Radiation exposure assessment

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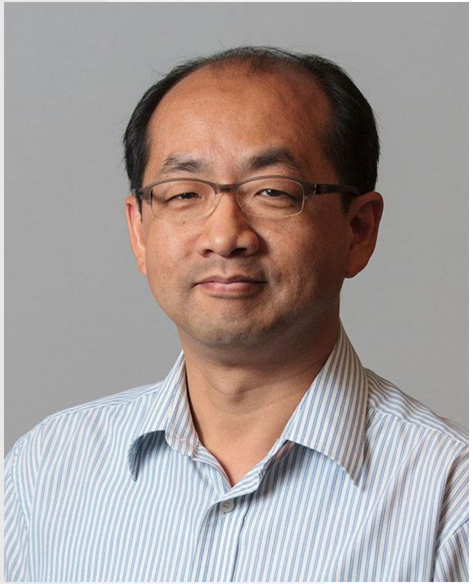


DCEG Radiation Epidemiology and Dosimetry Course 2019

Objectives

To understand:

- The challenges in dosimetry for epidemiological studies;
- Input data for dosimetry in epidemiological studies;
- Different approaches for dosimetry;
- The methods to quantify dosimetric uncertainty.

Background

Exposure assessment for epidemiological studies

- A fundamental foundation of high quality epidemiologic studies is accurate exposure assessment.
- Background physics, methods and techniques for radiation exposure assessment have been developed relatively robust compared to other exposure types.

Types of radiation exposure (1)

Medical Exposure

Occupational Exposure

Environmental Exposure

Types of radiation exposure (2)

Medical Exposure

Patients receiving FGIP*

Occupational Exposure

Physicians performing FGIP

Environmental Exposure

*FGIP: Fluoroscopically-guided interventional procedures

Types of radiation exposure (3)

Medical Exposure

Radiation technologist receiving chest x-ray as a patient

Occupational Exposure

Radiation technologists working for nuclear medicine patients

Environmental Exposure

*FGIP: Fluoroscopically-guided interventional procedures

Types of radiation exposure (4)

Medical Exposure

Occupational Exposure

Chernobyl clean-up workers

Environmental Exposure

Populations who lived in Chernobyl region

Types of radiation exposure (5)

Medical Exposure

Occupational Exposure

Atomic bomb survivors receiving radiological exams

Environmental Exposure

Hiroshima/Nagasaki population exposed to the atomic bomb

Types of radiation exposure (6)

Medical/occupational exposure

- Planned and controlled
- Relatively well documented

Environmental exposure

Dosimetric quantities*

Kinetic energy <u>deposited</u> in matter

Organ Absorbed Dose (Gy) $\xrightarrow{w_R}$ Equivalent Dose (Sv) $\xrightarrow{w_T}$ Effective Dose (Sv)

w_R: Radiation Weighting Factor

w_T: Tissue Weighting Factor

$$H_T = \sum_R w_R D_{T,R}$$

$$E = \sum_T w_T \left[\frac{H_T^M + H_T^F}{2} \right]$$

Organ Absorbed Dose (Gy) ⇕ Kerma (Gy)

Kinetic energy <u>released</u> in matter

*** ICRP Publication 103 (2007)**

Radiation weighting factor*

Organ Absorbed Dose (Gy) $\xrightarrow{w_R}$ Equivalent Dose (Sv) $\xrightarrow{w_T}$ Effective Dose (Sv)

Radiation Weighting Factor (w_R)

Tissue Weighting Factor (w_T)

Table 2. Recommended radiation weighting factors.

Radiation type	Radiation weighting factor, w_R
Photons	1
Electrons[a] and muons	1
Protons and charged pions	2
Alpha particles, fission fragments, heavy ions	20
Neutrons	A continuous function of neutron energy (see Fig. 1 and Eq. 4.3)

$$w_R = \begin{cases} 2.5 + 18.2\, e^{-[\ln(E_n)]^2/6}, & E_n < 1\ \text{MeV} \\ 5.0 + 17.0\, e^{-[\ln(2E_n)]^2/6}, & 1\ \text{MeV} \leqslant E_n \leqslant 50\ \text{MeV} \\ 2.5 + 3.25\, e^{-[\ln(0.04E_n)]^2/6}, & E_n > 50\ \text{MeV} \end{cases}$$

*** ICRP Publication 103 (2007)**

Tissue weighting factor*

Organ Absorbed Dose (Gy) $\xrightarrow{w_R}$ Equivalent Dose (Sv) $\xrightarrow{w_T}$ Effective Dose (Sv)

(w_R: Radiation Weighting Factor; w_T: **Tissue Weighting Factor**)

Table 3. Recommended tissue weighting factors.

Tissue	w_T	$\sum w_T$
Bone-marrow (red), Colon, Lung, Stomach, Breast, Remainder tissues*	0.12	0.72
Gonads	0.08	0.08
Bladder, Oesophagus, Liver, Thyroid	0.04	0.16
Bone surface, Brain, Salivary glands, Skin	0.01	0.04
	Total	1.00

* Remainder tissues: Adrenals, Extrathoracic (ET) region, Gall bladder, Heart, Kidneys, Lymphatic nodes, Muscle, Oral mucosa, Pancreas, Prostate (♂), Small intestine, Spleen, Thymus, Uterus/cervix (♀).

*** ICRP Publication 103 (2007)**

Dosimetric quantities*

Individualized organ dose

w_R

Radiation Weighting Factor

Equivalent Dose (Sv)

w_T

Tissue Weighting Factor

Effective Dose (Sv)

$$H_T = \sum_R w_R D_{T,R}$$

$$E = \sum_T w_T \left[\frac{H_T^M + H_T^F}{2} \right]$$

Kerma (Gy)

Kinetic energy released in matter

*** ICRP Publication 103 (2007)**

Challenges

Challenges in dosimetry for epidemiological studies (1)

Example #1: CT dose reconstruction

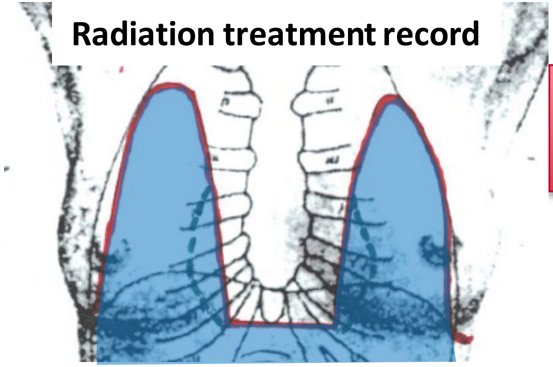
"Reconstruct organ dose for 180,000 pediatric and young adults who underwent CT scans in the United Kingdom 1985 – 2002*"

*Pearce et al. Lancet (2012)

Challenges in dosimetry for epidemiological studies (2)

Example #2: Radiotherapy dose reconstruction*

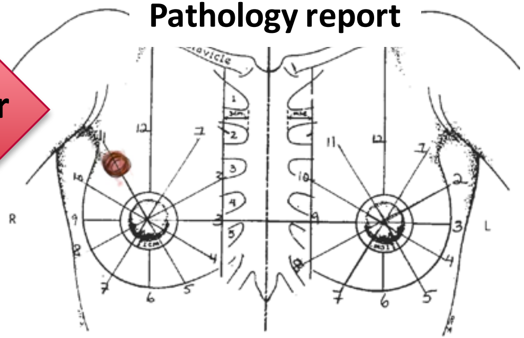
1970



A patient was treated for **Hodgkin Lymphoma (HL)**

20 years later

1990



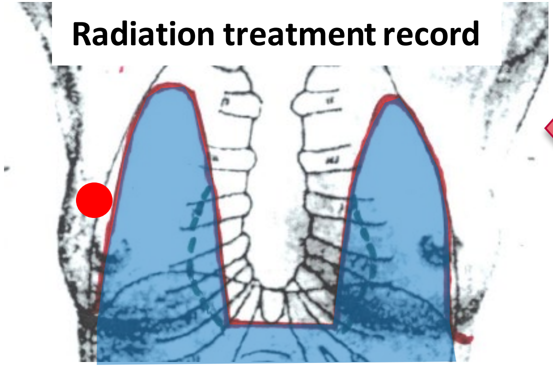
The patient was diagnosed with **Breast Cancer**

Challenges in dosimetry for epidemiological studies (3)

Example #2: Radiotherapy dose reconstruction*

1970

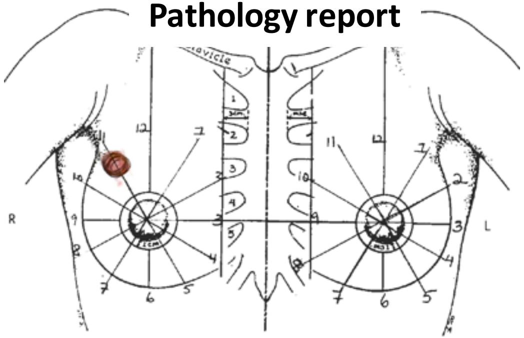
Radiation treatment record



Going back

1990

Pathology report



A patient was treated for **Hodgkin Lymphoma (HL)**

The patient was diagnosed with **Breast Cancer**

Challenges in dosimetry for epidemiological studies (4)

- Individualized organ dose required
- Large size cohorts
- Limited input for dose reconstruction
- Uncertainty needs to be quantified

Input

Data used for exposure assessment - Environmental

- Environmental radiation exposure
  - Measurements (direct or indirect)
  - Records on weather, building maps, working environment
  - Questionnaire: residential history, dietary, housing style, protection measures, etc.

Exposure Modeling for Chernobyl Accident

3D model of Pripyat-town (left) and building structure (right) close to the Chernobyl accident site used for dosimetry

Part of the questionnaire used for the mothers in Belarus/Ukraine cohort

Раздел II. **Мои следующие вопросы о периоде времени в 1986 году после Чернобыльской аварии.**
Вспомните о потреблении молочных и других продуктов в апреле-мае 86 года.

* 4. **Я хочу, чтобы Вы сказали мне о потреблении молока во всех местах, где Вы находились во время и сразу после аварии.**
(Внесите в колонку «a» первый населенный пункт (НП) из таблицы вопроса #7 основной анкеты и задайте вопрос колонки «b». Запишите название каждого источника на отдельной строке колонки «b» и задавайте вопросы из каждой колонки для каждого источника молока, следуя инструкциям в таблице. После этого перенесите название следующего НП из вопроса #7 и повторите указанную выше процедуру, пока не запишите информацию о всех источниках молока во всех НП)

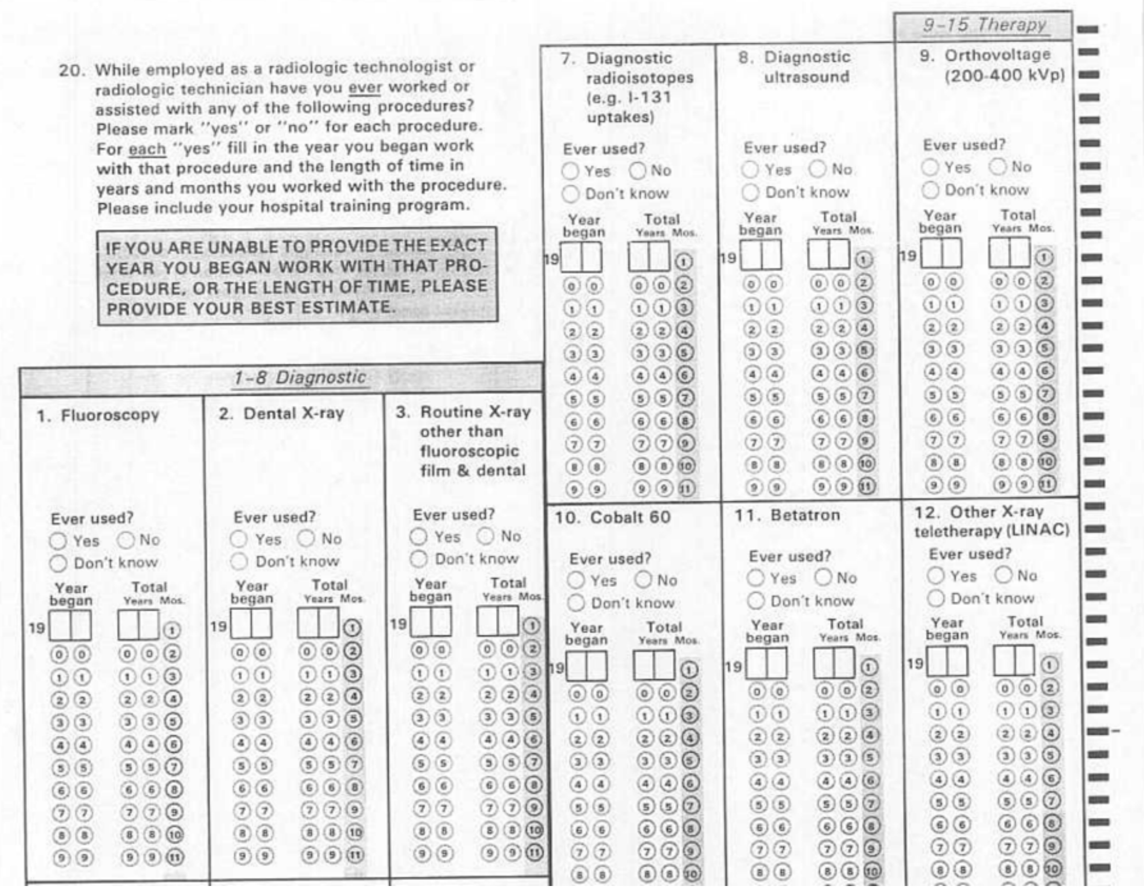
*Если мать не помнит, когда она начала пить молоко из данного источника, спросите "Было ли это в **конце апреля** (**1**)?; **начале мая** (**2**)?; **средине мая** (**3**)?; **конце мая** (**4**)?"; «**не знаю**» (**9**)?. Внесите соответствующий код в колонку «Период».)*

#	a. **Населенный пункт** (*Внесите название НП из вопроса #7 (осн.); задайте все вопросы для каждого НП, прежде, чем перейти к следующему)*	b. **Какое молоко Вы пили в** *(НП)*? **Было ли это** (*прочтите все источники ниже и запишите на отдельных строках название тех, для которых ответ «да»*)	c. **С какого времени Вы начали потреблять** *(источник)* **молоко в** *(НП)*? *(Запишите дату, когда субъект начал пить молоко для каждого источника)*			d. **Начиная с** *(дата)*, **как часто Вы пили** *(источник)* **молоко?**				e. **Начиная с** *(дата)*, **сколько** *(источник)* **молока Вы обычно выпивали за день?** *(Покажите Карточку #2)* *(В первую колонку впишите количество, во вторую – единицы измерения, такие, которые указал респондент)*			f. **В период проживания в** *(НП)*, **изменили ли Вы количество выпиваемого** *(источник)* **молока?** *(Если ответ «Нет» или «Не знаю», переходите к следующей строке, следующему источнику,НП или к вопросу #5)*			g. **Когда Вы изменили количество потребляемого** *(источник)* **молока?**	
		Коровье: *из* **частного** *сектора*, Из **магазина**, **Козье**, **Сухое**, **Не пила**, Не знаю	**С начала пребывания**	**Дата**	**Период**	**Каждый день**	**Несколько раз в неделю**	**Раз в неделю и реже**	Не знаю	Количество (*цифра*)	Единицы измерения (***литров****(1)*, ***стаканов****(2)*, ***кружек****(3)*, ***кринок литровых****(4)*, ***банок литровых****(5)*, ***бутылок*** *молочных* ***пол-литровых****(6)*, ***пакетов*** *молочных* ***пол-литровых****(7))*	Не знаю	**Да** *(переход к g)*	**Нет** *(переход к следующему источнику, НП или #5)*	Не знаю *(переход к следующему источнику, НП, или #5)*	**Дата**	**Период**
1			1❑	__/__		1❑	2❑	3❑	9❑			9❑	1❑	2❑	9❑	__/__	
2			1❑	__/__		1❑	2❑	3❑	9❑			9❑	1❑	2❑	9❑	__/__	
3			1❑	__/__		1❑	2❑	3❑	9❑			9❑	1❑	2❑	9❑	__/__	
4			1❑	__/__		1❑	2❑	3❑	9❑			9❑	1❑	2❑	9❑	__/__	
5			1❑	__/__		1❑	2❑	3❑	9❑			9❑	1❑	2❑	9❑	__/__	
6			1❑	__/__		1❑	2❑	3❑	9❑			9❑	1❑	2❑	9❑	__/__	
7			1❑	__/__		1❑	2❑	3❑	9❑			9❑	1❑	2❑	9❑	__/__	
8			1❑	__/__		1❑	2❑	3❑	9❑			9❑	1❑	2❑	9❑	__/__	
9			1❑	__/__		1❑	2❑	3❑	9❑			9❑	1❑	2❑	9❑	__/__	
10			1❑	__/__		1❑	2❑	3❑	9❑			9❑	1❑	2❑	9❑	__/__	
11			1❑	__/__		1❑	2❑	3❑	9❑			9❑	1❑	2❑	9❑	__/__	
12			1❑	__/__		1❑	2❑	3❑	9❑			9❑	1❑	2❑	9❑	__/__	
13			1❑	__/__		1❑	2❑	3❑	9❑			9❑	1❑	2❑	9❑	__/__	

Data used for exposure assessment - Occupational

- Occupational radiation exposure
  - Dose monitoring records (e.g., badge dose)
  - Questionnaire on work history, time, medical procedures, safety measures employed
  - Literature search: x-ray energy, filtration, machine types

Example page of the questionnaire used for the United States Radiologic Technologists study: type of procedures



20. While employed as a radiologic technologist or radiologic technician have you ever worked or assisted with any of the following procedures? Please mark "yes" or "no" for each procedure. For each "yes" fill in the year you began work with that procedure and the length of time in years and months you worked with the procedure. Please include your hospital training program.

IF YOU ARE UNABLE TO PROVIDE THE EXACT YEAR YOU BEGAN WORK WITH THAT PROCEDURE, OR THE LENGTH OF TIME, PLEASE PROVIDE YOUR BEST ESTIMATE.

1–8 Diagnostic

1. Fluoroscopy
2. Dental X-ray
3. Routine X-ray other than fluoroscopic film & dental
7. Diagnostic radioisotopes (e.g. I-131 uptakes)
8. Diagnostic ultrasound

9–15 Therapy

9. Orthovoltage (200-400 kVp)
10. Cobalt 60
11. Betatron
12. Other X-ray teletherapy (LINAC)

For each procedure:

Ever used? ◯ Yes ◯ No ◯ Don't know

Year began: 19 __ __ (0–9, 0–9)

Total: Years __ __ (0–9, 0–9) Mos. (1–11)

Example page of the questionnaire used for the United States Radiologic Technologists study: safety measures

21a. If you wore a dosimetry badge (film badge, TLD, pocket chamber, etc.) where did you usually wear it? (Mark only the one that is used most often.)

- ◯ Never wore a dosimeter
- ◯ Belt loop, waist or side pocket
- ◯ Breast pocket
- ◯ Lapel
- ◯ Other (describe below)

PLEASE PRINT —
STAY WITHIN BOX

21b. Did you also usually wear a hand or wrist dosimeter?

◯ Yes ◯ No

22. When you were first working as a radiologic technologist or radiologic technician, did you usually wear a lead apron or stand behind a protective shield?

◯ Yes ◯ No

IF YOU ARE NOT CURRENTLY WORKING AS A RADIOLOGIC TECHNOLOGIST OR RADIOLOGIC TECHNICIAN, SKIP TO QUESTION 25.

Data used for exposure assessment - Medical

- <u>Medical</u> radiation exposure
  - Patient information system at hospitals (e.g., RIS*)
  - Paper medical records
  - Electronic medical records (e.g., DICOM-RT)
  - Literature search

*RIS: Radiological Information System

Sample screen of a Radiological Information System

Status	Name-2	Date-1	TimeSch	Procedure	Referral	Modality	
Transcribed	[redacted]	09/16/2009	9:00a	MAMMO,DIGITAL SCREE	[redacted]	MAMMO M	M
Dictated	[redacted]	09/16/2009	7:30a	BONE SCAN 78300	[redacted]	BONE DEN	M
Posted	[redacted]	09/16/2009	10:00a	CT LUMBAR W & WO CO	[redacted]	Computed	M
Posted	[redacted]	09/16/2009	10:30a	MRI LUMBAR SPINE 7214	[redacted]	Magnetic R	M
Completed	[redacted]	09/16/2009	8:30a	US THYROID 76536	[redacted]	Ultrasound	M
Transcribed	[redacted]	09/16/2009	11:00a	MAMMO,DIGITAL SCREE	[redacted]	MAMMO M	M
Completed	[redacted]	09/16/2009	9:30a	MRI CERVICAL SPINE 72	[redacted]	Magnetic R	M
Arrived	[redacted]	09/16/2009	10:30a	CT THORACIC W/O CON	[redacted]	Computed	M
In Progress	[redacted]	09/16/2009	8:30a	BONE DENSITY SPINE HIP	[redacted]	BONE MAR	M
Completed	[redacted]	09/16/2009	11:30a	MRI UPPER EXTREMITY 7	[redacted]	Magnetic R	M
Completed	[redacted]	09/16/2009	9:00a	CHEST - AP AND LATERA	[redacted]	X-RAY XR	M
Dictated	[redacted]	09/16/2009	7:30a	US BREAST 76645	[redacted]	Ultrasound	M
Dictated	[redacted]	09/16/2009	7:00a	MAMMO,DIGITAL,DIAGN	[redacted]	MAMMO M	M
Completed	[redacted]	09/16/2009	8:00a	US BREAST 76645	[redacted]	Ultrasound	M
Completed	[redacted]	09/16/2009	8:30a	MAMMO,DIGITAL SCREE	[redacted]	MAMMO M	M
Completed	[redacted]	09/16/2009	10:00a	MRI LUMBAR SPINE 7214	[redacted]	Magnetic R	M
Dictated	[redacted]	09/16/2009	7:00a	BONE DENSITY SPINE HIP	[redacted]	BONE DEN	M
Posted	[redacted]	09/16/2009	10:00a	MAMMO,DIGITAL SCREE	[redacted]	MAMMO M	M
In Progress	[redacted]	09/16/2009	9:00a	BONE DENSITY SPINE HIP	[redacted]	BONE DEN	M
Arrived	[redacted]	09/16/2009	10:00a	BONE DENSITY SPINE HIP	[redacted]	BONE DEN	M
Arrived	[redacted]	09/16/2009	1:30p	MR CEVICAL SPINE W/CO	[redacted]	Magnetic R	M
Transcribed	[redacted]	09/16/2009	9:30a	CT ABDOMEN W/CONTRA	[redacted]	Computed	M
Dictated	[redacted]	09/16/2009	7:30a	CT LUMBAR W/O CONTR	[redacted]	Computed	M
Dictated	[redacted]	09/16/2009	7:30a	MAMMO,DIGITAL SCREE	[redacted]	MAMMO M	M

Sample CT DICOM Dose Report

Patient Name: Exam no: 215

Accession Number: Feb 14 2008

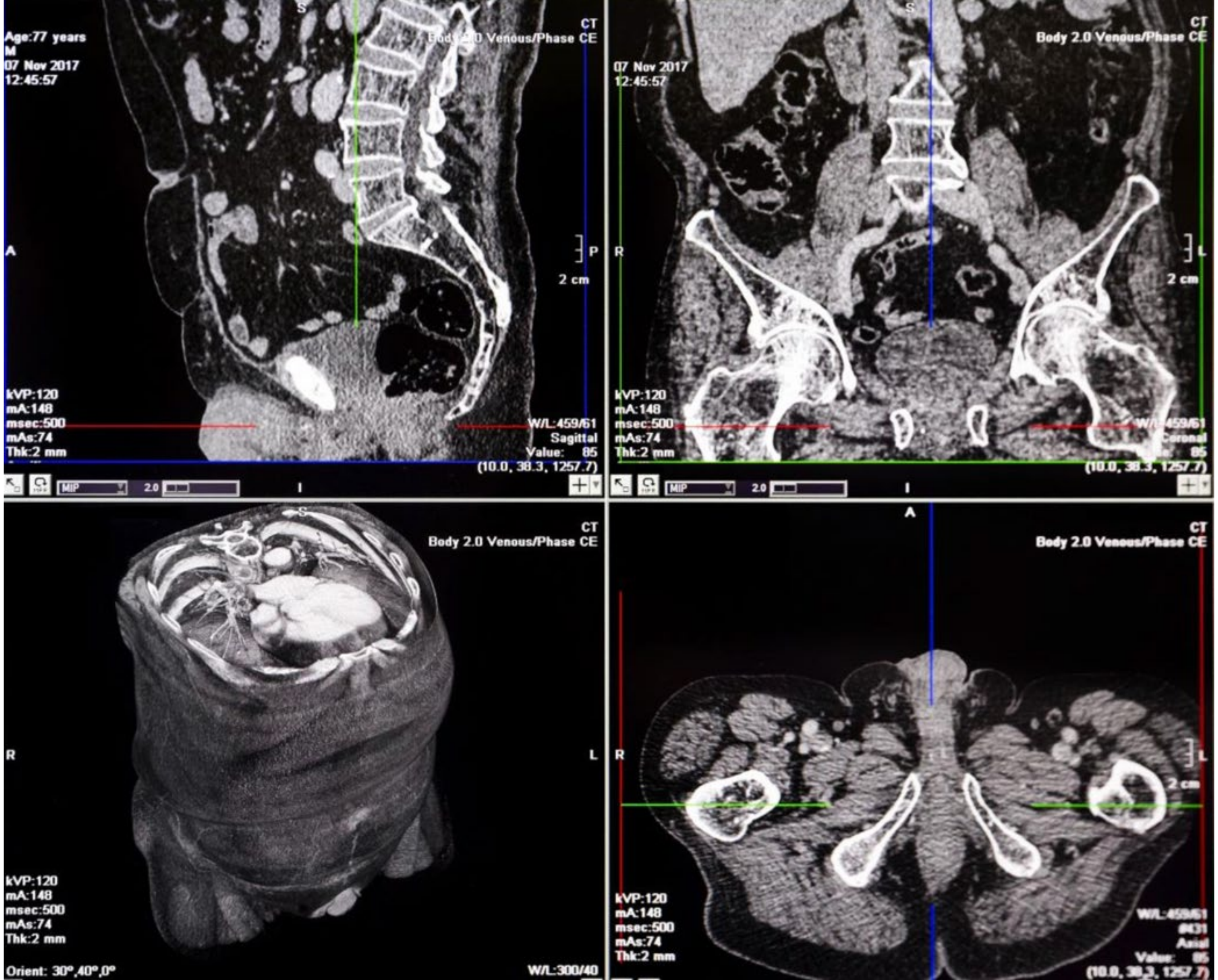
Patient ID: LightSpeed VCT

Exam Description: PRE/POST KIDNEY

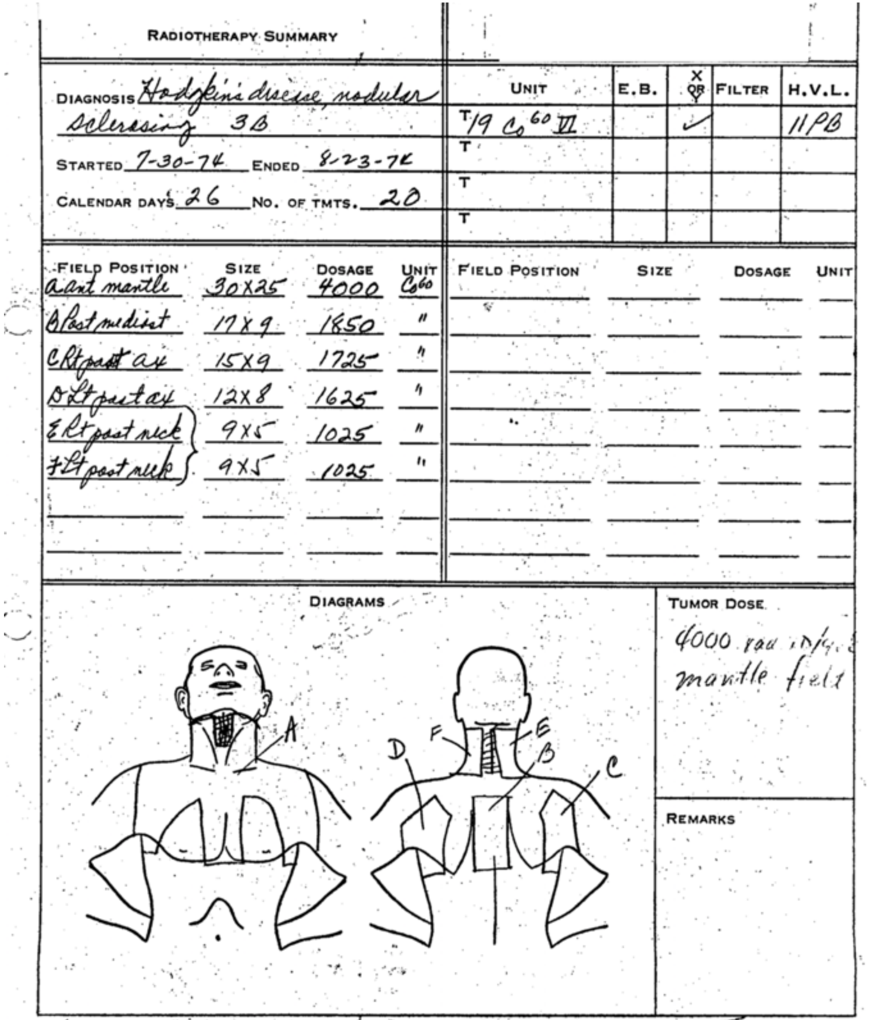
Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Axial	S0.000-I97.500	94.69	946.93	Head 16
2	Helical	I61.650-I101.650	60.81	371.96	Head 16
2	Cine	S12.490-I2.510	121.14	242.29	Head 16
3	Axial	S0.000-I97.500	94.69	946.93	Head 16
3	Helical	I61.650-I101.650	60.81	371.96	Head 16
3	Cine	S12.490-I2.510	121.14	242.29	Head 16
			Total Exam DLP:	3122.36	

Sample CT Images



Example paper medical records of a radiotherapy patient



RADIOTHERAPY SUMMARY

DIAGNOSIS Hodgkin's disease, nodular sclerosing 3B

STARTED 7-30-74 ENDED 8-23-74

CALENDAR DAYS 26 NO. OF TMTS. 20

UNIT	E.B.	X OR γ	FILTER	H.V.L.
T 19 Co^{60} VI		✓		11PB
T				
T				
T				

FIELD POSITION	SIZE	DOSAGE	UNIT	FIELD POSITION	SIZE	DOSAGE	UNIT
A ant mantle	30X25	4000	Co^{60}				
B Post mediast	17X9	1850	"				
C Rt post ax	15X9	1725	"				
D Lt post ax	12X8	1625	"				
E Rt post neck	9X5	1025	"				
F Lt post neck	9X5	1025	"				

DIAGRAMS

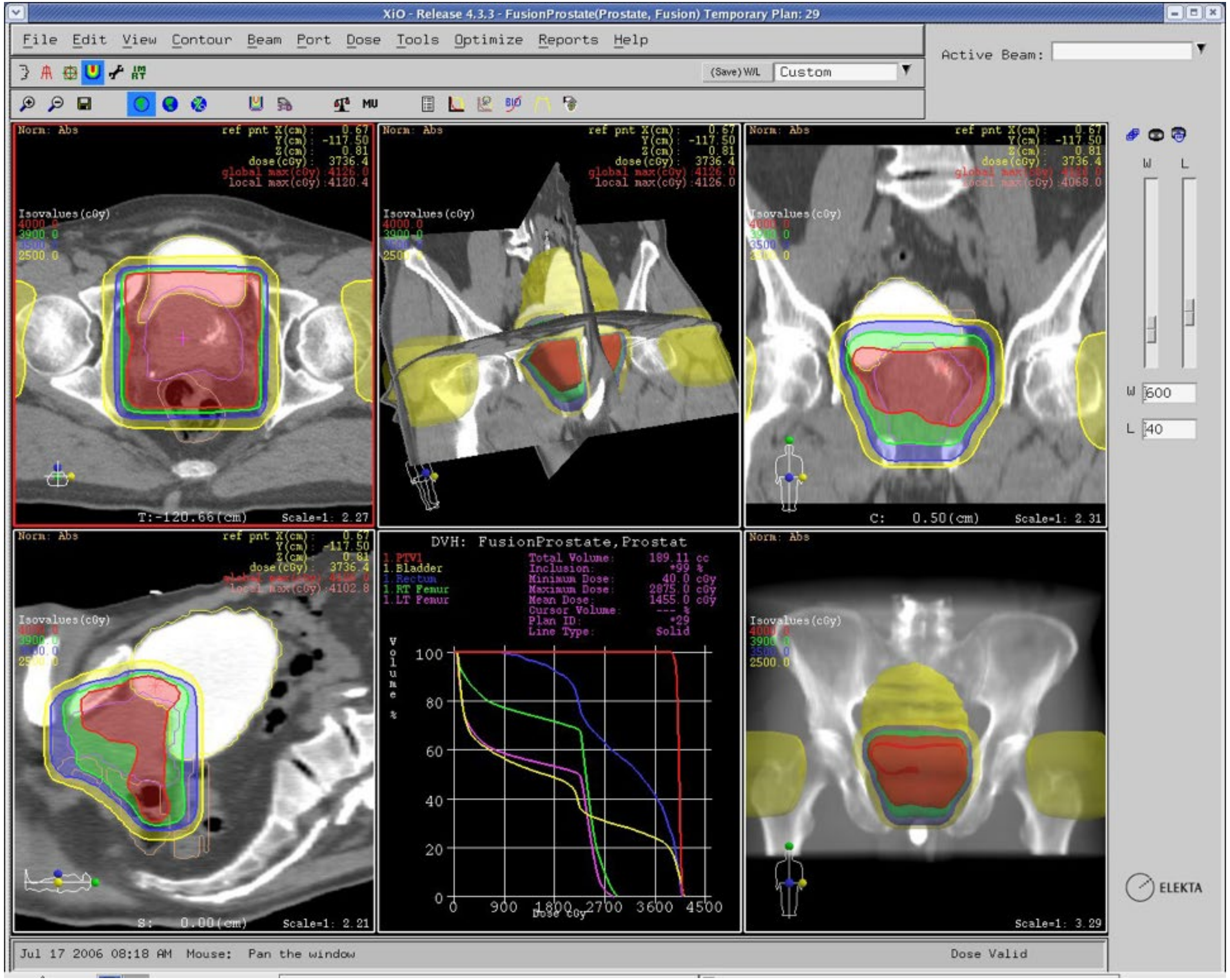
A D F E B C

TUMOR DOSE

4000 rad in/4 mantle field

REMARKS

Example DICOM-RT visualized on a treatment planning system

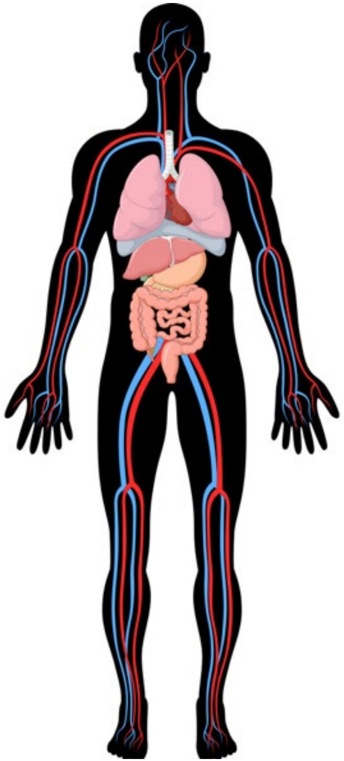


Approaches

Dosimetry approaches: external exposure (1)

Source reconstruction

Organ dose calculation



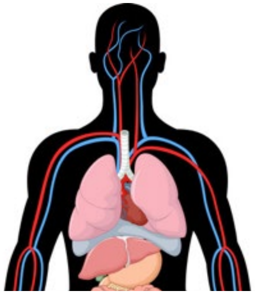
Dosimetry approaches: external exposure (2)

Source reconstruction

Examples:

- Radioactivity from ground contamination in Chernobyl
- Scanner model, tube potential, filtration in CT scans

Organ dose calculation

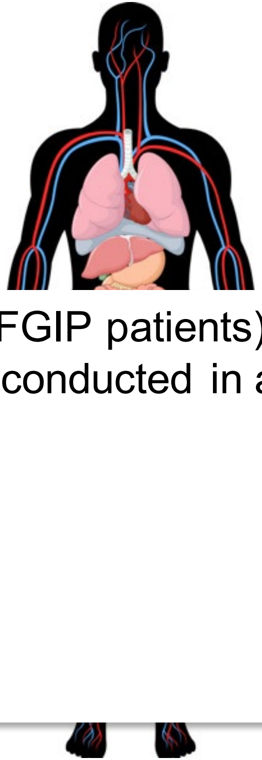


Organ dose conversion coefficients from computer simulation using computational human phantoms

Dosimetry approaches: external exposure (3)

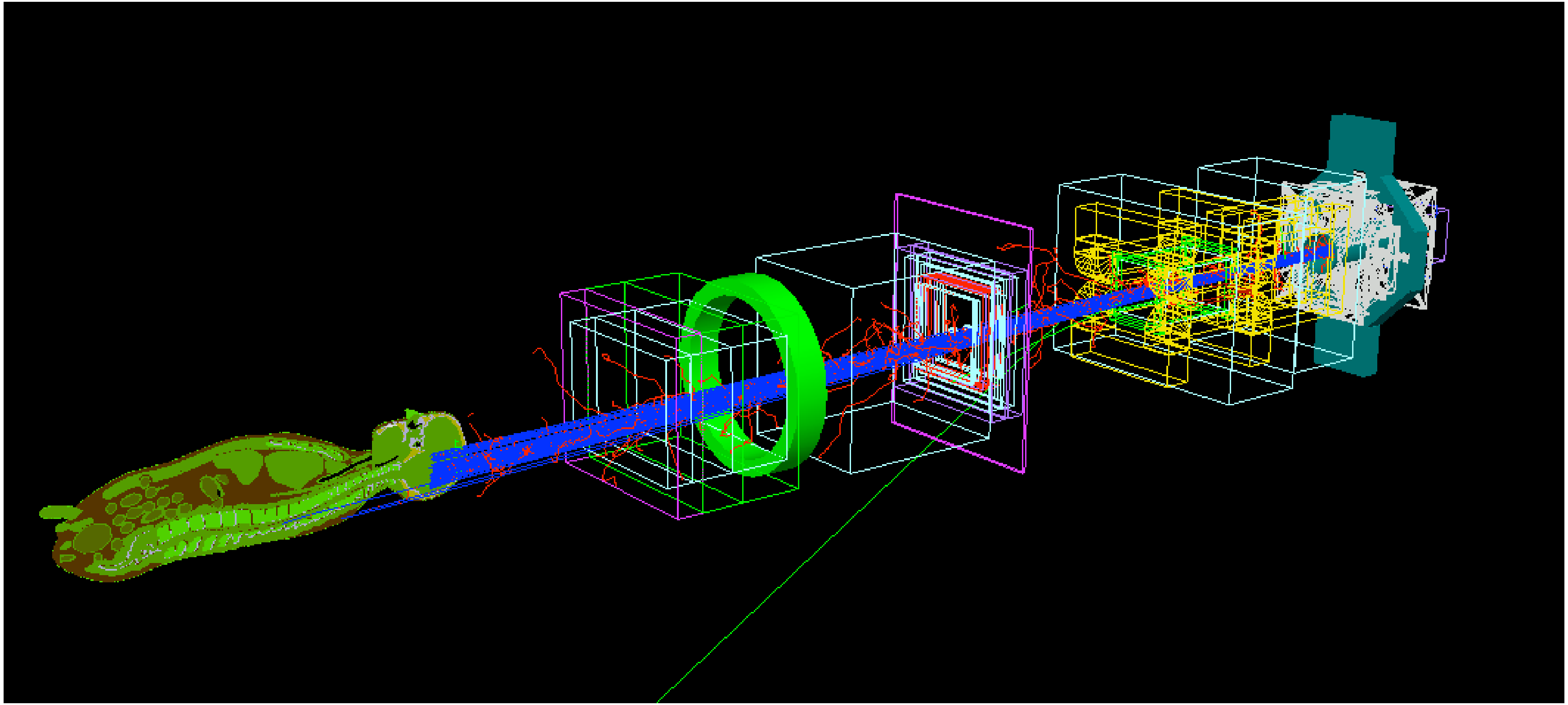
Source reconstruction

Organ dose calculation



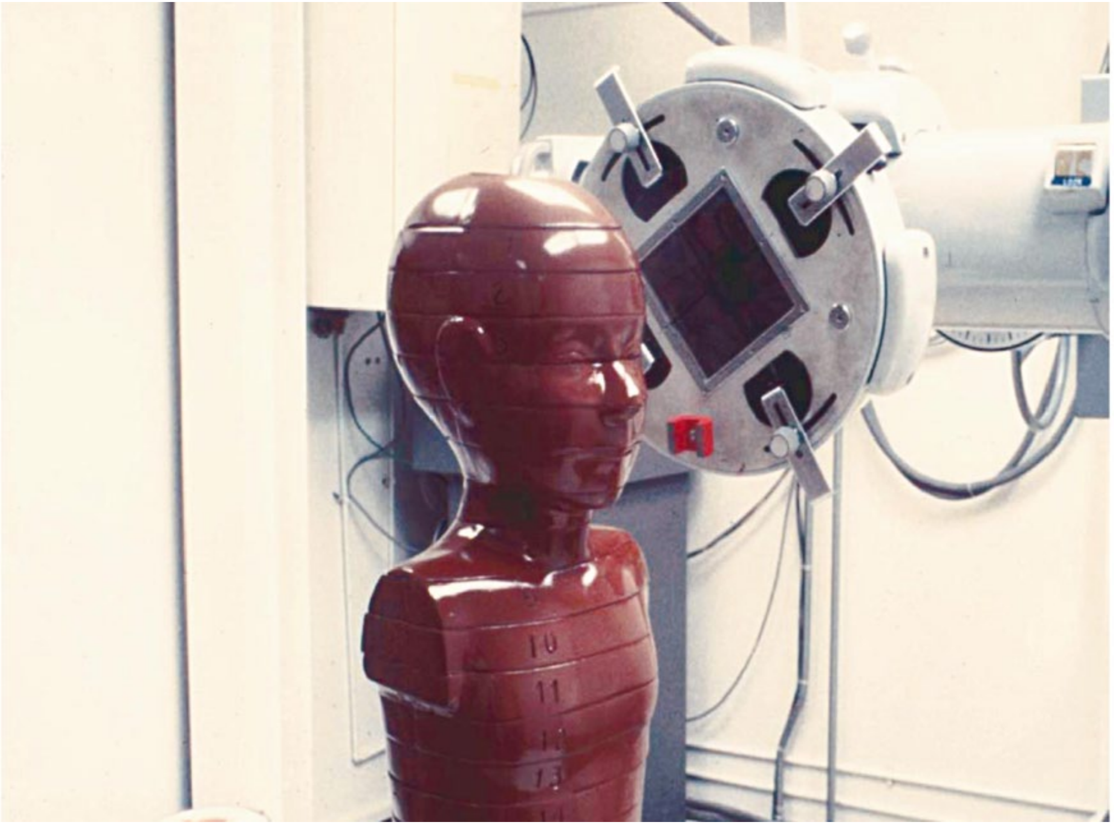
In some medical dosimetry (e.g., radiotherapy, FGIP patients), both the source reconstruction and dose calculation are conducted in a computer simulation or a measurement setup.

Simulation of IBA Proton Therapy beam line coupled with the NCI adult male phantom in TOPAS*



*Yeom et al. (in preparation)

Physical phantom to simulate the tonsil irradiation*

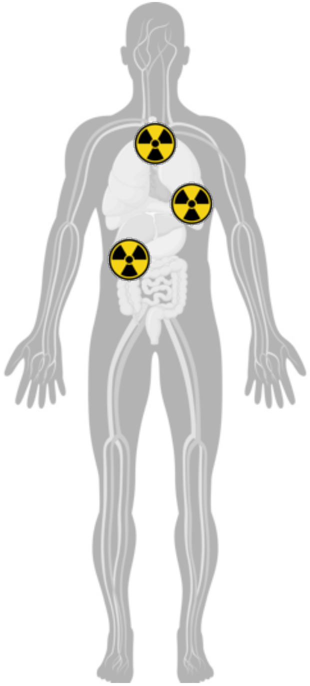


* Stovall et al, Rad Res 2006

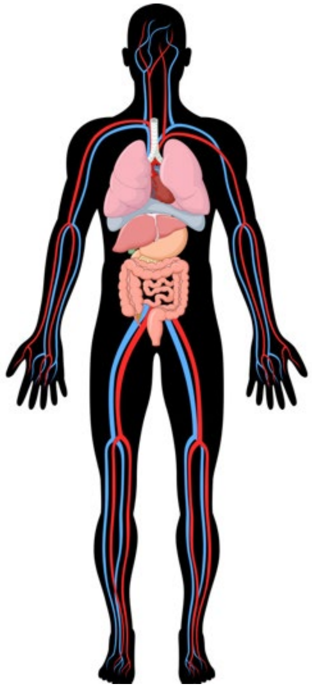
Dosimetry approaches: internal exposure (1)

Source reconstruction #1
(outside the anatomy)

Source reconstruction #2
(inside the anatomy)



Organ dose calculation

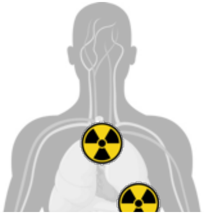


Dosimetry approaches: internal exposure (2)

Source reconstruction #1
(outside the anatomy)

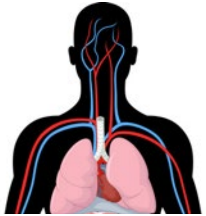
Examples:
- Ecological analysis for contaminated food consumption in Chernobyl area

Source reconstruction #2
(inside the anatomy)



Bio-kinetic models to simulate the movement of radioisotopes within the anatomy

Organ dose calculation



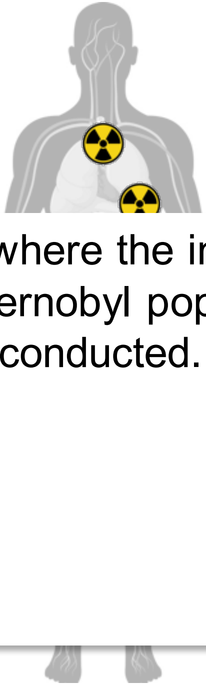
Organ dose conversion coefficients from computer simulation using computational human phantoms

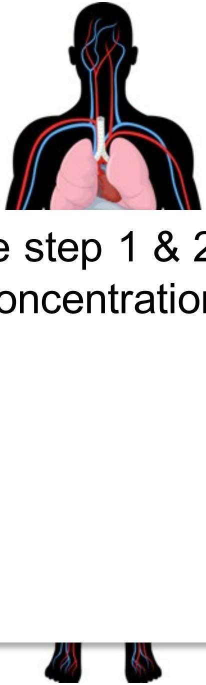
Dosimetry approaches: internal exposure (3)

Source reconstruction #1 (outside the anatomy)

Source reconstruction #2 (inside the anatomy)

Organ dose calculation



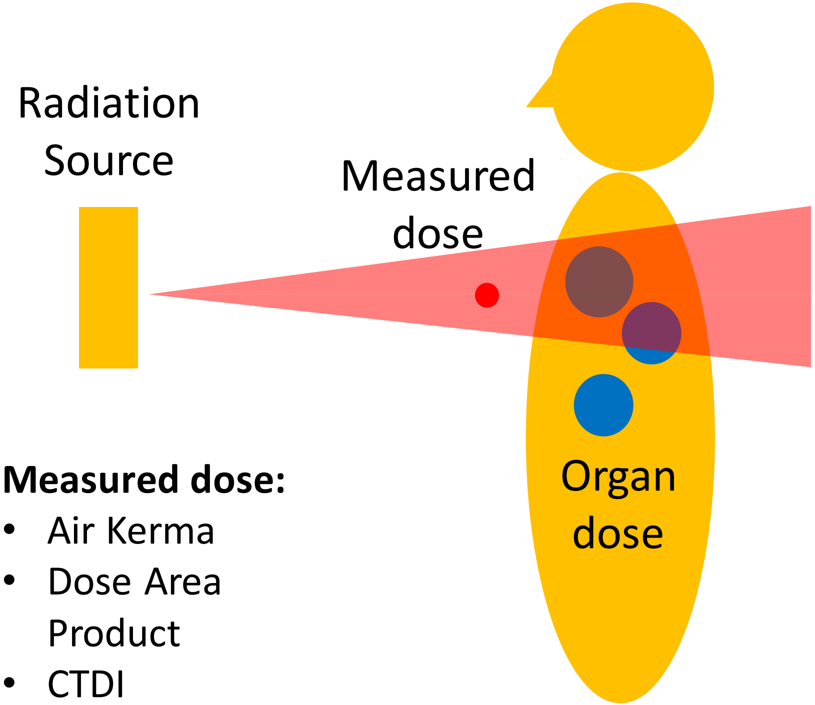


In some environmental dosimetry where the information for the step 1 & 2 are known (e.g., I-131 inhalation in Chernobyl population and its concentration in the thyroid), direct measurements are conducted.

Radioactivity measurements for the thyroid in Ukraine and Belarus

Organ dose conversion coefficients

Derived from computational human phantoms and computer simulation techniques, called Monte Carlo radiation transport

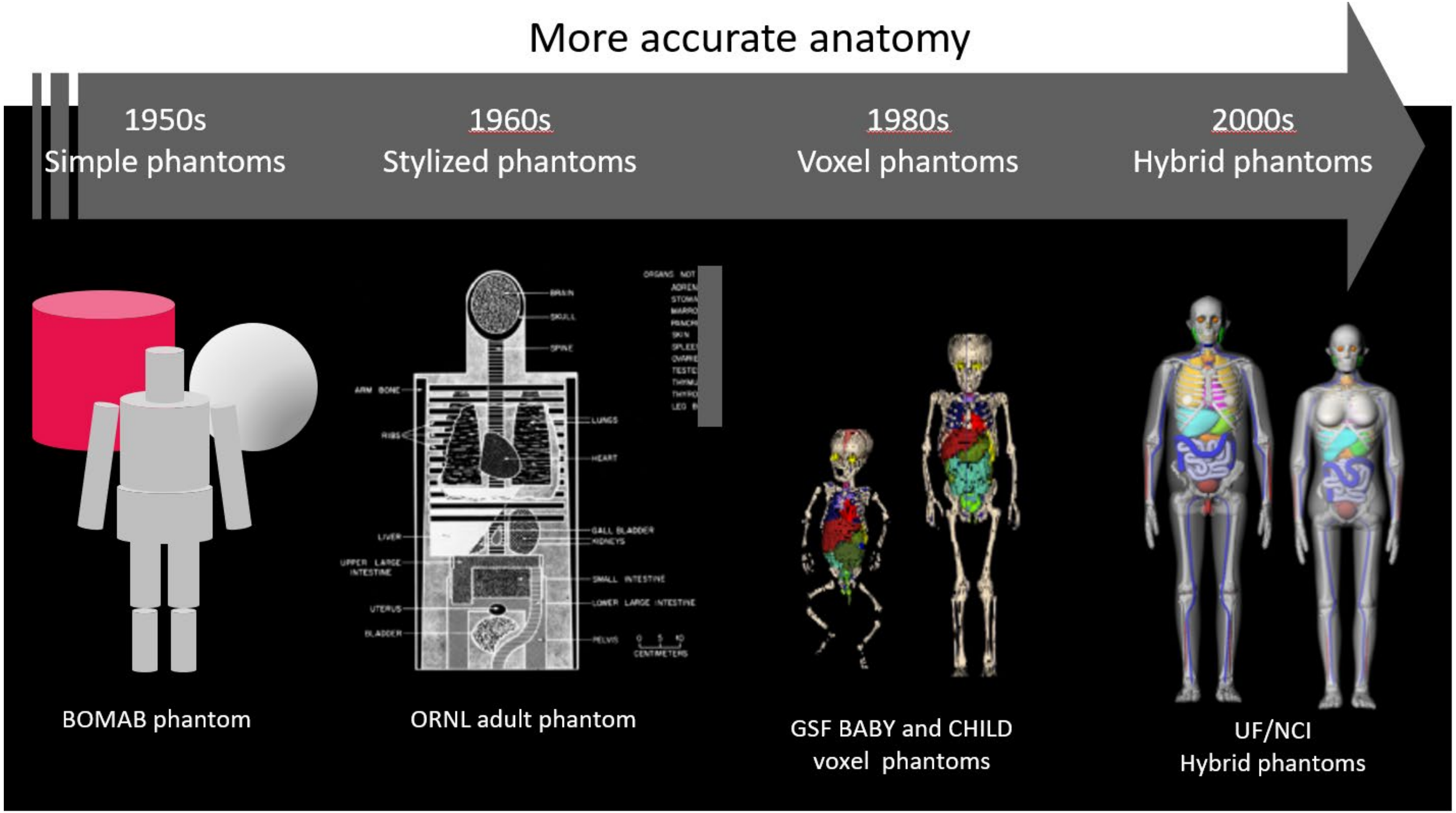


Measured dose:

- Air Kerma
- Dose Area Product
- CTDI

$$\text{Conversion coefficients} = \frac{\text{Organ dose}}{\text{Measured dose}}$$

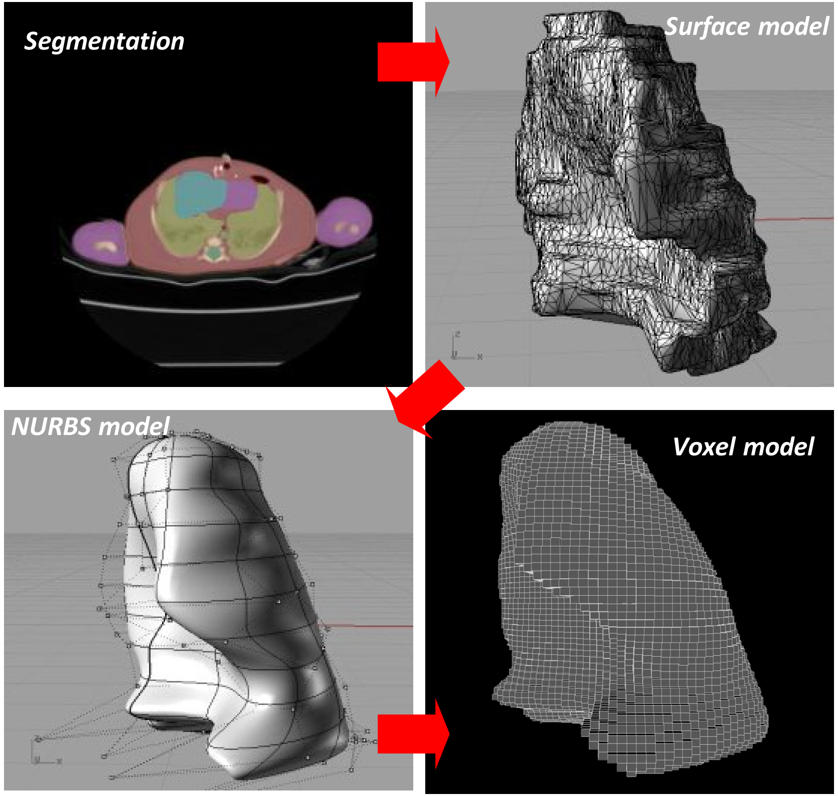
Evolution of Computational Human Phantoms



Procedure to develop hybrid phantom

Contour organs from CT images of patients

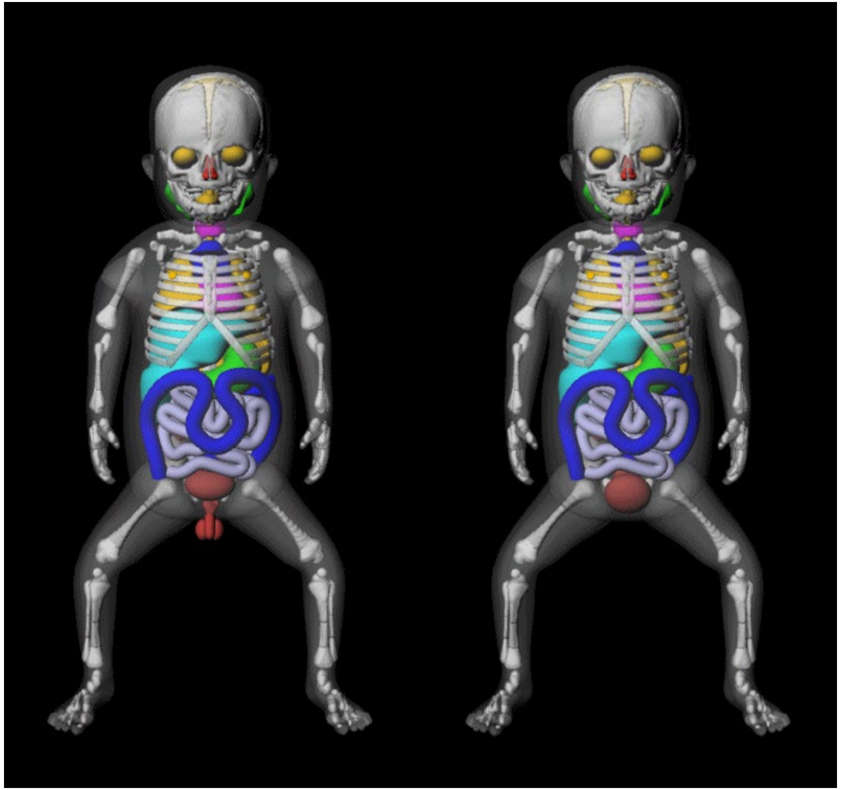
Build surface models from organ contours



Smoother and more flexible than surface models

Convert to voxel models for Monte Carlo calculations

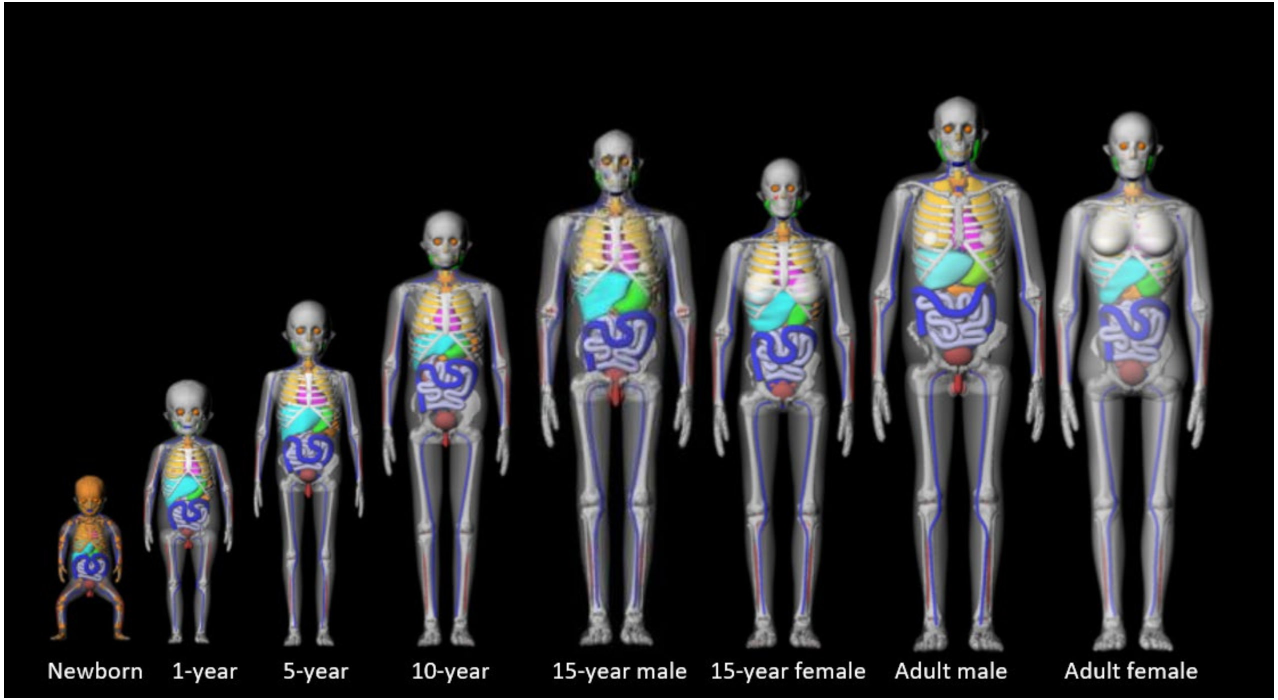
World-first newborn hybrid phantom*



UF/NCI hybrid male (left) and female (right) newborn phantoms

*Lee et al. PMB 2007

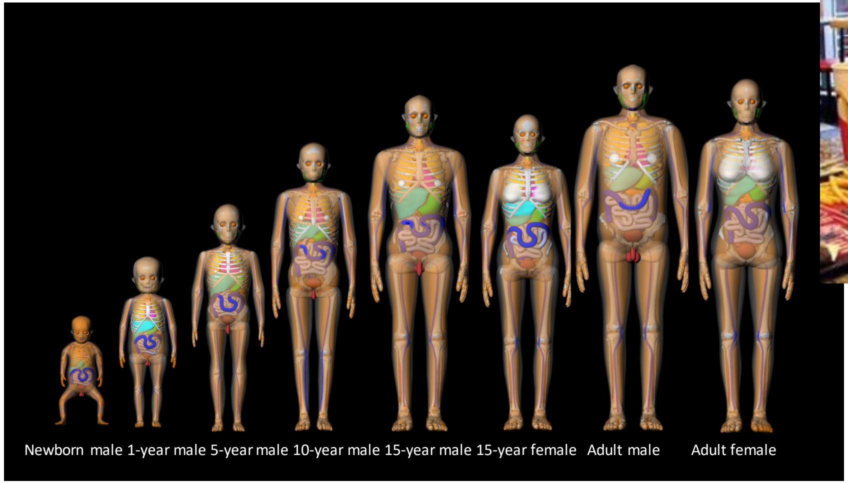
A series of Hybrid Phantoms (2006-2013)



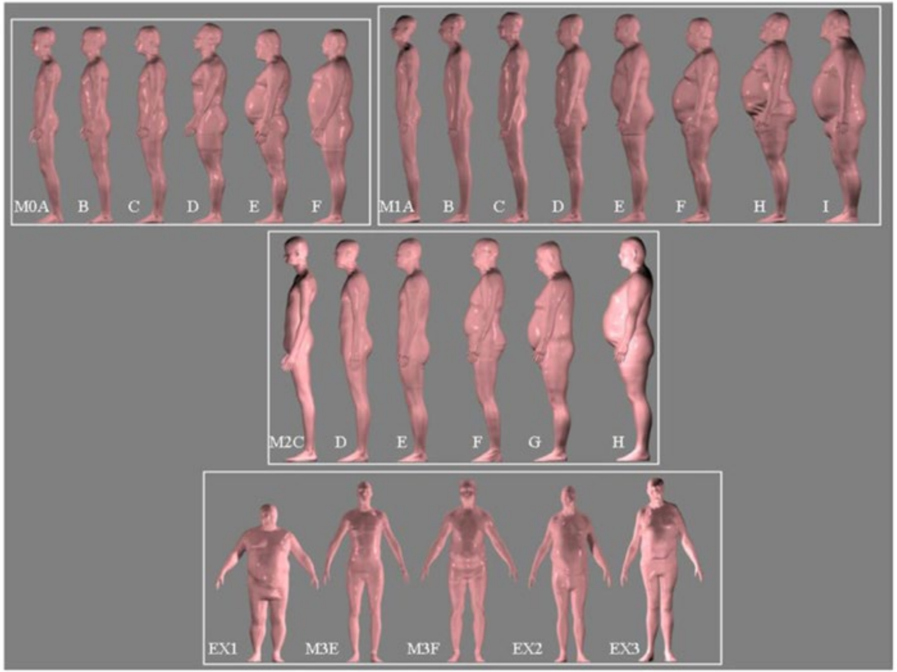
* Lee et al, PMB 2007, MP 2008, PMB 2010

Body size-specific phantoms (1)

- Body size significantly varies among patients at the same age
- Radiation dose depends on body size



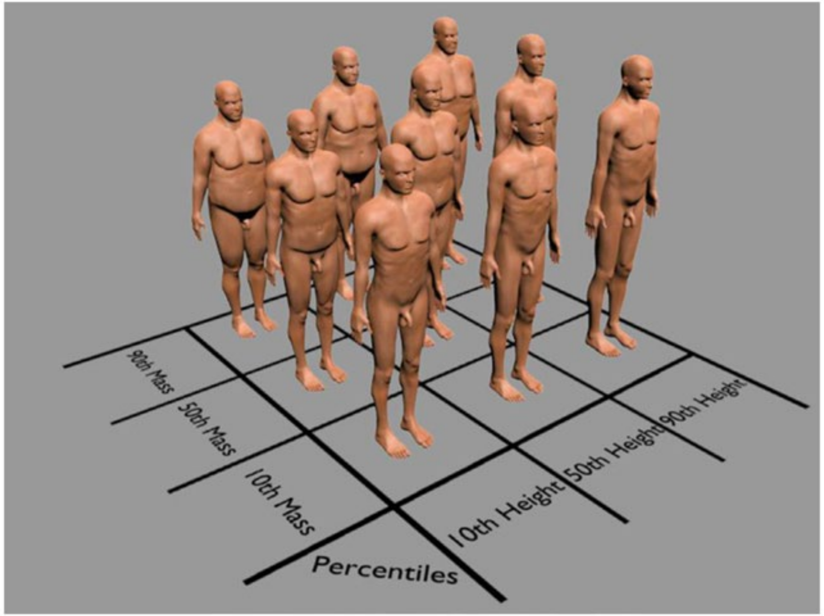
Body size-specific phantoms (2)



Extension of MASH and FASH **adult male/female** phantoms

***Broggio et al. PMB 2011**

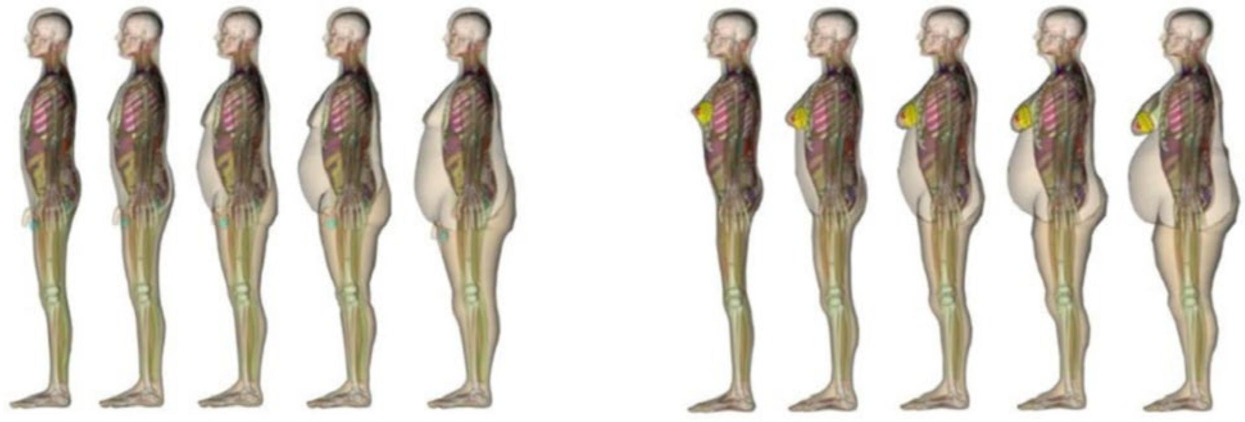
Body size-specific phantoms (3)



Extension of MASH and FASH **adult male/female** phantoms

***Cassola et al. PMB 2011**

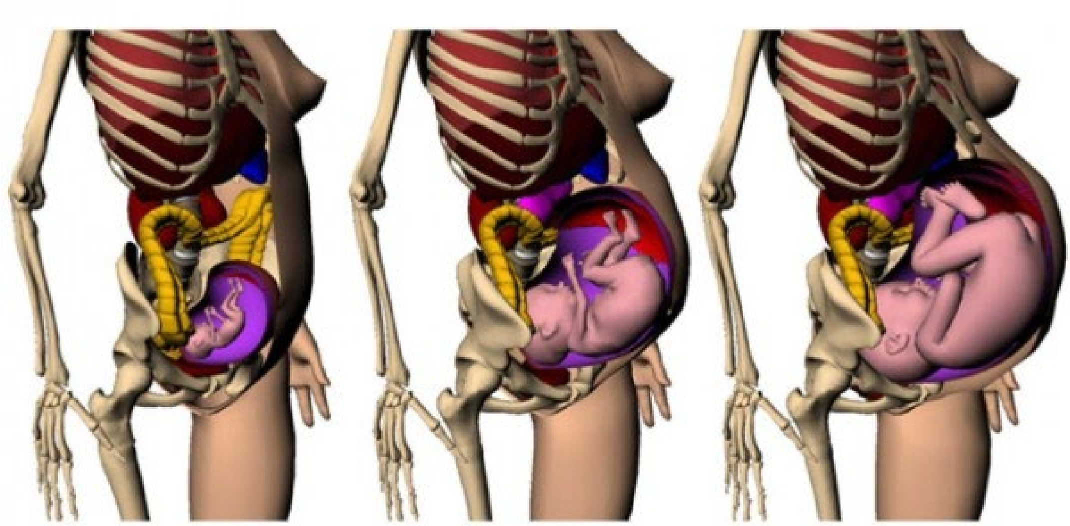
Body size-specific phantoms (4)



Extension of RPI **adult male/female** phantoms

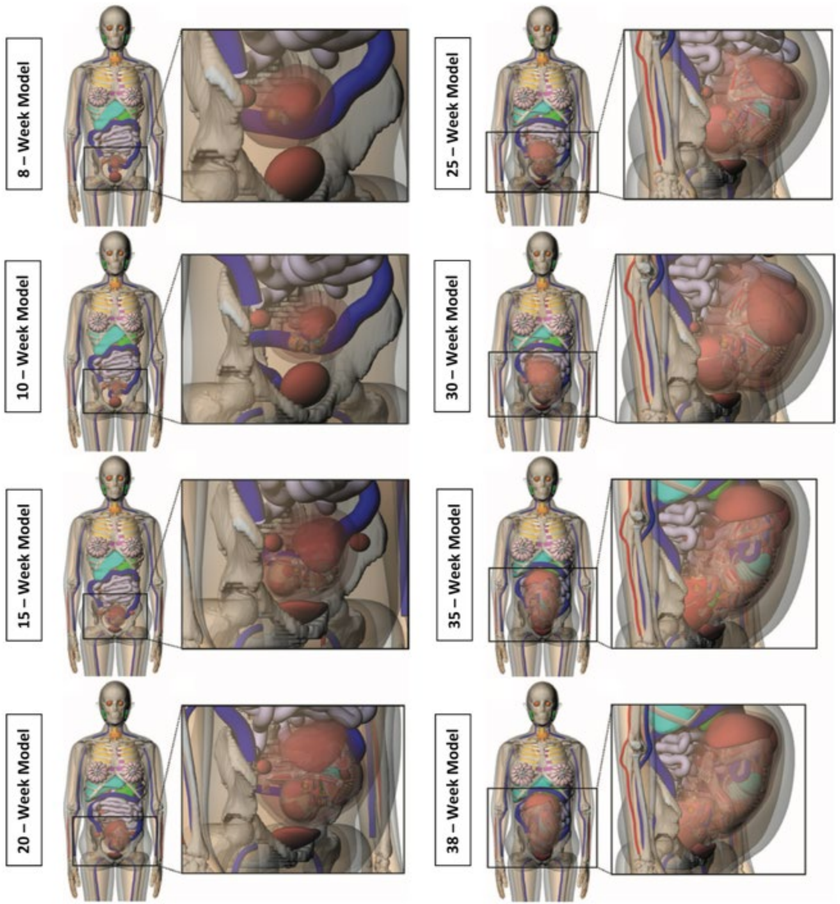
***Ding et al. PMB 2012**

Rensselaer Polytechnic Institute Pregnant Phantom Series*



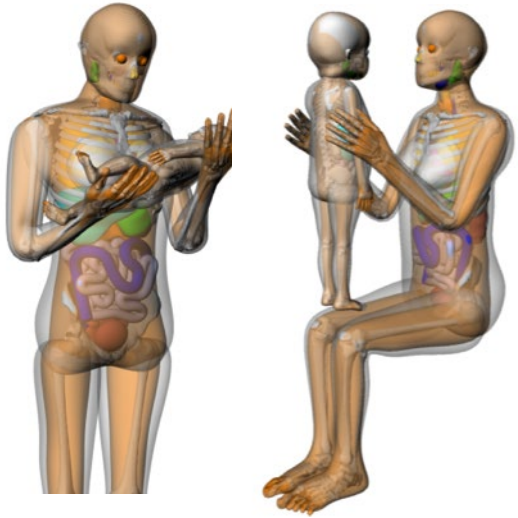
*Xu et al. PMB 2007

University of Florida Pregnant Phantom Series*

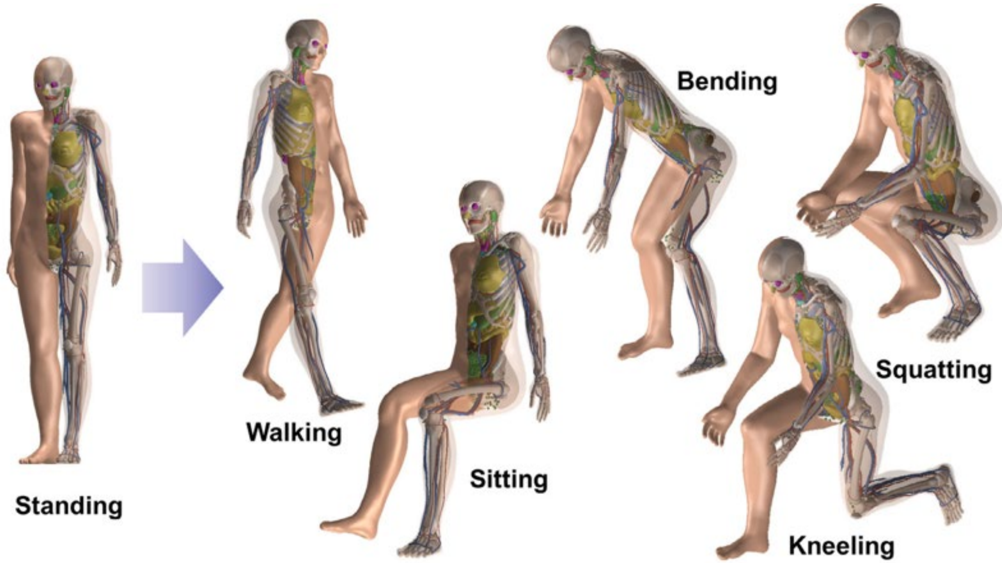


*Maynard et al. PMB 2014

Phantoms in different postures (1)



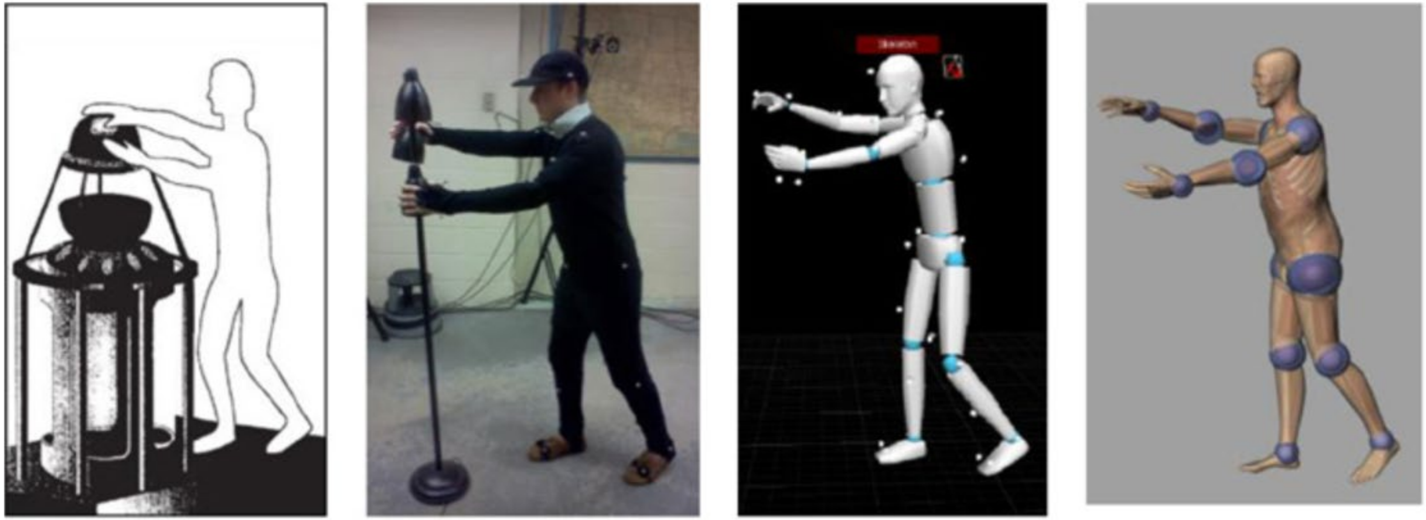
Patient and baby phantoms used in the study of release criteria for patients treated by I-131*



ICRP adult female phantom in different postures**

***Han et al. MP 2013, ** Yeom et al. PMB 2019**

Phantoms in different postures (2)

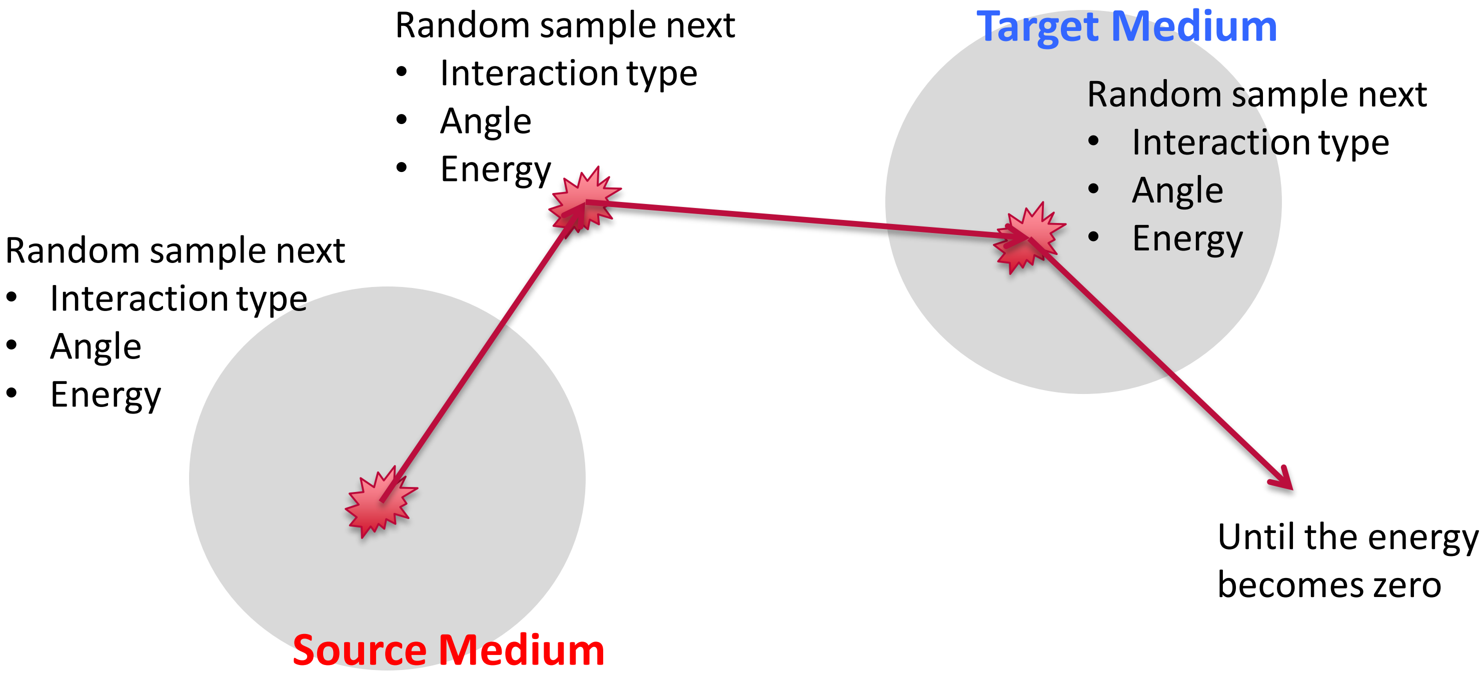


Body posture-specific phantom developed from motion capture technology*

***Vazquez et al. PMB 2014**

3D Monte Carlo radiation transport

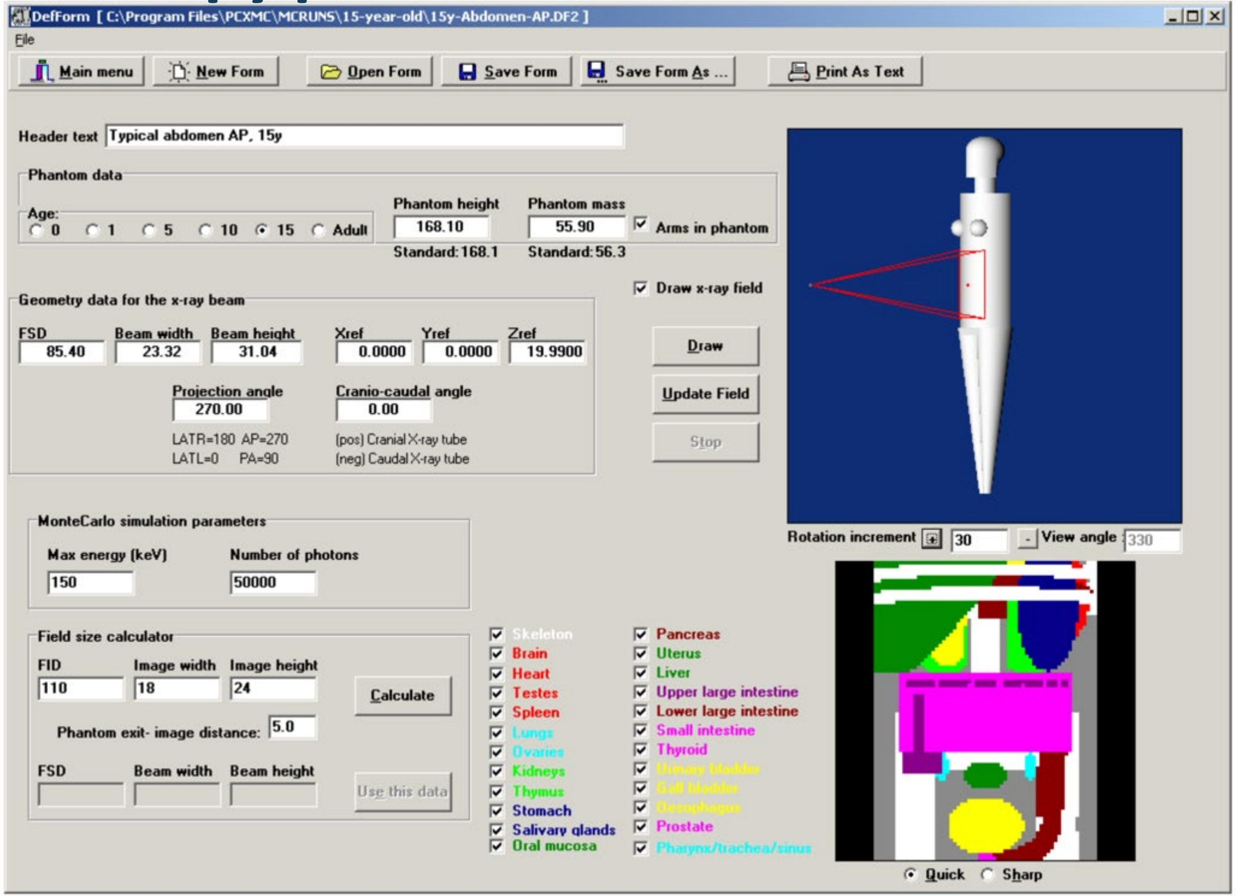
A statistical approach for the physical phenomena based upon random number and the probability functions



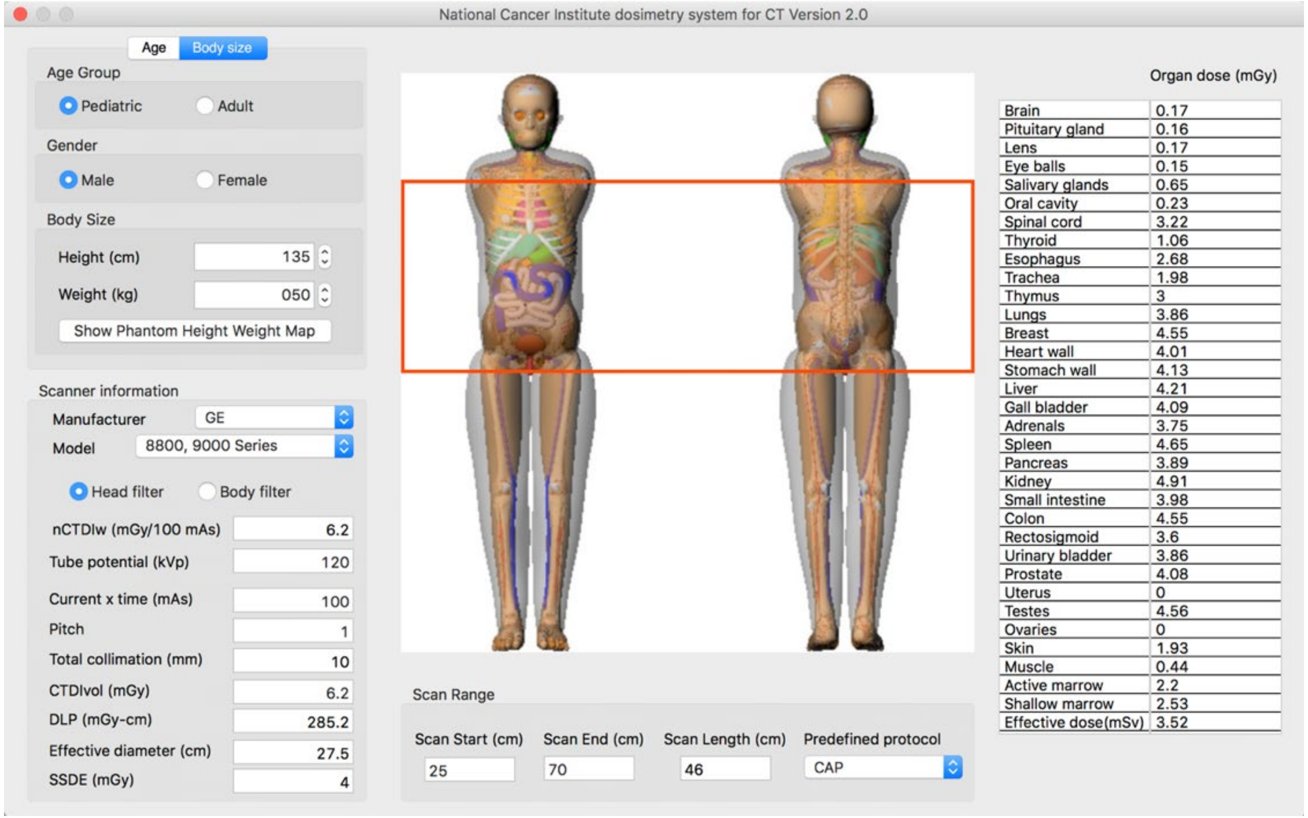
Types of dose conversion coefficients

- **Environmental**
  - Ground contamination
  - Internal dosimetry for ingestion or inhalation of radioisotope
- **Occupational**
  - External exposure in idealized geometries (ICRP Publication 51, 74, and 103)
- **Medical**
  - Radiography/simple fluoroscopy
  - Computed tomography scans
  - Nuclear medicine

PCXMC, organ dose calculator for radiography/fluoroscopy procedures

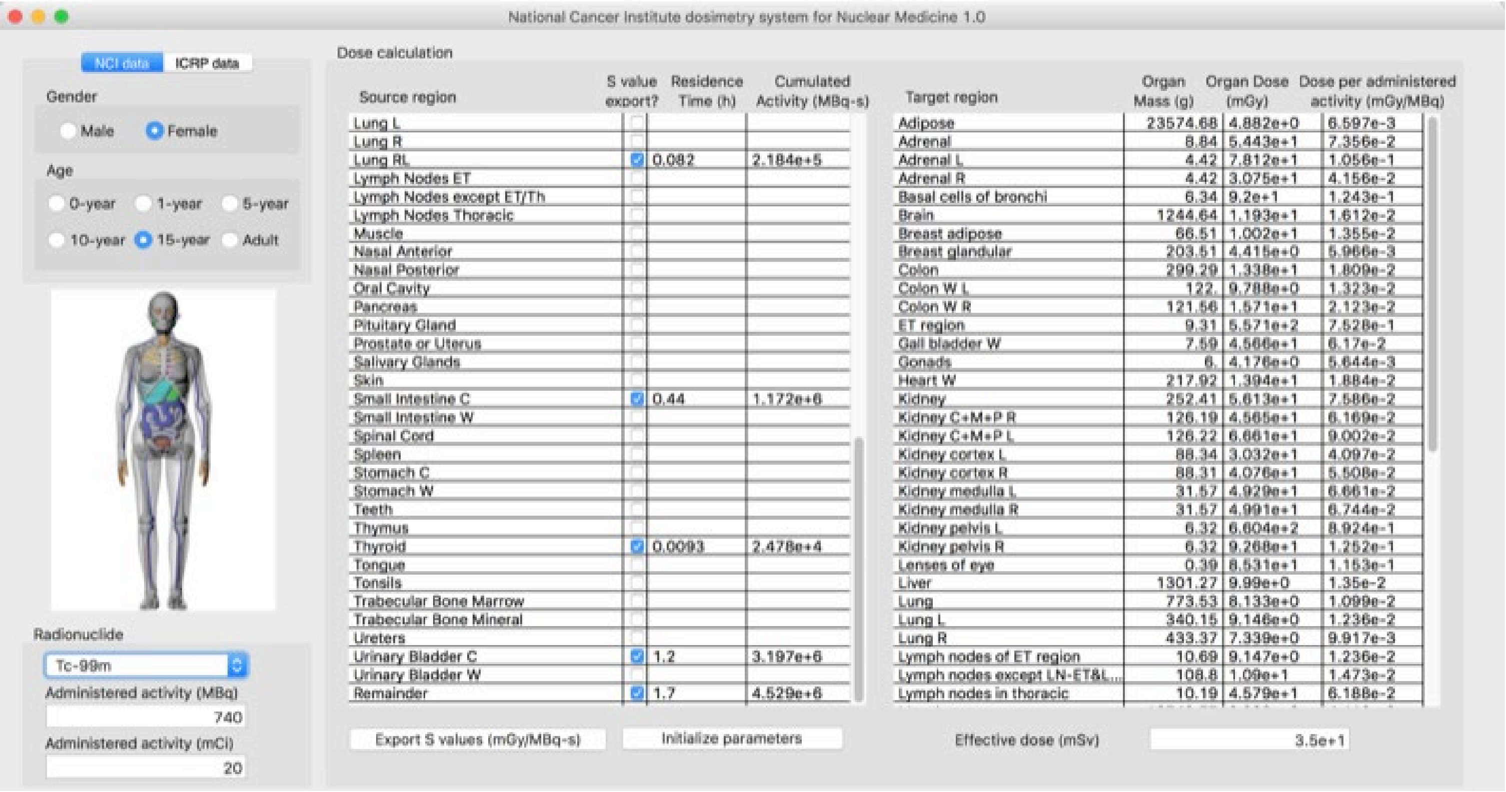


NCICT: National Cancer Institute dosimetry system for Computed Tomography



Lee et al. JRP (2015)

NCINM: National Cancer Institute dosimetry system for Nuclear Medicine



Villoing et al. (in preparation)

NCI Dose Website - http://ncidose.cancer.gov

NATIONAL CANCER INSTITUTE
Division of Cancer Epidemiology & Genetics

NCIDose

Home | Phantoms | NCICT | NCINM | Dose Coefficients | References | Agreement

NCIDOSE is a collection of medical radiation dosimetry tools developed by radiation physicists from the National Cancer Institute (NCI), Division of Cancer Epidemiology and Genetics, Radiation Epidemiology Branch. These tools can be used to estimate the radiation organ doses received by patients undergoing diagnostic or therapeutic procedures. The resources are the product of years of research and development in collaboration with a number of institutions, much of which has been published in the peer-reviewed literature. As a governmental resource these tools are available to the public free-of-charge for non-commercial research purposes.

The following resources are currently available or under development:

- PHANTOMS, three-dimensional computational human anatomy models
- NCICT, NCI dosimetry system for Computed Tomography
- NCINM, NCI dosimetry system for Nuclear Medicine
- NCIRF, NCI dosimetry system for Radiography and Fluoroscopy (under development)
- Dose Conversion Coefficients

How Can I Request These Resources?

Non-Commercial Research Use
There is no charge to use for non-commercial research purposes. Please submit a Software Transfer Agreement form to Dr. Choonsik Lee.

Commercial or Other Use
Contact Dr. Kevin Chang of the NCI Technology Transfer Center to discuss the licensing process.

Uncertainties

Uncertainty increases when unknowns increase in CT (1)

Patient anatomy, scan start/end, scanner model, tube potential, current-time product, pitch

Uncertainty increases when unknowns increase in CT (2)

Patient anatomy, scan start/end, scanner model, tube potential, current-time product, pitch

Patient side parameters

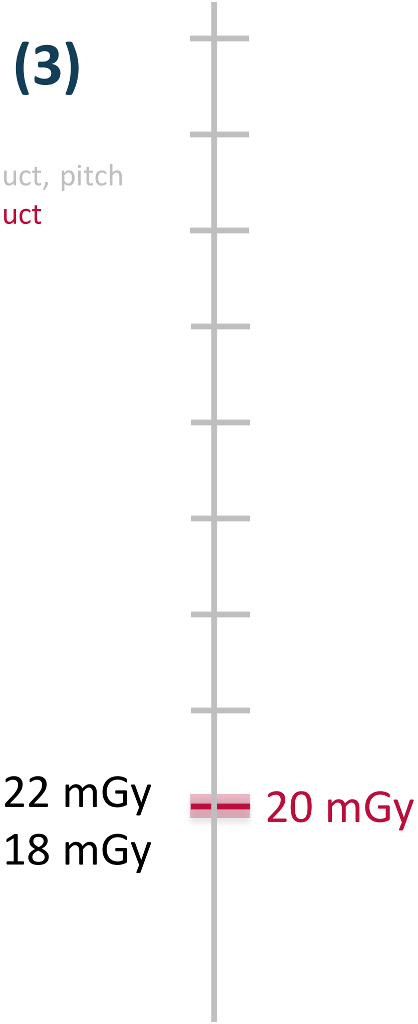
Machine side parameters

Liver dose in abdominal CT scan: 20 mGy

Uncertainty increases when unknowns increase in CT (3)

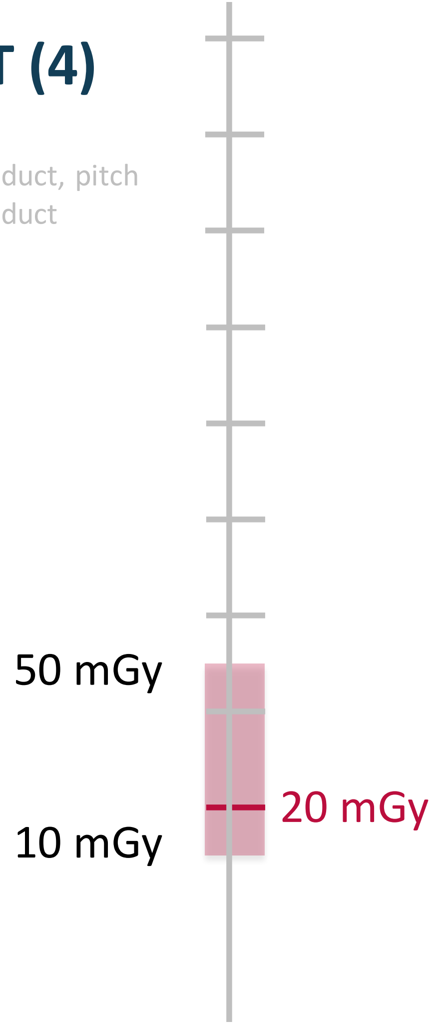
Patient anatomy, scan start/end, scanner model, tube potential, current-time product, pitch

Patient anatomy, scan start/end, scanner model, tube potential, current-time product



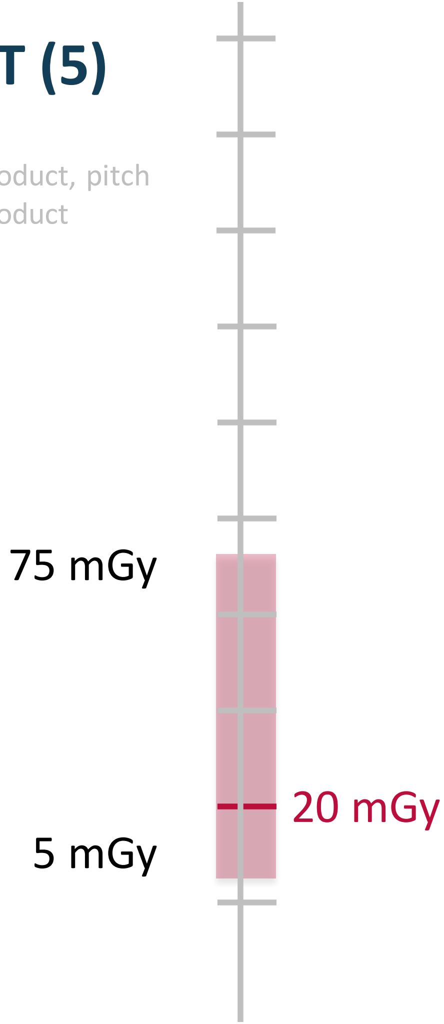
Uncertainty increases when unknowns increase in CT (4)

Patient anatomy, scan start/end, scanner model, tube potential, current-time product, pitch
Patient anatomy, scan start/end, scanner model, tube potential, current-time product
Patient anatomy, scan start/end, scanner model, tube potential



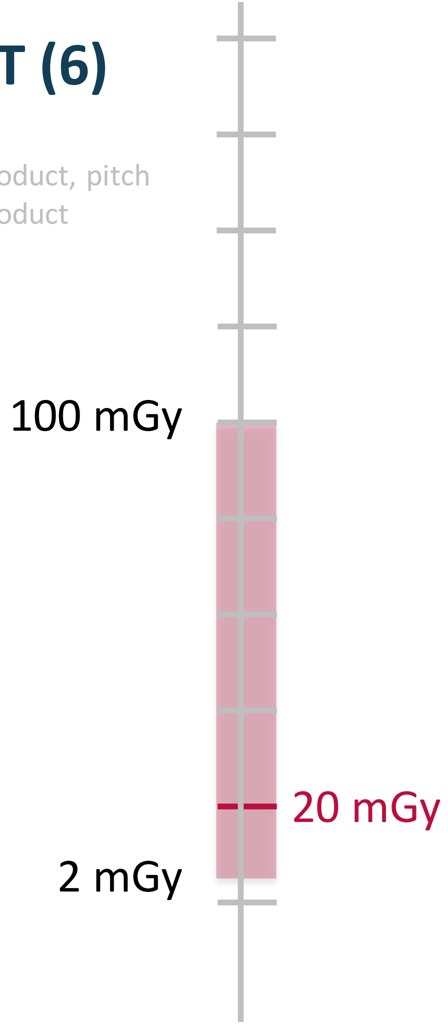
Uncertainty increases when unknowns increase in CT (5)

Patient anatomy, scan start/end, scanner model, tube potential, current-time product, pitch
Patient anatomy, scan start/end, scanner model, tube potential, current-time product
Patient anatomy, scan start/end, scanner model, tube potential
Patient anatomy, scan start/end, scanner model



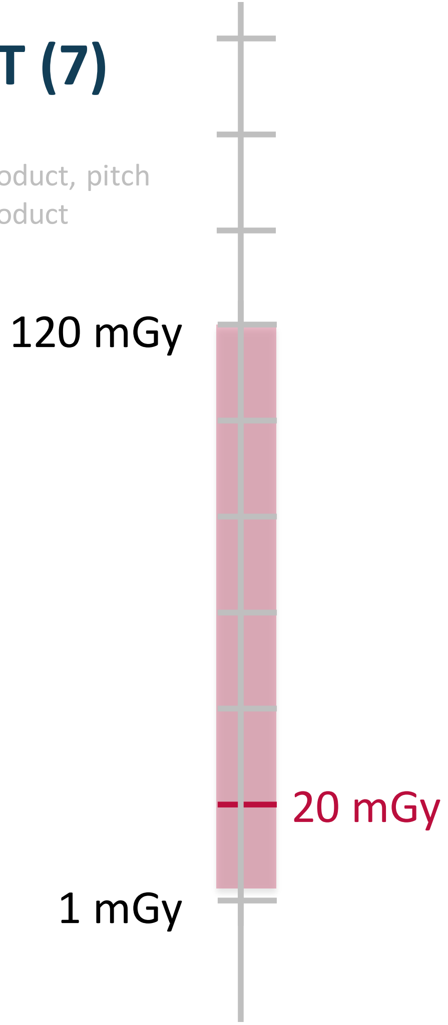
Uncertainty increases when unknowns increase in CT (6)

Patient anatomy, scan start/end, scanner model, tube potential, current-time product, pitch
Patient anatomy, scan start/end, scanner model, tube potential, current-time product
Patient anatomy, scan start/end, scanner model, tube potential
Patient anatomy, scan start/end, scanner model
Patient anatomy, scan start/end

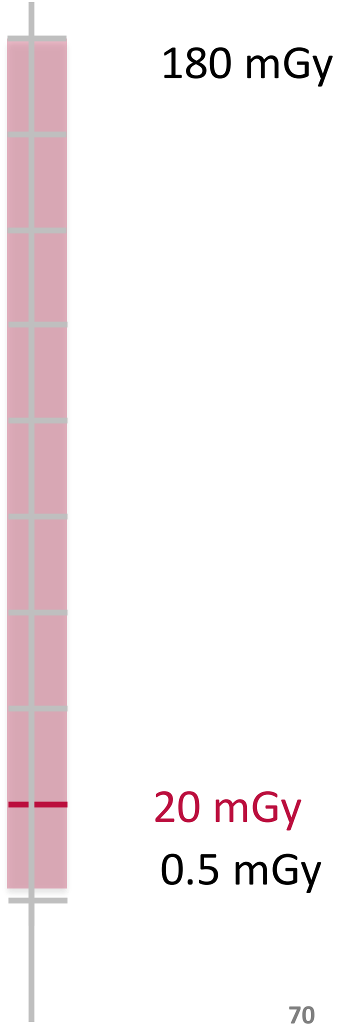


Uncertainty increases when unknowns increase in CT (7)

Patient anatomy, scan start/end, scanner model, tube potential, current-time product, pitch
Patient anatomy, scan start/end, scanner model, tube potential, current-time product
Patient anatomy, scan start/end, scanner model, tube potential
Patient anatomy, scan start/end, scanner model
Patient anatomy, scan start/end
Patient anatomy



Uncertainty increases when unknowns increase in CT (8)



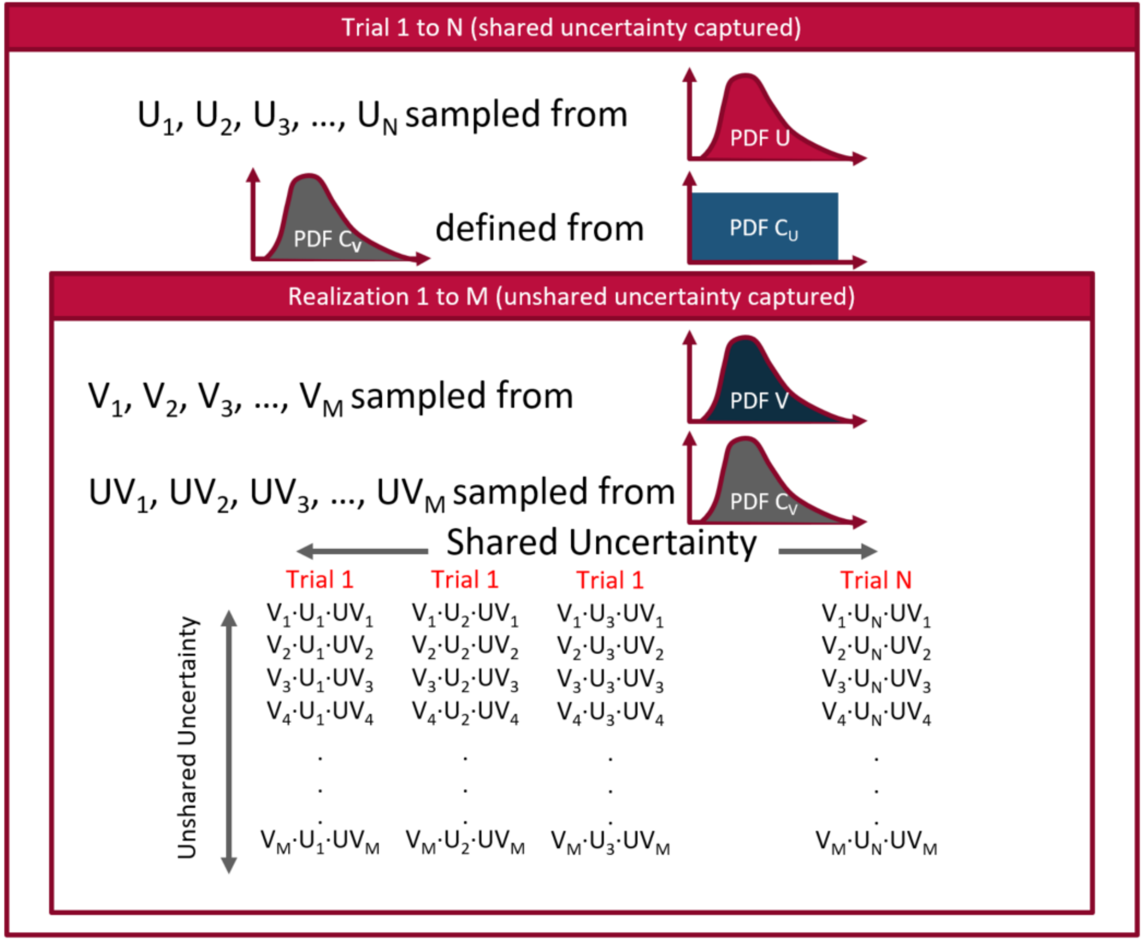
Patient anatomy, scan start/end, scanner model, tube potential, current-time product, pitch
Patient anatomy, scan start/end, scanner model, tube potential, current-time product
Patient anatomy, scan start/end, scanner model, tube potential
Patient anatomy, scan start/end, scanner model
Patient anatomy, scan start/end
Patient anatomy
Patient age

Uncertainty-incorporated dosimetry: 2DMC technique*

- Provides alternative (possibly true) sets of doses for an entire cohort rather than a single set
- Shared and unshared uncertainties are properly incorporated into dosimetry

*Simon et al. Radiation Research 183:27-41 (2015)

2-Dimensional Monte Carlo method to calculation multiple doses incorporating uncertainty and variability



Summary

- Accurate exposure assessment is crucial in high quality epidemiological studies of cohorts exposed to environmental, occupational, and medical radiation sources
- Reconstruction of accurate and individualized organ dose for a large number of subjects often involves many challenges
- Dosimetry approaches in epidemiological studies include internal and external dosimetry depending on the irradiation scenarios
- Uncertainty must be recognized, quantified, and incorporated into risk analysis

Quiz question #1

What is the dose quantity that can be used for epidemiological investigations?

1. Effective dose
2. Organ dose
3. Equivalent dose
4. Kerma

Quiz question #1

What is the dose quantity that can be used for epidemiological investigations?

1. Effective dose
2. Organ dose
3. Equivalent dose
4. Kerma

Quiz question #2:

You have a kerma measurement of 10 mGy and the kerma-to-lung dose conversion coefficients of 0.7 mGy/mGy. What is your lung dose?

1. 0.7 mGy
2. 7 mGy
3. 10 mGy
4. 70 mGy

Quiz question #2:

You have a kerma measurement of 10 mGy and the kerma-to-lung dose conversion coefficients of 0.7 mGy/mGy. What is your lung dose?

1. 0.7 mGy
2. 7 mGy
3. 10 mGy
4. 70 mGy

Quiz question #3

What would be the uncertainty factor you do not have to consider in your dose reconstruction for patients undergoing computed tomography scans?

1. Patient body size
2. Size of the CT room
3. CT scanner model
4. Body part included in the scan coverage

Quiz question #3

What would be the uncertainty factor you do not have to consider in your dose reconstruction for patients undergoing computed tomography scans?

1. Patient body size
2. Size of the CT room
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