UK Health Security Agency

CT Dosimetry Calculators: new UKHSA and ImPACT — update of progress, overview of differences

UKHSA calculator (Work in Progress)

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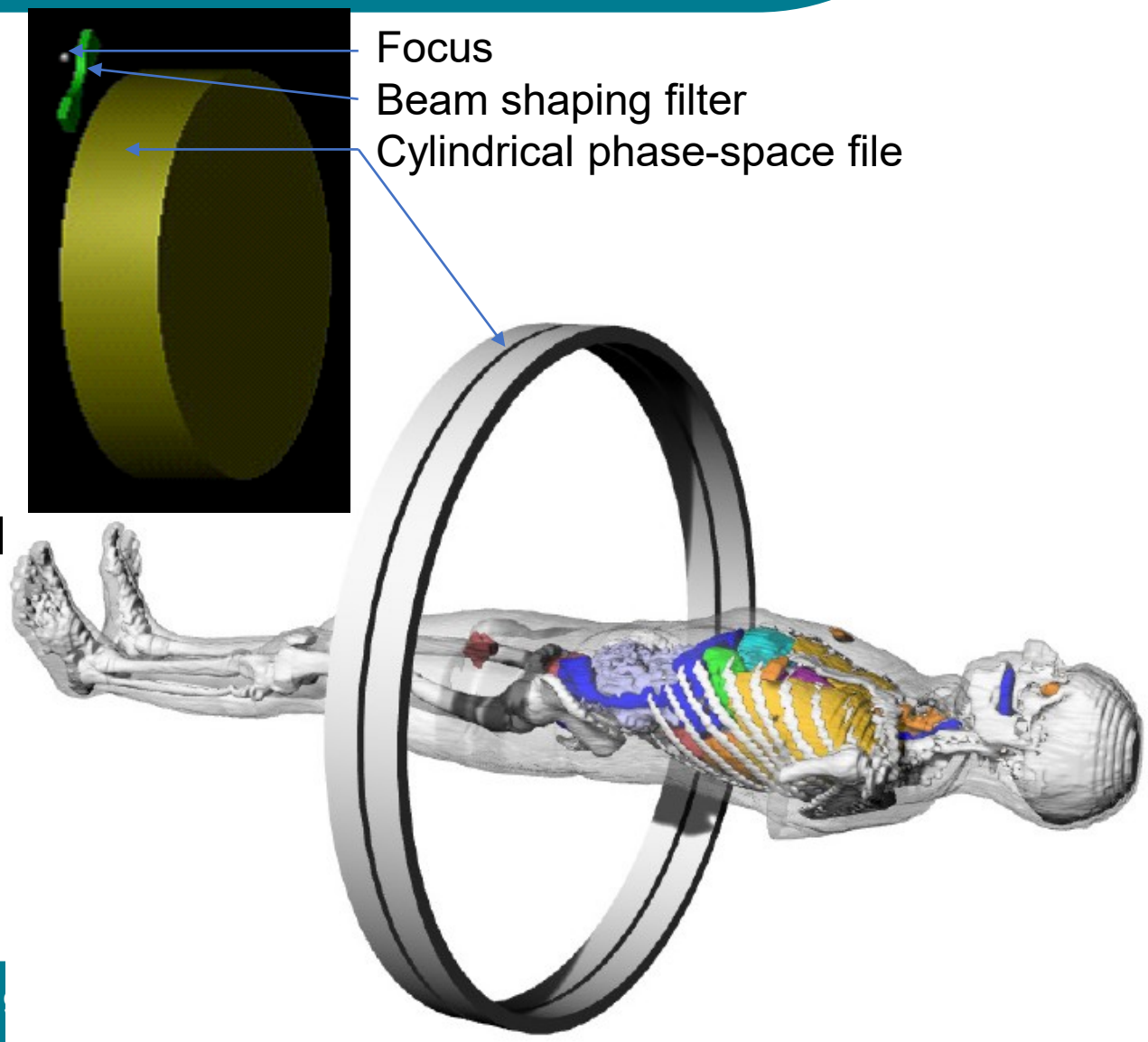
UKHSA under NDA: CT models by Paul Shrimpton

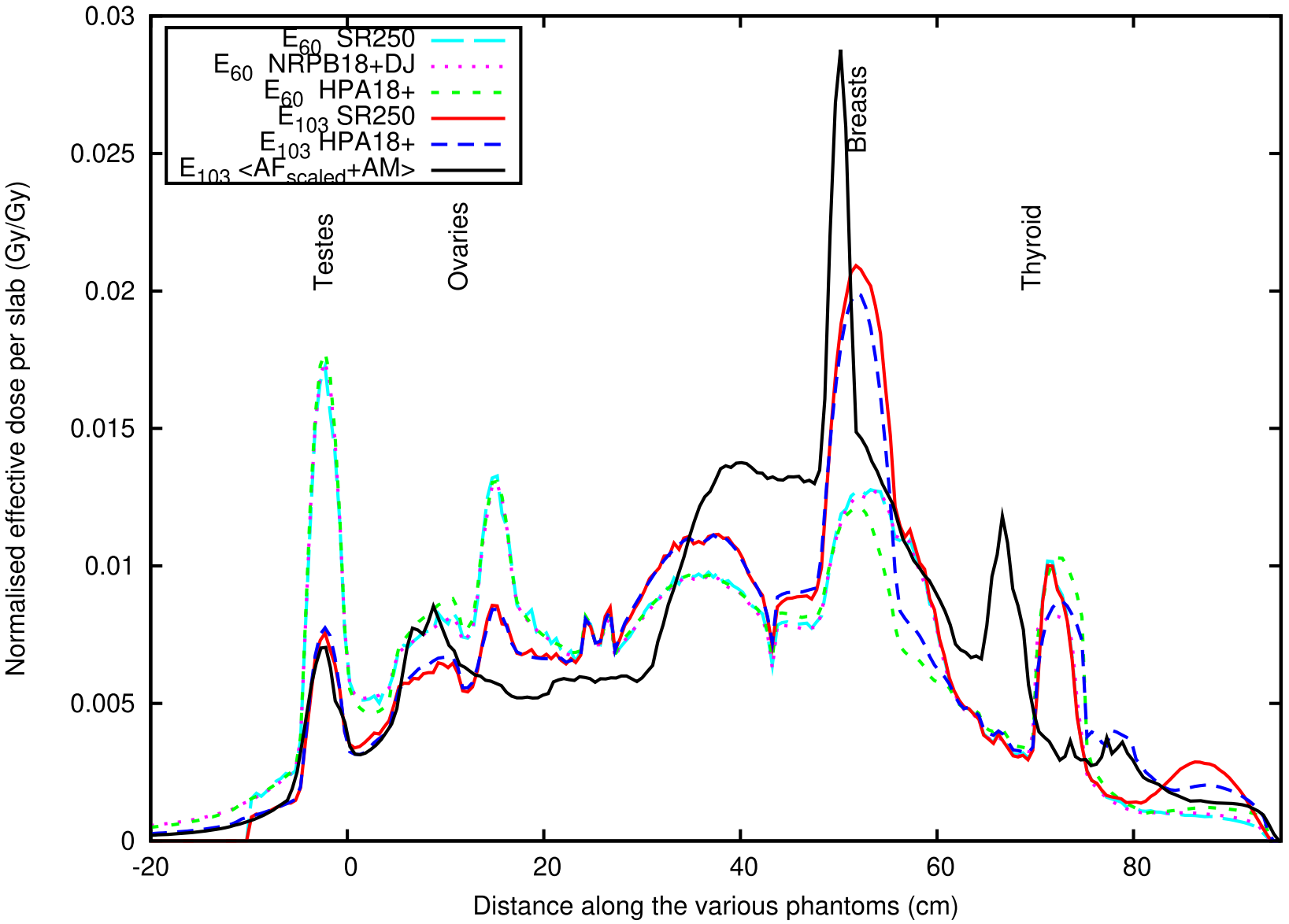
Manufacturer	CT Model	Potential (kV)	Beam shaping filter	Fan size
	Brightspeed 16 Elite	80, 100, 120, 140	Large, small	–
General	Discovery CT750 HD	80, 100, 120, 140	Large, medium, small	–
Electric (GE)	Optima CT660	80, 100, 120, 140	Large, small	–
	Lightspeed VCT	80, 100, 120, 140	Large, medium, small	–
Philips	Brilliance CT 64	80, 120, 140	–	–
	Brilliance iCT 256	80, 100, 120, 140	Body, head, baby	–
	Somatom Definition	80, 100, 120, 140	Body, head	Full, Small
	Somatom Emotion 6	80, 110, 130	–	–
Siemens	Somatom Sensation 16	80, 100, 120, 140	Body, head	–
	Somatom Sensation 64	80, 100, 120, 140	–	–
	Somatom Sensation Open	80, 100, 120, 140	–	–
Toshiba	Aquilion 16	80, 100, 120, 135	Dose reduction, large, small	–

Set-Up Monte Carlo method

- First Monte Carlo simulation with the CT scanner in a fixed position and writing the photons hitting the cylinder to a phase space file
- Rotate these photons by an arbitrary angle
- Transport these photons through an ICRP reference voxel phantom, or free-in-air, or 16 cm or 32 cm CT dosimetry phantom
- Tally the absorbed organ dose and the CTDI dose
- Normalize the absorbed organ doses by dividing to the $CTDI_{free\text{-}in\text{-}air}$
- Transfer the phantom through the gantry with voxel size steps



Comparison of effective dose E_{60} versus E_{103} models



- For effective dose according to ICRP Publication 60 the remainder rule is not applied on a slice bases.

Phantoms:

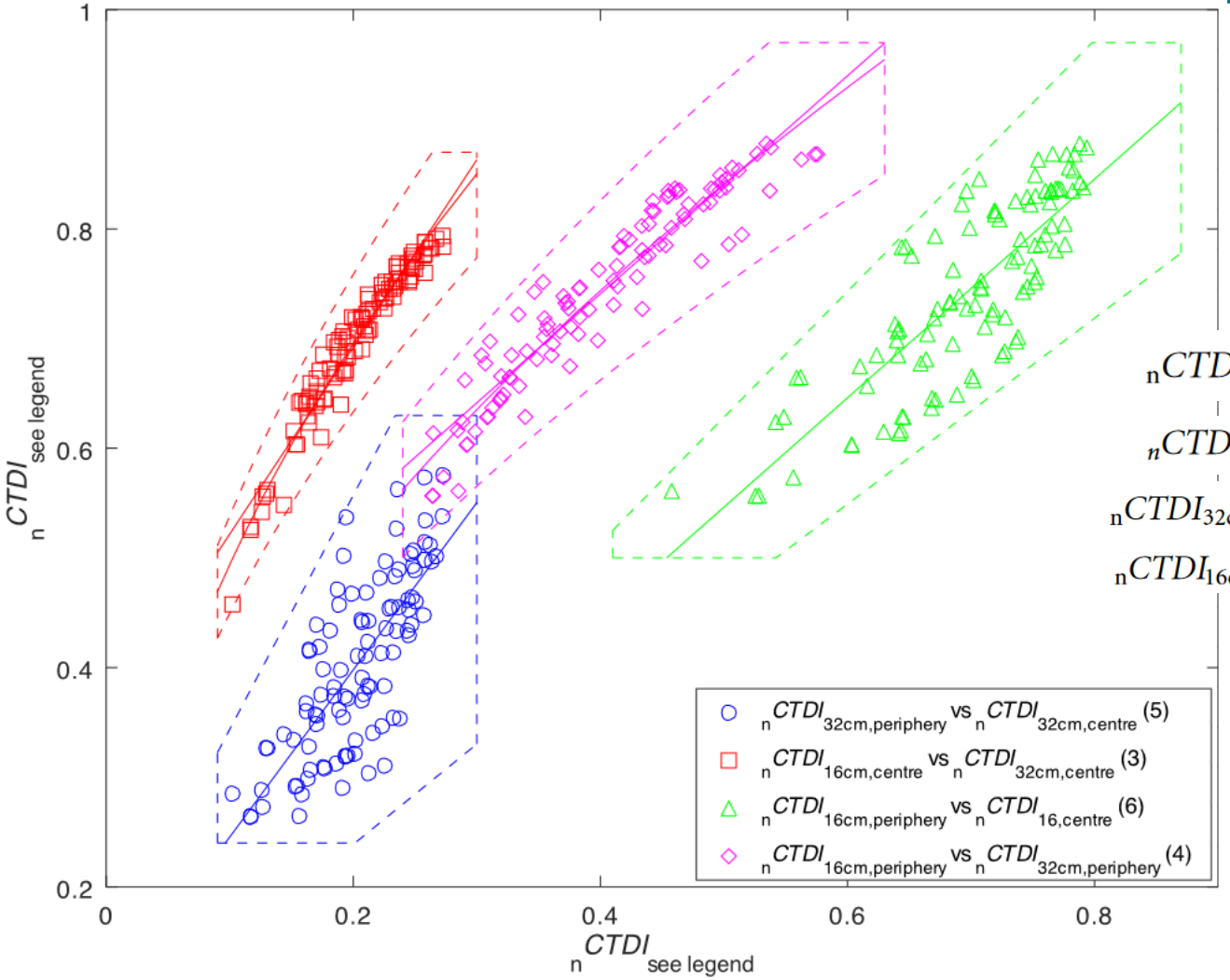
SR250	Stylized (MIRD) phantom as implemented by David Jones in its own code
NRPB18+DJ	David Jones phantom mimicked in MCNP version
HPA18+	Stylized phantom with added ICRP-103 organs
AM	Adult Male ICRP Reference Computational voxel Phantom
AF	Adult Female ICRP Reference Computational voxel Phantom

New CT scanner fitting used for matching

- Phantom (phan) dependent, whole body exposure fitting, *T* is tissue or organ or effective dose.
- 16 and 32 cm CT Dosimetry phantom with CTDI centre and peripheral and free-in-air.
- 5 P values are the fitting parameters from 102 CT scanner models with operation conditions, using a linear model.
- δ is the residual (error) value and is minimized.

$$\frac{D_{T,phan}}{CTDI_{\mathrm{free-in-air}}} = P_{T,phan,32\mathrm{cm,centre}}\frac{CTDI_{32\mathrm{cm,centre}}}{CTDI_{\mathrm{free-in-air}}} + P_{T,phan,32\mathrm{cm,peripheral}}\frac{CTDI_{32\mathrm{cm,peripheral}}}{CTDI_{\mathrm{free-in-air}}}$$
$$+ P_{T,phan,16\mathrm{cm,centre}}\frac{CTDI_{16\mathrm{cm,centre}}}{CTDI_{\mathrm{free-in-air}}} + P_{T,phan,16\mathrm{cm,peripheral}}\frac{CTDI_{16\mathrm{cm,peripheral}}}{CTDI_{\mathrm{free-in-air}}}$$
$$+ P_{T,phan,\mathrm{offset}} + \delta_{T,phan}.$$

$_{n}$CTDI dependence



$$ {}_{n}CTDI_{16cm,centre} \approx C_{16cm,centre} *_{n} CTDI_{32cm,centre}^{G_{16cm,centre}} \quad (3) $$

$$ {}_{n}CTDI_{16cm,periphery} \approx C_{16cm,periphery} *_{n} CTDI_{32cm,periphery}^{G_{16cm,periphery}} \quad (4) $$

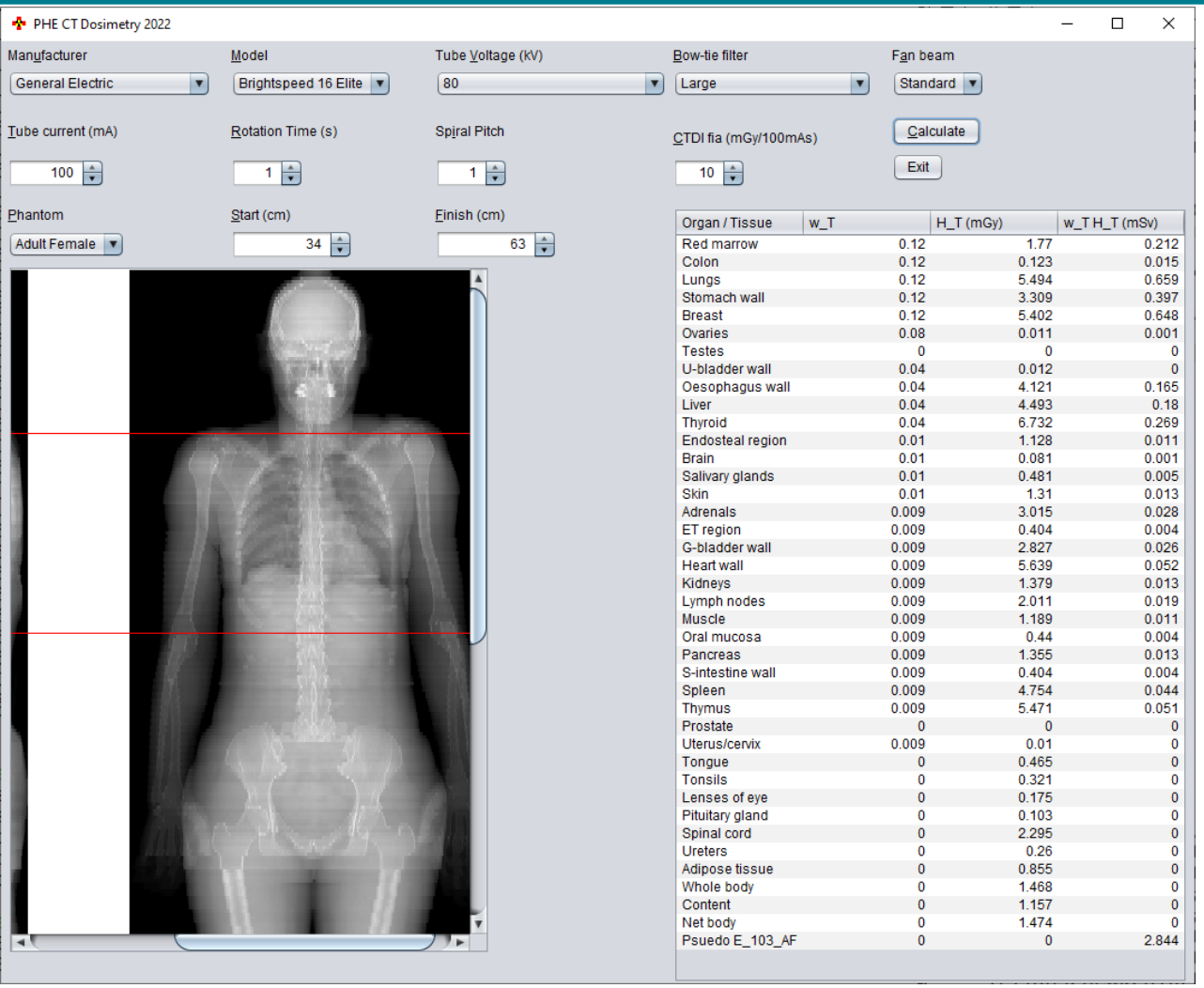
$$ {}_{n}CTDI_{32cm,periphery} \approx A_{32cm,periphery} + B_{32cm,periphery} *_{n} CTDI_{32cm,centre} \quad (5) $$

$$ {}_{n}CTDI_{16cm,periphery} \approx A_{16cm,periphery} + B_{16cm,periphery} *_{n} CTDI_{16cm,centre} \quad (6) $$

UKHSA CT Dosimetry calculator (GUI)

- Monte Carlo generated data files
- Programming language Java with at least version 8
- Graphical User Interface (GUI) with Java Swing (Tutorials)
  - https://docs.oracle.com/javase/tutorial/uiswing/
  - https://www.javatpoint.com/java-swing
- Uses the JVM (Java Virtual Machine) (like ImageJ) from Java or Oracle
  - https://openjdk.org/ or https://jdk.java.net/21/ (current latest version)
  - https://www.java.com/en/download/manual.jsp
- Write once, run everywhere
  - Runs on Microsoft Windows, MacOS, and Linux (AArch64 and X64)

CT dose calculator GUI (Work in progress)



Organ / Tissue	w_T	H_T (mGy)	w_T H_T (mSv)
Red marrow	0.12	1.77	0.212
Colon	0.12	0.123	0.015
Lungs	0.12	5.494	0.659
Stomach wall	0.12	3.309	0.397
Breast	0.12	5.402	0.648
Ovaries	0.08	0.011	0.001
Testes	0	0	0
U-bladder wall	0.04	0.012	0
Oesophagus wall	0.04	4.121	0.165
Liver	0.04	4.493	0.18
Thyroid	0.04	6.732	0.269
Endosteal region	0.01	1.128	0.011
Brain	0.01	0.081	0.001
Salivary glands	0.01	0.481	0.005
Skin	0.01	1.31	0.013
Adrenals	0.009	3.015	0.028
ET region	0.009	0.404	0.004
G-bladder wall	0.009	2.827	0.026
Heart wall	0.009	5.639	0.052
Kidneys	0.009	1.379	0.013
Lymph nodes	0.009	2.011	0.019
Muscle	0.009	1.189	0.011
Oral mucosa	0.009	0.44	0.004
Pancreas	0.009	1.355	0.013
S-intestine wall	0.009	0.404	0.004
Spleen	0.009	4.754	0.044
Thymus	0.009	5.471	0.051
Prostate	0	0	0
Uterus/cervix	0.009	0.01	0
Tongue	0	0.465	0
Tonsils	0	0.321	0
Lenses of eye	0	0.175	0
Pituitary gland	0	0.103	0
Spinal cord	0	2.295	0
Ureters	0	0.26	0
Adipose tissue	0	0.855	0
Whole body	0	1.468	0
Content	0	1.157	0
Net body	0	1.474	0
Psuedo E_103_AF	0	0	2.844

- For effective dose, E_{103}, both the Adult Female and Adult Male results need to be averaged.
- The Adult Female and Adult Male examination ranges are probably different.
- The exposure parameters:
  - Tube current (mA)
  - Rotation Time (s)
  - Spiral Pitch
  - CTDI fia (mGy/100mAs)

  will be combined in a $CTDI_{vol}$.

Thank you for your attention

UKHSA Publications CT organ DCC project

- Publications
  - Set-up
    - Jan T M Jansen and Paul C Shrimpton. Development of Monte Carlo simulations to provide scanner-specific organ dose coefficients for contemporary CT. Physics in Medicine and Biology, 2016 Jul 21;61(14):5356-77. doi: 10.1088/0031-9155/61/14/5356.
  - Bone dosimetry
    - Jan TM Jansen, Paul C Shrimpton, John Holroyd and Sue Edyvean. Selection of bone dosimetry models for application in Monte Carlo simulations to provide CT scanner-specific organ dose coefficients. Physics in Medicine and Biology, 2018 Jun 19;63(12):25015 (22pp) doi: 10.1088/1361-6560/aac717.
  - Adults results
    - Jan TM Jansen, Paul C Shrimpton and Sue Edyvean. CT scanner-specific organ dose coefficients generated by Monte Carlo calculation for the ICRP adult male and female reference computational phantoms. Physics in Medicine and Biology, 2022 Nov 16;67(22):225015. doi: 10.1088/1361-6560/ac9e3d.
  - New scanners
    - Jan TM Jansen, Paul C Shrimpton, and Sue Edyvean. Development of a generalized method to allow the estimation of doses to the ICRP reference adults from CT, on the basis of normalized organ and CTDI dose data determined by Monte Carlo calculation for a range of contemporary scanners. Physics in Medicine and Biology, 68 (2023) 035022 https://doi.org/10.1088/1361-6560/acb2a8.