |
| Ovaries | 2 | | | | | | Pancreas | | | | | | Salivary glands | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | 0.49 | 11.0% | 0.62 | 9.2% | −21% |
| | 20 | | | | | | | 0.016 | 9.7% | 0.018 | 10.2% | −10% | | 35.43 | 1.4% | 32.15 | 1.4% | 10% |
| | 30 | | | | | | | 0.035 | 7.9% | 0.035 | 8.8% | 0% | | 218.77 | 0.8% | 202.53 | 0.8% | 8% |
| | 50 | | | | | | | 0.197 | 6.7% | 0.203 | 8.9% | −3% | | 676.89 | 0.6% | 645.25 | 0.6% | 5% |
| | 100 | | | | | | | 268.07 | 0.8% | 235.01 | 0.8% | 14% | | 1262.88 | 0.4% | 1223.25 | 0.4% | 3% |
| | 150 | 1265.66 | 1.0% | 1234.00 | 0.9% | 3% | | 1382.71 | 0.4% | 1293.81 | 0.3% | 7% | | 1237.77 | 0.4% | 1186.21 | 0.4% | 4% |
| | 200 | 1145.19 | 0.8% | 1057.83 | 0.8% | 8% | | 1089.13 | 0.4% | 1030.79 | 0.4% | 6% | | 928.88 | 0.4% | 887.33 | 0.4% | 5% |
| | 500 | 644.51 | 1.0% | 601.31 | 1.0% | 7% | | 647.75 | 0.4% | 604.01 | 0.4% | 7% | | 598.36 | 0.5% | 570.44 | 0.4% | 5% |
| | 1000 | 607.33 | 1.3% | 572.15 | 1.3% | 6% | | 620.58 | 0.5% | 575.57 | 0.5% | 8% | | 558.64 | 0.6% | 532.39 | 0.6% | 5% |
| | 2000 | 611.32 | 1.6% | 581.03 | 1.4% | 5% | | 621.48 | 0.6% | 585.45 | 0.6% | 6% | | 556.74 | 0.7% | 527.38 | 0.7% | 6% |
| | 5000 | 686.20 | 1.6% | 655.04 | 1.6% | 5% | | 695.56 | 0.6% | 653.58 | 0.6% | 6% | | 630.37 | 0.9% | 600.22 | 0.8% | 5% |
| | 10 000 | 835.54 | 1.7% | 790.57 | 1.6% | 6% | | 834.09 | 0.7% | 778.21 | 0.7% | 7% | | 734.11 | 0.9% | 699.69 | 0.9% | 5% |
| ROT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) |
| Small intestine | 2 | | | | | | Skin | 304.52 | 0.0% | 311.49 | 0.0% | −2% | Spleen | | | | | |
| | 5 | | | | | | | 752.85 | 0.0% | 769.44 | 0.0% | −2% | | | | | | |
| | 10 | 0.0034 | 9.8% | 0.0035 | 9.5% | −1% | | 1458.91 | 0.0% | 1487.11 | 0.0% | −2% | | | | | | |
| | 20 | 0.013 | 4.6% | 0.015 | 4.5% | −11% | | 2093.17 | 0.0% | 2121.46 | 0.0% | −1% | | 0.018 | 11.0% | 0.015 | 9.7% | 20% |
| | 30 | 0.035 | 3.4% | 0.036 | 3.3% | −3% | | 1602.71 | 0.0% | 1634.51 | 0.0% | −2% | | 0.044 | 7.4% | 0.040 | 6.6% | 11% |
| | 50 | 1.20 | 2.8% | 2.73 | 1.9% | −56% | | 1152.24 | 0.0% | 1198.49 | 0.0% | −4% | | 34.20 | 1.3% | 23.62 | 1.4% | 45% |
| | 100 | 332.92 | 0.3% | 384.79 | 0.2% | −13% | | 1002.05 | 0.1% | 1061.98 | 0.0% | −6% | | 800.72 | 0.5% | 746.46 | 0.5% | 7% |
| | 150 | 1288.93 | 0.2% | 1240.62 | 0.1% | 4% | | 953.39 | 0.0% | 995.85 | 0.0% | −4% | | 1061.01 | 0.4% | 1007.39 | 0.4% | 5% |
| | 200 | 1070.86 | 0.2% | 1017.69 | 0.1% | 5% | | 926.51 | 0.0% | 919.56 | 0.0% | 1% | | 1105.23 | 0.3% | 1030.27 | 0.3% | 7% |
| | 500 | 635.74 | 0.2% | 602.80 | 0.2% | 5% | | 578.48 | 0.1% | 568.11 | 0.0% | 2% | | 645.40 | 0.4% | 605.36 | 0.4% | 7% |
| | 1000 | 606.10 | 0.2% | 573.02 | 0.2% | 6% | | 532.17 | 0.1% | 521.88 | 0.1% | 2% | | 614.20 | 0.5% | 578.39 | 0.5% | 6% |
| | 2000 | 606.25 | 0.3% | 574.27 | 0.2% | 6% | | 524.08 | 0.1% | 512.52 | 0.1% | 2% | | 610.72 | 0.6% | 577.51 | 0.6% | 6% |
| | 5000 | 678.27 | 0.3% | 645.81 | 0.3% | 5% | | 611.12 | 0.1% | 595.92 | 0.1% | 3% | | 699.95 | 0.6% | 649.57 | 0.6% | 8% |
| | 10 000 | 816.45 | 0.3% | 773.66 | 0.3% | 6% | | 708.80 | 0.1% | 688.34 | 0.1% | 3% | | 831.07 | 0.6% | 778.73 | 0.7% | 7% |

(*Continued*)

**Table B.5.** (*Continued*)

| ROT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) |
| Stomach | 2 | | | | | | Thymus | | | | | | Thyroid | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | | | | |
| | 20 | 0.018 | 7.7% | 0.017 | 7.2% | 7% | | | | | | | | | | | | |
| | 30 | 0.039 | 5.7% | 0.038 | 6.4% | 2% | | | | | | | | | | | | |
| | 50 | 0.21 | 8.1% | 0.19 | 6.1% | 11% | | | | | | | | 486.58 | 1.2% | 474.24 | 1.2% | 3% |
| | 100 | 670.09 | 0.4% | 636.18 | 0.4% | 5% | | 804.59 | 1.0% | 776.21 | 0.9% | 4% | | 999.93 | 0.9% | 977.84 | 0.8% | 2% |
| | 150 | 1121.99 | 0.3% | 1097.57 | 0.3% | 2% | | 1568.42 | 0.7% | 1474.80 | 0.6% | 6% | | 1328.69 | 0.6% | 1274.85 | 0.6% | 4% |
| | 200 | 1043.74 | 0.3% | 1006.90 | 0.3% | 4% | | 1015.61 | 0.6% | 950.24 | 0.6% | 7% | | 935.85 | 0.6% | 896.36 | 0.6% | 4% |
| | 500 | 628.69 | 0.3% | 603.47 | 0.3% | 4% | | 612.87 | 0.8% | 572.20 | 0.7% | 7% | | 593.10 | 0.8% | 573.84 | 0.8% | 3% |
| | 1000 | 596.57 | 0.4% | 575.87 | 0.4% | 4% | | 574.88 | 1.0% | 542.66 | 1.0% | 6% | | 559.02 | 1.1% | 532.62 | 1.0% | 5% |
| | 2000 | 600.65 | 0.5% | 577.87 | 0.5% | 4% | | 578.11 | 1.2% | 540.82 | 1.2% | 7% | | 556.81 | 1.3% | 533.35 | 1.3% | 4% |
| | 5000 | 676.03 | 0.5% | 648.56 | 0.5% | 4% | | 650.03 | 1.4% | 607.03 | 1.2% | 7% | | 618.60 | 1.4% | 614.08 | 1.4% | 1% |
| | 10000 | 809.40 | 0.6% | 771.41 | 0.5% | 5% | | 783.33 | 1.4% | 731.69 | 1.3% | 7% | | 725.34 | 1.5% | 719.61 | 1.4% | 1% |

| ROT | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) |
| Tonsil | 2 | | | | | | Urinary bladder | | | | | | Uterus | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | | | | |
| | 20 | | | | | | | | | | | | | | | | | |
| | 30 | | | | | | | 0.03 | 9.7% | 0.04 | 7.2% | −24% | | 0.027 | 10.9% | 0.038 | 8.1% | −29% |
| | 50 | | | | | | | 0.14 | 11.0% | 0.19 | 7.0% | −29% | | | | | | |
| | 100 | 1824.71 | 1.5% | 1743.33 | 1.4% | 5% | | 76.98 | 1.8% | 417.87 | 0.7% | −82% | | 1.87 | 6.6% | 2.03 | 5.6% | −8% |
| | 150 | 1259.83 | 1.2% | 1206.09 | 1.1% | 4% | | 924.83 | 0.5% | 1051.30 | 0.4% | −12% | | 1130.66 | 0.5% | 1386.65 | 0.4% | −18% |
| | 200 | 959.21 | 1.3% | 907.21 | 1.2% | 6% | | 1108.68 | 0.4% | 1039.73 | 0.3% | 7% | | 1125.74 | 0.4% | 1054.93 | 0.4% | 7% |
| | 500 | 616.65 | 1.6% | 588.45 | 1.7% | 5% | | 622.13 | 0.4% | 595.69 | 0.4% | 4% | | 644.24 | 0.5% | 605.43 | 0.5% | 6% |
| | 1000 | 595.14 | 2.3% | 542.60 | 2.1% | 10% | | 598.76 | 0.6% | 570.96 | 0.6% | 5% | | 613.30 | 0.6% | 575.47 | 0.6% | 7% |
| | 2000 | 613.36 | 2.7% | 559.46 | 3.0% | 10% | | 602.60 | 0.7% | 574.51 | 0.7% | 5% | | 622.62 | 0.7% | 580.82 | 0.7% | 7% |
| | 5000 | 653.73 | 2.9% | 654.28 | 5.9% | 0% | | 687.71 | 0.8% | 645.48 | 0.8% | 7% | | 704.38 | 0.8% | 650.35 | 0.7% | 8% |
| | 10000 | 793.26 | 3.1% | 794.28 | 5.3% | −0.1% | | 830.28 | 1.0% | 771.96 | 0.8% | 8% | | 838.69 | 0.9% | 780.15 | 0.7% | 8% |

(*Continued*)

**Table B.5.** (*Continued*)

| ROT | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Bone surface | | | | | Red bone marrow | | | | |
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Muscle | 2 | 0.017 | 1.4% | 0.017 | 1.3% | 0% | | | | | | | | | | |
| | 5 | 0.258 | 0.6% | 0.261 | 0.5% | −1% | | | | | | | | | | |
| | 10 | 1.81 | 0.3% | 1.81 | 0.3% | 0% | 0.05 | 4.9% | 0.06 | 4.1% | −19% | 0.019 | 5.5% | 0.024 | 4.5% | −22% |
| | 20 | 28.86 | 0.1% | 29.70 | 0.1% | −3% | 4.10 | 0.7% | 4.08 | 0.6% | 1% | 1.20 | 0.9% | 1.18 | 0.9% | 2% |
| | 30 | 99.13 | 0.1% | 103.00 | 0.1% | −4% | 39.58 | 0.3% | 40.47 | 0.3% | −2% | 14.17 | 0.4% | 13.17 | 0.3% | 8% |
| | 50 | 335.07 | 0.1% | 371.43 | 0.0% | −10% | 288.64 | 0.1% | 291.32 | 0.1% | −1% | 147.13 | 0.2% | 139.61 | 0.2% | 5% |
| | 100 | 882.19 | 0.0% | 998.40 | 0.0% | −12% | 1005.27 | 0.1% | 1121.77 | 0.1% | −10% | 700.82 | 0.1% | 684.57 | 0.1% | 2% |
| | 150 | 1034.04 | 0.0% | 1081.70 | 0.0% | −4% | 1062.84 | 0.1% | 1119.61 | 0.1% | −5% | 1101.14 | 0.1% | 1085.29 | 0.1% | 1% |
| | 200 | 1000.45 | 0.0% | 964.75 | 0.0% | 4% | 960.47 | 0.1% | 943.18 | 0.1% | 2% | 1076.46 | 0.1% | 1003.08 | 0.1% | 7% |
| | 500 | 610.84 | 0.1% | 588.79 | 0.0% | 4% | 601.37 | 0.1% | 581.48 | 0.1% | 3% | 634.28 | 0.1% | 593.44 | 0.1% | 7% |
| | 1000 | 575.99 | 0.1% | 554.16 | 0.1% | 4% | 568.69 | 0.1% | 549.88 | 0.1% | 3% | 605.34 | 0.1% | 566.57 | 0.1% | 7% |
| | 2000 | 576.57 | 0.1% | 553.79 | 0.1% | 4% | 565.82 | 0.1% | 545.28 | 0.1% | 4% | 602.47 | 0.1% | 563.61 | 0.1% | 7% |
| | 5000 | 661.16 | 0.1% | 631.50 | 0.1% | 5% | 636.76 | 0.1% | 610.00 | 0.1% | 4% | 673.98 | 0.1% | 627.97 | 0.1% | 7% |
| | 10000 | 785.79 | 0.1% | 749.38 | 0.1% | 5% | 763.43 | 0.1% | 728.82 | 0.1% | 5% | 809.50 | 0.2% | 755.10 | 0.2% | 7% |

**Table B.6.** Absorbed dose per unit fluence (pGy cm$^2$) under ISO geometry from monoenergetic protons for UFH/NCI in standing and sitting posture.

| ISO | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) |
| Adrenals | 2 | | | | | | Brain | | | | | | Breast | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | 0.0028 | 8.5% | 0.0031 | 9.4% | −9% | | 0.02 | 10.0% | 0.03 | 10.3% | −32% |
| | 20 | | | | | | | 0.0142 | 3.9% | 0.0144 | 4.8% | −1% | | 2.59 | 1.1% | 4.10 | 1.0% | −37% |
| | 30 | 0.030 | 9.8% | 0.027 | 10.8% | 10% | | 0.0388 | 2.9% | 0.0386 | 3.1% | 0.5% | | 142.48 | 0.2% | 153.96 | 0.2% | −7% |
| | 50 | 0.16 | 17.1% | 0.13 | 6.8% | 22% | | 53.84 | 0.3% | 53.77 | 0.3% | 0.1% | | 740.27 | 0.1% | 785.08 | 0.2% | −6% |
| | 100 | 377.05 | 1.1% | 377.16 | 1.2% | 0.0% | | 1041.61 | 0.1% | 1043.14 | 0.1% | −0.1% | | 905.25 | 0.2% | 960.28 | 0.2% | −6% |
| | 150 | 632.93 | 0.7% | 629.29 | 0.8% | 1% | | 1171.08 | 0.1% | 1174.82 | 0.2% | −0.3% | | 763.43 | 0.2% | 754.11 | 0.2% | 1% |
| | 200 | 967.29 | 0.5% | 1001.32 | 0.6% | −3% | | 860.92 | 0.1% | 864.83 | 0.2% | −0.5% | | 871.83 | 0.1% | 870.74 | 0.2% | 0.1% |
| | 500 | 596.15 | 0.6% | 590.29 | 0.6% | 1% | | 560.40 | 0.1% | 559.73 | 0.2% | 0.1% | | 562.26 | 0.1% | 556.47 | 0.2% | 1% |
| | 1000 | 560.78 | 0.7% | 566.14 | 0.8% | −1% | | 523.60 | 0.2% | 522.82 | 0.2% | 0.2% | | 524.80 | 0.2% | 517.95 | 0.2% | 1% |
| | 2000 | 572.17 | 0.9% | 561.95 | 1.0% | 2% | | 525.83 | 0.2% | 522.85 | 0.2% | 1% | | 521.46 | 0.2% | 513.86 | 0.2% | 1% |
| | 5000 | 635.05 | 0.9% | 645.35 | 1.0% | −2% | | 602.06 | 0.2% | 601.15 | 0.2% | 0.2% | | 607.03 | 0.2% | 600.66 | 0.3% | 1% |
| | 10 000 | 767.37 | 1.0% | 776.38 | 1.1% | −1% | | 715.69 | 0.2% | 712.70 | 0.3% | 0.4% | | 713.60 | 0.3% | 705.34 | 0.3% | 1% |

| ISO | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative difference (RD) |
| Colon | 10 | 0.002 | 7.2% | 0.003 | 8.7% | −12% | Oesophagus | | | | | | Gall bladder | | | | | |
| | 20 | 0.013 | 3.8% | 0.012 | 4.0% | 8% | | 0.013 | 8.4% | 0.009 | 10.7% | 45% | | | | | | |
| | 30 | 0.029 | 2.7% | 0.030 | 3.4% | −3% | | 0.028 | 6.7% | 0.029 | 6.9% | −2% | | 0.02 | 8.9% | 0.03 | 9.0% | −12% |
| | 50 | 1.45 | 2.3% | 0.93 | 3.0% | 56% | | 0.15 | 8.2% | 0.14 | 5.1% | 2% | | 0.129 | 10.0% | 0.131 | 11.9% | −1% |
| | 100 | 330.60 | 0.2% | 389.11 | 0.2% | −15% | | 215.35 | 0.8% | 220.78 | 1.0% | −2% | | 1.51 | 9.5% | 1.53 | 9.7% | −1% |
| | 150 | 756.52 | 0.1% | 820.85 | 0.2% | −8% | | 1087.19 | 0.3% | 1076.62 | 0.4% | 1% | | 838.95 | 0.5% | 868.55 | 0.6% | −3% |
| | 200 | 939.40 | 0.1% | 913.83 | 0.1% | 3% | | 938.17 | 0.3% | 941.79 | 0.3% | −0.4% | | 989.79 | 0.4% | 1016.45 | 0.5% | −3% |
| | 500 | 589.97 | 0.1% | 585.54 | 0.1% | 1% | | 585.98 | 0.3% | 582.73 | 0.4% | 1% | | 599.23 | 0.5% | 592.68 | 0.6% | 1% |
| | 1000 | 565.37 | 0.2% | 559.51 | 0.2% | 1% | | 558.13 | 0.5% | 553.40 | 0.5% | 1% | | 569.38 | 0.7% | 570.43 | 0.8% | −0.2% |
| | 2000 | 568.89 | 0.2% | 562.12 | 0.2% | 1% | | 561.11 | 0.5% | 557.14 | 0.6% | 1% | | 571.44 | 0.8% | 564.39 | 0.9% | 1% |
| | 5000 | 653.41 | 0.2% | 647.00 | 0.2% | 1% | | 638.99 | 0.6% | 638.99 | 0.8% | 0.0% | | 666.67 | 1.5% | 644.54 | 1.1% | 3% |
| | 10 000 | 784.18 | 0.2% | 775.36 | 0.3% | 1% | | 767.22 | 0.7% | 768.89 | 0.8% | −0.2% | | 799.13 | 1.4% | 800.37 | 2.8% | −0.2% |

(*Continued*)

**Table B.6.** (*Continued*)

| ISO | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Heart | 2 | | | | | | Kidneys | | | | | | Liver | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | 0.003 | 7.6% | 0.002 | 8.1% | 8% |
| | 20 | 0.0118 | 4.9% | 0.0115 | 5.7% | 2% | | 0.013 | 5.1% | 0.012 | 6.1% | 12% | | 0.012 | 3.4% | 0.011 | 4.2% | 7% |
| | 30 | 0.030 | 4.8% | 0.028 | 4.2% | 11% | | 0.034 | 4.2% | 0.033 | 4.3% | 1% | | 0.029 | 2.7% | 0.028 | 3.1% | 3% |
| | 50 | 0.14 | 4.0% | 0.15 | 4.5% | −2% | | 61.26 | 0.5% | 61.40 | 0.6% | 0% | | 1.07 | 1.4% | 0.53 | 2.0% | 100% |
| | 100 | 306.60 | 0.3% | 306.34 | 0.3% | 0.1% | | 665.13 | 0.2% | 606.29 | 0.3% | 10% | | 284.69 | 0.2% | 289.39 | 0.2% | −2% |
| | 150 | 1010.38 | 0.2% | 1019.93 | 0.2% | −1% | | 654.30 | 0.2% | 682.21 | 0.2% | −4% | | 830.39 | 0.1% | 848.38 | 0.1% | −2% |
| | 200 | 936.97 | 0.2% | 943.89 | 0.2% | −1% | | 862.81 | 0.2% | 898.16 | 0.2% | −4% | | 940.84 | 0.1% | 959.15 | 0.1% | −2% |
| | 500 | 585.97 | 0.2% | 584.33 | 0.2% | 0.3% | | 577.43 | 0.2% | 576.36 | 0.2% | 0.2% | | 586.42 | 0.1% | 585.55 | 0.1% | 0.1% |
| | 1000 | 559.32 | 0.2% | 554.66 | 0.2% | 1% | | 550.70 | 0.2% | 549.59 | 0.3% | 0.2% | | 560.47 | 0.1% | 559.25 | 0.2% | 0.2% |
| | 2000 | 562.74 | 0.3% | 557.37 | 0.3% | 1% | | 554.35 | 0.3% | 550.64 | 0.3% | 1% | | 565.62 | 0.2% | 563.38 | 0.2% | 0.4% |
| | 5000 | 643.83 | 0.3% | 639.81 | 0.3% | 1% | | 639.85 | 0.3% | 637.07 | 0.3% | 0.4% | | 647.27 | 0.2% | 644.18 | 0.2% | 0.5% |
| | 10 000 | 767.71 | 0.3% | 765.52 | 0.3% | 0.3% | | 764.09 | 0.3% | 761.07 | 0.3% | 0.4% | | 777.20 | 0.2% | 774.55 | 0.2% | 0.3% |
| ISO | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Lungs | 2 | | | | | | Extrathoracic region | | | | | | Oral mucosa | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | 0.0027 | 5.4% | 0.0028 | 6.3% | −4% | | 1.56 | 6.5% | 1.44 | 8.0% | 8% | | | | | | |
| | 20 | 0.012 | 2.6% | 0.013 | 3.0% | −3% | | 15.11 | 2.6% | 15.73 | 3.0% | −4% | | | | | | |
| | 30 | 0.031 | 2.0% | 0.030 | 2.4% | 5% | | 51.66 | 1.5% | 52.70 | 1.8% | −2% | | 6.39 | 2.8% | 6.50 | 3.3% | −2% |
| | 50 | 2.33 | 1.2% | 2.02 | 1.5% | 15% | | 201.62 | 0.8% | 208.92 | 1.0% | −3% | | 78.32 | 1.2% | 78.93 | 1.4% | −1% |
| | 100 | 753.70 | 0.1% | 757.24 | 0.1% | −0.5% | | 892.99 | 0.4% | 893.74 | 0.5% | −0.1% | | 1075.65 | 0.4% | 1070.72 | 0.5% | 0.5% |
| | 150 | 1020.39 | 0.1% | 1024.27 | 0.1% | −0.4% | | 961.63 | 0.4% | 962.71 | 0.4% | −0.1% | | 1015.24 | 0.3% | 1006.72 | 0.4% | 1% |
| | 200 | 901.50 | 0.1% | 907.80 | 0.1% | −1% | | 899.49 | 0.4% | 898.70 | 0.4% | 0.1% | | 891.66 | 0.3% | 889.65 | 0.4% | 0.2% |
| | 500 | 575.00 | 0.1% | 572.55 | 0.1% | 0.4% | | 556.14 | 0.4% | 555.73 | 0.5% | 0.1% | | 567.46 | 0.4% | 563.40 | 0.4% | 1% |
| | 1000 | 540.67 | 0.1% | 537.45 | 0.1% | 1% | | 521.77 | 0.5% | 521.22 | 0.7% | 0.1% | | 532.56 | 0.5% | 531.69 | 0.6% | 0.2% |
| | 2000 | 548.82 | 0.1% | 543.99 | 0.2% | 1% | | 527.65 | 0.7% | 526.08 | 0.8% | 0.3% | | 537.77 | 0.6% | 534.68 | 0.7% | 1% |
| | 5000 | 633.72 | 0.2% | 630.18 | 0.2% | 1% | | 600.31 | 0.7% | 607.59 | 0.8% | −1% | | 610.29 | 0.6% | 617.35 | 0.7% | −1% |
| | 10 000 | 761.02 | 0.2% | 754.50 | 0.2% | 1% | | 717.46 | 0.8% | 720.82 | 0.9% | −0.5% | | 732.20 | 0.7% | 725.52 | 0.7% | 1% |

(*Continued*)

**Table B.6.** (*Continued*)

| ISO | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Ovaries | 2 | | | | | | Pancreas | | | | | | Salivary glands | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | 0.88 | 5.5% | 0.87 | 6.4% | 1% |
| | 20 | | | | | | | 0.011 | 7.9% | 0.011 | 8.7% | −2% | | 18.45 | 1.4% | 18.04 | 1.7% | 2% |
| | 30 | | | | | | | 0.026 | 5.3% | 0.025 | 6.0% | 2% | | 128.65 | 0.7% | 127.91 | 0.9% | 1% |
| | 50 | 0.117 | 7.7% | 0.123 | 14.9% | −5% | | 0.15 | 7.1% | 0.13 | 7.0% | 16% | | 444.80 | 0.5% | 448.37 | 0.6% | −1% |
| | 100 | 1.56 | 10.6% | 3.28 | 8.4% | −53% | | 122.73 | 0.7% | 105.18 | 0.9% | 17% | | 867.27 | 0.3% | 869.63 | 0.4% | −0.3% |
| | 150 | 973.08 | 0.7% | 933.40 | 0.8% | 4% | | 808.26 | 0.3% | 817.17 | 0.3% | −1% | | 1023.29 | 0.3% | 1020.33 | 0.3% | 0.3% |
| | 200 | 1000.37 | 0.6% | 969.49 | 0.6% | 3% | | 956.92 | 0.3% | 997.89 | 0.3% | −4% | | 872.62 | 0.3% | 872.28 | 0.3% | 0.0% |
| | 500 | 592.03 | 0.6% | 596.90 | 0.7% | −1% | | 594.82 | 0.3% | 592.30 | 0.3% | 0.4% | | 558.63 | 0.3% | 559.10 | 0.4% | −0.1% |
| | 1000 | 568.38 | 0.8% | 566.89 | 0.9% | 0.3% | | 570.69 | 0.3% | 567.38 | 0.4% | 1% | | 525.50 | 0.4% | 524.56 | 0.5% | 0.2% |
| | 2000 | 570.02 | 1.0% | 562.98 | 1.0% | 1% | | 572.91 | 0.4% | 569.79 | 0.4% | 1% | | 525.06 | 0.5% | 521.73 | 0.6% | 1% |
| | 5000 | 655.83 | 1.4% | 651.89 | 1.1% | 1% | | 654.43 | 0.4% | 655.97 | 0.4% | −0.2% | | 600.69 | 0.5% | 602.24 | 0.6% | −0.3% |
| | 10 000 | 785.26 | 1.3% | 771.78 | 1.2% | 2% | | 786.16 | 0.4% | 785.20 | 0.5% | 0.1% | | 711.55 | 0.6% | 712.93 | 0.7% | −0.2% |
| ISO | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Small intestine | 2 | | | | | | Skin | 242.36 | 0.0% | 238.73 | 0.0% | 2% | Spleen | | | | | |
| | 5 | | | | | | | 596.70 | 0.0% | 588.74 | 0.0% | 1% | | | | | | |
| | 10 | 0.00280 | 6.9% | 0.00277 | 7.9% | 1% | | 1142.08 | 0.0% | 1132.34 | 0.0% | 1% | | | | | | |
| | 20 | 0.0118 | 3.4% | 0.0116 | 3.7% | 2% | | 1739.74 | 0.0% | 1764.54 | 0.0% | −1% | | 0.0136 | 7.1% | 0.0140 | 8.2% | −3% |
| | 30 | 0.027 | 2.4% | 0.029 | 2.6% | −5% | | 1412.18 | 0.0% | 1450.79 | 0.0% | −3% | | 0.037 | 5.0% | 0.031 | 7.7% | 18% |
| | 50 | 0.50 | 2.5% | 0.98 | 2.3% | −49% | | 1031.04 | 0.0% | 1062.93 | 0.0% | −3% | | 10.72 | 1.4% | 7.83 | 1.8% | 37% |
| | 100 | 161.89 | 0.2% | 212.50 | 0.2% | −24% | | 867.17 | 0.0% | 891.58 | 0.0% | −3% | | 571.28 | 0.4% | 535.44 | 0.4% | 7% |
| | 150 | 784.39 | 0.1% | 865.24 | 0.1% | −9% | | 846.93 | 0.0% | 858.94 | 0.0% | −1% | | 803.54 | 0.3% | 815.84 | 0.3% | −2% |
| | 200 | 974.54 | 0.1% | 938.37 | 0.1% | 4% | | 813.76 | 0.0% | 809.32 | 0.0% | 1% | | 894.71 | 0.3% | 924.55 | 0.3% | −3% |
| | 500 | 592.82 | 0.1% | 588.67 | 0.1% | 1% | | 532.66 | 0.0% | 529.43 | 0.0% | 1% | | 578.97 | 0.3% | 576.88 | 0.3% | 0.4% |
| | 1000 | 568.69 | 0.1% | 563.82 | 0.2% | 1% | | 490.01 | 0.1% | 486.00 | 0.1% | 1% | | 550.37 | 0.3% | 548.69 | 0.4% | 0.3% |
| | 2000 | 573.10 | 0.2% | 568.72 | 0.2% | 1% | | 483.21 | 0.1% | 478.92 | 0.1% | 1% | | 552.97 | 0.4% | 550.17 | 0.4% | 1% |
| | 5000 | 655.88 | 0.2% | 651.51 | 0.2% | 1% | | 565.47 | 0.1% | 561.35 | 0.1% | 1% | | 640.20 | 0.4% | 637.62 | 0.5% | 0.4% |
| | 10 000 | 788.49 | 0.2% | 782.69 | 0.2% | 1% | | 656.36 | 0.1% | 650.67 | 0.1% | 1% | | 770.41 | 0.5% | 760.78 | 0.5% | 1% |

(*Continued*)

**Table B.6.** (*Continued*)

| ISO | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Stomach | 2 | | | | | | Thymus | | | | | | Thyroid | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | | | | |
| | 20 | 0.01 | 5.7% | 0.01 | 7.2% | −7% | | | | | | | | | | | | |
| | 30 | 0.03 | 4.1% | 0.03 | 4.6% | 5% | | 0.03 | 10.0% | 0.03 | 11.9% | 26% | | 1.24 | 9.9% | 1.92 | 9.6% | −35% |
| | 50 | 0.16 | 5.9% | 0.14 | 4.9% | 12% | | | | | | | | 297.39 | 1.1% | 305.90 | 1.2% | −3% |
| | 100 | 331.85 | 0.4% | 361.02 | 0.4% | −8% | | 613.94 | 0.7% | 610.67 | 0.8% | 1% | | 730.90 | 0.7% | 742.25 | 0.8% | −2% |
| | 150 | 845.56 | 0.2% | 851.98 | 0.3% | −1% | | 1119.43 | 0.5% | 1111.09 | 0.6% | 1% | | 933.03 | 0.5% | 937.67 | 0.6% | 0% |
| | 200 | 933.86 | 0.2% | 954.48 | 0.2% | −2% | | 901.65 | 0.5% | 905.16 | 0.5% | 0% | | 945.02 | 0.5% | 948.96 | 0.5% | 0% |
| | 500 | 590.42 | 0.2% | 586.53 | 0.2% | 1% | | 586.16 | 0.5% | 570.88 | 0.6% | 3% | | 564.84 | 0.5% | 564.17 | 0.6% | 0% |
| | 1000 | 564.88 | 0.3% | 561.41 | 0.3% | 1% | | 546.51 | 0.7% | 547.75 | 0.8% | 0% | | 530.48 | 0.7% | 530.65 | 0.8% | 0% |
| | 2000 | 569.03 | 0.3% | 563.81 | 0.4% | 1% | | 549.11 | 0.8% | 545.02 | 0.9% | 1% | | 533.34 | 0.9% | 537.55 | 1.1% | −1% |
| | 5000 | 650.21 | 0.3% | 643.97 | 0.4% | 1% | | 618.73 | 0.9% | 628.08 | 1.0% | −1% | | 630.56 | 1.0% | 618.47 | 1.2% | 2% |
| | 10 000 | 784.01 | 0.4% | 771.00 | 0.4% | 2% | | 743.73 | 0.9% | 752.52 | 1.6% | −1% | | 741.29 | 1.0% | 718.49 | 1.2% | 3% |

| ISO | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Tonsil | 2 | | | | | | Urinary bladder | | | | | | Uterus | | | | | |
| | 5 | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | | | | | | | | | | | |
| | 20 | | | | | | | 0.01 | 7.4% | 0.01 | 8.1% | −12% | | 0.012 | 8.3% | 0.010 | 10.0% | 19% |
| | 30 | | | | | | | 0.03 | 5.7% | 0.03 | 6.1% | −14% | | 0.026 | 7.8% | 0.023 | 8.4% | 13% |
| | 50 | | | | | | | 0.14 | 6.8% | 0.18 | 11.2% | −18% | | 0.12 | 6.8% | 0.16 | 8.5% | −23% |
| | 100 | 953.89 | 1.4% | 952.68 | 1.6% | 0% | | 151.20 | 0.8% | 359.26 | 0.6% | −58% | | 66.08 | 1.3% | 22.77 | 2.2% | 190% |
| | 150 | 1154.38 | 0.9% | 1125.08 | 1.1% | 3% | | 801.59 | 0.3% | 736.15 | 0.4% | 9% | | 900.68 | 0.4% | 939.32 | 0.4% | −4% |
| | 200 | 883.53 | 0.9% | 858.05 | 1.0% | 3% | | 994.48 | 0.2% | 978.61 | 0.3% | 2% | | 985.58 | 0.3% | 999.69 | 0.3% | −1% |
| | 500 | 580.40 | 1.1% | 564.53 | 1.3% | 3% | | 589.89 | 0.3% | 584.67 | 0.3% | 1% | | 594.31 | 0.3% | 599.05 | 0.3% | −1% |
| | 1000 | 545.62 | 1.6% | 523.19 | 1.5% | 4% | | 568.29 | 0.4% | 563.24 | 0.4% | 1% | | 570.59 | 0.4% | 569.73 | 0.4% | 0.2% |
| | 2000 | 538.75 | 1.7% | 542.46 | 2.3% | −1% | | 573.33 | 0.5% | 565.46 | 0.5% | 1% | | 573.78 | 0.4% | 576.84 | 0.5% | −1% |
| | 5000 | 608.55 | 2.0% | 601.19 | 2.3% | 1% | | 651.11 | 0.5% | 651.13 | 0.6% | 0% | | 654.16 | 0.5% | 662.13 | 0.6% | −1% |
| | 10 000 | 739.18 | 2.1% | 697.87 | 2.3% | 6% | | 782.56 | 0.6% | 770.21 | 0.6% | 2% | | 788.50 | 0.6% | 790.61 | 0.6% | −0.3% |

(*Continued*)

**Table B.6.** (*Continued*)

| ISO | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | | Sitting phantom | | Standing phantom | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy (MeV) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) | $D_T/\Phi$ (pGy cm²) | Relative error | $D_T/\Phi$ (pGy cm²) | Relative error | Relative diference (RD) |
| Muscle | | | | | | | Bone surface | | | | | Red bone marrow | | | | |
| | 2 | 1.11 | 0.1% | 0.82 | 0.2% | 36% | 0.012 | 2.9% | 0.013 | 3.0% | −12% | 0.0005 | 9.3% | 0.0010 | 8.0% | −43% |
| | 5 | 3.08 | 0.1% | 2.31 | 0.2% | 33% | 0.050 | 2.3% | 0.047 | 2.6% | 6% | 0.008 | 4.4% | 0.009 | 4.5% | −18% |
| | 10 | 7.89 | 0.1% | 6.19 | 0.1% | 28% | 0.23 | 1.6% | 0.19 | 1.9% | 20% | 0.05 | 2.3% | 0.06 | 2.6% | −10% |
| | 20 | 34.69 | 0.1% | 30.16 | 0.1% | 15% | 3.62 | 0.5% | 3.34 | 0.6% | 8% | 1.12 | 0.7% | 1.12 | 0.8% | −1% |
| | 30 | 97.05 | 0.1% | 89.85 | 0.1% | 8% | 41.59 | 0.2% | 39.93 | 0.2% | 4% | 15.17 | 0.2% | 14.98 | 0.3% | 1% |
| | 50 | 281.82 | 0.0% | 275.35 | 0.0% | 2% | 253.65 | 0.1% | 241.41 | 0.1% | 5% | 120.02 | 0.1% | 116.40 | 0.1% | 3% |
| | 100 | 742.65 | 0.0% | 777.73 | 0.0% | −5% | 854.53 | 0.1% | 871.03 | 0.1% | −2% | 509.15 | 0.1% | 492.02 | 0.1% | 3% |
| | 150 | 893.11 | 0.0% | 912.95 | 0.0% | −2% | 947.77 | 0.1% | 971.82 | 0.1% | −2% | 865.80 | 0.1% | 877.14 | 0.1% | −1% |
| | 200 | 879.06 | 0.0% | 879.06 | 0.0% | 0.0% | 865.81 | 0.0% | 874.61 | 0.1% | −1% | 906.98 | 0.1% | 915.52 | 0.1% | −1% |
| | 500 | 565.71 | 0.0% | 563.29 | 0.0% | 0.4% | 560.11 | 0.1% | 560.10 | 0.1% | 0.0% | 574.27 | 0.1% | 575.97 | 0.1% | −0.3% |
| | 1000 | 533.60 | 0.0% | 530.41 | 0.0% | 1% | 528.66 | 0.1% | 528.11 | 0.1% | 0.1% | 547.43 | 0.1% | 548.29 | 0.1% | −0.2% |
| | 2000 | 535.28 | 0.0% | 531.62 | 0.0% | 1% | 526.68 | 0.1% | 526.12 | 0.1% | 0.1% | 547.45 | 0.1% | 548.47 | 0.1% | −0.2% |
| | 5000 | 618.10 | 0.0% | 614.58 | 0.0% | 1% | 597.62 | 0.1% | 596.48 | 0.1% | 0.2% | 620.54 | 0.1% | 622.42 | 0.1% | −0.3% |
| | 10000 | 735.18 | 0.1% | 730.95 | 0.1% | 1% | 715.18 | 0.1% | 714.34 | 0.1% | 0.1% | 746.00 | 0.1% | 749.55 | 0.1% | −0.5% |

## References

Bozkurt A and Xu X G 2004 Fluence-to-dose conversion coefficients for monoenergetic proton beams based on the VIP-man anatomical model *Radiat. Prot. Dosim.* **112** 219–35

Briesmeister J F 1997 *MCNP—A General Monte Carlo N-Particle Transport Code, Version 4B* Report No. LA-12625-M (Los Alamos, NM: Los Alamos National Laboratory)

Briesmeister J F 2000 *MCNP—A general Monte Carlo N-Particle Transport Code* Report LA-13709-M (Los Almos, NM: Los Alamos National laboratory)

ICRP 2007 The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103 *Ann. ICRP* **37** (2–4) (Oxford: Pergamon)

ICRP 2010 Conversion Coefficients for Radiological Protection Quantities for External Radiation Exposures. ICRP Publication 116 *Ann. ICRP* **40** (2–5) (Amsterdam: Elsevier)

Kramer R, Khoury H J,Vieira J W, Loureiro E C M, Lima V J M, Lima F R A and Hoff G 2004 All about FAX: a Female Adult voXel phantom for Monte Carlo calculation in radiation protection dosimetry *Phys. Med. Biol.* **49** 5203–16

Lee C, Lodwick D, Hasenauer D, Williams J L, Lee C and Bolch W E 2007 Hybrid computational phantoms of the male and female newborn patient: NURBS-based whole-body models *Phys. Med. Biol.* **52** 3309–33

Lee C, Lodwick D, Hurtado J, Pafundi D, Williams J L and Bolch W E 2010 The UF family of reference hybrid phantoms for computational radiation dosimetry *Phys. Med. Biol.* **55** 339–63

Pelowitz D B 2011 *MCNPX User's Manual Version 2.7.0* LA-CP-11-00438 (Los Alamos: Los Alamos National Laboratory)

Piegl L 1991 On NURBS: a survey *IEEE Comput. Graph. Appl.* **11** 55–71

Sato T, Endo A, Zankl M, Petoussi-Henss N and Niita K 2009 Fluence-to-dose conversion coefficients for neutrons and protons calculated using the PHITS code and ICRP/ICRU adult reference computational phantoms *Phys. Med. Biol.* **54** 1997–2014

Townsend L W 2001 Radiation exposures of aircrew in high altitude flight *J. Radiol. Prot.* **21** 5–8

Reitz G 1993 Radiation environment in the stratosphere *Radiat. Prot. Dosim.* **48** 5–20

Xu X G 2010 Computational phantoms for radiation dosimetry: a 40 year history of evolution *Handbook of Anatomical Models for Radiation Dosimetry* ed X G Xu and K F Eckerman (Boca Raton, FL: Taylor & Francis)

Zhang G, Liu Q, Zeng S and Luo Q 2008 Organ dose calculations by Monte Carlo modeling of the updated VCH adult male phantom against idealized external proton exposure *Phys. Med. Biol.* **53** 3697–722