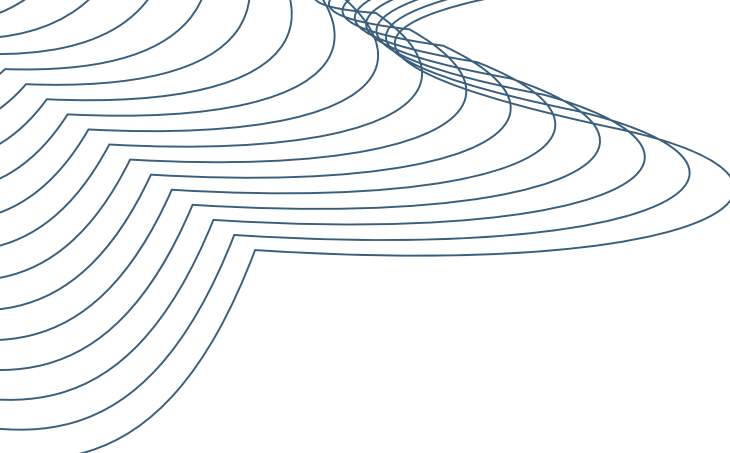




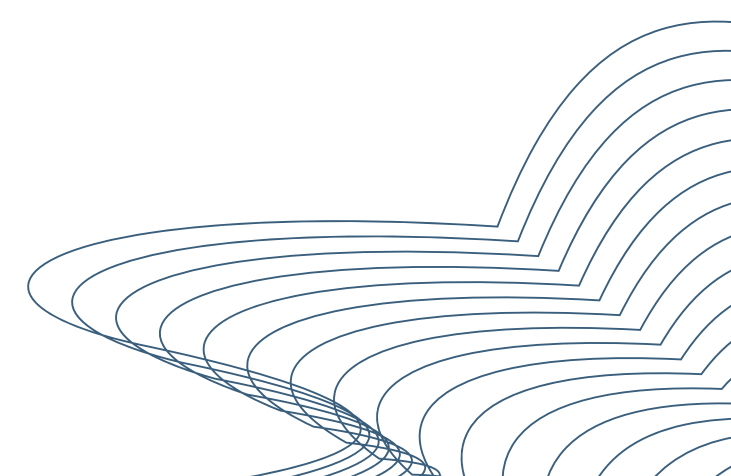
ICTP College on Medical Physics 2026 , Trieste, Italy

UTEROUS DOSE EVALUATION SOFTWARE



Alessandro Michele Ferrara

School of Specialisation in Medical Physics, University of Padua, Italy
Medical Physics Resident at ASUGI, Trieste, Italy





INTRODUCTION

- The **effects of radiation** on **pregnancies** depend on **dose and timing** (phase of pregnancy) of irradiation.
- The International Commission on Radiological Protection (**ICRP**) has defined that embryo/fetal **doses below 100 mGy should not be considered a reason to justify termination of pregnancy** on the basis of radiological risk alone. This is the embryo/fetal absorbed dose threshold for deterministic effect.
- As **Medical Physicists** working in diagnostic imaging we could be presented with **three situations** in which **embryo/fetal dose assessment may be required**.



APPLICATION

1) The patient was **unaware of the pregnancy** at the time of the examination, and **embryo/fetal dose is assessed retrospectively**. This may also apply to pregnant patients who require urgent or emergency imaging or interventional procedures, where the exposure cannot be postponed.



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- 2) The **patient is known to be pregnant**, but the examination or procedure is clinically indicated. **Embryo/fetal dose may be estimated prospectively**, before the exposure, to support justification and optimization and to assess whether the expected embryo/fetal dose is compatible with the clinical circumstances.



APPLICATION

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 - 2) The **patient is known to be pregnant**, but the examination or procedure is clinically indicated. **Embryo/fetal dose may be estimated prospectively**, before the exposure, to support justification and optimization and to assess whether the expected embryo/fetal dose is compatible with the clinical circumstances.
 - 3) A **radiation worker**, e.g., an interventional radiologist, **may later discover that she was pregnant while working**. Embryo/fetal **dose assessment can then be performed retrospectively**, based on occupational exposure records, dosimetry data, workload, and the working conditions during the period of potential exposure. It may also be used prospectively after declaration of pregnancy to support optimization of working conditions.
- 

INTRODUCTION

- How can we **estimate** the embryo/fetal dose received by these women?

Dedicated software exist to help us.

Gestational age, month
0-3

Tube voltage, kVp
100kVp

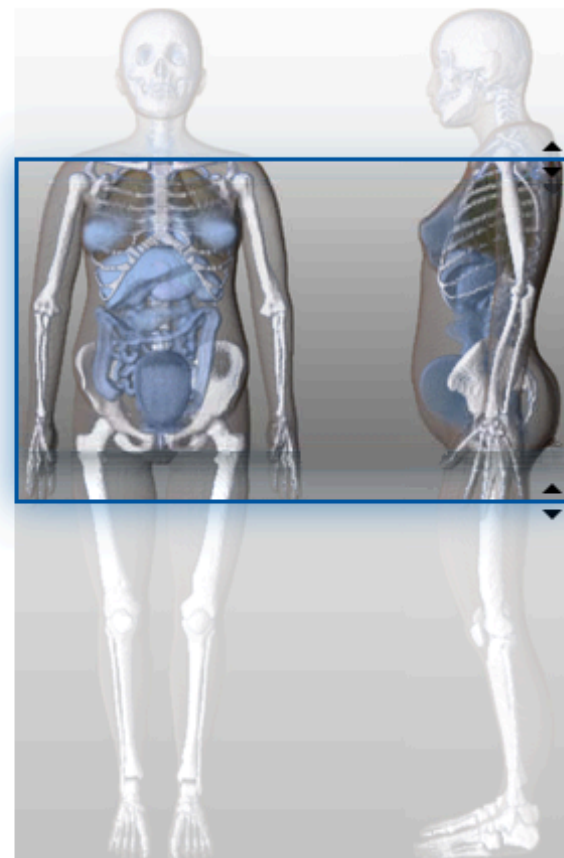
CTDIvol, mGy

Volume CT Dose Index obtained from patient radiation dose report.

Maternal perimeter, mm (optional)

Maternal perimeter in mm defined from the CT section containing the central area of the uterus.

Calculate



Upper position, mm
1350

Lower position, mm
690

Patient ID (optional)

fetaldose.org

SOURCES

Review paper

Fetal dose assessment in diagnostic and interventional radiology: a systematic review and European survey on methods, tools and dose ranges

Francesca De Monte^{a,*} , Christelle Huet^b, Céline Bassinet^b , Abdulhamid Chaikh^b,
Dario Faj^{c,d} , Vjekoslav Kopacin^{e,f} , Ivana Kralik^g , Dragana Krstic^h, Riccardo Lombardiⁱ ,
Anja Tomić^f, Tajana Turk^{e,f} , Hrvoje Brkic^{c,d} 

A comparative evaluation of six Monte Carlo-based software tools for fetal dose estimation from CT examinations

Huda Nasser^{1,*}  and Adnan Lahham^{2,†}

Fetal dose in pregnant CT patients: a comparison of four software packages

Joël Greffier^{1*} , Asma Arjoun¹, Chris Serrand², Jean-Paul Beregi¹ and Djamel Dabli¹



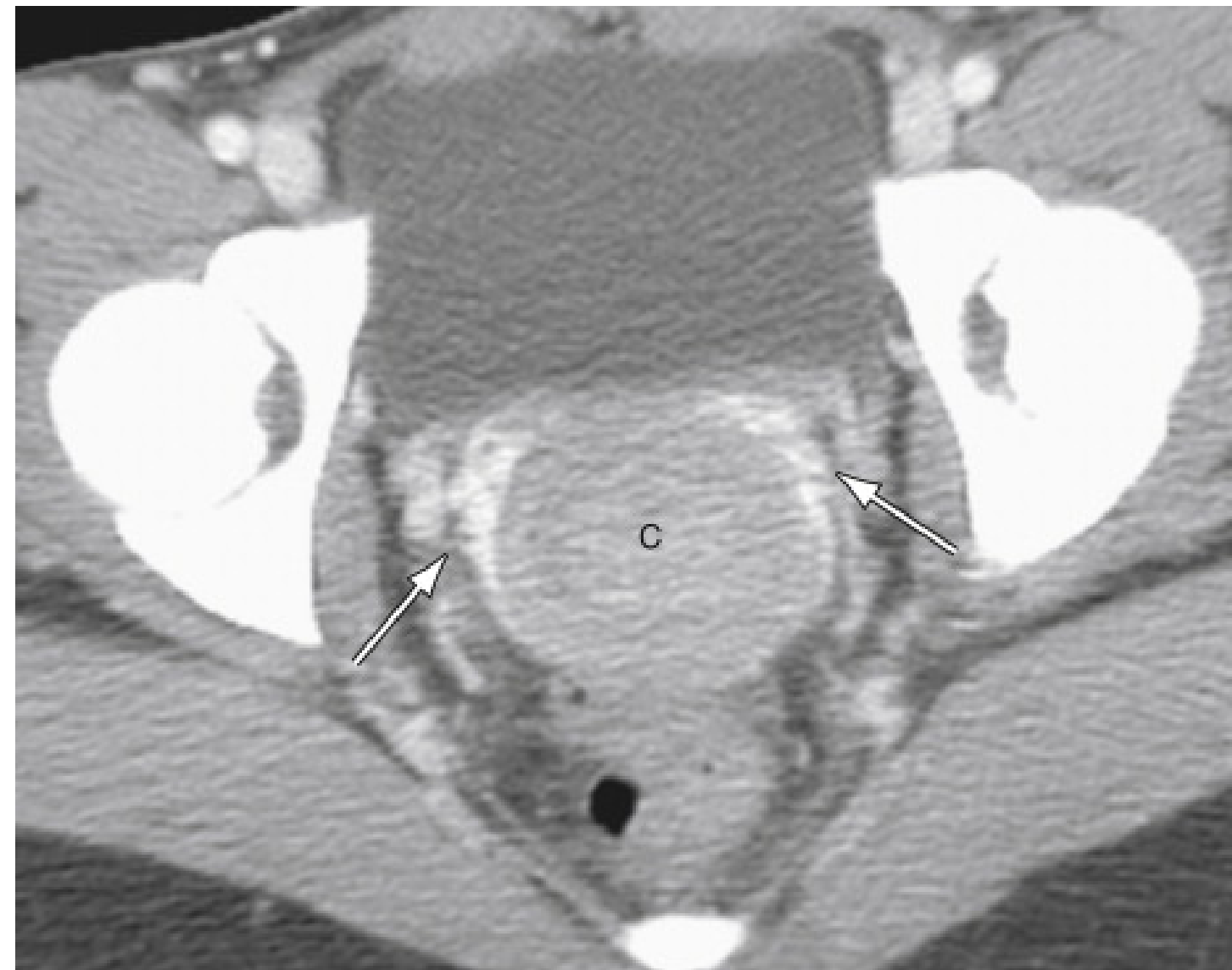
MODALITIES

- The **most important** medical imaging modalities requiring embryo/fetal dose estimation include:
 - **CT.**
 - **Fluoroscopy.**
 - **Conventional Radiography.**
 - **Nuclear Medicine.**

	Fetal Exposure
Procedure	cGy (rad)
Chest x-ray (2 views)	$2-7 \times 10^{-5}$
Mammogram (4 views)	0.01-0.04
Abdominal x-ray (1 view)	0.1-0.3
Pelvic x-ray (1 view)	0.2-0.35
Ventilation-perfusion scan	0.01-0.04
Helical CT chest	$1-10 \times 10^{-3}$
CT abdomen	1.7-3.5
CT pelvis	1.0-4.6

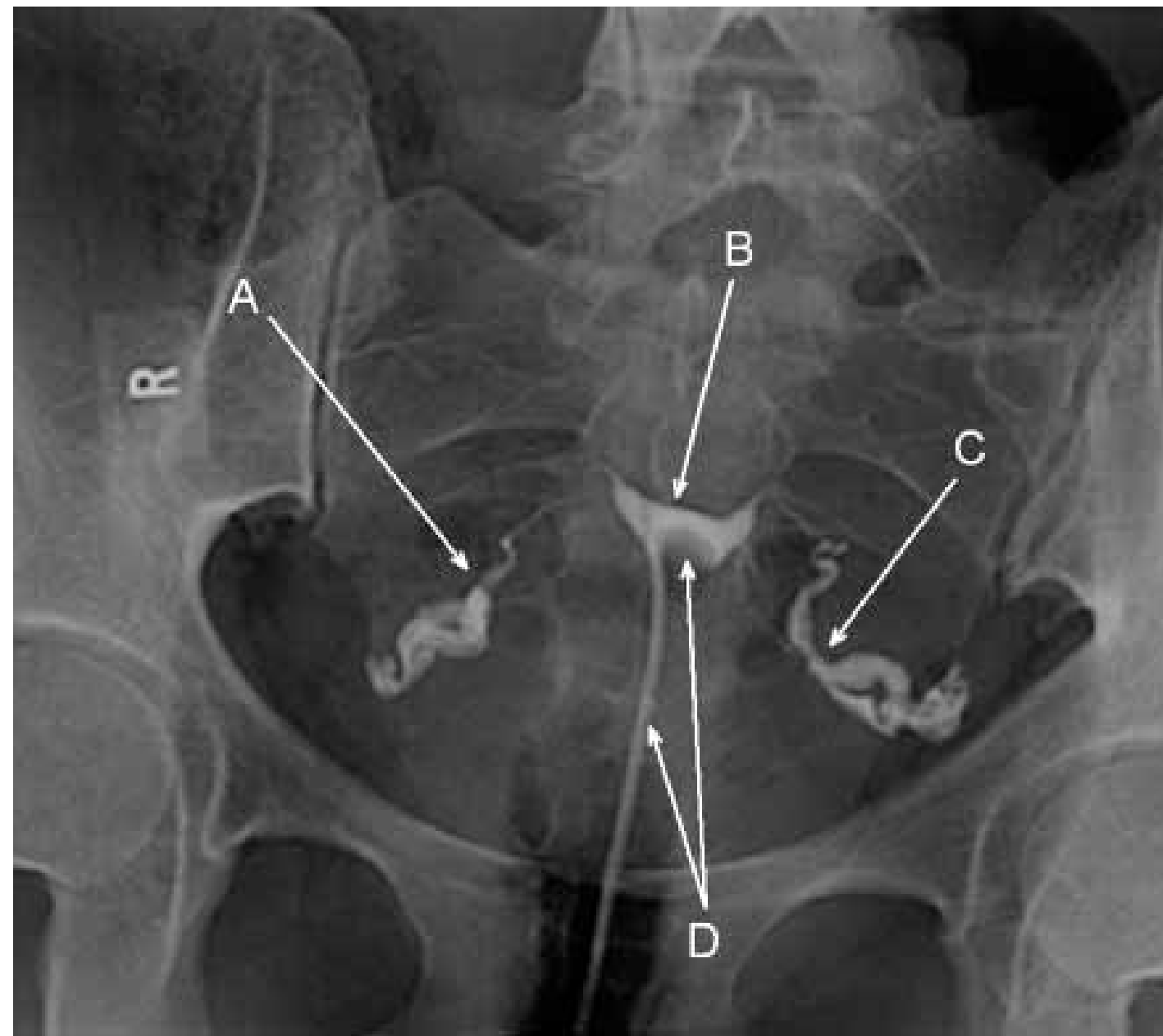
CT

- Fetal dose estimation in **CT is particularly important**, because the embryo/fetus may receive a substantial dose, CT examinations are **widely used** in clinical practice, and they are frequently performed in **emergency settings** where pregnancy may be unknown or where the examination cannot be postponed.



RADIOGRAPHY

- Embryo/fetal dose from **conventional radiography** is generally **simpler to assess** and the dose to the embryo/fetus is **typically much lower**.



FLUOROSCOPY

- Fluoroscopy-guided procedures are **less frequently performed during pregnancy** and are often **scheduled in advance**. However, complex or emergency interventional procedures **can result in substantial embryo/fetal exposure** and therefore warrant dedicated assessment.

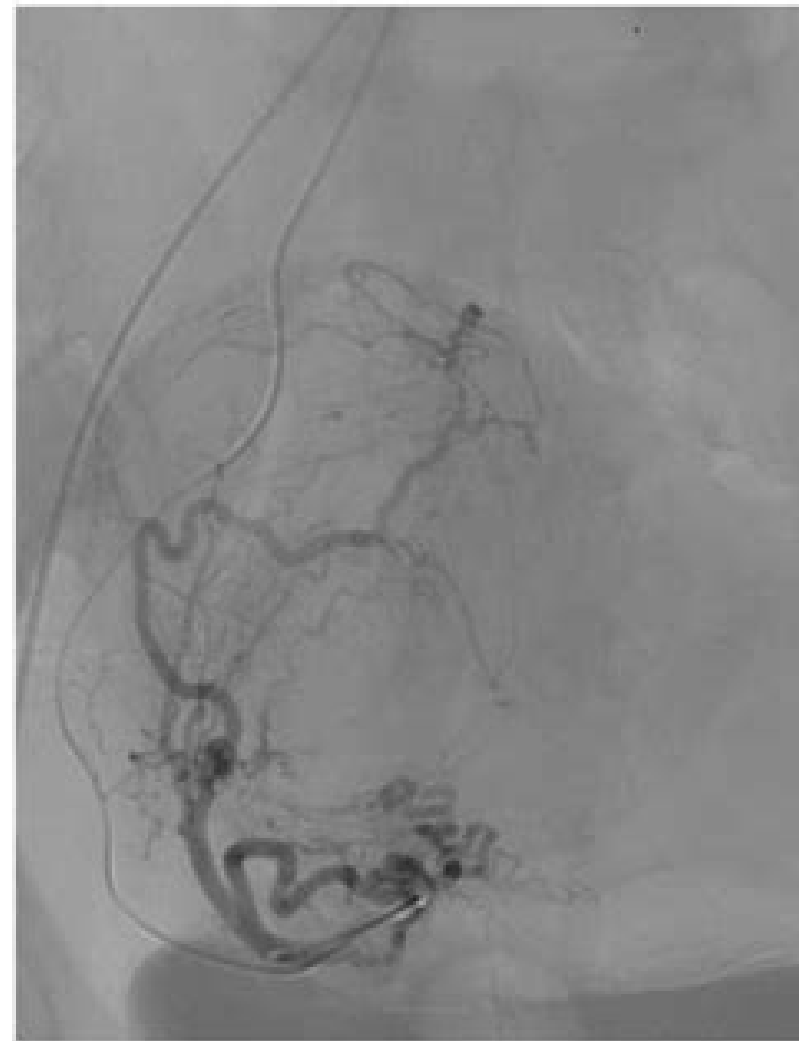
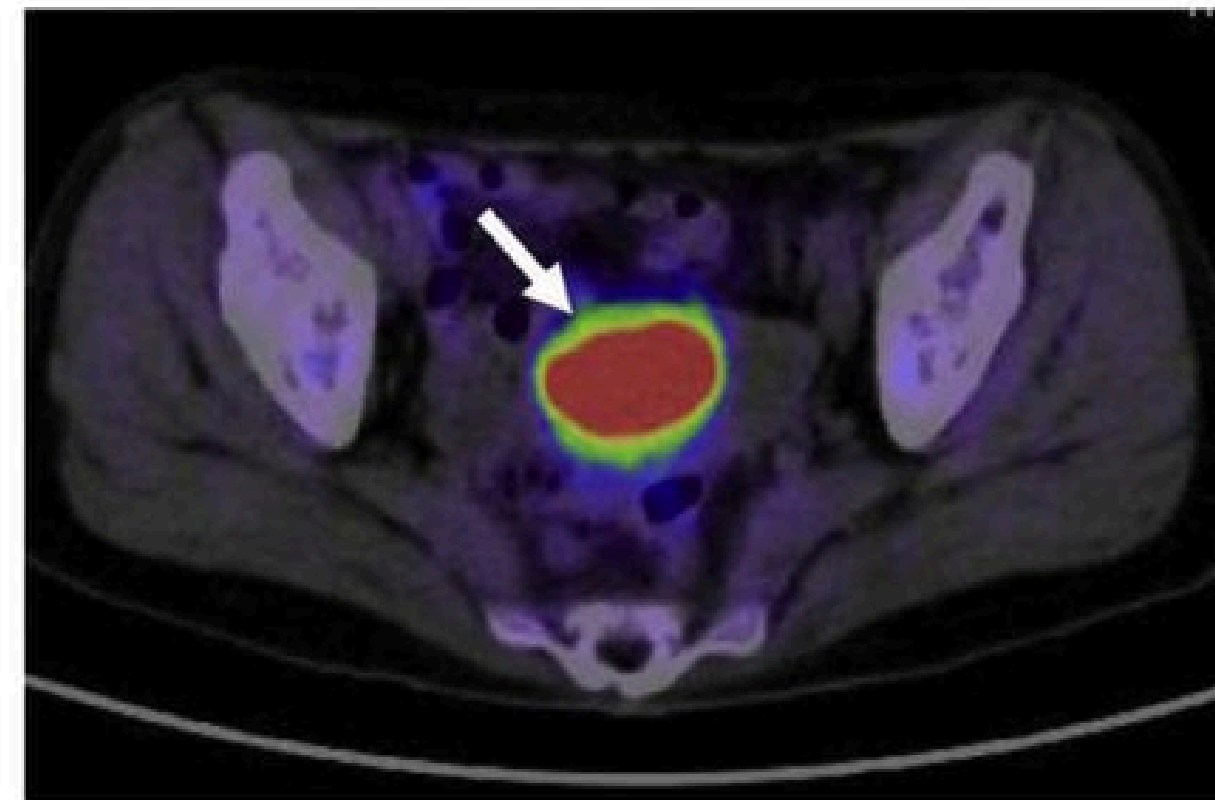


Figure 6. Selective catheterization of the right uterine artery. Image obtained before uterine artery embolization in a 44-year-old woman with no history of abdominopelvic surgery.

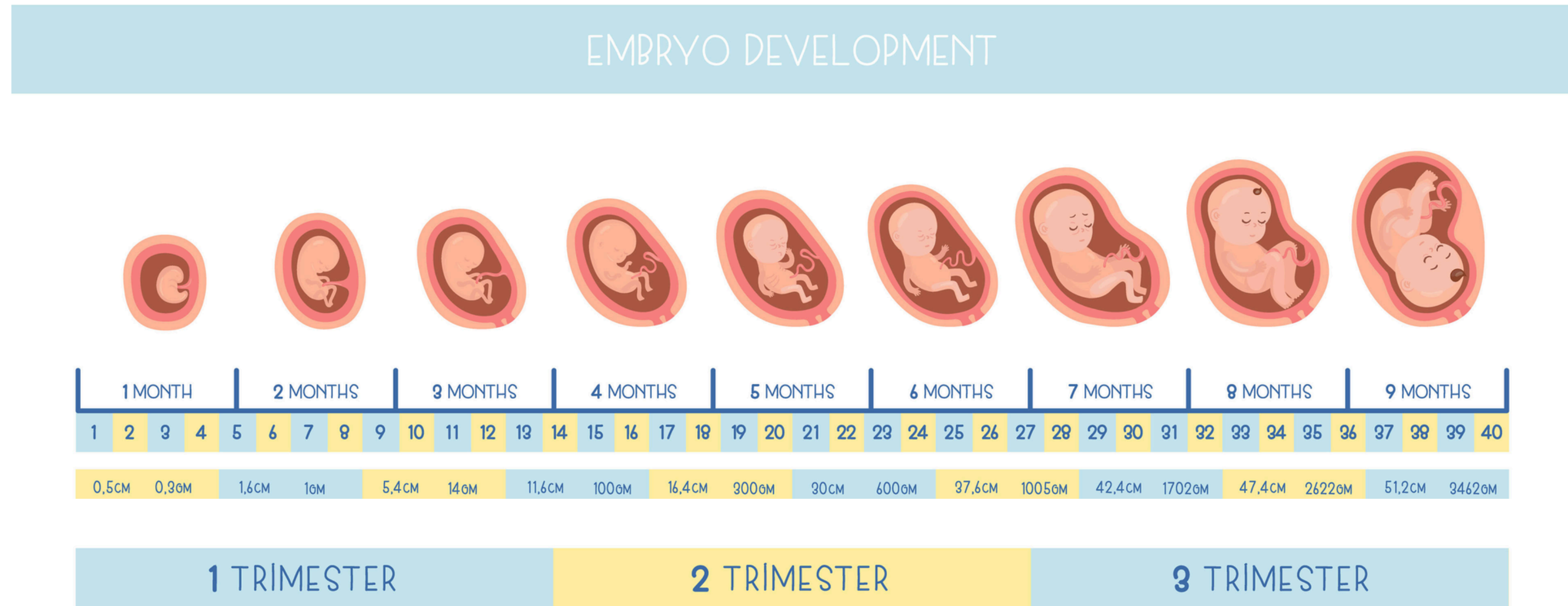
NUCLEAR MEDICINE

- Nuclear medicine requires a **fundamentally different dosimetric approach** (e.g. based on **MIRD formalism**), because the **radiation source is internal** rather than external.
- Consequently, **dose calculations** are **highly patient-specific** and depend critically on the choice of **radiopharmaceutical**, the patient's **anatomy**, and the tracer **biokinetics**.



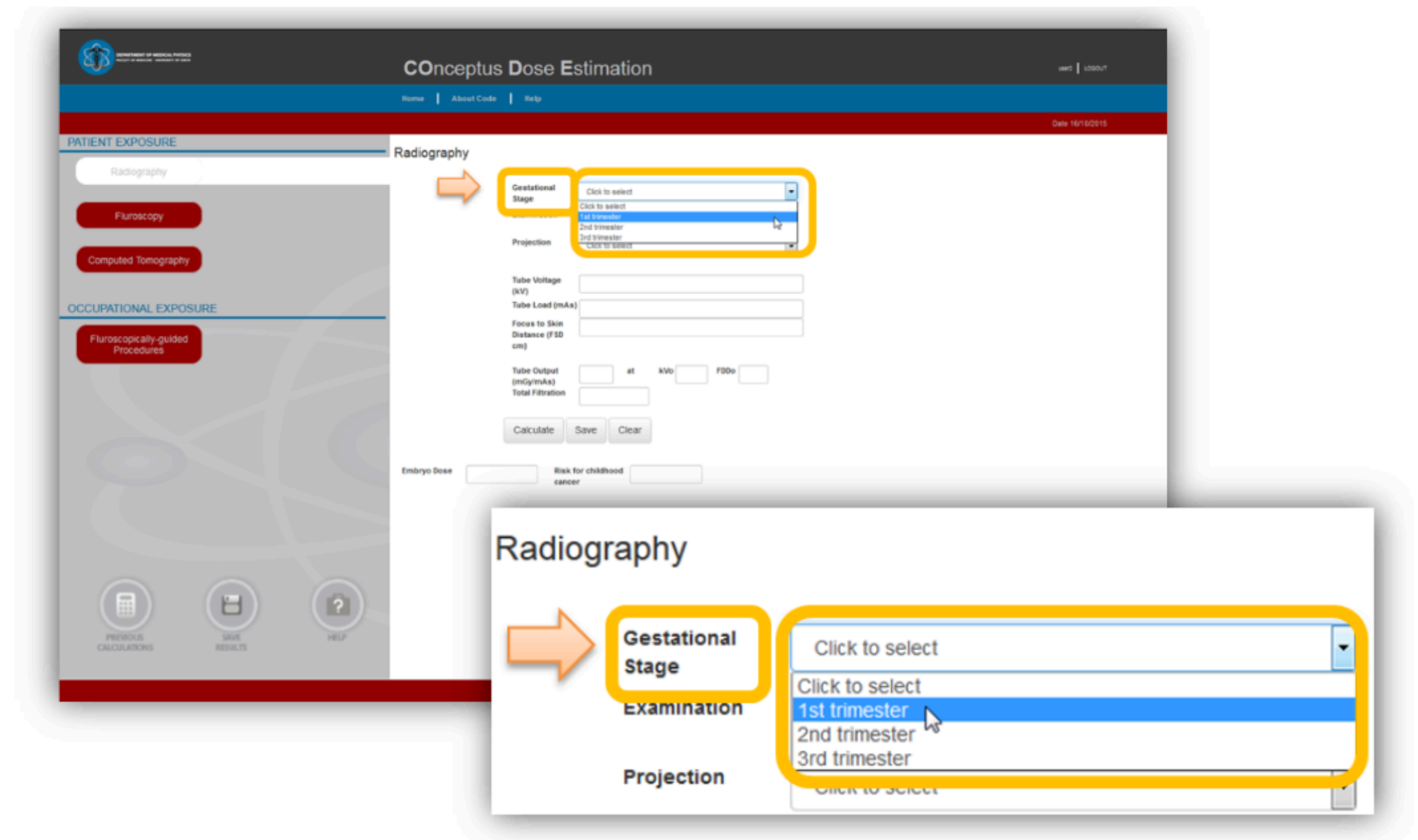
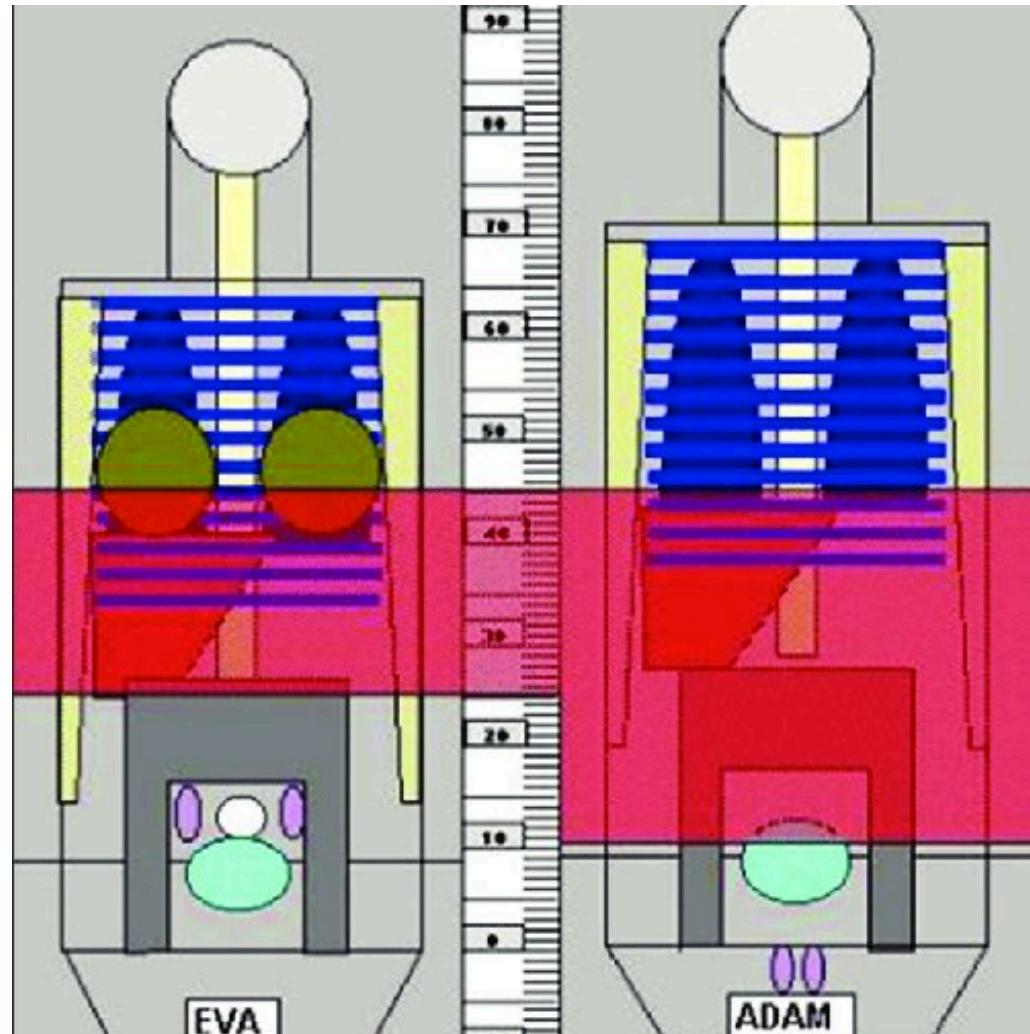
FETUS OR UTERUS DOSE

- During the **first 10-11th weeks of pregnancy**, the **embryo sits entirely within the pelvis**, and has a **negligible self-mass**.
- This means the radiation absorbed by the maternal **uterine tissue** is a highly **reasonable approximation** of the exposure to the embryo.



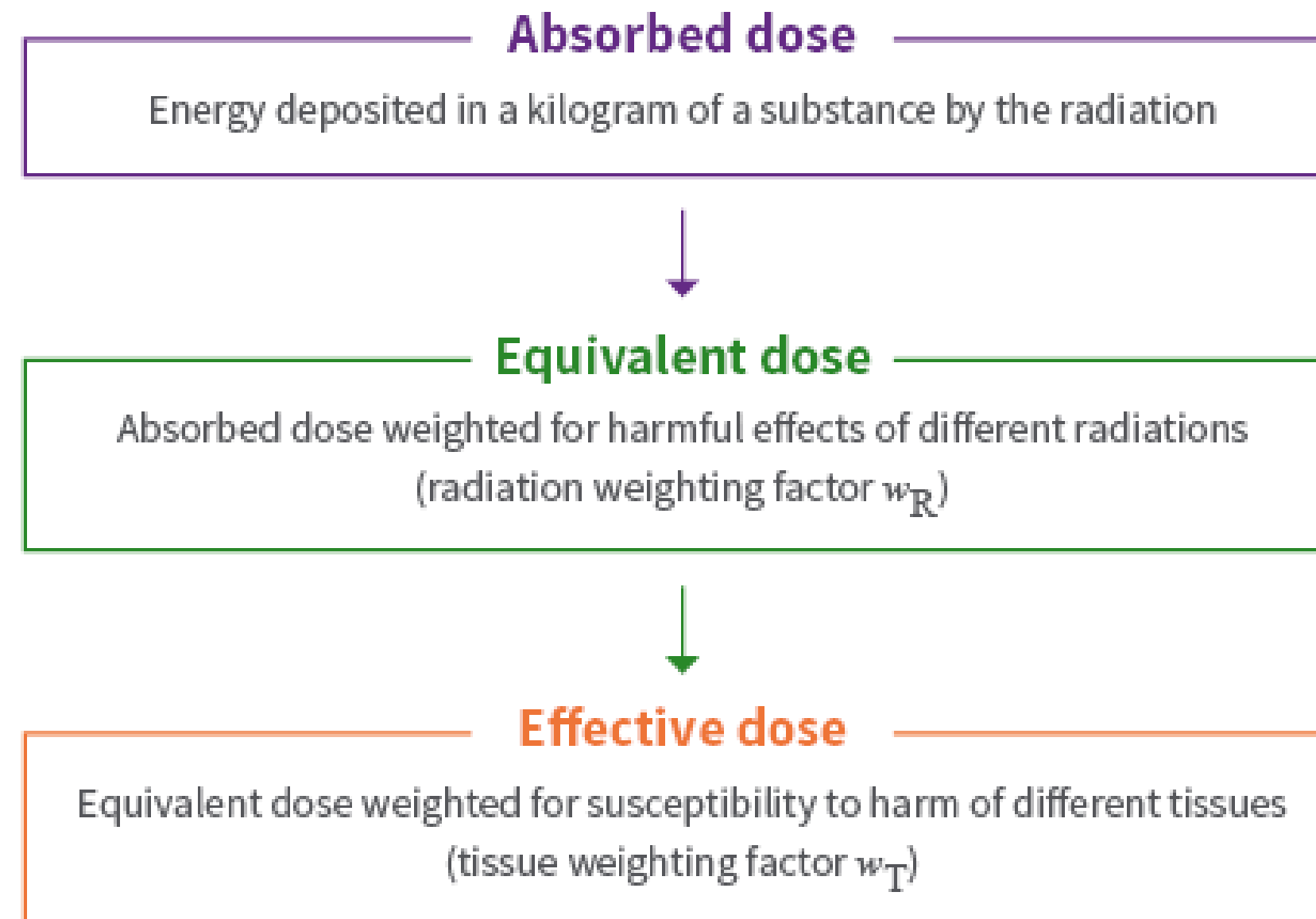
FETUS OR UTERUS DOSE

- Some softwares use **standard phantom models** and **do not account for gestational variations**. Thus the radiation dose is estimated for the uterus (e.g. CTEXPO).
- Conversely, other software tools are designed to report **maternal organ doses and embryo/fetal dose**, since they incorporate **gestational variation** (e.g. CODE).



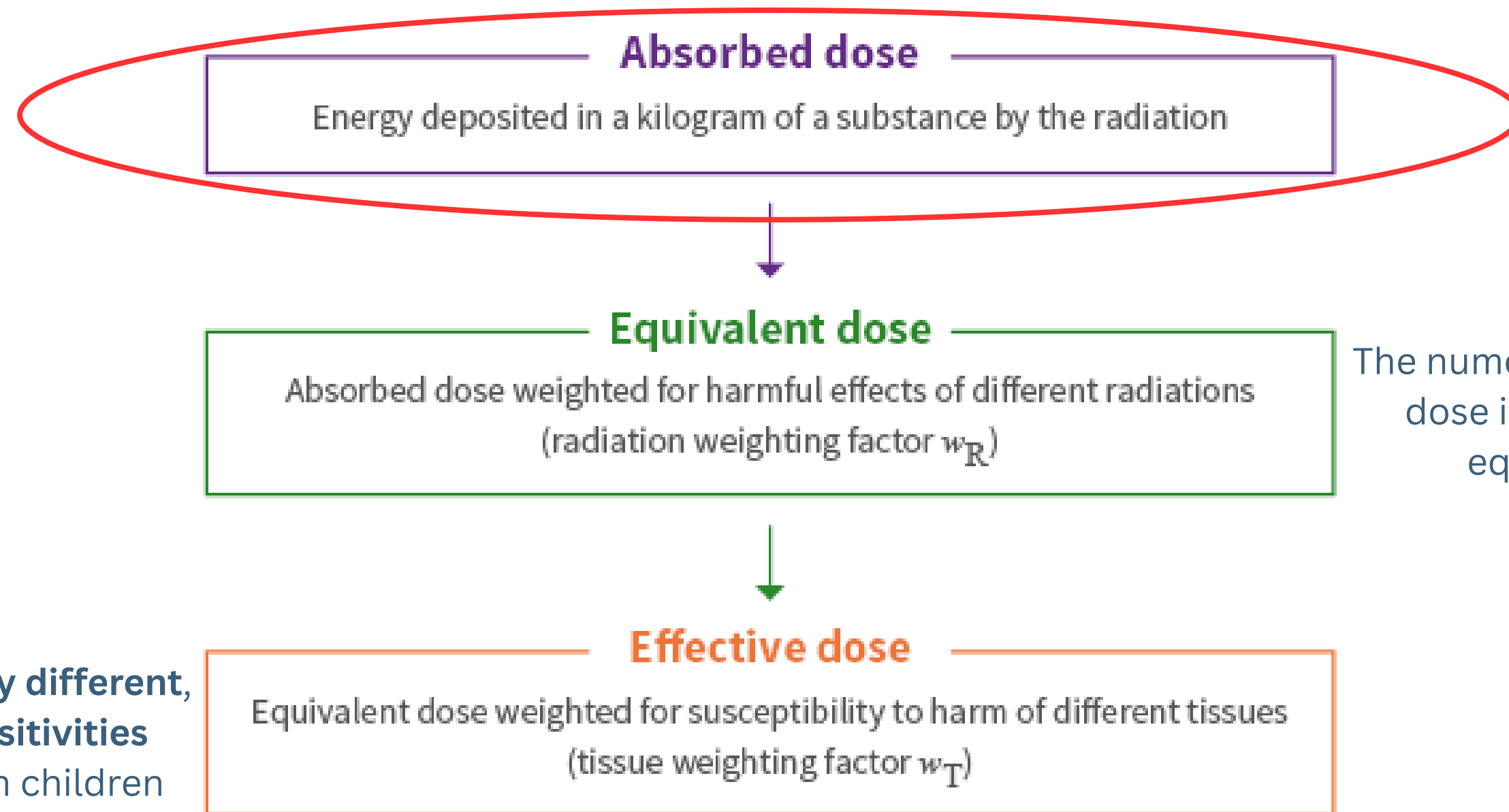
WHICH DOSE?

- What **dose** do we want to compute when we ask for embryo/fetal?



WHICH DOSE?

- What **dose** do we want to compute when we ask for embryo/fetal dose?

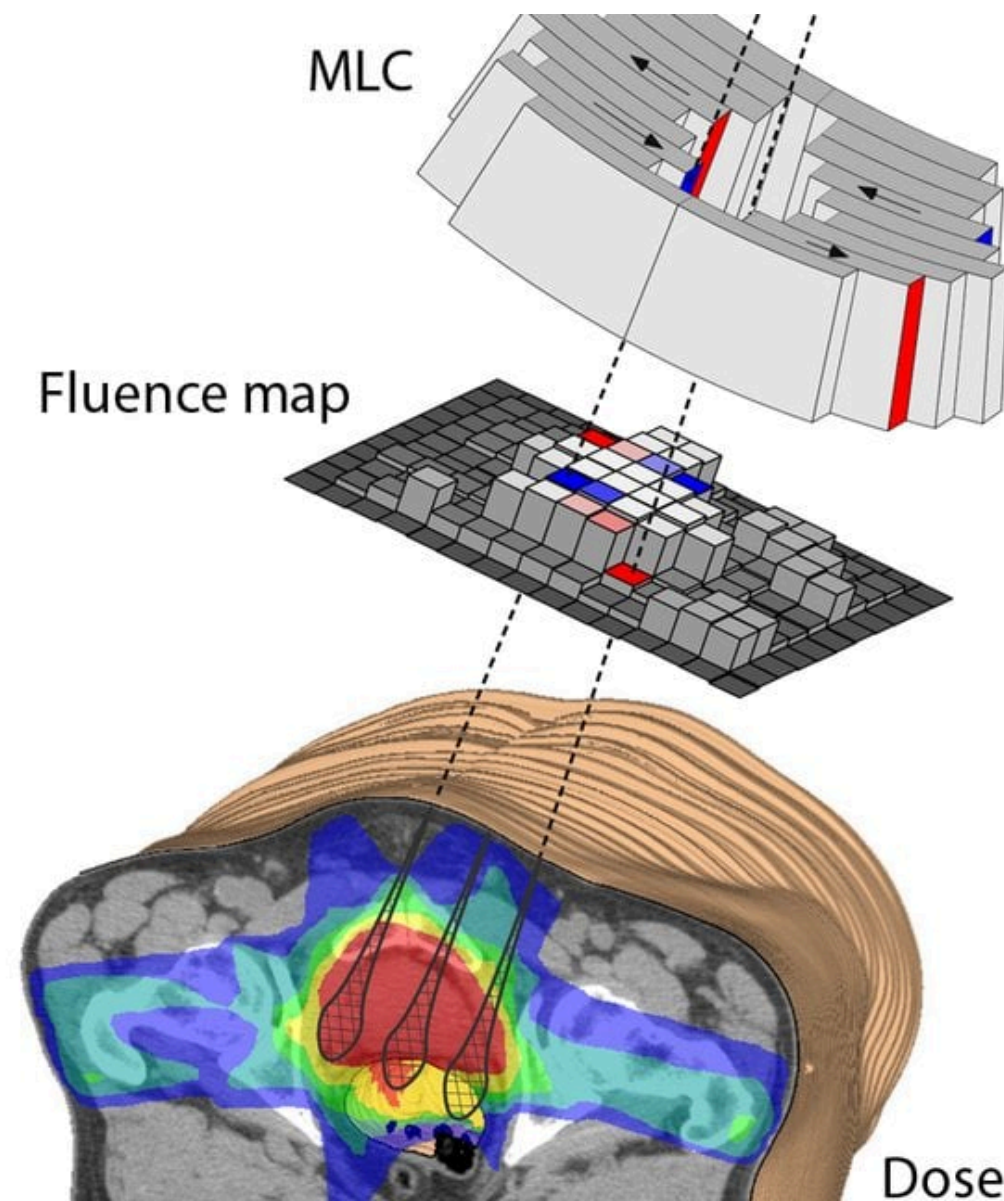


The numerical value of the absorbed dose in mGy is **identical** to the equivalent dose in mSv

Fetal organs have **completely different**, rapidly changing **radiosensitivities** compared to adults or even children

SOFTWARE BASICS

- While a **full MC simulation** would be the absolute best, simulating billions of individual virtual x-ray photons traveling through a patient's body is far **too computationally complex and slow** for **routine clinical** environments.
 - Would this at least be practicable when we have the **CT images**?



SOFTWARE BASICS

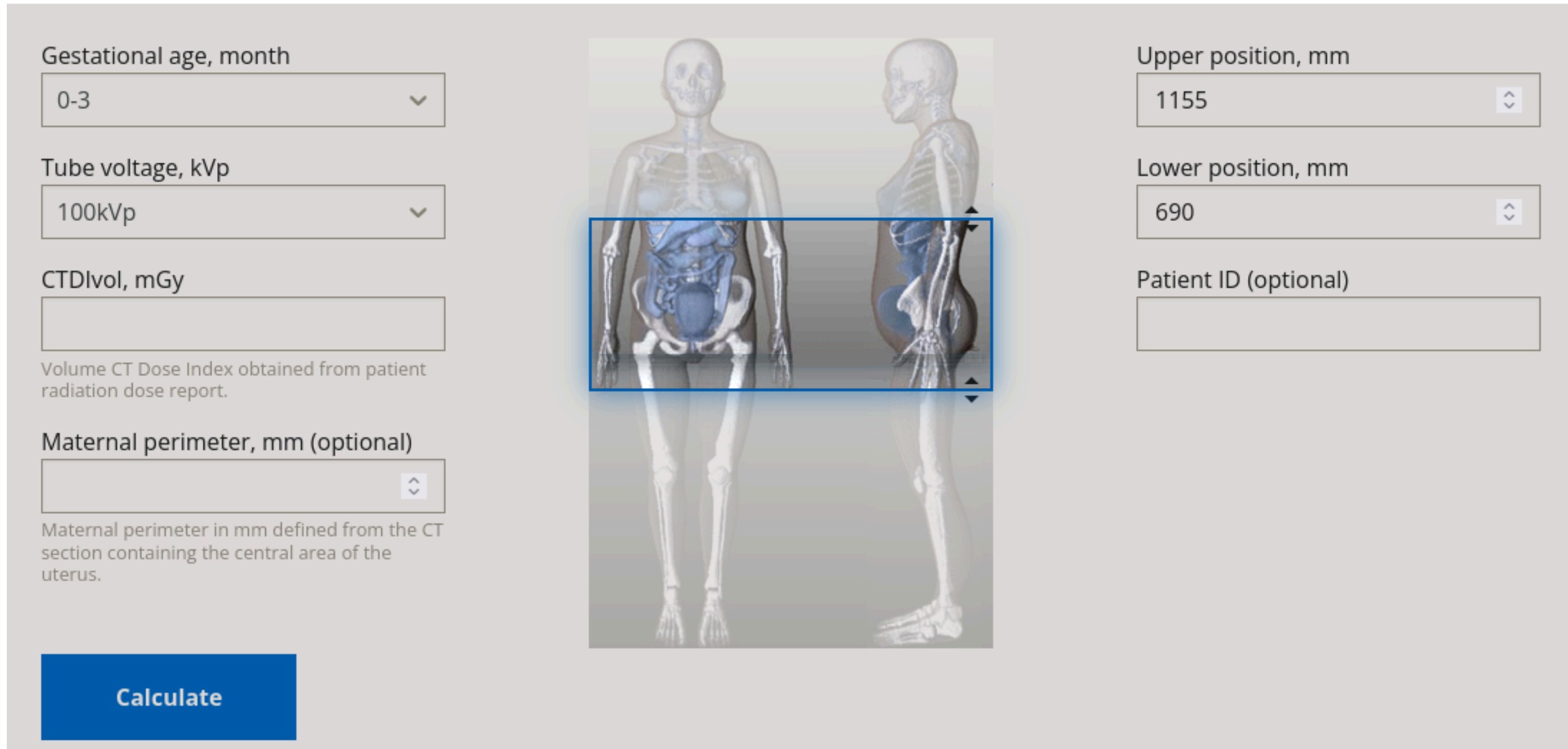
- **Different software** can use fundamentally **different approaches**.
- In general the developers perform thousands of exhaustive "**offline**" **Monte Carlo simulations** using either:
 - a. **Stylized/Mathematical phantoms** (older tools like PCXMC or CT-Expo) use basic **geometric shapes** (cylinders, ellipsoids) to represent maternal organs. Here, the non-pregnant uterus is typically used as a surrogate for the embryo.
 - b. **Virtual phantoms** (used by VirtualDose-CT or fetaldose.org) are reconstructed from **real patient CT/MRI scans**.
 - c. **Hybrid phantoms**, combining properties of the **first two** categories.

The UF Family of hybrid phantoms of the pregnant female for computational radiation dosimetry

Matthew R Maynard¹, Nelia S Long¹, Nash S Moawad²,
Roger Y Shifrin³, Amy M Geyer¹, Grant Fong⁴ and
Wesley E Bolch^{1,5}

SOFTWARE BASICS

- For a specific imaging modality, simulations are run for **thousands of variations** such as different scanner model, tube voltage (kVp), beam width, and slice-by-slice position along the patient's longitudinal (z) axis.
- This is **highly software-specific**.



The software interface is designed for calculating fetal radiation dose. It features a central 3D anatomical model of a pregnant woman, showing the fetus in the uterus. The model is displayed in two views: a front view and a side view. A blue rectangular box highlights the fetal region in both views. The interface includes several input fields and a 'Calculate' button.

Inputs:

- Gestational age, month: 0-3
- Tube voltage, kVp: 100kVp
- CTDIvol, mGy: (empty field)
- Volume CT Dose Index obtained from patient radiation dose report. (text label)
- Maternal perimeter, mm (optional): (empty field)
- Maternal perimeter in mm defined from the CT section containing the central area of the uterus. (text label)
- Upper position, mm: 1155
- Lower position, mm: 690
- Patient ID (optional): (empty field)

Calculate

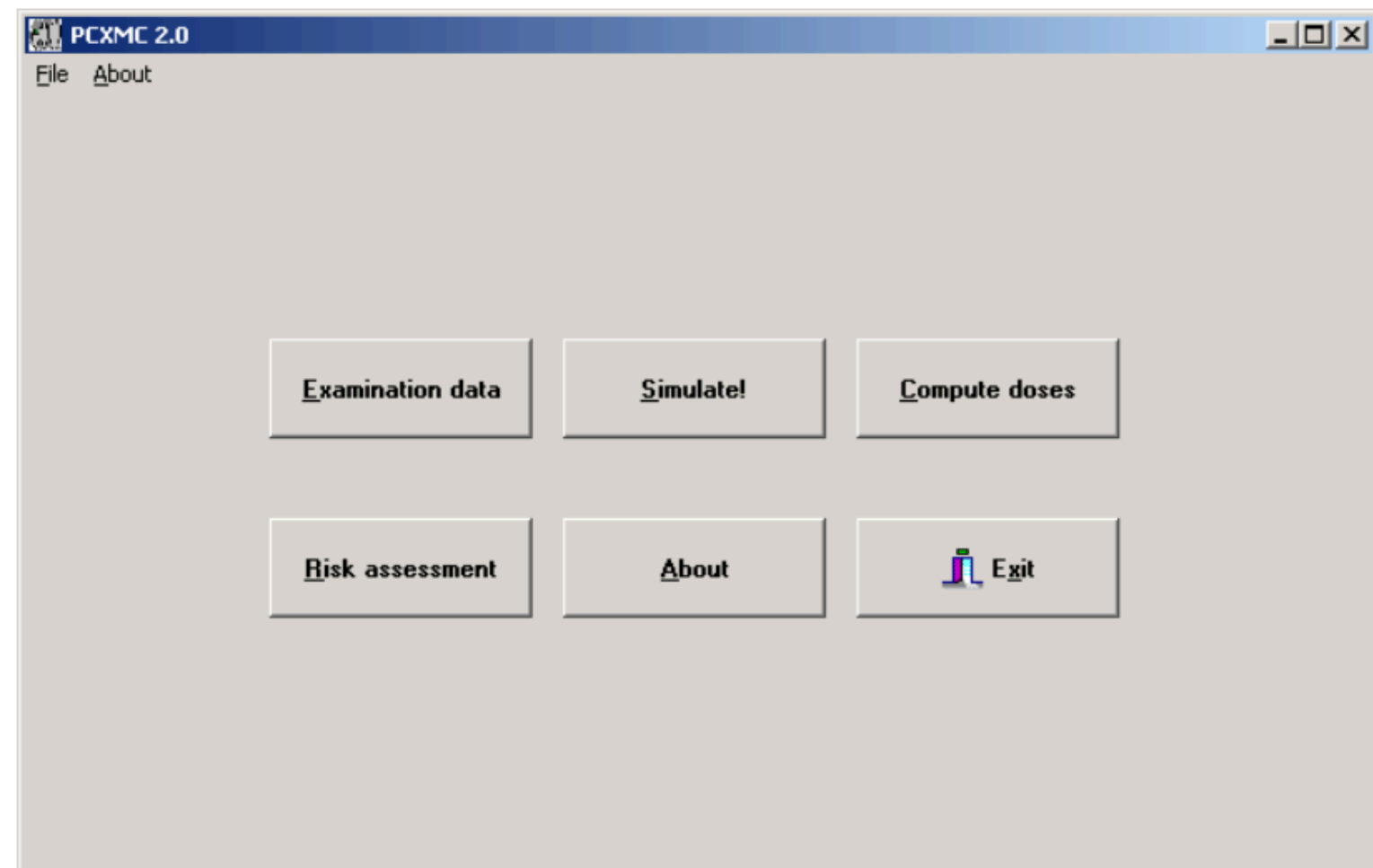
PCXMC 2.0

- **PCXMC 2.0** has been developed at **STUK** (Radiation and Nuclear Safety Authority in Finland). It is available free of charge.
- The program can calculate patients organ doses and effective doses for **radiography and fluoroscopy**.
- The organ doses are calculated in **29 organs and tissues**.
- The anatomical data are based on the mathematical **hermaphrodite phantom models of Cristy and Eckerman (1987)**.

PCXMC 2.0

User's Guide

Markku Tapiovaara, Teemu Siiskonen



PCXMC 2.0

- To perform dose calculations:
 - (1) Defining the **examination conditions**.
 - (2) Performing the **Monte Carlo simulation**.
 - (3) **Calculating the organ doses** for a specified x-ray spectrum and patient input dose.

Table I. Standard measures of the phantoms in PCXMC.

Age (y)	Height (cm)	Weight (kg)
Newborn	50.9	3.4
1y	74.4	9.2
5y	109.1	19.0
10y	139.8	32.4
15y	168.1	56.3
Adult	178.6	73.2

Calculation of x-ray spectrum

X-ray tube potential

120

kV

X-ray tube Anode Angle

17.00

degree

Filter #1 : Material

13

Atomic Number

Al

Chemical Symbol

Filter #1 : Thickness

3.00

mm

0.8106

g/cm²

Filter #2 : Material

29

Atomic Number

Cu

Chemical Symbol

Filter #2 : Thickness

0.10

mm

0.0894

g/cm²

Exit: Generate this spectrum!

Exit: Keep old spectrum

PCXMC 2.0

- It is possible to specify the **patient input dose** as **different quantities** commonly reported on the RDSR of the DICOM file of the examination, such as **incident air kerma, KAP, mAs**.

Patient input dose

Input dose value:
 mGy

Incident air kerma value used in calculations:
 mGy

[Corresponds to about 9.7mAs]

Input dose quantity and unit:

- ☒ Incident air kerma (mGy)
- ☐ Dose-Area Product (mGycm²)
- ☐ Entrance exposure (mR)
- ☐ Exposure -Area Product (Rcm²)
- ☐ Current -Time Product (mAs)

[Input dose quantities are for measurements without BSF]

OK ! Cancel

PCXMC 2.0

DefForm [C:\Program Files\PCXMC\MCRUNS\15-year-old\15y-Abdomen-AP.DF2]

File

Main menu New Form Open Form Save Form Save Form As ... Print As Text

Header text Typical abdomen AP, 15y

Phantom data

Age: ☐ 0 ☐ 1 ☐ 5 ☐ 10 ☒ 15 ☐ Adult

Phantom height 168.10 Standard: 168.1

Phantom mass 55.90 Standard: 56.3

☒ Arms in phantom

Geometry data for the x-ray beam

FSD 85.40 Beam width 23.32 Beam height 31.04 Xref 0.0000 Yref 0.0000 Zref 19.9900

Projection angle 270.00

Cranio-caudal angle 0.00

LATR=180 AP=270 LATL=0 PA=90

(pos) Cranial X-ray tube (neg) Caudal X-ray tube

☒ Draw x-ray field

Draw Update Field Stop

MonteCarlo simulation parameters

Max energy (keV) 150 Number of photons 50000

Field size calculator

FID 110 Image width 18 Image height 24 Calculate

Phantom exit- image distance: 5.0

FSD Beam width Beam height Use this data

☒ Skeleton ☒ Brain ☒ Heart ☒ Testes ☒ Spleen ☒ Lungs ☒ Ovaries ☒ Kidneys ☒ Thymus ☒ Stomach ☒ Salivary glands ☒ Oral mucosa

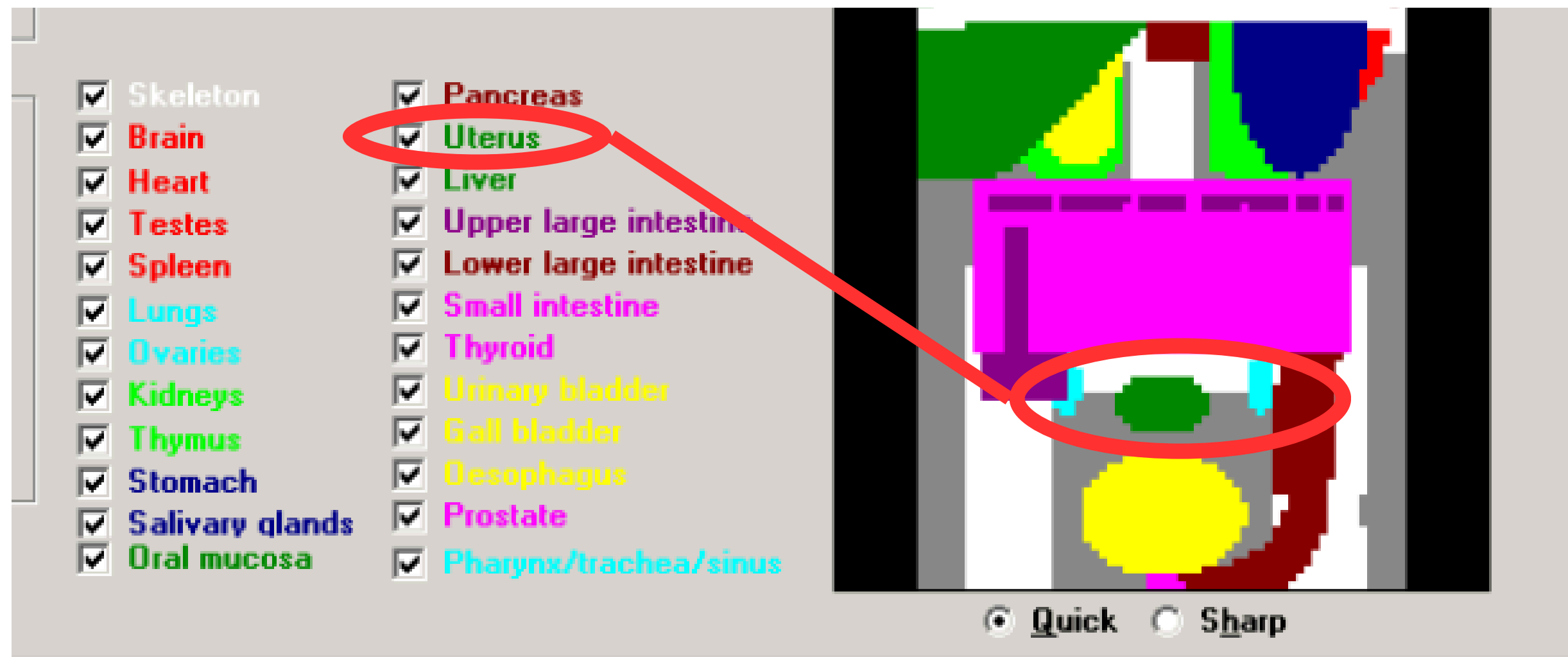
☒ Pancreas ☒ Uterus ☒ Liver ☒ Upper large intestine ☒ Lower large intestine ☒ Small intestine ☒ Thyroid ☒ Urinary bladder ☒ Gall bladder ☒ Oesophagus ☒ Prostate ☒ Pharynx/trachea/sinus

Rotation increment 30 View angle 330

Quick Sharp

PCXMC 2.0

- The program automatically **notifies** the user if the **dose in the uterus** of a woman in child-bearing age **exceeds 100 mGy**.
- PCXMC allows us to calculate the **dose to the uterus**, not directly to the fetus.



PCXMC 2.0

- “**Number of photons**” represents the number of photon histories that will be generated for the **MC simulation**. A minimum value of 10 000 is recommended by Stuk.

PCXMC- Simulation

File

File name:

Header text:

Age:

SkinPoint:

Focus:

Energy (keV):	Lot No:	Photons in the lot:
30	3	3000

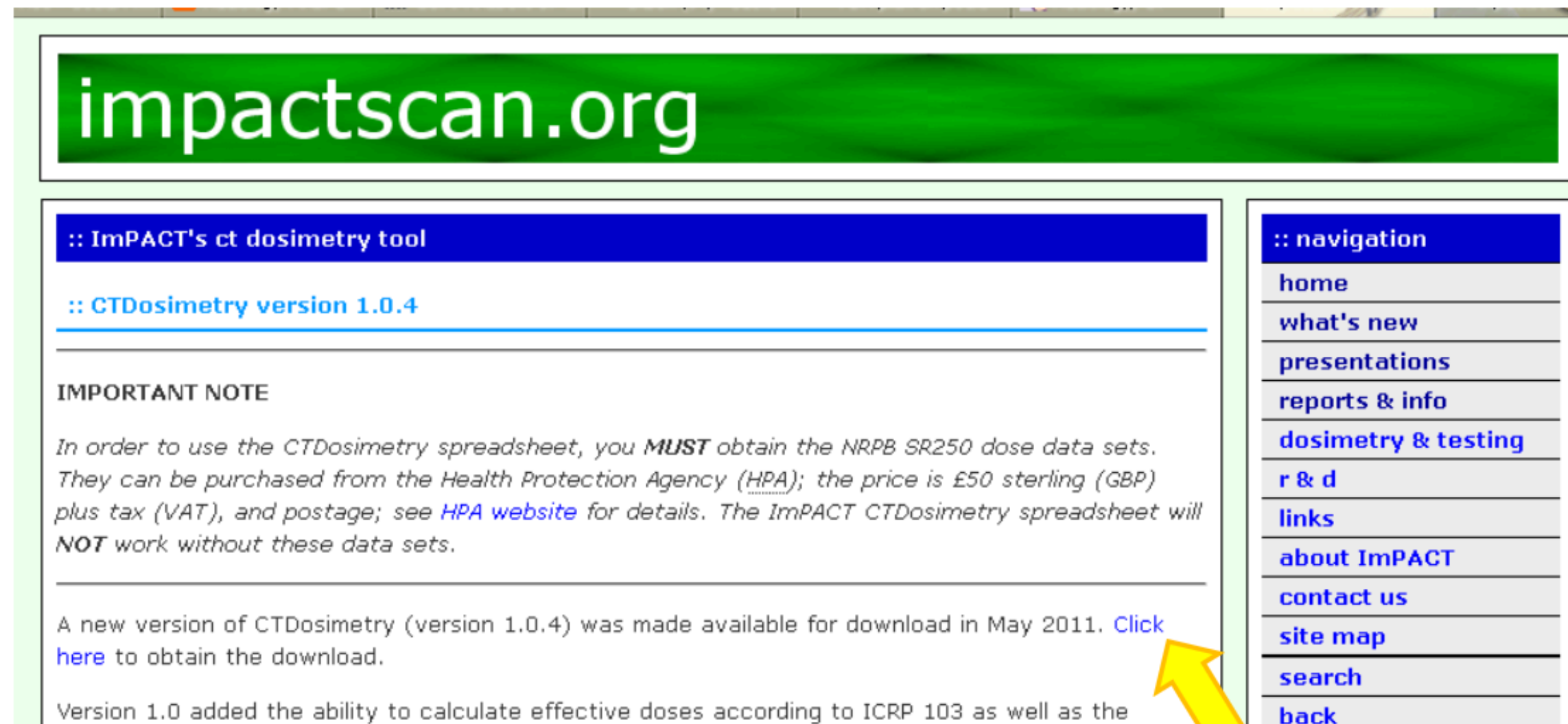
PCXMC 2.0

- Results are presented as the **average absorbed dose in any of the organs considered.**

Organs	Dose (mGy)	Error (%)	Organs	Dose (mGy)	Error (%)
Active bone marrow	0,052206	0,1	(Scapulae)	0,400557	0,4
Adrenals	0,154045	1,7	(Clavicles)	0,060160	1,4
Brain	0,000822	3,3	(Ribs)	0,288670	0,2
Breasts	0,035366	0,9	(Upper arm bones)	0,035092	1,0
Colon (Large intestine)	0,003454	1,5	(Middle arm bones)	0,039175	1,0
(Upper large intestine)	0,005363	1,6	(Lower arm bones)	0,006518	1,8
(Lower large intestine)	0,000929	4,3	(Pelvis)	0,002112	2,1
Extrathoracic airways	0,007761	4,7	(Upper leg bones)	0,000026	18,1
Gall bladder	0,027439	2,1	(Middle leg bones)	0,000001	47,8
Heart	0,058200	0,6	(Lower leg bones)	0,000000	NA
Kidneys	0,092431	0,6	Skin	0,024164	0,2
Liver	0,065439	0,3	Small intestine	0,004068	1,4
Lungs	0,131340	0,2	Spleen	0,124134	0,8
Lymph nodes	0,035024	0,4	Stomach	0,037965	1,1
Muscle	0,027625	0,1	Testicles	0,000001	69,9
Oesophagus	0,081588	1,0	Thymus	0,029615	3,1
Oral mucosa	0,002377	6,2	Thyroid	0,023657	3,7
Ovaries	0,000911	21,3	Urinary bladder	0,000195	17,7
Pancreas	0,073502	1,1	Uterus	0,000731	8,1
Prostate	0,000068	83,9	Average dose in total body	0,035716	0,1
Salivary glands	0,004203	3,5	Effective dose ICRP60 (mSv)	0,042921	0,3
Skeleton	0,074937	0,1	Effective dose ICRP103 (mSv)	0,045029	0,2
(Skull)	0,004391	1,5			
(Upper Spine)	0,044352	1,2			
(Middle Spine)	0,326392	0,3			
(Lower Spine)	0,075329	0,9	Abs. energy fraction (%)	58,042776	

IMPACT CT DOSIMETRY

- **ImPACT CT Patient Dosimetry Calculator** was possibly the **first software** package developed for embryo/fetal dose estimations in **CT**.
- Developed from the Scanner Evaluation Centre, **United Kingdom National Health Service**.



IMPACT CT DOSIMETRY

- It is possible to **insert your own CT scanner** if it is missing from the list, measurements of **CTDI in phantoms and in air are required**, recommended with standard kV, mAs and rotation time, ~10mm collimation. Values are then normalized to 100 mAs.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Scanner	kVp	Sub-group	Scanner	CTDI (Head, mGy/100mAs)			CTDI (Body, mGy/100mAs)			ImPACT Factor		Scanner Match			
2	Group				Air	Centre	Perip	Air					Head		Body	
57	GE.p	120	GE.p.120	GE LightSpeed VCT (small hd, large bd)	34.9	22.4	22.5	27.9					17		20	21
58	GE.p	140	GE.p.140	GE LightSpeed VCT (small hd, large bd)	46.8	31.3	31.0	38.8					19		20	16
59	PH.a	120	PH.a.120	Philips 310, 350 (GE2, no Cu)	32.8	18.7	21.2				0.87		10	5	13	14
60	PH.b	120	PH.b.120	Philips 310, 350 (GE2, w. Cu)	15.8	11.2	11.6				1.00		14	5	14	14
61	PH.c	120	PH.c.120	Philips 310, 350 (GE3, no Cu)				21.7			0.90		3	15	15	15
62	PH.d	120	PH.d.120	Philips 310, 350 (GE3, w. Cu)							1.11	1.14	20	20	16	16
63	PH.e	80	PH.e.080	Philips AV, LX, SR7000	4.3	2.6	3.0	8.7			0.93	0.73	11	11	20	5
64	PH.e	100	PH.e.100	Philips AV, LX, SR7000	13.2	8.8	9.6	13.2			0.98	0.89	13	13	22	22
65	PH.e	120	PH.e.120	Philips AV, LX, SR7000	19.2	13.6	14.8	19.3			1.03	1.01	16	16	19	19
66	PH.e	130	PH.e.130	Philips AV, LX, SR7000	22.6	16.0	17.6	22.8			1.04	1.05	17	18	23	23
67	PH.e	140	PH.e.140	Philips AV, LX, SR7000	26.0	19.0	20.3	26.0			1.05	1.07	18	19	21	12
68	PH.f	120	PH.f.120	Philips CX, CX/S	20.5	14.2	15.4	19.2			1.01	0.90	15	14	18	18
69	PH.g	120	PH.g.120	Philips SR4000	18.2	12.5	13.5	18.2			1.00	0.92	13	15	14	15
70	PH.h	120	PH.h.120	Philips SR												

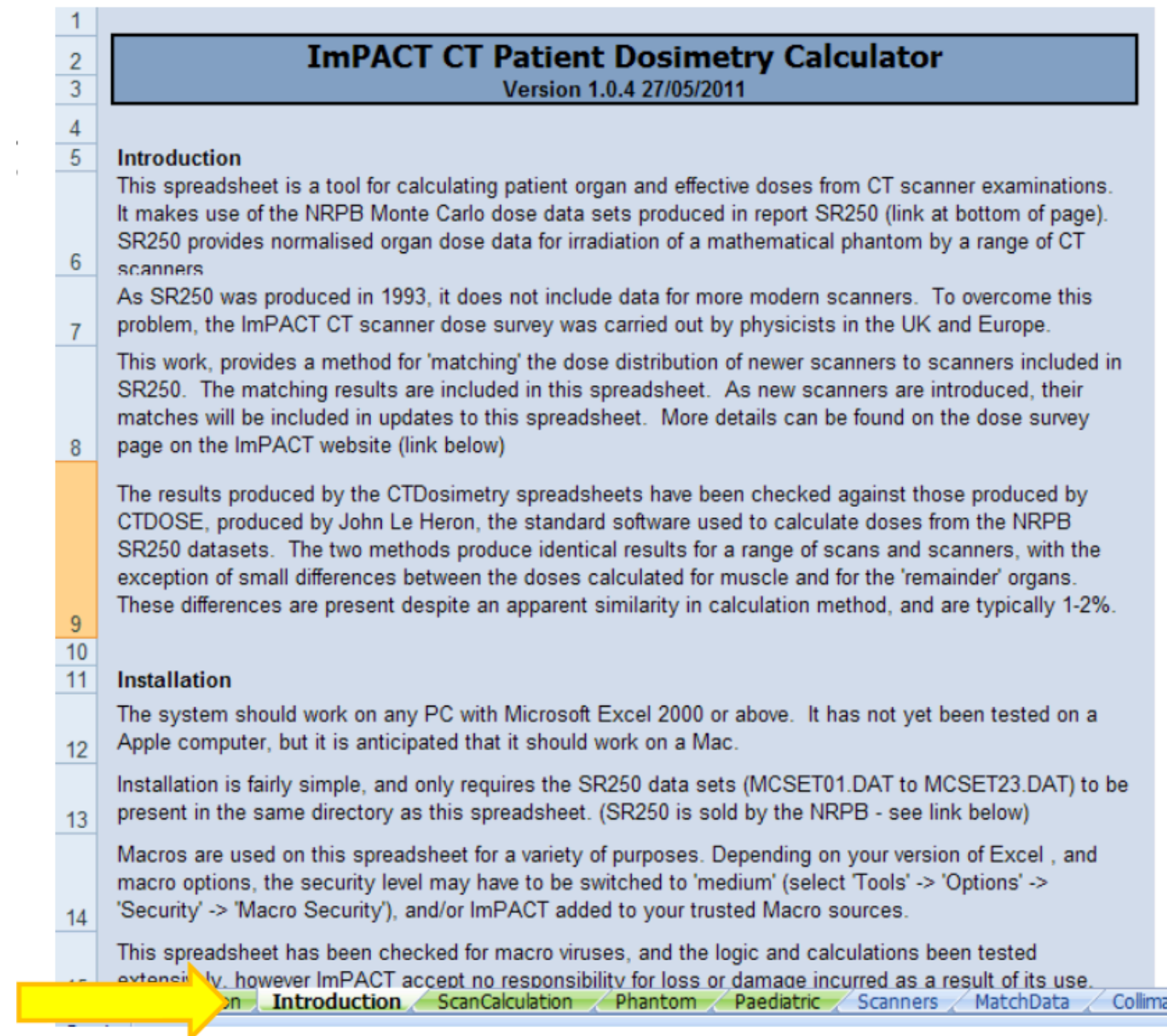
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Scanner	kVp	Sub-group	Scanner	CTDI (Head, mGy/100mAs)			CTDI (Body, mGy/100mAs)			ImPACT Factor		Scanner Match			
2	Group				Air	Centre	Perip	Air	Centre	Perip	Head	Body			Head	Body
57	GE.p	120	GE.p.120	GE LightSpeed VCT (small hd, large bd)	34.9	22.4	22.5	27.9	6.5	13.1	0.90	1.04	10	17	20	21
58	GE.p	140	GE.p.140	GE LightSpeed VCT (small hd, large bd)	46.8	31.3	31.0	38.8	9.6	18.5	0.92	1.10	11	19	20	16
59																
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62																
63	PH.a	120	PH.a.120	Philips 310, 350 (GE2, no Cu)	32.8	18.7	21.2				0.87		10	5	13	14
64	PH.b	120	PH.b.120	Philips 310, 350 (GE2, w. Cu)	15.8	11.2	11.6				1.00		14	5	14	14
65	PH.c	120	PH.c.120	Philips 310, 350 (GE3, no Cu)							0.90		3	15	15	15
66	PH.d	120	PH.d.120	Philips 310, 350 (GE3, w. Cu)							1.11	1.14	20	20	16	16
67	PH.e	80	PH.e.080	Philips AV, LX, SR7000	4.3	2.6	3.0	8.7	1.4	3.5	0.93	0.73	11	11	20	5
68	PH.e	100	PH.e.100	Philips AV, LX, SR7000	13.2	8.8	9.6	13.2	2.6	5.7	0.98	0.89	13	13	22	22
69	PH.e	120	PH.e.120	Philips AV, LX, SR7000	19.2	13.6	14.8	19.3	4.3	9.0	1.03	1.01	16	16	19	19
70	PH.e	130	PH.e.130	Philips AV, LX, SR7000	22.6	16.0	17.6	22.8	5.3	11.1	1.04	1.05	17	18	23	23

CTUG Oct 2013 _SE et al

IMPACT 2012

IMPACT CT DOSIMETRY

- The mathematical phantom was a **single phantom** with **nonvarying anatomy** of an average adult, **not specifically designed to represent a pregnant woman**.
- The radiation **dose to the uterus** was assumed to be **equivalent to the estimated FD**.



ImPACT CT Patient Dosimetry Calculator
Version 1.0.4 27/05/2011

Introduction

This spreadsheet is a tool for calculating patient organ and effective doses from CT scanner examinations. It makes use of the NRPB Monte Carlo dose data sets produced in report SR250 (link at bottom of page). SR250 provides normalised organ dose data for irradiation of a mathematical phantom by a range of CT scanners.

As SR250 was produced in 1993, it does not include data for more modern scanners. To overcome this problem, the ImPACT CT scanner dose survey was carried out by physicists in the UK and Europe.

This work, provides a method for 'matching' the dose distribution of newer scanners to scanners included in SR250. The matching results are included in this spreadsheet. As new scanners are introduced, their matches will be included in updates to this spreadsheet. More details can be found on the dose survey page on the ImPACT website (link below)

The results produced by the CTDosimetry spreadsheets have been checked against those produced by CTDOSE, produced by John Le Heron, the standard software used to calculate doses from the NRPB SR250 datasets. The two methods produce identical results for a range of scans and scanners, with the exception of small differences between the doses calculated for muscle and for the 'remainder' organs. These differences are present despite an apparent similarity in calculation method, and are typically 1-2%.

Installation

The system should work on any PC with Microsoft Excel 2000 or above. It has not yet been tested on a Apple computer, but it is anticipated that it should work on a Mac.

Installation is fairly simple, and only requires the SR250 data sets (MCSET01.DAT to MCSET23.DAT) to be present in the same directory as this spreadsheet. (SR250 is sold by the NRPB - see link below)

Macros are used on this spreadsheet for a variety of purposes. Depending on your version of Excel, and macro options, the security level may have to be switched to 'medium' (select 'Tools' -> 'Options' -> 'Security' -> 'Macro Security'), and/or ImPACT added to your trusted Macro sources.

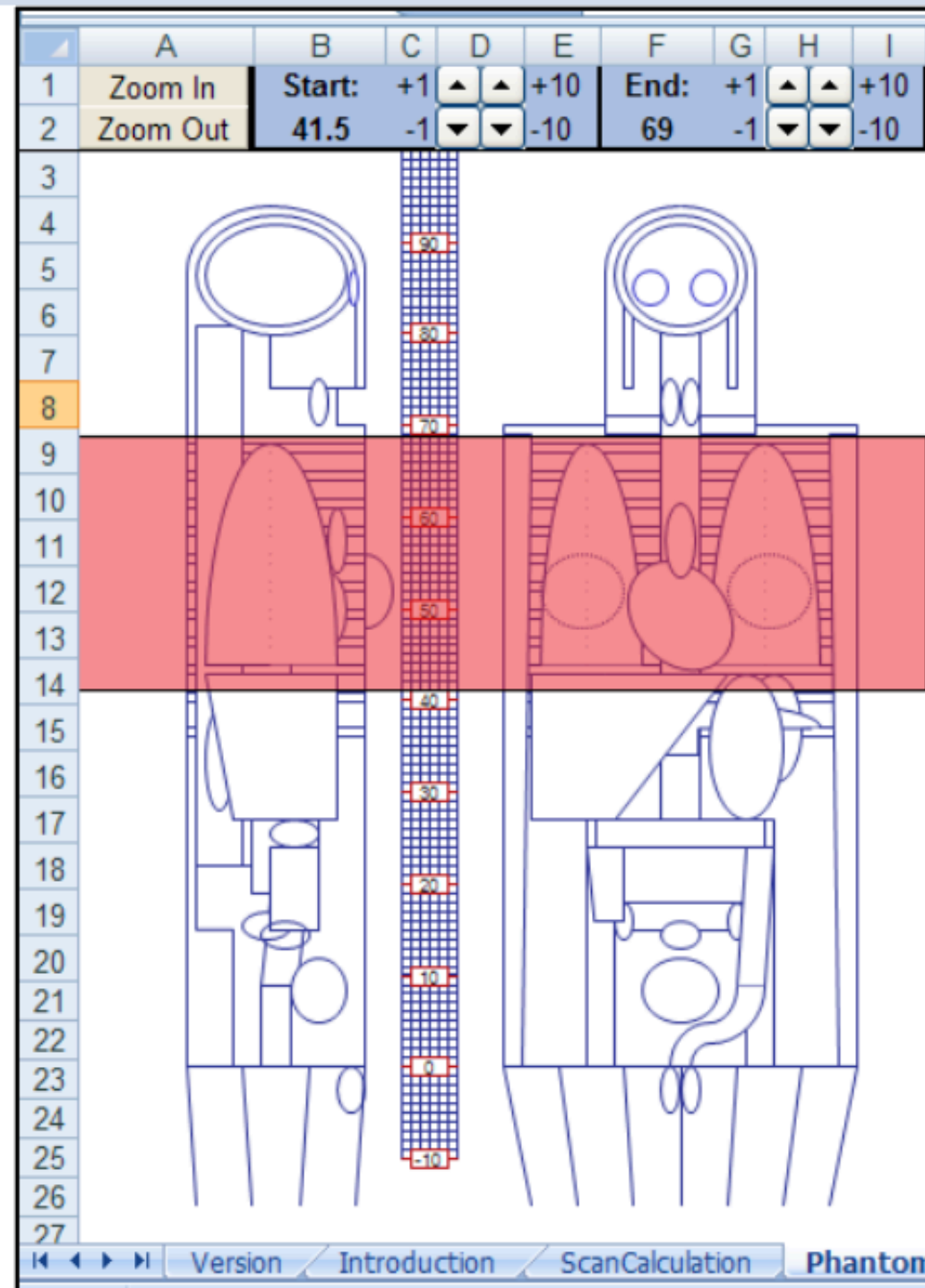
This spreadsheet has been checked for macro viruses, and the logic and calculations been tested extensively, however ImPACT accept no responsibility for loss or damage incurred as a result of its use.

Navigation tabs: Introduction, ScanCalculation, Phantom, Paediatric, Scanners, MatchData, Collima

IMPACT CT DOSIMETRY

ImPACT CT Patient Dosimetry Calculator

Version 1.0.4 27/05/2011



nCTDI_w $= (VLOOKUP(MatchGroup, Matches, IF(BodyRegion=1,4,7)) + 2 * VLOOKUP(M$

ImPACT CT Patient Dosimetry Calculator

Version 1.0.4 27/05/2011

Scanner Model:

Manufacturer: Siemens
Scanner: Siemens Balance, Emotion
kV: 130
Scan Region: Head
Data Set: MCSET14
Current Data: MCSET14

Acquisition Parameters:

Tube current	30	mA
Rotation time	1	s
Spiral pitch	1	
mAs / Rotation	30	mAs
Effective mAs	30	mAs
Collimation	10	mm
Rel. CTDI	Look up	1.00 at selected collimation
CTDI (air)	Look up	33.2 mGy/100mAs
CTDI (soft tissue)	Look up	35.5 mGy/100mAs
nCTDI _w	Look up	24.1 mGy/100mAs

Scan range

Start Position: 32.5 cm
End Position: 62 cm

Organ weighting scheme: ICRP 103

Organ	w _T	H _T (mGy)	w _T · H _T
Gonads	0.08	0.038	0.003
Bone Marrow	0.12	1.6	0.19
Colon	0.12	0.24	0.029
Lung	0.12	5.4	0.64
Stomach	0.12	3.8	0.46
Bladder	0.04	0.021	0.00083
Breast	0.12	4.5	0.54
Liver	0.04	4.2	0.17
Oesophagus (Thymus)	0.04	6.1	0.24
Thyroid	0.04	0.28	0.011

Remainder Organs	H _T (mGy)
Adrenals	5.2
Small Intestine	0.28
Kidney	3
Pancreas	4.5
Spleen	4.4
Thymus	6.1
Uterus / Prostate (Bladder)	0.04
Muscle	1.2
Gall Bladder	2.3
Heart	6

CTDI_w: 7.2 mGy
CTDI_{vol}: 7.2 mGy
DLP: 213 mGy·cm

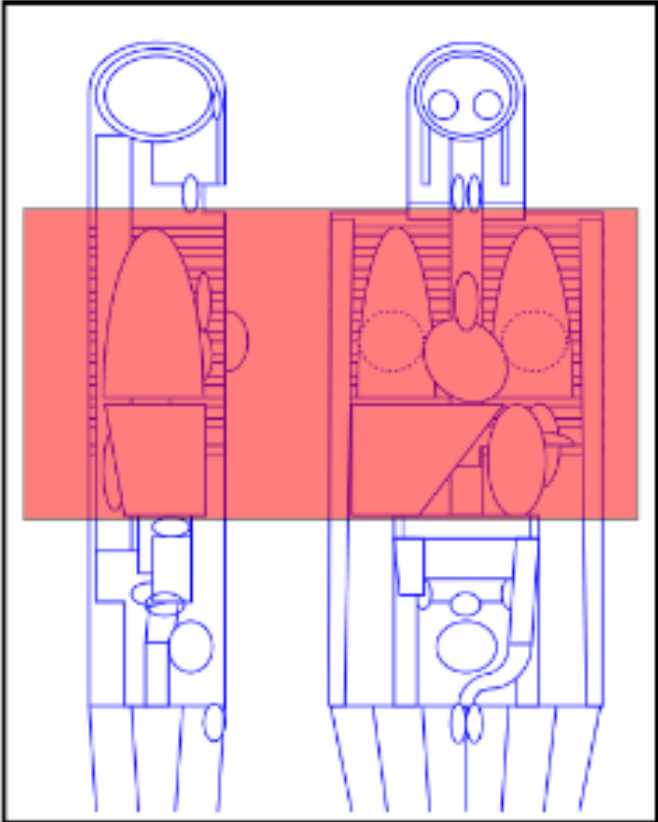
ScanCalculation Phantom Paediatric Scanners MatchData Collimation MonteCarloData

input CTDI_{free-in air} (dose to air)

IMPACT CT DOSIMETRY

- A **web-based** version was released, however **scanner availability may be inferior** to that of the spreadsheet version.

IPEM CT dose calculator



Start: +1 ↑ ↑ +10 End: +1 ↑ ↑ +10
27 -1 ↓ ↓ -10 70.5 -1 ↓ ↓ -10

sst: 75
nsl: 87
position: 247
slcs: 130.5

Manufacturer: Siemens
Model: Definition AS
Physical filter: Body
kVp: 120
Collimation: 19.2 (32 x 0.6)
mA: 200.0
Rotation time (s): 1.0
Effective mAs: 200.00
pitch: 1.0
NRPB SR250 data set: 15
(Relative CTDI: 1.32)

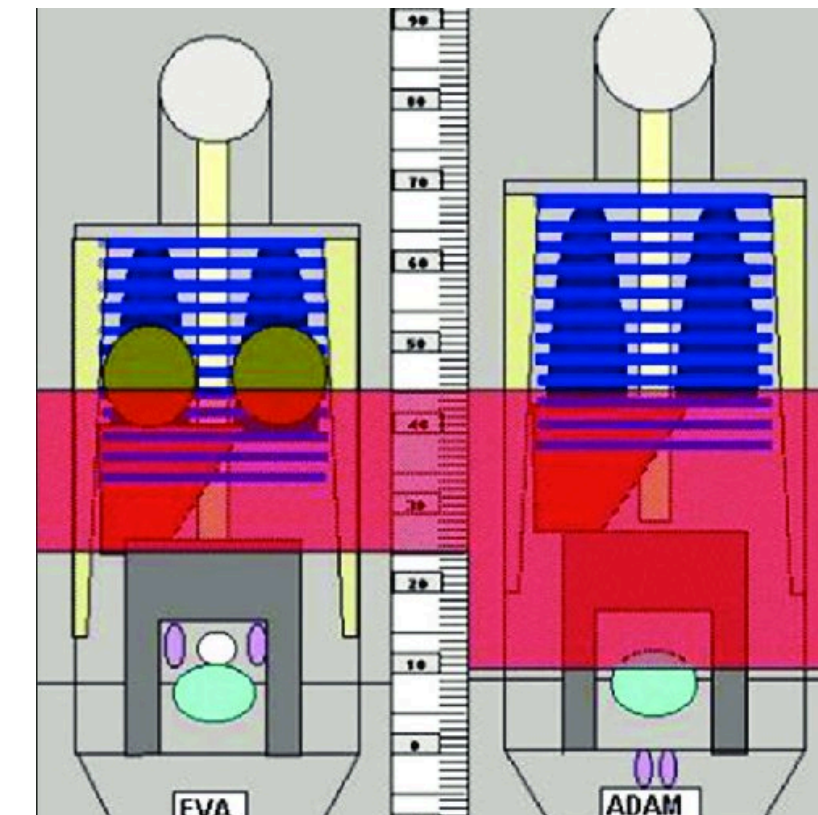
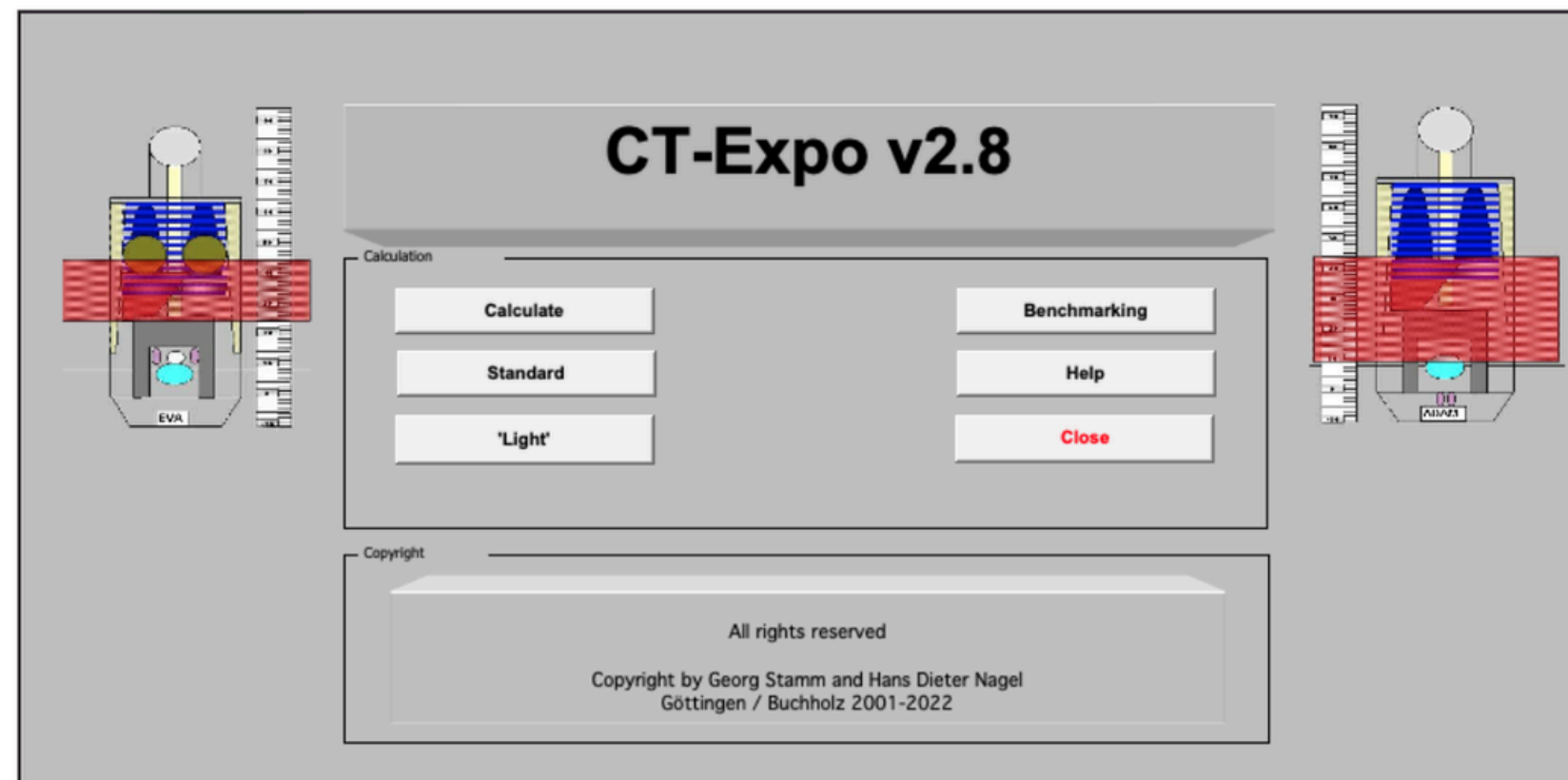
Effective dose: 13.10
CTDI_{vol} (mGy): 14.78
DLP (mGy.cm): 642.86

Common scan ranges: Chest-Abdomen

Show organ

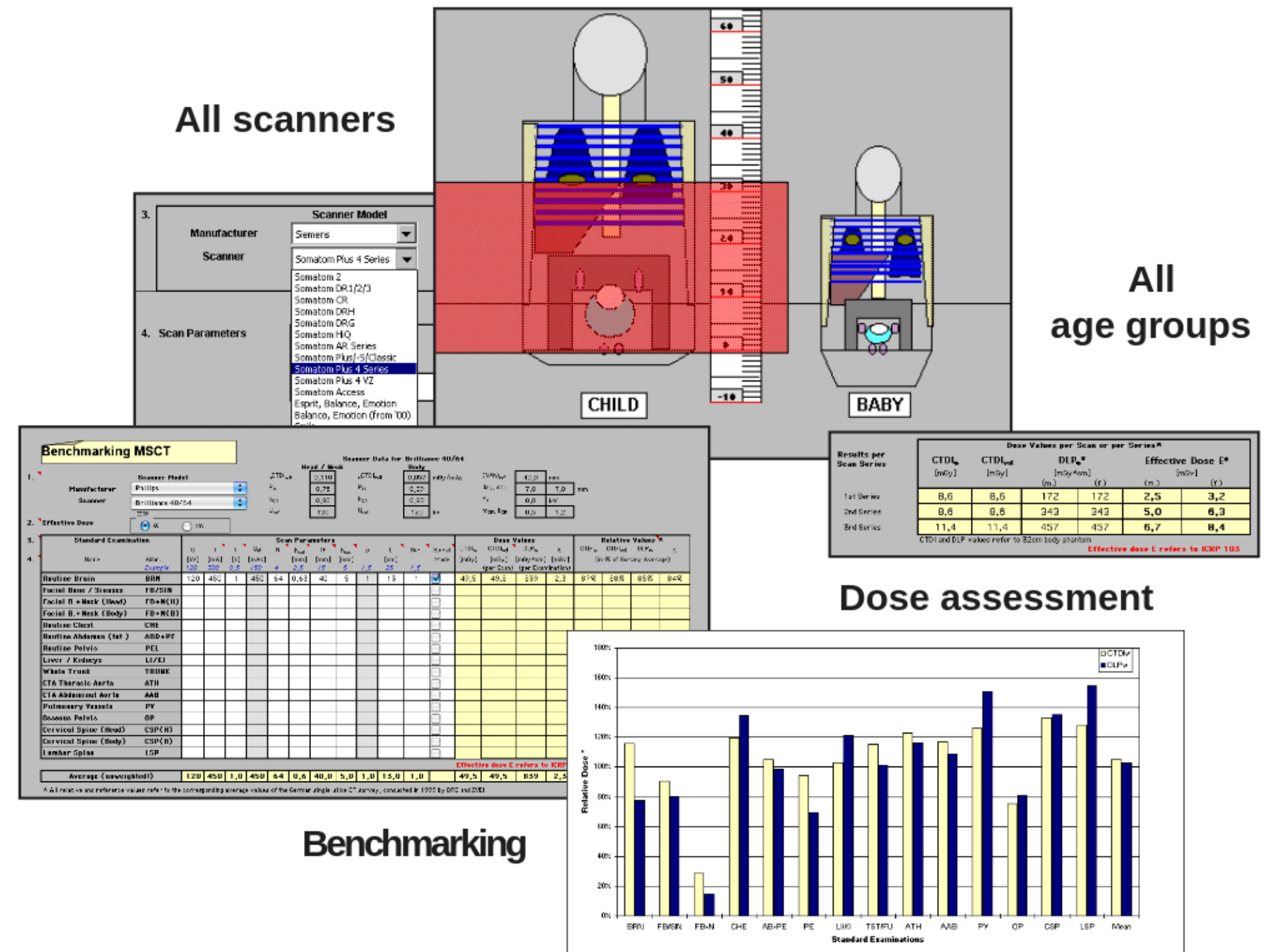
CT-EXPO

- **CT-Expo** is a **Microsoft Excel-based application** designed for dose estimation in adult and pediatric patients undergoing **CT examinations** in accordance with **ICRP 103**.
- CT-Expo relies on extensive **MC simulations** implemented for a **large library of CT scanners**.
- CT examinations can be simulated using a **female geometric phantom model**, assuming the **uterine dose to be equivalent to the embryo dose**, with the **limitations** previously discussed beyond the first 8th weeks of gestation.
- When using **stylized phantoms** or even fixed phantom models, accuracy is limited by the uncertainty in the **depth of the conceptus**. **Bladder volume** can also have important effects.



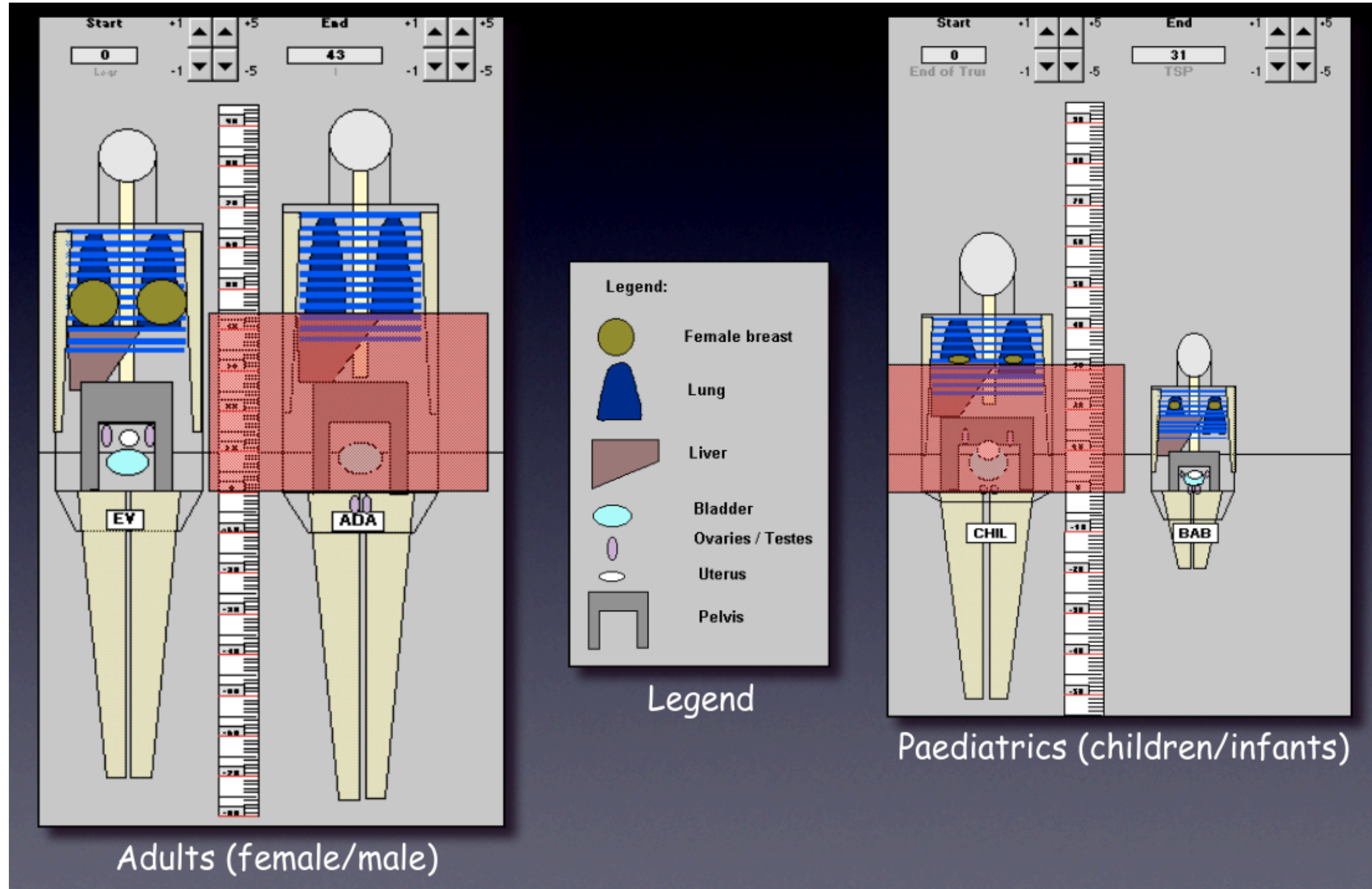
CT-EXPO

- CT-Expo allows the calculation of the **following dose quantities**:
- CTDI_w
- CTDI_{vol}
- Size-Specific Dose Estimate (SSDE)
- Dose-length product
- Organ doses
- Effective dose(ICRP 60 and ICRP 103)



CT-EXPO

This is CT-EXPO
input scan page



CT-EXPO

This is CT-EXPO
calculation page

Calculate

1. Age Group
Adult

Gender
☒ male ☐ female

2. Scan Range

 **Get Values**

Scan Range Data (Slice Positions)		
Scan Range z		L
from z-	to z+	[cm]
0	43	43

3. Scanner Model
Manufacturer: Philips
Scanner: Mx8000 IDT/Brilliance 16

Scanner Data for Scan Region "Body"					
$nCTDI_w$	U_{ref}	$P_{B,H}$	k_{C1}	k_{C2}	ΔL
[mGy/mAs]	[kV]				[cm]
0,067	120	0,39	0,80	1,00	3,6

4. Select mode
☐ Body mode for head/neck region ☒ Spiral mode

5. Scan Parameters

Please Enter Actual Settings:									
U	I	t	Q_{di}	Q	$N * h_{col}$	TF	h_{rec}	p	Ser.
[kV]	[mA]	[s]	[mAs]	[mAs]	[mm]	[mm]	[mm]		
120			131	150	24,0	21,0	5,0	0,9	1

6. Results

Dose Values per Scan or per Series*				
$CTDI_w$	$CTDI_{vol}$	DLP	E	D_{uterus}
[mGy]	[mGy]	[mGy*cm]	[mSv]	[mSv]
8,8	10,1	474	7,7	n.a.

Child/Baby: all CTDI and DLP values refer to 16cm head phantom!

Dose Values per Examination		
DLP	E	D_{uterus}
[mGy*cm]	[mSv]	[mSv]
474	7,7	n.a.

Effective dose E refers to ICRP 60

Please note:
All organ doses H_T are based on conversion coefficients for stand-
ard and patients (ADAM, EVA, CHILD, BABY) and serve for information
purposes only (In particular organs outside the scan range)!

Tissue or Organ	H_T per Series [mSv]	Remainder Organs	H_T per Series [mSv]
Thyroid	0,0	Brain	0,0
Breasts	0,0	Thymus	0,4
Oesophagus	0,4	Spleen	13,7
Lungs	2,8	Pancreas	11,1
Liver	13,4	Adrenals	11,0
Stomach	14,0	Kidneys	14,4
Colon	11,8	Small intest.	12,7
Testicles	7,3	Upp. large int.	13,5
Ovaries	0,0	Uterus	0,0
Bladder	13,3		
Bone marrow	6,2		
Bone surface	9,5		
Skin	5,4		

Misc.	H_T per Series [mSv]
Eye lenses	0,0

NCICT

- The **National Cancer Institute Dosimetry System for Computed Tomography (NCICT)** is a system developed by the **National Cancer Institute (NCI), USA**, for estimating organ absorbed doses and effective dose from **CT**.
- NCICT is based on **precalculated organ dose conversion coefficients** derived from **Monte Carlo** radiation transport simulations, **multiple computational human phantom models**, and a reference CT scanner framework.

Calculation Workflow

Step	Description
1	Define patient characteristics
2	Enter scanner parameters
3	Define scan coverage
4	Review organ and effective dose output
5	Optionally run multiple cases through Batch Calculation Mode

NCICT

- NCICT includes **three phantom libraries** to support matching of patient anatomy and body dimensions:
 - **ICRP** reference **pediatric and adult** phantoms (**n=12**)
 - **Body size-dependent pediatric and adult** phantoms (**n=362**)
 - **Pregnant women and fetal phantoms** at **8, 10, 15, 20, 25, 30, 35, and 38 weeks**.
- When detailed body size information is unavailable, users may select one of the ICRP-defined reference age and sex groups

Reference phantom	Height (cm)	Weight (kg)
Newborn female or male	47	4
1-year female or male	76	10
5-year female or male	110	19
10-year female or male	140	32
15-year female	161	53
15-year male	166	56
Adult female	168	60
Adult male	178	73

NCICT

- When **CTDIvol** is not available, it can be **reconstructed** from the scanner model, tube potential (kVp), tube current (mA), rotation time (sec), pitch, and total collimation (mm).
- If **CTDIvol** is available (for 16 or 32cm phantom type) this **value overrides all other scanner parameters**.
- NCICT uses a **scanner-independent** organ dose calculation algorithm, so CTDIvol drives organ dose estimation even when a specific scanner model is not listed.
- A generic longitudinal **tube current modulation (TCM)** model is implemented for illustrative purposes. It is not vendor-specific. TCM strength ranges from 0 (no modulation) to 1 (maximum modulation).

Scanner information

Manufacturer	GE	↕
Model	8800; 9000 Series	↕
☐ Head Phantom ☒ Body Phantom		
nCTDIw mGy/100 mAs	3.5	
Tube potential kVp	120	
Current mA	200	Limit 600
Rotation time sec	0.5	
TCM strength 0-1	0.5	
Pitch	1	
Total collimation mm	10	
Average CTDIvol mGy	2	
DLP mGy-cm	56	
Water Equivalent Diameter cm	24.9	
SSDE mGy	3	

NCICT

● ● ● National Cancer Institute dosimetry system for CT 4.20260502

ICRP

Size

Fetus

Mother

Age Group

Pediatric

Adult

Gender

Male

Female

Body Size

Height cm150

Weight kg40

Phantom Height Weight Map

Scanner information

ManufacturerGE

Model8800; 9000 Series

Head Phantom

Body Phantom

nCTDIw mGy/100 mAs3.5

Tube potential kVp120

Current mA200Limit600

Rotation time sec0.5

TCM strength 0-10.5

Pitch1

Total collimation mm10

Average CTDIvol mGy1.5

DLP mGy-cm57

Water Equivalent Diameter cm21.4

SSDE mGy2.5

Tube Current mA

0300600

Organ

Dose mGy

Brain0

Pituitary gland0

Lens0

Eye balls0

Salivary glands0.01

Oral cavity0.01

Spinal cord0.89

Thyroid0.02

Esophagus0.44

Trachea0.05

Thymus0.05

Lungs0.26

Breast0.22

► Heart wall0.28

Stomach wall2.45

Liver2.25

Gall bladder2.35

Adrenals2.16

Spleen2.48

Pancreas2.47

Kidney2.93

Small intestine2.52

Colon2.8

Rectosigmoid1.85

Urinary bladder2.04

Prostate

Uterus1.69

Testes

Ovaries1.95

Skin0.77

Muscle0.08

Blood Vessel0.2

Active marrow1.04

Shallow marrow0.74

Effective dose (mSv)1.33

Scan Coverage

Scan Start cm43

Scan End cm81

Scan Length cm38

Predefined protocolAP

Batch Calculation

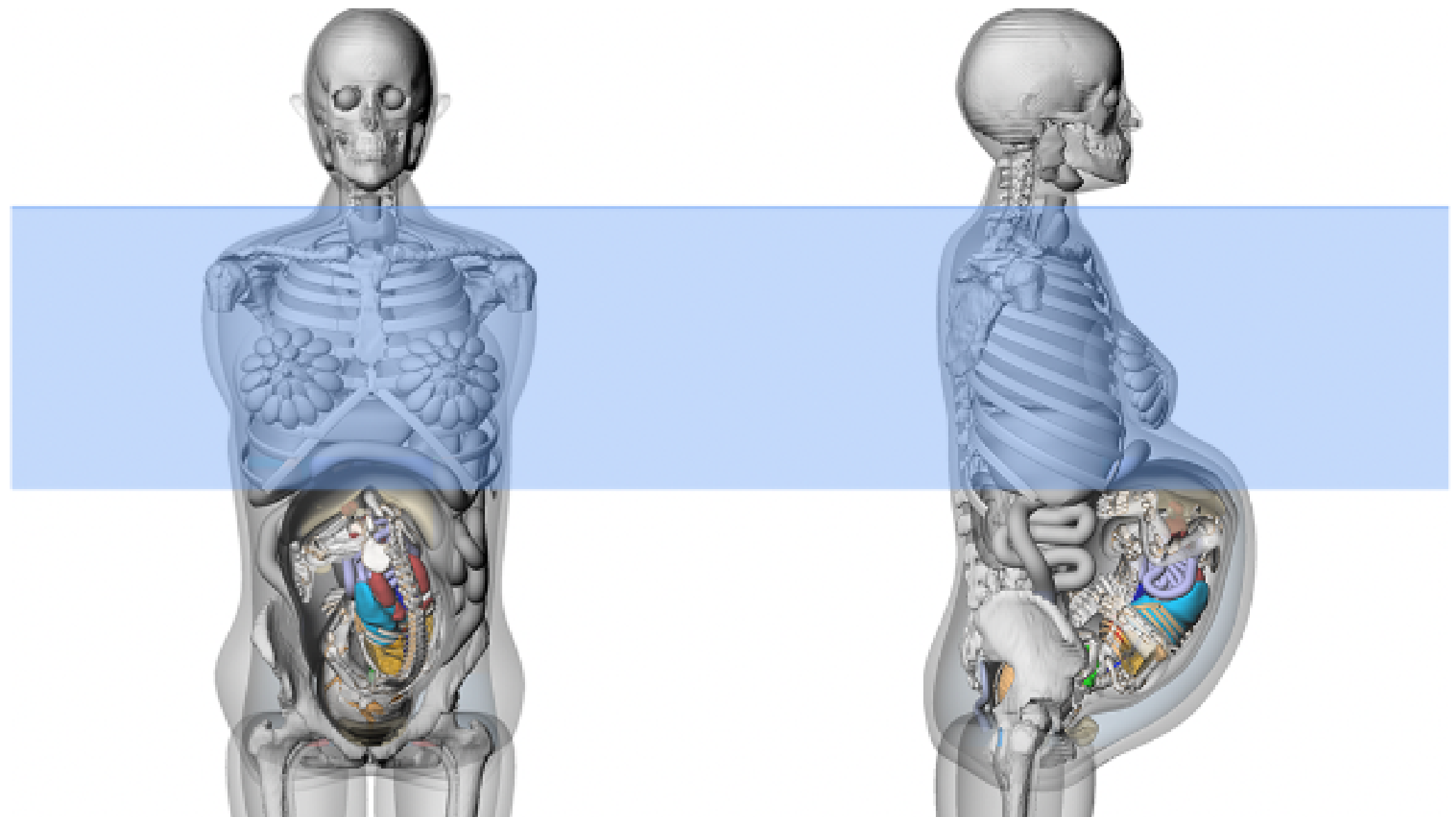
NCICT

- When **fetal organ doses** are of interest, users can select the "**Fetus**" **tab** and specify fetal age (8–38 weeks)
- The **maximum maternal abdominal diameter (cm)**, which is commonly measured during prenatal visits, is also displayed to help select the most appropriate pregnancy phantom

ICRP | Size | **Fetus** | Mother

Gestational Age, Mother's perimeter

☐ 8 wk, 90 cm	☐ 10 wk, 91 cm
☐ 15 wk, 94 cm	☐ 20 wk, 95 cm
☐ 25 wk, 97 cm	☐ 30 wk, 104 cm
☐ 35 wk, 106...	☒ 38 wk, 108 cm



NCICT: FETUS MODE

● ● ● National Cancer Institute dosimetry system for CT 4.20260502

ICRP

Size

Fetus

Mother

Gestational Age, Mother's perimeter

8 wk, 90 cm

10 wk, 91 cm

15 wk, 94 cm

20 wk, 95 cm

25 wk, 97 cm

30 wk, 104 cm

35 wk, 106...

38 wk, 108 cm

Scanner information

Manufacturer

GE

Model

8800; 9000 Series

Head Phantom

Body Phantom

nCTDIw mGy/100 mAs

3.5

Tube potential kVp

120

Current mA

200

Limit

600

Rotation time sec

0.5

TCM strength 0-1

0.5

Pitch

1

Total collimation mm

10

Average CTDIvol mGy

2.8

DLP mGy-cm

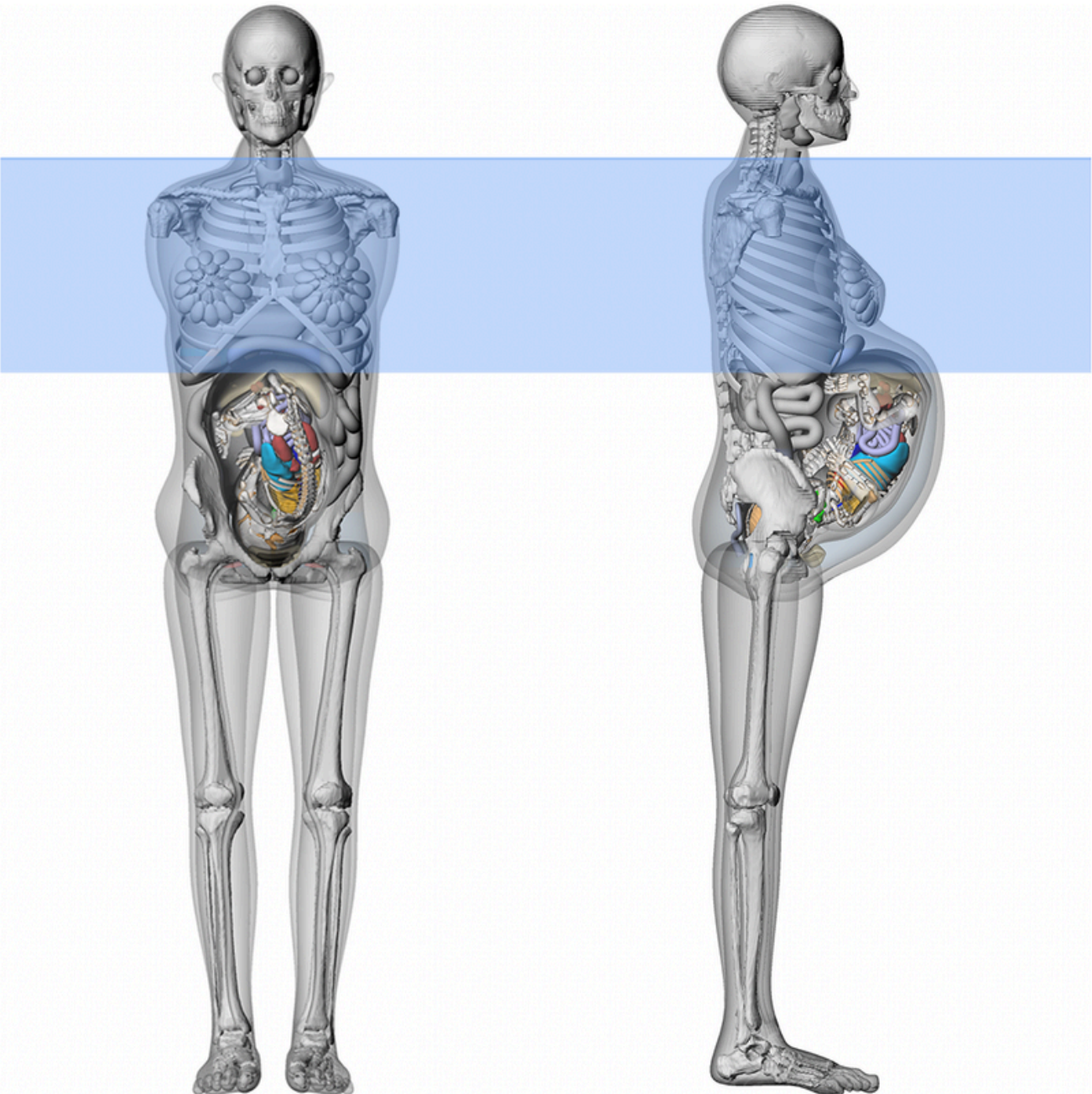
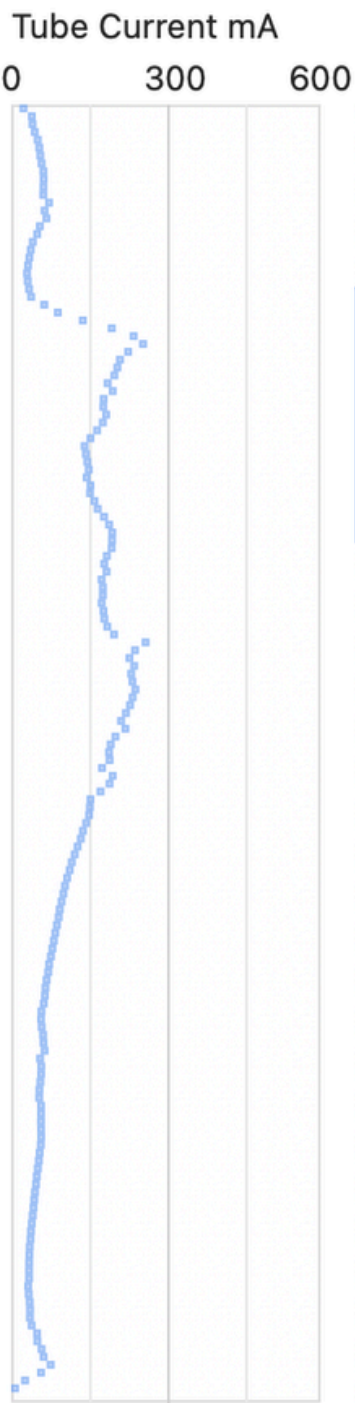
89.6

Water Equivalent Diameter cm

13.8

SSDE mGy

6.3



Organ	Dose mGy
Brain	0.02
Pituitary gland	0.03
Lens	0.05
Eye balls	0.04
Salivary glands	0.03
Oral cavity	0.04
Spinal cord	0.06
Thyroid	0.04
Esophagus	0.04
Trachea	0.03
Thymus	0.04
Lungs	0.05
Breast	0.08
Heart wall	0.07
Stomach wall	0.15
Liver	0.08
Gall bladder	0.1
Adrenals	0.07
Spleen	0.12
Pancreas	0.17
Kidney	0.15
Small intestine	0.26
Colon	0.23
Rectosigmoid	0.37
Urinary bladder	0.5
Prostate	0.61
Uterus	0.39
Testes	0.74
Ovaries	0.32
Skin	0.21
Muscle	0.17
Blood Vessel	0.17
Active marrow	0.35
Shallow marrow	0.35
Effective dose (mSv)	0.24

Scan Coverage

Scan Start cm

23

Scan End cm

55

Scan Length cm

32

Predefined protocol

Chest

Batch Calculation

NCICT: MOTHER MODE

● ● ● National Cancer Institute dosimetry system for CT 4.20260502

ICRPSizeFetusMother

Gestational Age, Mother's perimeter

8 wk, 90 cm

10 wk, 91 cm

15 wk, 94 cm

20 wk, 95 cm

25 wk, 97 cm

30 wk, 104 cm

35 wk, 106...

38 wk, 108 cm

Scanner information

Manufacturer

GE

Model

8800; 9000 Series

Head Phantom

Body Phantom

nCTDIw mGy/100 mAs

3.5

Tube potential kVp

120

Current mA

200

Limit

600

Rotation time sec

0.5

TCM strength 0-1

0.5

Pitch

1

Total collimation mm

10

Average CTDIvol mGy

2.8

DLP mGy-cm

89.6

Water Equivalent Diameter cm

13.8

SSDE mGy

6.3

Tube Current mA

0300600

Scan Coverage

Scan Start cm

23

Scan End cm

55

Scan Length cm

32

Predefined protocol

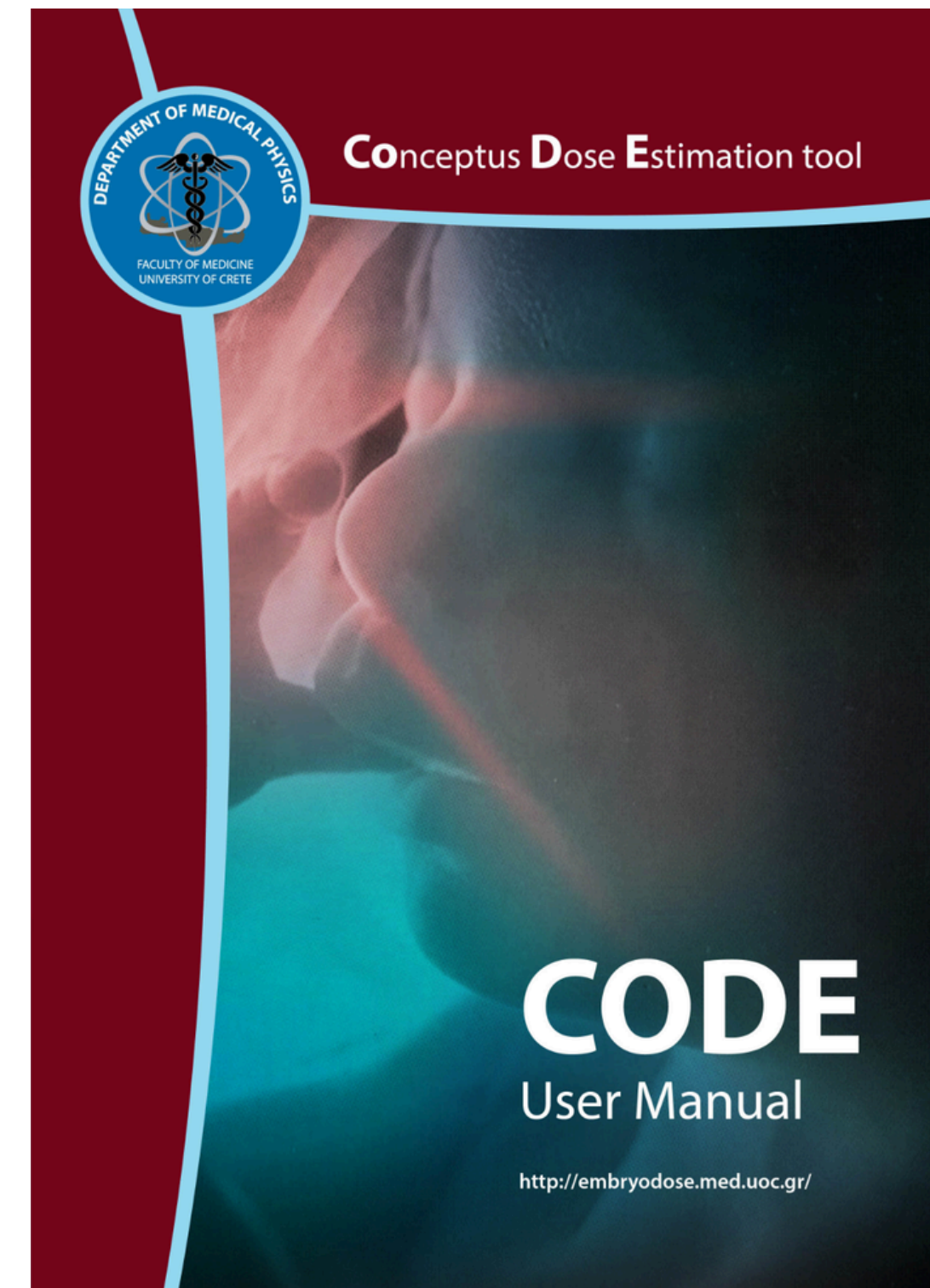
Chest

Organ	Dose mGy
Brain	0.06
Pituitary gland	0.08
Lens	0.07
Eye balls	0.06
Salivary glands	0.41
Oral cavity	0.28
Spinal cord	1.73
Thyroid	5.66
Esophagus	3.24
Trachea	3.59
Thymus	3.83
Lungs	3.58
Breast	3.62
Heart wall	3.67
Stomach wall	2.49
Liver	2.93
Gall bladder	2.37
Adrenals	2.33
Spleen	2.83
Pancreas	1.06
Kidney	0.62
Small intestine	0.34
Colon	1.41
Rectosigmoid	0.06
Urinary bladder	0
Prostate	
Uterus	0.29
Testes	
Ovaries	0.15
Skin	0.57
Muscle	0.7
Blood Vessel	0.7
Active marrow	1.17
Shallow marrow	1.2
Effective dose (mSv)	2.14

Batch Calculation

CODE

- **CO**nceptus **D**ose **E**stimation (**CODE**) is a freely accessible **web-based application** (<http://embryodose.med.uoc.gr/>) developed by the **Department of Medical Physics at the University of Crete** for embryo/fetal dose estimation in **radiography, fluoroscopy and CT**
- CODE uses MC-derived normalized dose coefficients calculated in **pregnant female phantoms** at **different gestational stages**.
- **CODE occupational exposure** from fluoroscopically guided interventional procedures module provides prospective or retrospective estimates of **absorbed dose to the embryo/fetus of a pregnant employee**.



CODE - RADIOGRAPHY

- CODE radiography module provides estimates for the embryo/fetus absorbed dose.
- We can select the **gestational stage** of the patient as **1st, 2nd or 3rd trimester**.

Radiography

➔

Gestational Stage

Click to select

Click to select

1st trimester

2nd trimester

3rd trimester

Click to select

Projection

Tube Voltage (kV)

Tube Load (mAs)

Focus to Skin Distance (FSD cm)

Tube Output (mGy/mAs)

Total Filtration

Calculate Save Clear

Embryo Dose

Risk for childhood cancer

Table 1. Radiographic examinations				
Body region under examination	Projections*	Field Size (cm ²)	Tube Voltage (kVp)	Filtration (mm Al)
Abdomen	AP	36x43	50-120	2.5-5.0
	PA	36x43	50-120	2.5-5.0
Chest	AP	36x43	50-120	2.5-5.0
	PA	36x43	50-120	2.5-5.0
	LAT	36x43	50-120	2.5-5.0
Kidneys	AP	36x24	50-120	2.5-5.0
	PA	36x24	50-120	2.5-5.0
Lumbar Spine	AP	36x43	50-120	2.5-5.0
	LAT	36x43	50-120	2.5-5.0
	LAT LSJ	18x24	50-120	2.5-5.0
	LPO	24x30	50-120	2.5-5.0
Pelvis/Colon	RPO	24x30	50-120	2.5-5.0
	AP	36x43	50-120	2.5-5.0
	PA	36x43	50-120	2.5-5.0
Thoracic Spine	AP Hip Joint	24x35	50-120	2.5-5.0
	AP	24x43	50-120	2.5-5.0
	LAT	20x49	50-120	2.5-5.0
Urinary Bladder	AP	24x21	50-120	2.5-5.0

*Note that the angulations of all projections refer to the position of the x-ray tube with respect to the patient body

CODE - FLUOROSCOPY

- CODE **fluoroscopy module** provides estimates for the embryo/fetus absorbed dose from fluoroscopically guided (FG) procedures performed on the pregnant patient.

Table 2A. Gastrointestinal fluoroscopically guided procedures

Procedure	Projection*	Field size (cm ²)	Tube Voltage (kVp)	Total Filtration (mm Al)
Barium Enema	AP Colon/Pelvis	24x30	50-120	2.5-9.0
	AP Rectum	15x15	50-120	2.5-9.0
	LAO Colon	35x35	50-120	2.5-9.0
	LAO Flexure	28x35	50-120	2.5-9.0
	LAT Rectum	17x17	50-120	2.5-9.0
	LPO Colon	35x35	50-120	2.5-9.0
	LPO Rectum	19x19	50-120	2.5-9.0
	PA Pelvis/Colon	40x40	50-120	2.5-9.0
	PA Rectum	15x15	50-120	2.5-9.0
	RAO Colon	35x35	50-120	2.5-9.0
	RAO Flexure	28x35	50-120	2.5-9.0
	RAO Rectum	19x19	50-120	2.5-9.0
Barium Follow Through	AP Small Intestine	22x18	50-120	2.5-9.0
	PA Small Intestine	22x18	50-120	2.5-9.0
Barium Meal	AP Duodenum	15x15	50-120	2.5-9.0
	AP Stomach	18x22	50-120	2.5-9.0
	AP Upper Stomach	15x15	50-120	2.5-9.0
	LAO Stomach	21x21	50-120	2.5-9.0
	LAT Stomach	19x24	50-120	2.5-9.0
	LPO Duodenum	19x19	50-120	2.5-9.0
	LPO Stomach	21x21	50-120	2.5-9.0
	PA Duodenum	15x15	50-120	2.5-9.0
	PA Stomach	18x21	50-120	2.5-9.0
	PA Upper Stomach	15x15	50-120	2.5-9.0
	RAO Duodenum	19x19	50-120	2.5-9.0
	RAO Stomach	21x21	50-120	2.5-9.0
Barium Swallow	LAO Oesophagus	13x47	50-120	2.5-9.0
	LAT Throat	18x24	50-120	2.5-9.0
	LPO Oesophagus	13x47	50-120	2.5-9.0
	RAO Oesophagus	13x47	50-120	2.5-9.0

*Note that the angulations of all projections refer to the position of the tube with respect to the patient body.

Table 2B. Cardiac fluoroscopically guided procedures

Procedures	Projection*	Field size (cm ²)	Tube Voltage (kVp)	Total Filtration (mm Al)
Coronary Angiography/Angioplasty	PA	12.5x12.5	70-100	3-13
	PA CRANIAL 30	12.5x12.5	70-100	3-13
	PA CAUDAL 30	12.5x12.5	70-100	3-13
	LLAT	12.5x12.5	70-100	3-13
	RAO 30	12.5x12.5	70-100	3-13
	LAO 40	12.5x12.5	70-100	3-13
	LAO45 CRANIAL 20	12.5x12.5	70-100	3-13
	RAO 20 CRANIAL 20	12.5x12.5	70-100	3-13
	RAO 20 CAUDAL 20	12.5x12.5	70-100	3-13
	LAO 40 CAUDAL 30	12.5x12.5	70-100	3-13
Pacemaker Implantation	PA	12.5x12.5	50-120	2.5-9.0
	RAO 30	14x14	50-120	2.5-9.0
	LAO30	14x14	50-120	2.5-9.0
Cardiac Ablation	AP	12.5x12.5	50-120	2.5-9.0
	LAO 30	14x14	50-120	2.5-9.0
	RAO 30	14x14	50-120	2.5-9.0
	Guidance iliac	6x6	70-100	3-13
	Guidance jugular	6x6	70-100	3-13

Table 2C. Orthopedic fluoroscopically guided procedures

Procedures	Projection*	Field size (cm ²)	Tube Voltage (kVp)	Total Filtration (mm Al)
Femoral Fractures	Hip joint LAT	15x15	70-100	3-13
	Hip joint PA	15x15	70-100	3-13
Kyphoplasty	AP Lumbar Spine	8x15	70-100	3-13
	LAT Lumbar Spine	8x15	70-100	3-13

*Note that the angulations of all projections refer to the position of the image intensifier with respect to the patient body.

Table 2D: Other fluoroscopically guided procedures

Procedures	Projection*	Field size (cm ²)	Tube Voltage (kVp)	Total Filtration (mm Al)
Endoscopic retrograde cholangio-pangratiography(ERCP)	LLAT Abdomen	20x20	80-100	2.5-9.0
Inferior Vena Cava filter placement	Guidance iliac	6x6	70-100	3-13
	Guidance jugular	6x6	70-100	3-13
	Suprenal placement	15x8	80-100	3-13
	Subrenal Placement	15x8	80-100	3-13
Cystourethrography	AP ^T Bladder	24x21	50-120	2.5-9.0
Prophylactic hypogastric artery balloon occlusion (HABO)**	PA ^T Left artery	18x22.5	80-100	3-13
	PA ^T Right artery	18x22.5	80-100	3-13
	RA 20 Left artery	18x22.5	80-100	3-13
	RAO 20 Righ artery	18x22.5	80-100	3-13
	LAO 20 left artery	18x22.5	80-100	3-13
	LAO 20 Right artery	18x22.5	80-100	3-13

*Note that the angulations of all projections refer to the position of the image intensifier with respect to patient body.

^T The angulation of these projections refers to the position of the tube with respect to patient body.

**NED data for HABO procedures have been produced only for the 3rd trimester of gestation, since this procedure is performed in parturient women.

CODE - FLUOROSCOPY

- The user has to **define the embryo depth** from the anterior skin surface. This field is **available only when selecting 'first trimester'** as the gestational stage and a projection associated with direct exposure of the embryo.

The screenshot displays the CODE Fluoroscopy software interface. On the left, a sidebar contains buttons for 'Radiography', 'Fluoroscopy', 'Computed Tomography', and 'Fluoroscopically-guided Procedures'. The main area is titled 'Fluoroscopy' and includes a 'Gestational Stage' dropdown set to '1st trimester'. Below this, there are tabs for 'Fluoroscopic projections' and 'Fluoroscopic Procedures'. Under 'Fluoroscopic projections', several checkboxes are visible, with 'Pelvis AP' and 'Colon RAO' highlighted by yellow boxes. Below these, two detailed exposure parameter panels are shown, also highlighted by yellow boxes. The first panel is for 'Lower Abdomen_Pelvis - Pelvis AP' and the second is for 'Lower Abdomen_Pelvis - Colon RAO'. Both panels include input fields for 'Embryo depth(cm)', 'Tube Voltage', 'Dose Area Product(Gy/cm²)', 'FSD (cm)', and 'Filtration'. The 'Embryo depth' field is highlighted with a yellow box in the Pelvis AP panel. At the bottom of the interface are 'Calculate', 'Save', and 'Clear' buttons. Two orange callout boxes with arrows point to the 'Pelvis AP' and 'Colon RAO' panels, containing the text: 'Exposure parameters for Pelvis PA projection' and 'Exposure parameters for Colon RAO projection'.

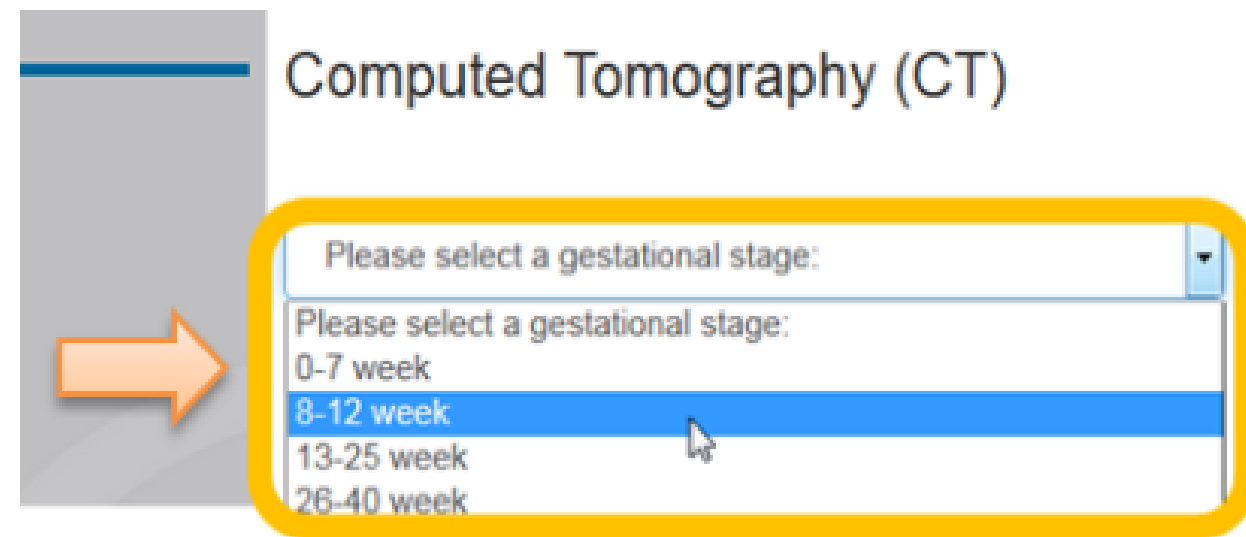
Exposure parameters for Pelvis PA projection

Exposure parameters for Colon RAO projection

The user has to define tube potential (kVp), tube inherent and added filtration (mm Al/Cu), focus to skin distance FSD, and DAP used for the specific fluoroscopic projection.

CODE - CT

- CODE **CT module** provides estimates for the embryo/fetus absorbed dose from CT scans performed on the pregnant patient.
- We define the **embryo depth only when selecting 0-7 weeks or 8-12 weeks**.
- We specify the **tube potential (kV)** and the **beam collimation**, the **tube load (mAs)**, and the **pitch**. Also the **abdominal maternal circumference** in cm.
- We set **CTDI_{free-in-air}** and **CTDI_w** (mGy/100mAs) of the scanner used, at the same kV and beam collimation (mm) set.



Embryo Depth (cm)

Tube Load (mAs) 350

Tube Voltage (kV) 110

Pitch 1.38

Beam Collimation (mm) 24

Patient Circumference (cm)

CTDI_{free-in-air} (mGy/100 mAs)

CTDI_w (mGy / 100 mAs)

Click to select:

- 100**
- 110
- 120
- 130
- 140

Start of scan cm End of scan cm

Calculate Save

A yellow highlight box encloses the Tube Load, Tube Voltage, Pitch, and Beam Collimation fields. A dropdown menu is open for Tube Voltage, showing options 100, 110, 120, 130, and 140. The '100' option is selected. To the right, a CT scan image is displayed with two vertical red lines indicating the start and end of the scan.

CODE - CT

- In addition to estimated embryo/fetal dose, **CODE reports** (in all modules) also an **estimation for the probability childhood cancers**.
- The risk for childhood cancer associated with in-utero exposure is estimated using a **risk coefficient of 1.2×10^{-2} per Gy** as recommended by ICRP report 90.

Notice the **differences in the probability of malformations** and childhood cancer between 0 mGy and 23.6 mGy

The screenshot displays the 'COncetus Dose Estimation' web application. The 'Computed Tomography (CT)' section is active, showing input fields for various parameters. A yellow box highlights the 'Calculate' button and the resulting 'Embryo Dose' and 'Risk for childhood cancer' fields. Below this, a table shows the probability of no malformation and no cancer for two different embryo doses: 0 mGy and 23.621 mGy. A second yellow box highlights the 'Calculate' button and the resulting 'Embryo Dose' and 'Risk for childhood cancer' fields, which are identical to the first one.

Embryo Dose (mGy)	Probability of no malformation (%)	Probability of no cancer (0-19y) (%)
0 mGy	97	99.7
23.621 mGy	97	99.697

CODE - FG FOR EMPLOYEES

- For **occupational exposures in fluoroscopy guided procedures**, a **C-arm unit** and an **anthropomorphic phantom** simulating an average patient were used to determine **scatter exposure rates at specific locations** over a 50 cm x 50 cm grid around the table, for 17 different fluoroscopic beam projections.
- The **cumulative embryo/fetus dose** from the selected exposures is then calculated.

Fluoroscopically-guided Procedures Clear

Anatomical region of interest: CHEST

Projection: PA

Tube Voltage (kV): 70

Filtration (mm Al + mm Cu): 5 + 0.2

Field Size (cm²): 12 × 12

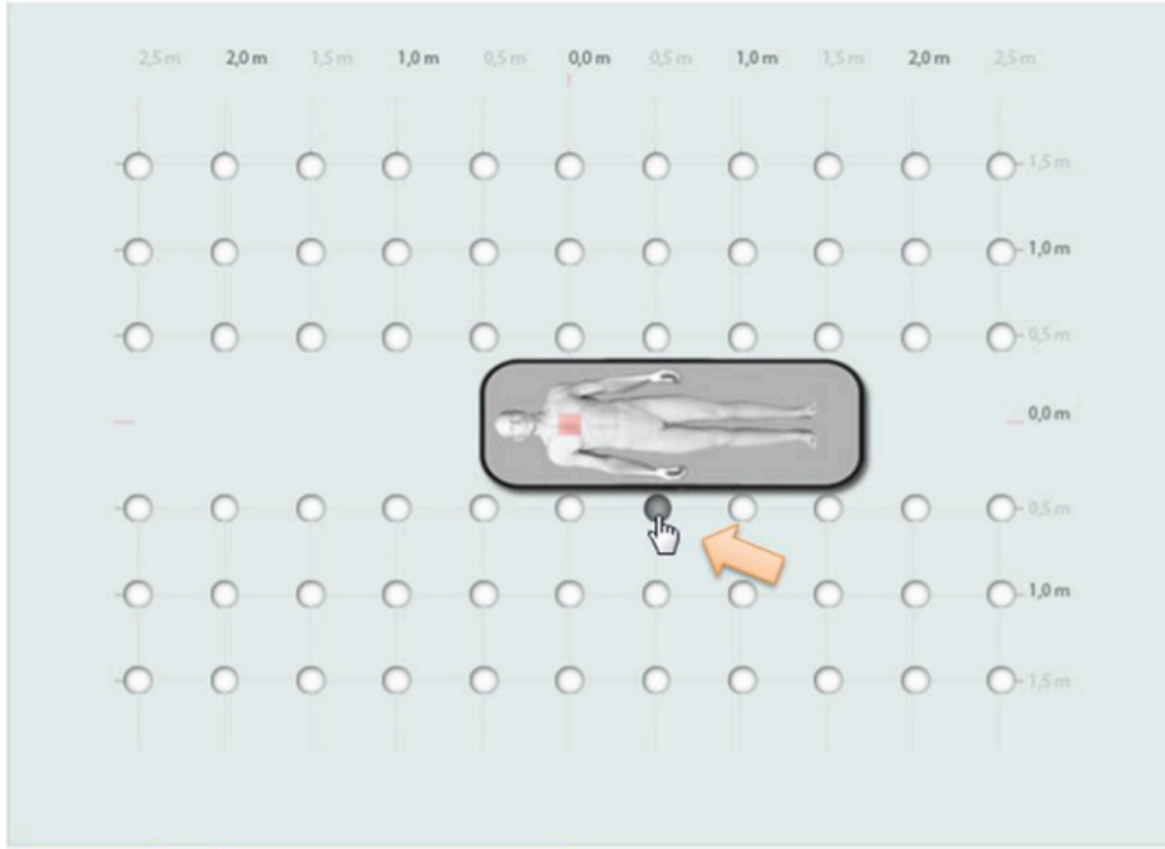
Projection DAP (Gycm²): 100

Gestational Stage

Apron lead equivalent protection (mm Pb)

Select:
1st trimester
2nd trimester
3rd trimester

Please select the position of pregnant operator in the Interventional Radiology Suite



Embryo Dose: 71.68 µGy

Exposure Chart Save Clear

CODE - FG FOR EMPLOYEES

Conceptus Dose Estimation

PATIENT EXPOSURE

Radiography

Fluoroscopy

Computed Tomography

OCCUPATIONAL EXPOSURE

Fluoroscopically-guided Procedures

Anatomical region of interest: CHEST

Projection: PA

Size (width x height): 12 x 12

Field size (cm): 12 x 12

Projection SAD (cm): 100

Isocenter: 100 cm

Aperture lead equivalent protection (mm Pb): 0.5

Please select the position of pregnant operator in the Interventional Radiology suite

Embryo Dose: 71.68 μ Sv

Exposure Chart

Save

Clear

PREVIOUS CALCULATIONS

SAVE RESULTS

HELP

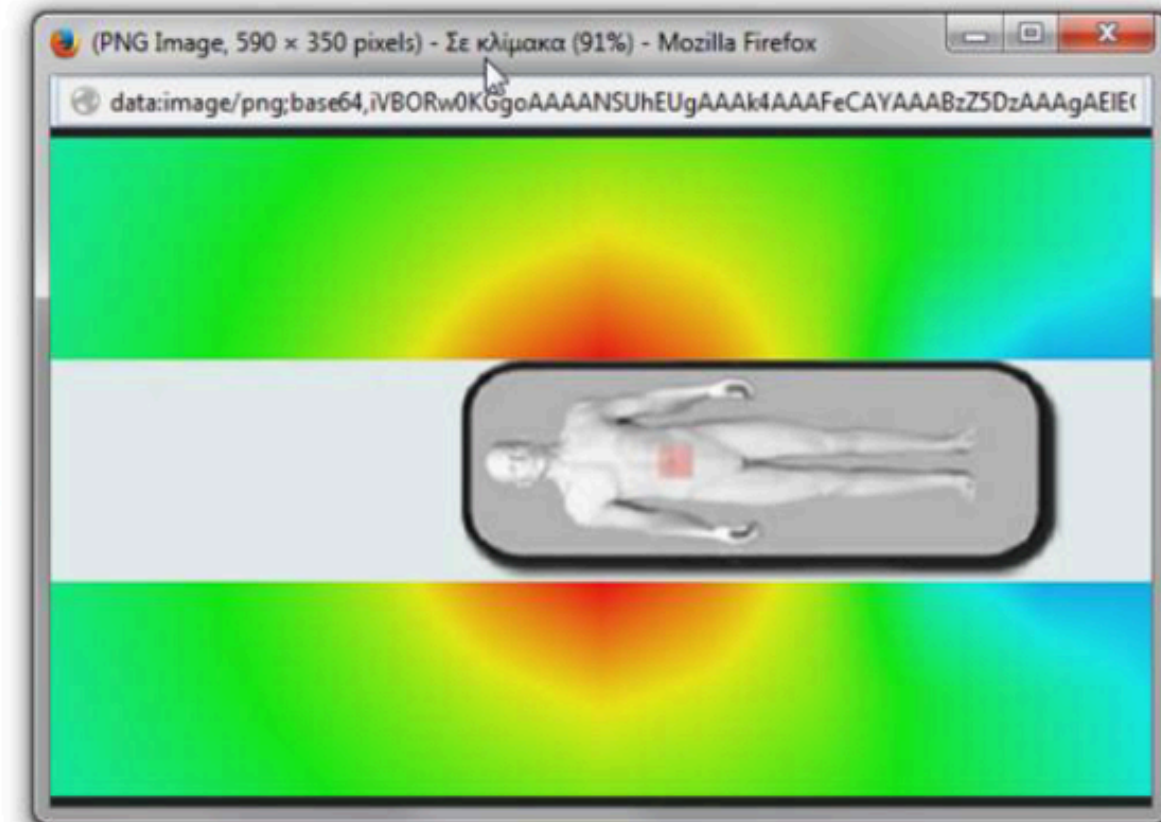
Please select the position of pregnant operator in the Interventional Radiology suite

Embryo Dose: 71.68 μ Sv

Exposure Chart

Save

Clear



FETALDOSE

- **FetalDose** was developed at the **University of Zurich** as a free **web-based tool** for FD estimation in **CT**.
- The software uses **MC simulations** performed on a **set of three hybrid computational phantoms** representing **pregnancy stages** at the end of the **third, sixth, and ninth months**.
- The tool **does not take into account** the **realistic shape** and starting angles of **tube current modulation** employed in the particular CT examination.

ORIGINAL ARTICLES



Radiation Dose to the Fetus From Computed Tomography of Pregnant Patients—Development and Validation of a Web-Based Tool

Natalia Saltybaeva*, Alexandra Platon[†], Pierre-Alexandre Poletti[†], Ricarda Hinzpeter*, Marta Sans Merce[†],
Hatem Alkadhi*

[Authors and Affiliations](#) >

Investigative Radiology 55(12):p 762-768, December 2020. | DOI: 10.1097/RLI.0000000000000701

FETALDOSE

- To account for **individual patient anatomy**, the **doses calculated in the hybrid pregnant phantom is corrected** by considering the patient's **maternal circumference**.
- Of course FetalDose **still can't account** for individual **patients' anatomy, specific fetus location in the body**, and **spatial distribution of organs**.
- The tool provided accurate estimates of embryo/fetal doses resulting in a **relative error compared to MC** patient specific simulations of **$11\% \pm 6\%$** when the maternal perimeter was considered.

- FD calculations are based on a **limited number of user-defined parameters**.

Gestational age, month
0-3

Tube voltage, kVp
100kVp

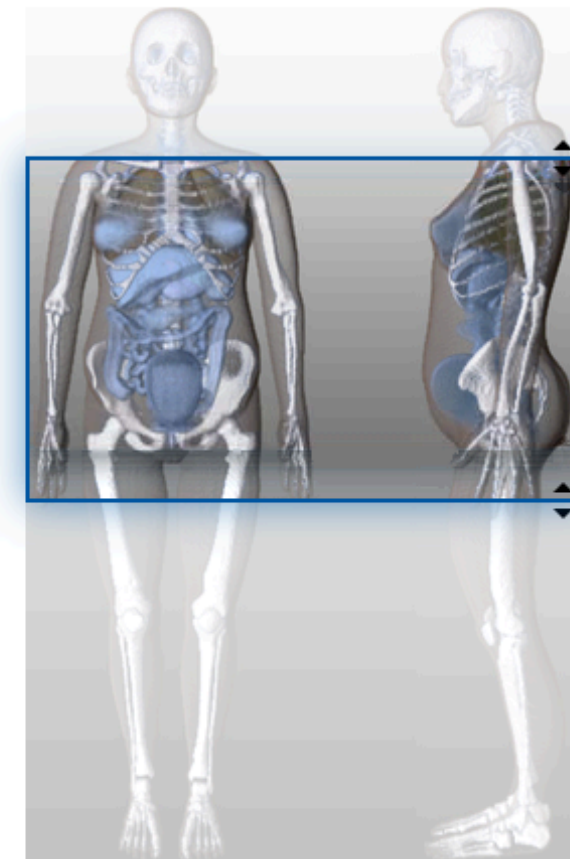
CTDIvol, mGy
|

Volume CT Dose Index obtained from patient radiation dose report.

Maternal perimeter, mm (optional)

Maternal perimeter in mm defined from the CT section containing the central area of the uterus.

Calculate



Upper position, mm
1350

Lower position, mm
690

Patient ID (optional)

VIRTUALDOSE-CT

- **VirtualDose-CT** (Virtual Phantoms Inc.) is a **web-based commercial software**. It uses a library of **25 anatomically realistic computational phantoms**, including the **three pregnant models representing 3, 6, and 9 months of gestation used by Fetaldose**.
- It includes a **large scanner database** covering **major manufacturers**.
- Users select the appropriate voxel-based phantom, and organ doses are estimated using **MC simulations**.

The screenshot displays the VirtualDose-CT web interface. On the left, a dropdown menu lists various phantom models, with '10-year-old Female' selected. The main panel contains several input fields and radio buttons for configuring the simulation. The 'Patient Phantoms' section shows 'Adult Male - RPI' selected. The 'Mode' section has 'Scanner Selection' and 'CTDIvol' buttons. The 'Scan Protocol' section has a dropdown menu. The 'kVp' section has a text input field with '120'. The 'CTDIvol' section has a text input field with '0'. The 'Z-Over Scan Length(mm)' section has radio buttons for 'No' (selected) and 'Yes'. The 'Bowtie filters' section has radio buttons for 'Head' and 'Body' (selected). The 'Beam Collimation(mm)' section has a text input field with '20'. The 'Organ Weighting Scheme' section has radio buttons for 'ICRP103' (selected) and 'ICRP60'. The 'Tube Current Modulation' section has radio buttons for 'No' (selected) and 'Yes'. At the bottom, there are two large buttons: 'Calculate Dose' and 'Create PDF Report'.

VirtualDose-CT

Patient Phantoms:
Adult Male - RPI

Mode:
Scanner Selection CTDI_{vol}

Scan Protocol:
---Select a protocol---

kVp:
120

CTDI_{vol}:
0

Z-Over Scan Length(mm):
☒ No ☐ Yes

Bowtie filters:
☐ Head ☒ Body

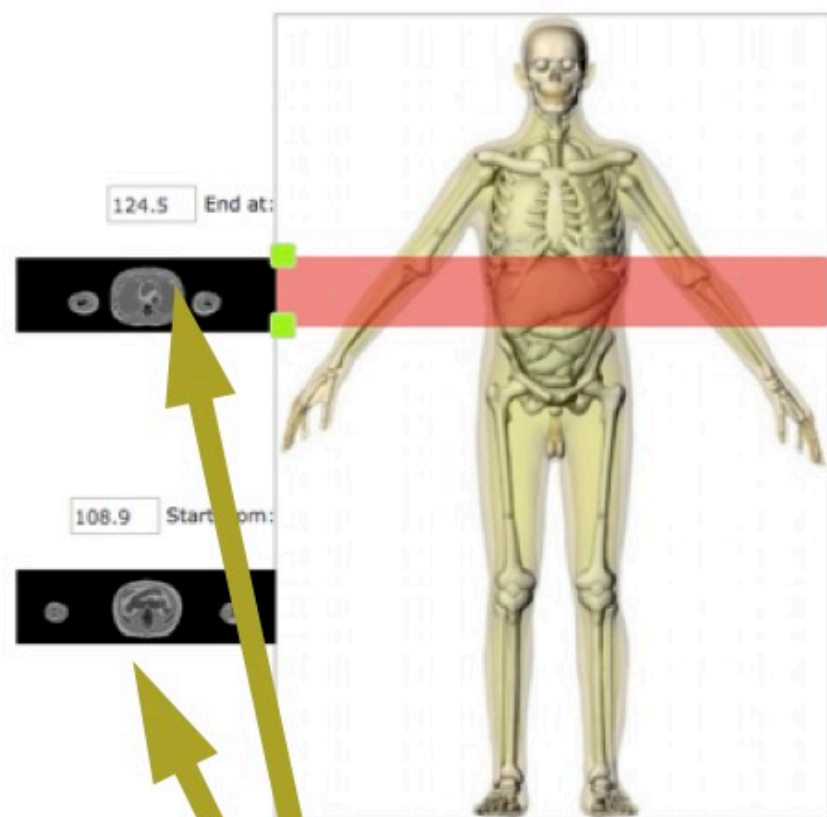
Beam Collimation(mm):
20

Organ Weighting Scheme:
☒ ICRP103 ☐ ICRP60

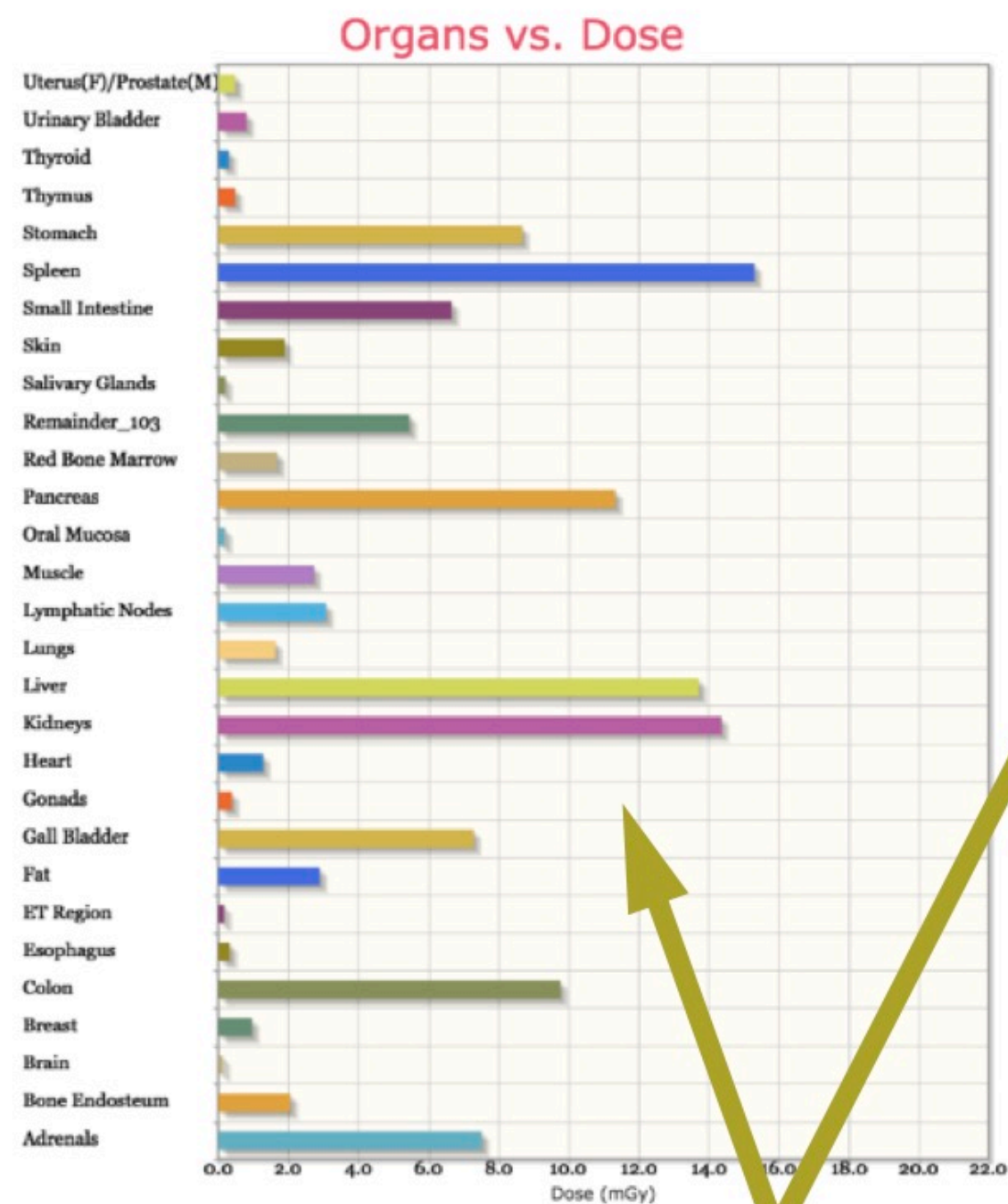
Tube Current Modulation:
☒ No ☐ Yes

Calculate Dose **Create PDF Report**

VIRTUALDOSE-CT



Simulated CT at
scan boundaries



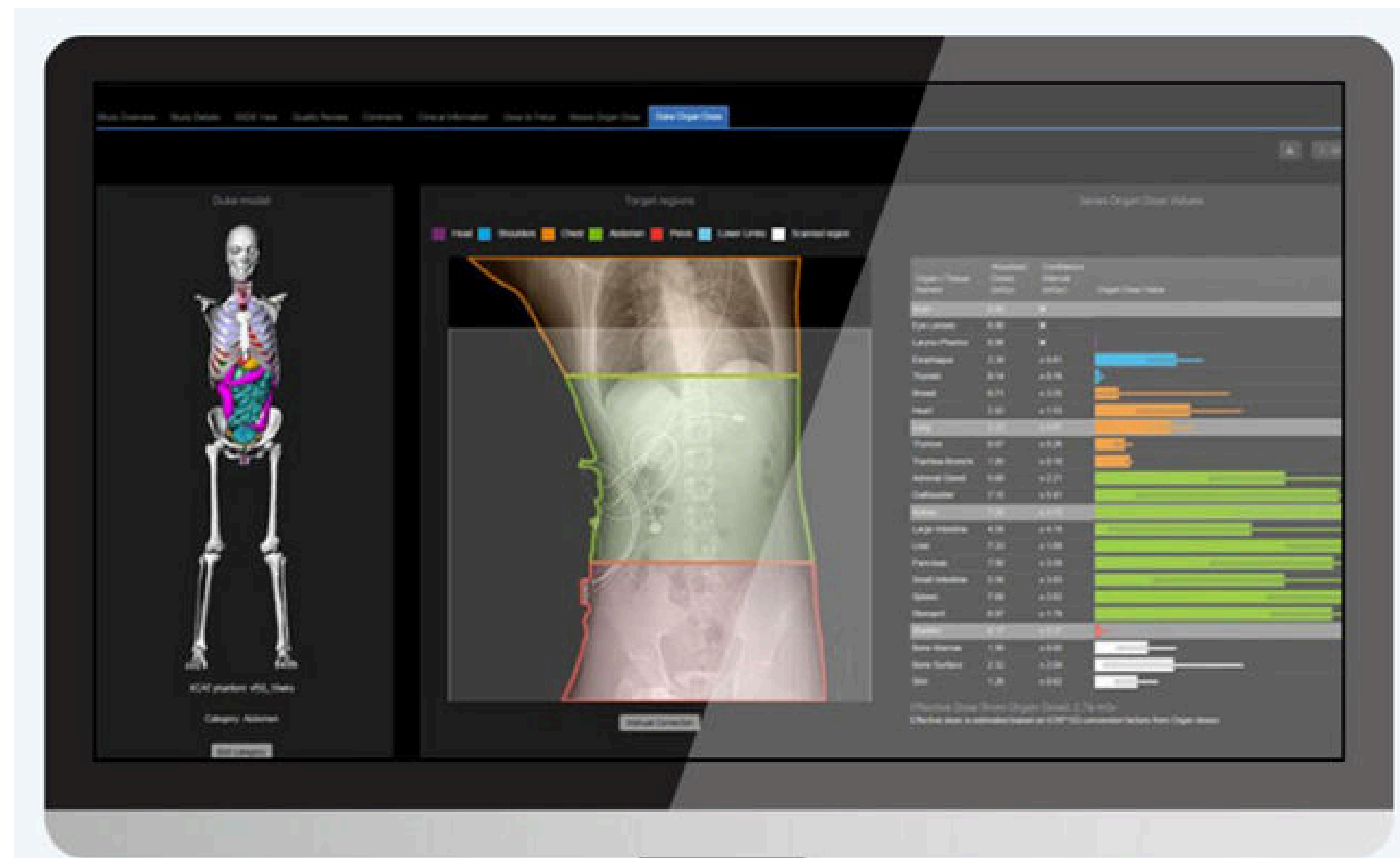
Graphical and
numerical results

Organ Dose	
Organ/Tissue Name	Doses (mGy)
Bone Endosteum	2.05
Brain	0.12
Breast	0.95
Colon	9.76
Esophagus	0.32
Gonads	0.38
Liver	13.72
Lungs	1.62
Red Bone Marrow	1.68
Remainder_103	5.45
Salivary Glands	0.19
Skin	1.89
Stomach	8.67
Thyroid	0.30
Urinary Bladder	0.80
Total Effective Dose(ICRP103) (mSv): 4.03	

Remainder Organs	
Remainder Organs	Doses (mGy)
Adrenals	7.52
ET Region	0.16
Fat	2.89
Gall Bladder	7.28
Heart	1.27
Kidneys	14.36
Lymphatic Nodes	3.07
Muscle	2.73
Oral Mucosa	0.18
Pancreas	11.33
Small Intestine	6.66
Spleen	15.31
Thymus	0.48
Uterus(F)/Prostate(M)	0.48

DUKE ORGAN DOSE

- **Duke Organ Dose (DOD)** is a **tool integrated inside a radiation dose index monitoring (RDIM) system** that assesses organ doses in patients undergoing **CT examinations**.
- **Developed by Duke University**, is available as a **module within GE's DoseWatch**.





PREFERRED METHODS

- The **survey from De Monte et al. (2026)** reported that the use of **dedicated software tools** is the **first choice** for all exposure modalities, followed by **tools integrated within RDIM, MC simulations**, and **data from published literature**.

Table 11
Survey responses to the question about the methods used for fetal dose estimation for the three exposure modalities investigated.

Methods for fetal dose estimation	Radiography	Fluoroscopy/ Angiography	Computed Tomography
Dedicated Software	19	10	23
Tool inside RDIM system	12	5	17
Monte-Carlo simulations (MC)	10	7	13
Published data from literature	14	5	10
Other tool or method	8	5	9
Data from National Guidelines or Legislation	4	3	7
Measurements in phantoms	2	2	1
Homemade Software/Tool	2	0	1
Fetal dose evaluation is not my job	8	0	6

UNCERTAINTIES

F.D. Monte et al.

Physica Medica 148 (2026) 105877

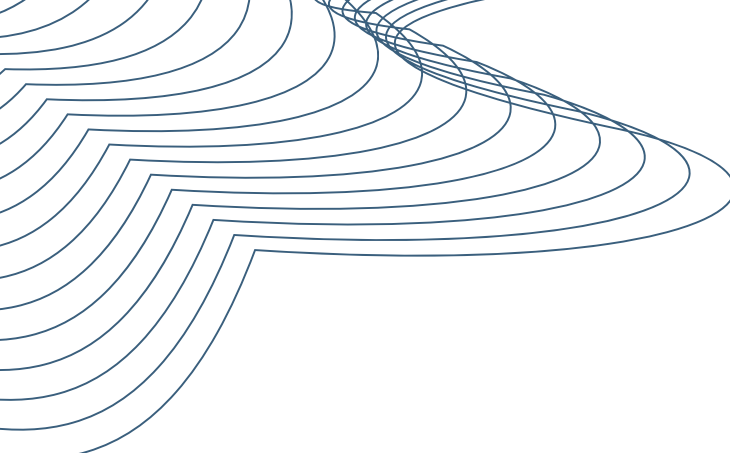
Table 14

Summary of systematic review findings on the source of uncertainties related to the methods used for fetal dose (FD) estimation and exposure modalities and their impact on FD. NR = not reported.

Methods	Source of uncertainty	Quantitative impact	Key Scientific Findings
Monte Carlo (MC) simulations	Intrinsic Statistical Uncertainty	< 1% to 5% [15,17,18,23,26]	Highly precise internally, but dependent on the model used.
	Structural/Modeling (segmentation)	~30% [19,20,22]	Overall uncertainties due to segmentation and phantom-to-image registration. Average dose difference between automated and manual segmentation methods was 0.12% ± 2.62% [22].
Software tools	Patient anatomy (primary determinant of variability)	2x [14]	Maternal perimeter, fetus depth and position (gestation period) can alter FD by a factor of 2.
	Software vs. Patient-specific MC simulations	−15.9% to + 40.0% [49] (average relative error 18% [51])	Available software tools often deviate significantly from “gold standard” MC simulations.
	Patient anatomy (size variation: maternal perimeter and fetal depth)	15–20% [45] – 50% [44]	Errors from 15 to 20% up to 50% due to patient size variation (maternal perimeter and fetal depth).
	Surrogate organ (uterus vs. fetus)	20%–60% underestimation [54]	Significant underestimation of FD when the uterus is used as a proxy for the fetus.
	Inter-software Variability	ICC < 0.50 [55]	Significant differences and poor concordance between different tools due to phantom morphology and the definition used for calculation (Fetus-total vs Embryo).
Physical measurements	Inter-scanner variability (CT)	< 10% [43]	Difference between modern CT scanners can affect FD less than 10%.
	Inter-observer variability	Ratio of 7.8 (max/min) [53]	The choice of tools and user interpretation is a major source of non-standardized error.
	TLD / RPL Accuracy	TLD: < ±5% [34,58,67,85]; ±10 [75]; ±15% [29,38]; ±17% [86] RPL: ~2.1% [77] – 3% [70]	Dosimeters accuracy is generally reported to be < ±5%. In [86], the authors reported a combined uncertainty including detector efficiency, stability correction factor, and reader calibration coefficient.
	Geometric / Field of View (FOV)	Up to ± 25% [29,75]	Uncertainty on measurements increases when the fetus is only partially within the scan range [29].
	Very low doses, low signals (radiography)	8.1% [58] – 45% [62]	Discrepancies between MC simulations and measurements are due to dosimeter sensitivity and differences between MC models and physical phantoms [58]. Measurement uncertainties depend on the dose levels to be measured (dental/chest: range 0.5% – 45%) [62].

UNCERTAINTIES

Exposure modalities	Source of uncertainty	Quantitative impact	Key Scientific Findings
Radiography	Anatomical / Fetal depth variation	1.7x to 3x (depth) [63]	Failure to account for fetal depth leads to underestimation (1.7x) or overestimation (3x).
Computed Tomography (CT)	Distance fetus – primary beam	< 1 – <5% [47] – 23% [48]	Distance between the fetus and the borde of the primary beam leads to differences up to 23%.
Fluoroscopy/ Angiography:	Fetus size and location vs. patient anatomy	12% – 19% [64,67]	Differences between MC simulations and phantom measurements increase with gestational age (lower in the 1st and higher in 3rd trimester), patient anatomy, and fetus position.
	Methodological variability	~30% [81]	Variations between independent calculations for the same procedure.
	Procedure complexity and geometry	NR	FD is largely dependent on procedure type, complexity, and geometry of the irradiation beams.



ICTP College on Medical Physics 2026 , Trieste, Italy

**THANK YOU
FOR THE ATTENTION**



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