Introduction to Paediatric Mesh-type Reference Computational Phantoms

(Background and Motivation)

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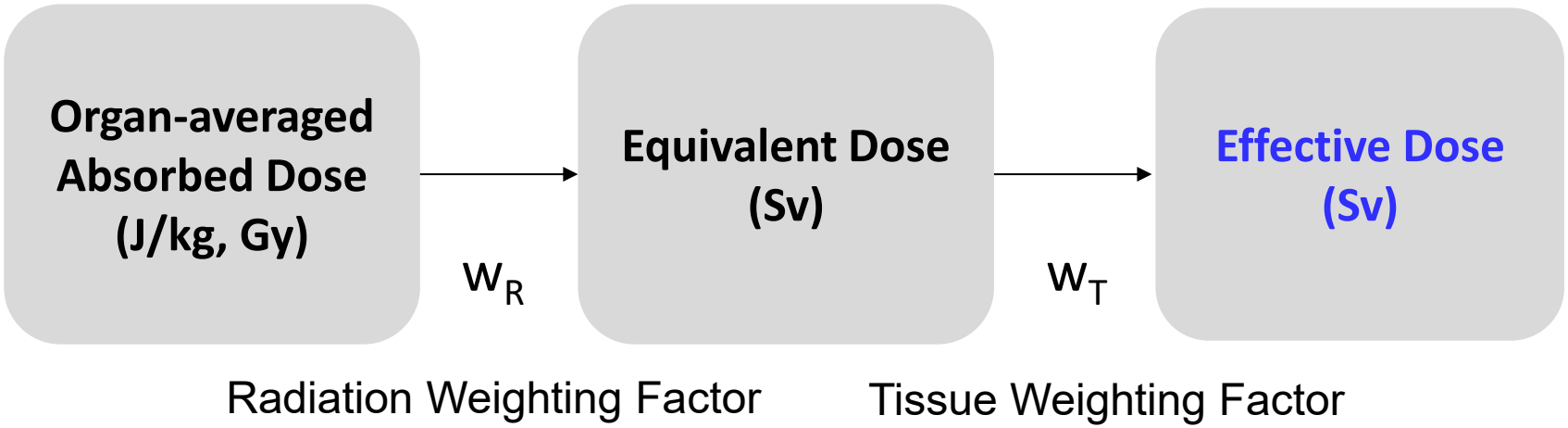
Member, ICRP Committee 2

Member, ICRP Task Group 103

ICRP Webinar, 6 August 2025

Dose Quantities in Radiological Protection

$$H_T = \sum_R w_R D_{T,R} \qquad E = \sum_T w_T \left[\frac{H_T^M + H_T^F}{2} \right]$$



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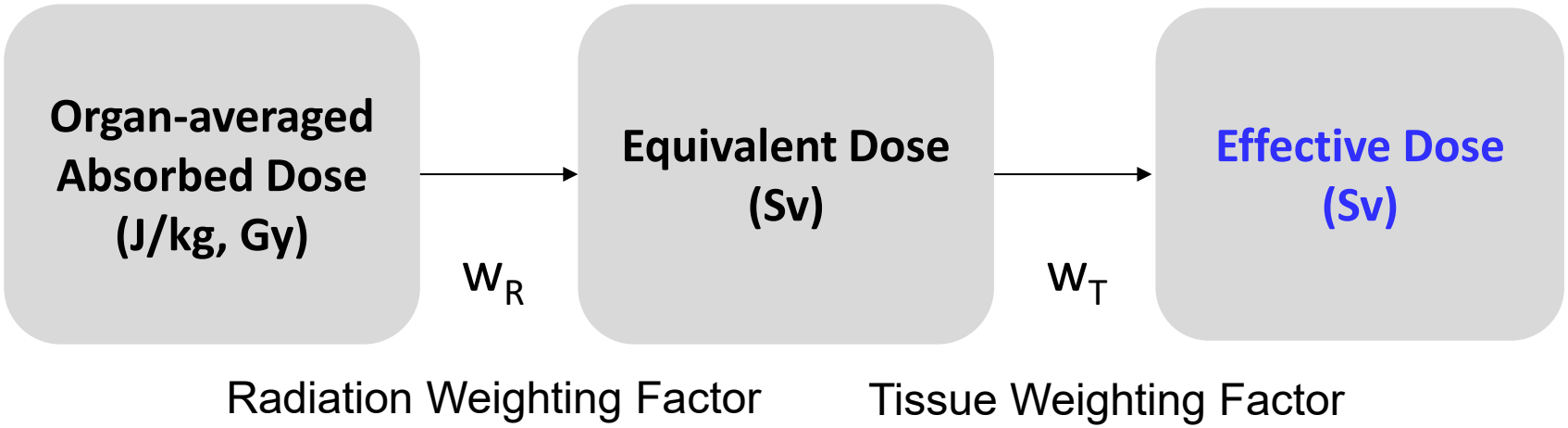

- **Reference Person (sex-averaged)**

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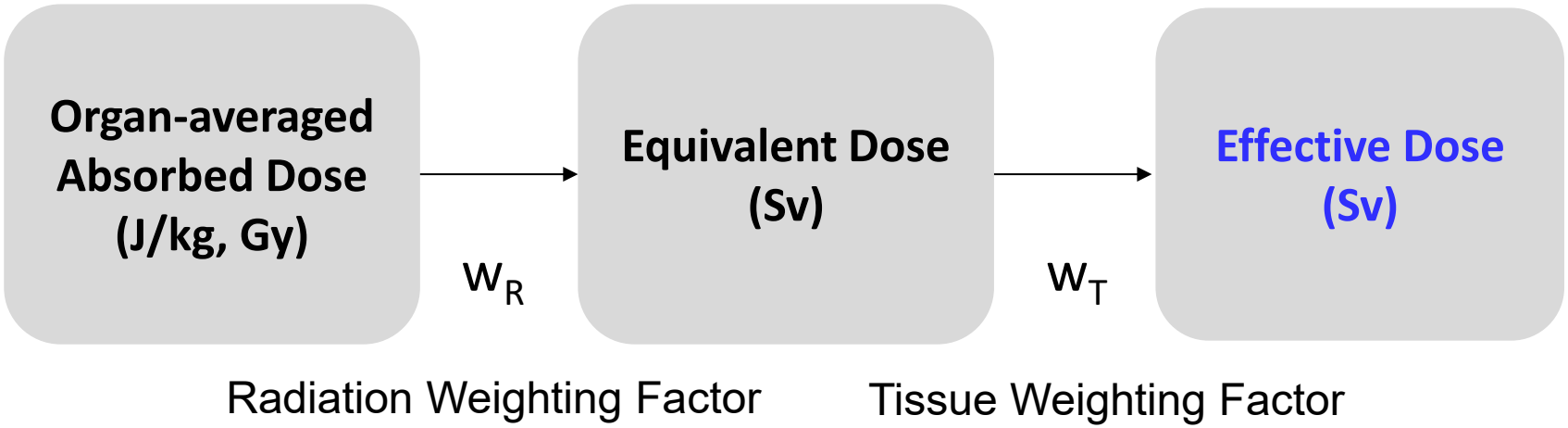

- Reference Person (sex-averaged)
- **Non measurable**

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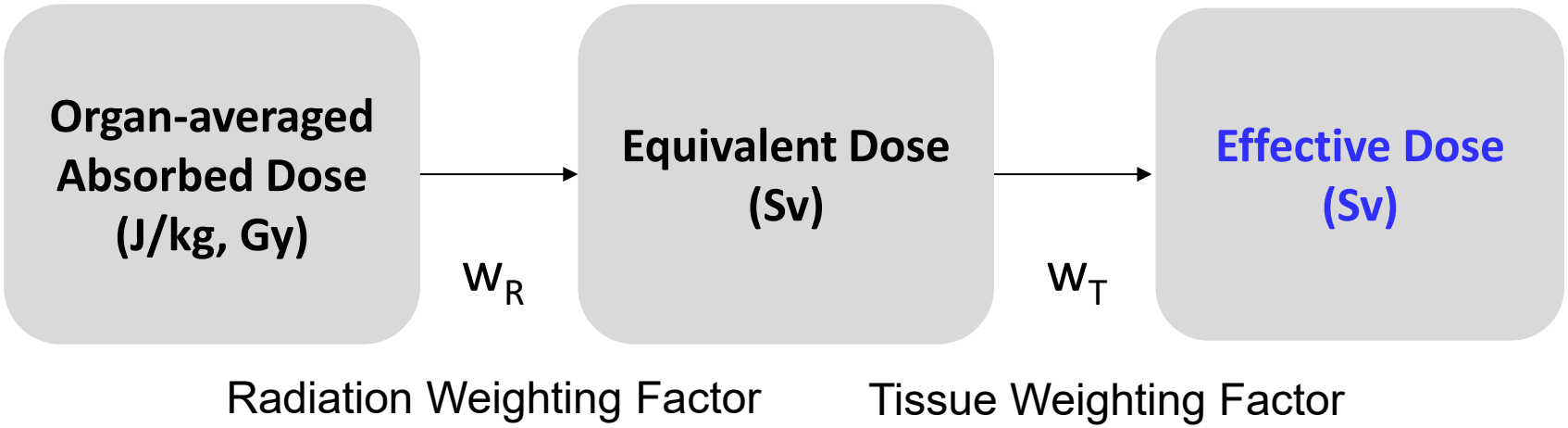

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  - ✓ **Phantoms + Monte Carlo + idealized exposure scenarios**

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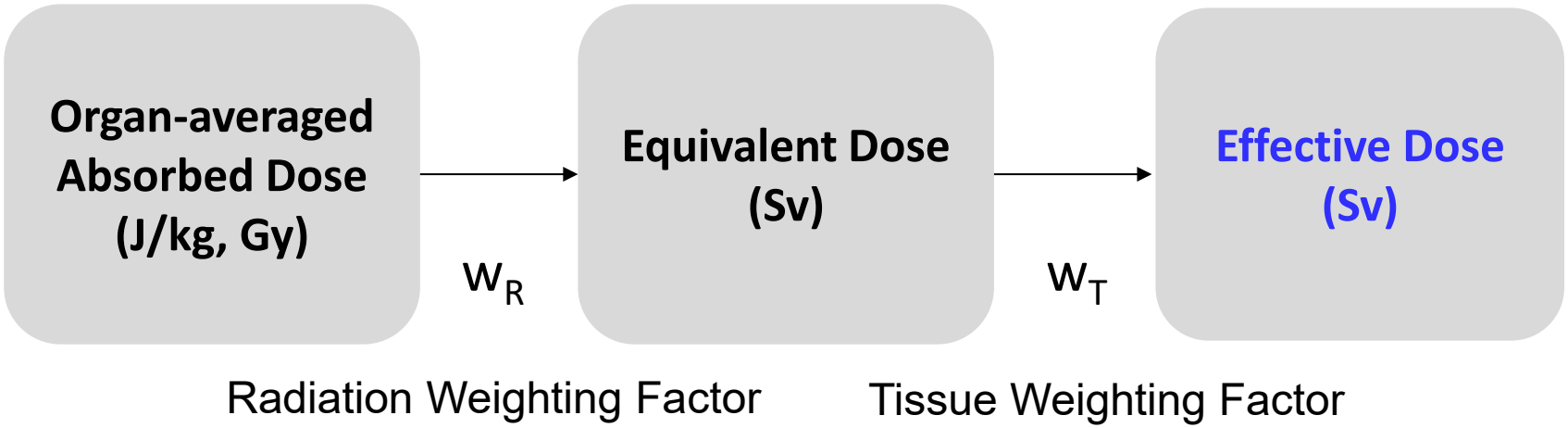
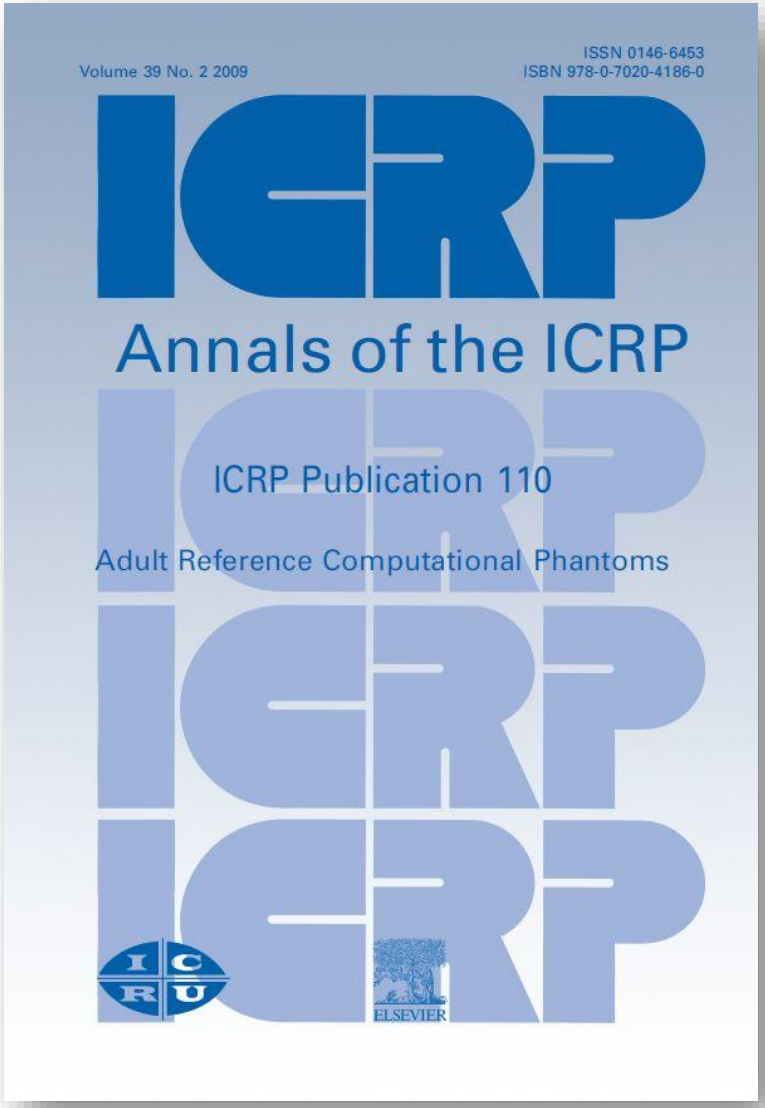


- Reference Person (sex-averaged)
- Non measurable
- Dose coefficients (e.g., fluence / intake → effective dose)
  - ✓ Phantoms + Monte Carlo + idealized exposure scenarios
- **Reference phantoms (ICRP 103 Recommendations)**

VRCPs (Voxel-type Reference Computational Phantoms)

- **Adults (2)** – adult male/female (ICRP 110, 2009)



ICRP Publication 110 (2009)

amVRCP afVRCP

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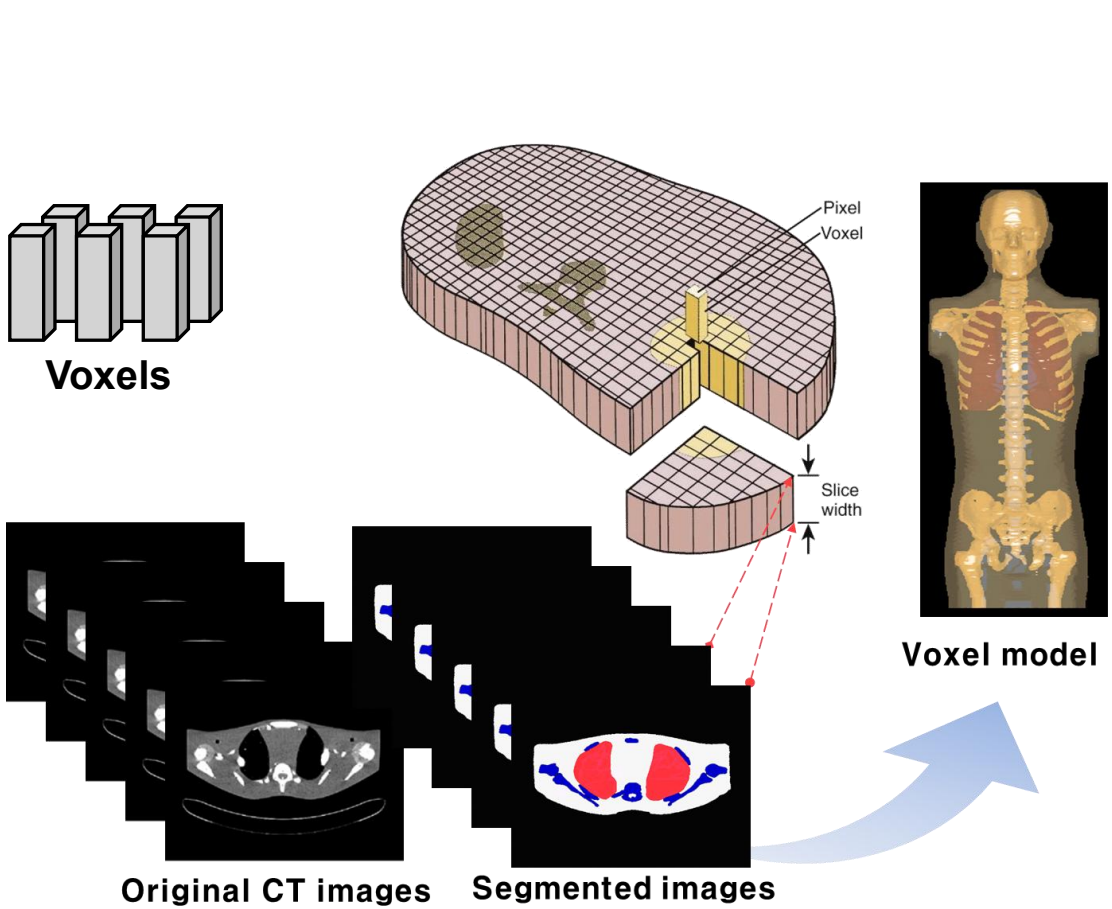

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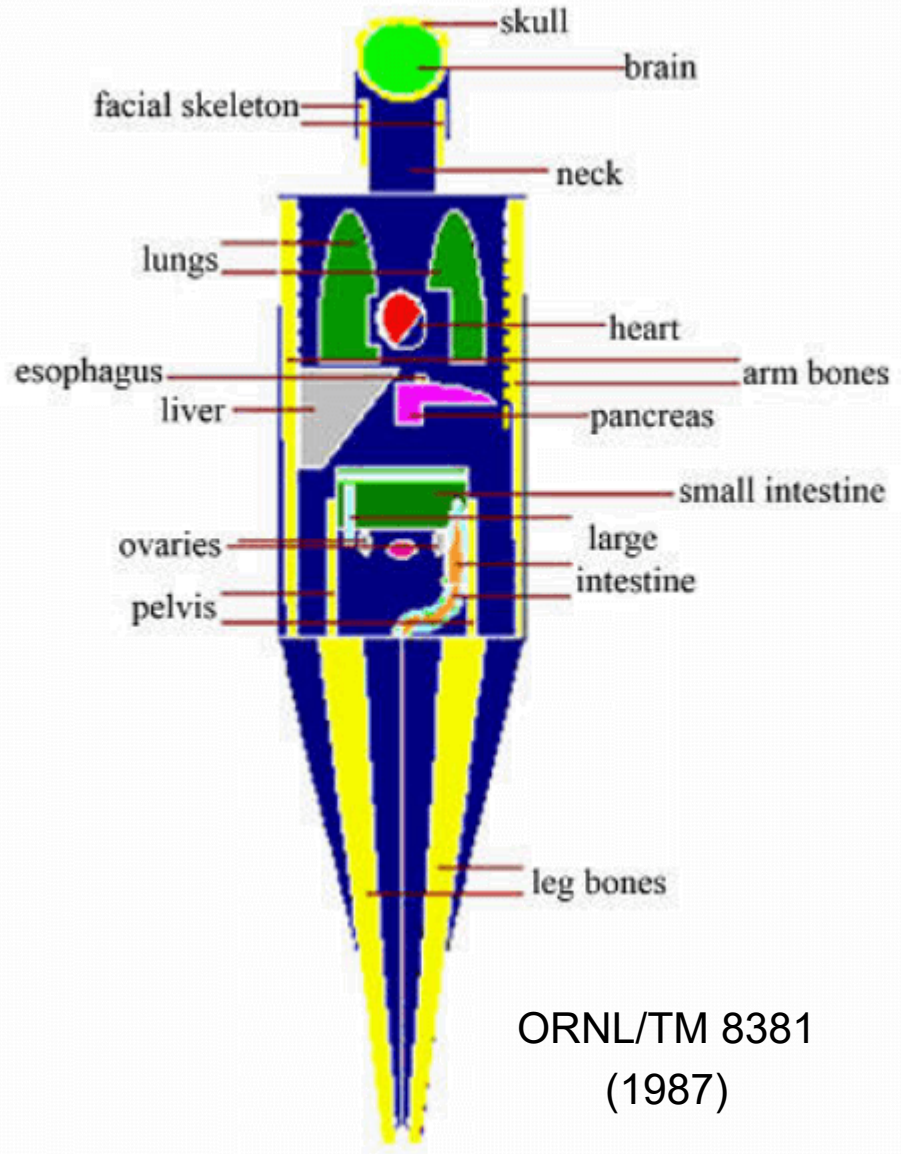
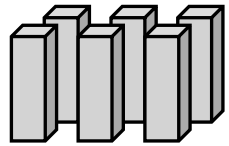


ORNL/TM 8381
(1987)



Voxels

amVRCP afVRCP

VRCPs (Voxel-type Reference Computational Phantoms)

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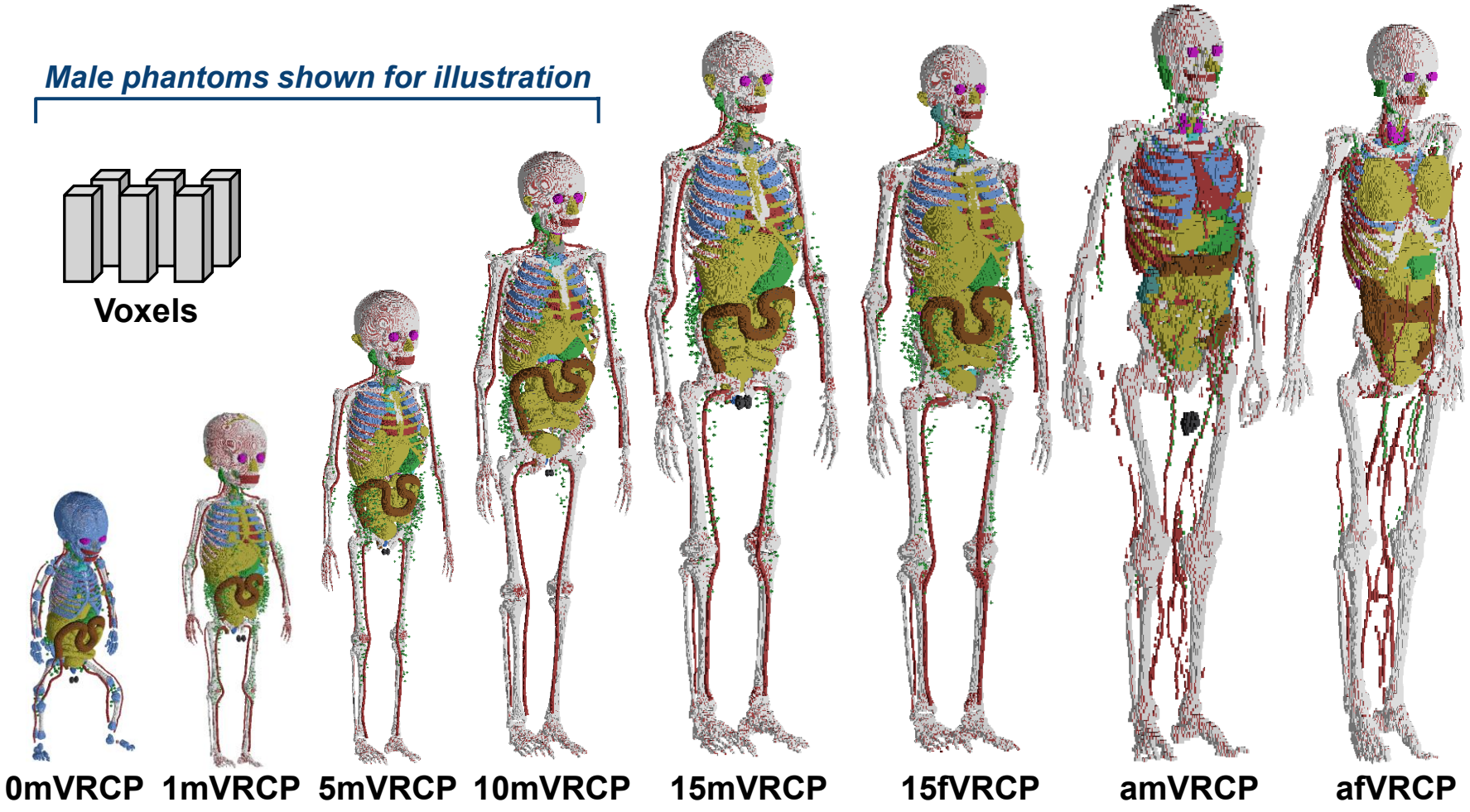
- **Children (10)** – newborn, 1, 5, 10, 15 years male/female (ICRP 143, 2020)



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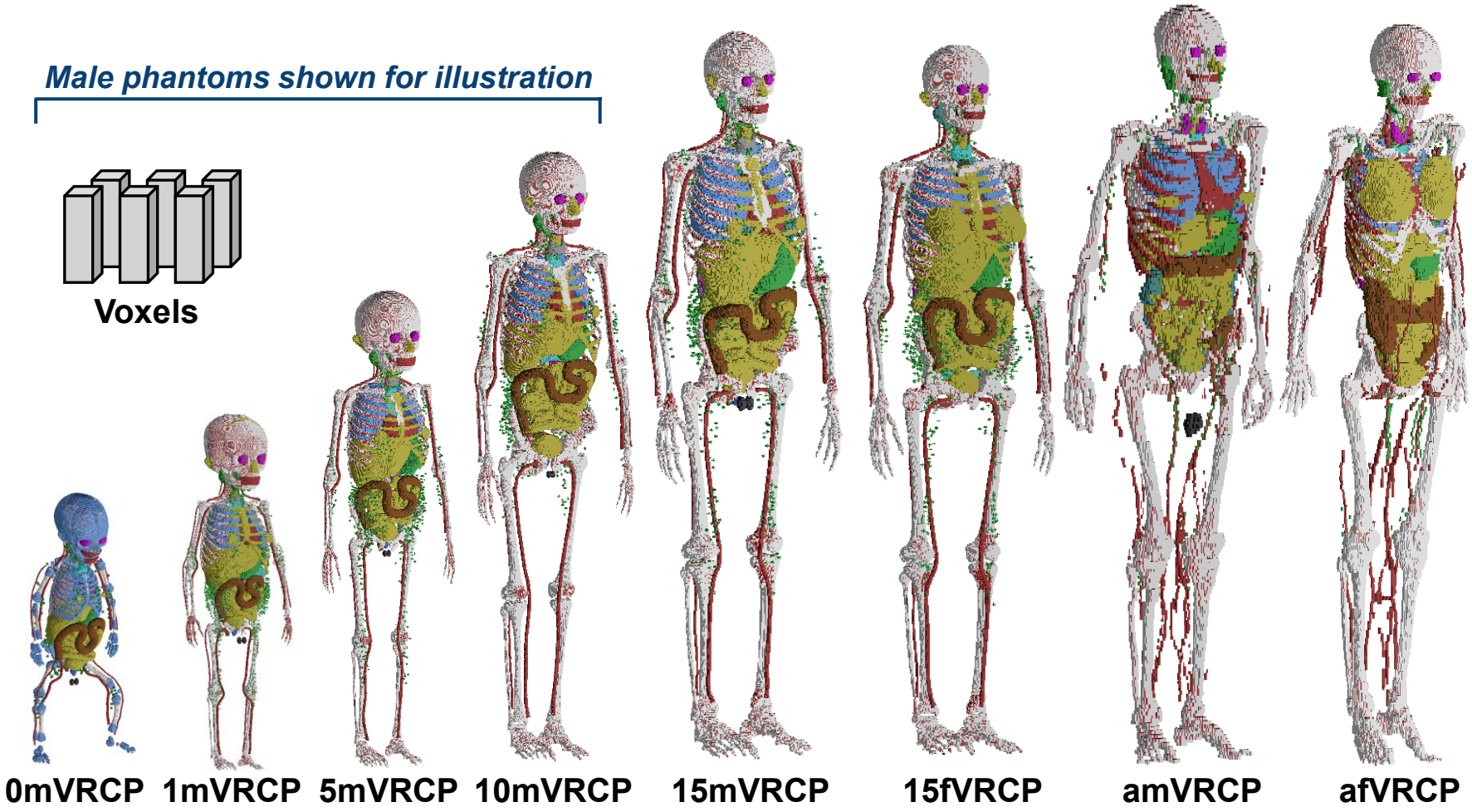
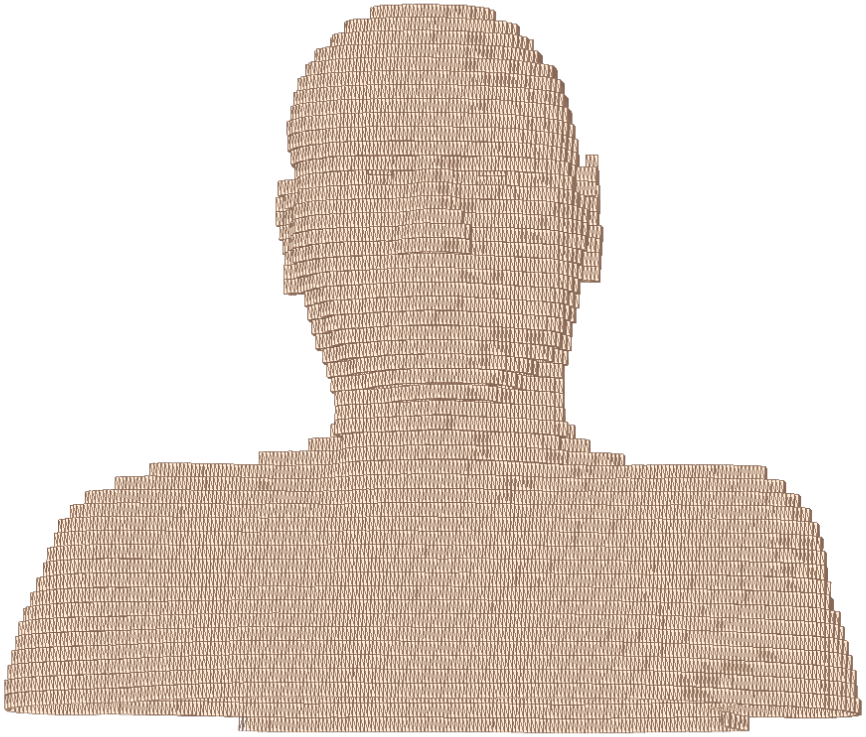
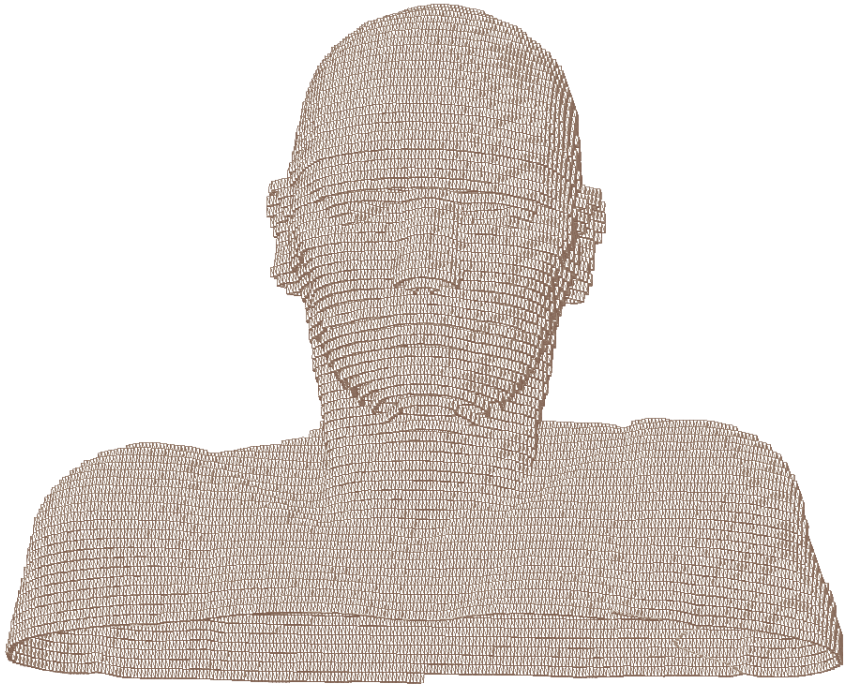


Voxel resolutions: 0.66 – 8.00 mm

VRCP Limitations (Skin)



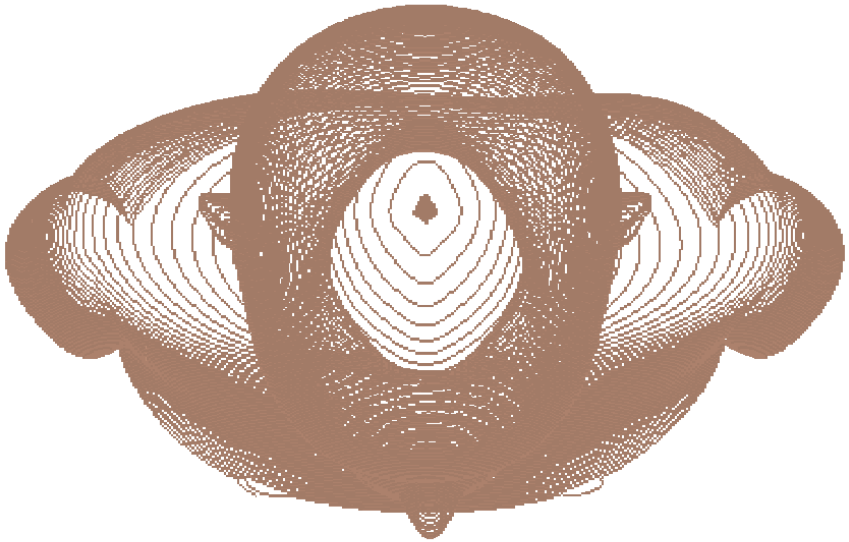
Adult male VRCP
(2.137 × 2.137 × 8 mm^3)



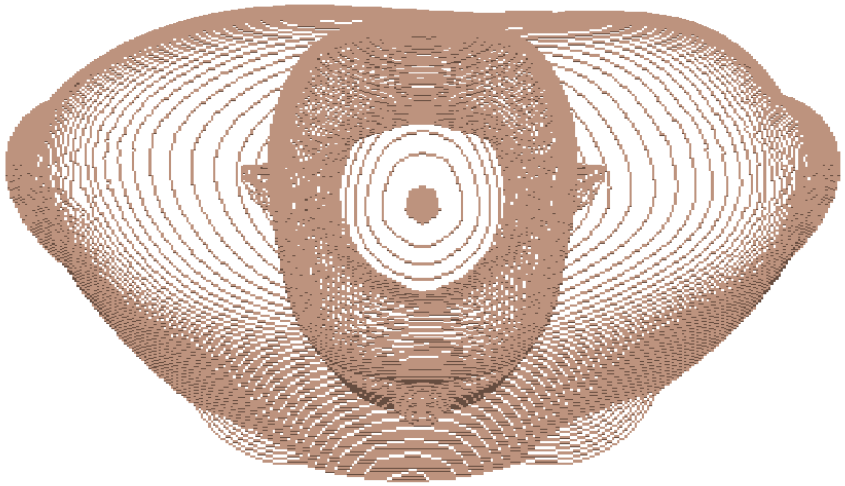
Adult female VRCP
(1.775 × 1.775 × 4.8 mm^3)

"*Discontinuous*"

VRCP Limitations (Skin)



5-year-male VRCP
(0.85 × 0.85 × 1.928 mm^3)

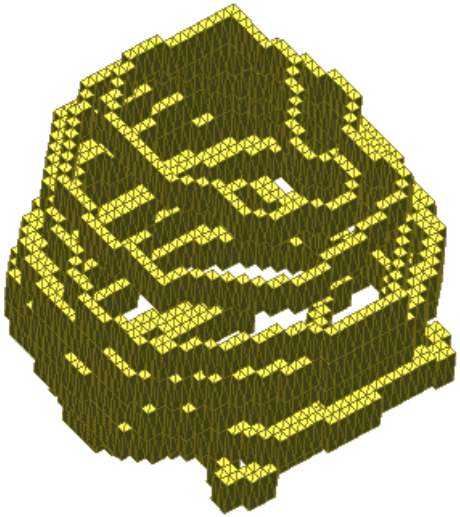


15-year-female VRCP
(1.2 × 1.2 × 2.828 mm^3)

"***Discontinuous***"

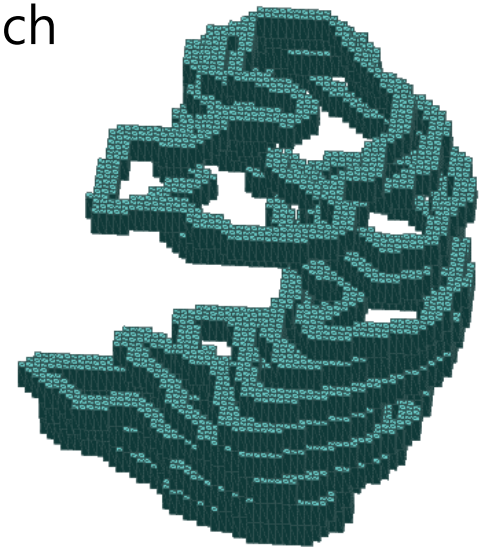
VRCP Limitations (Hollow Organs)

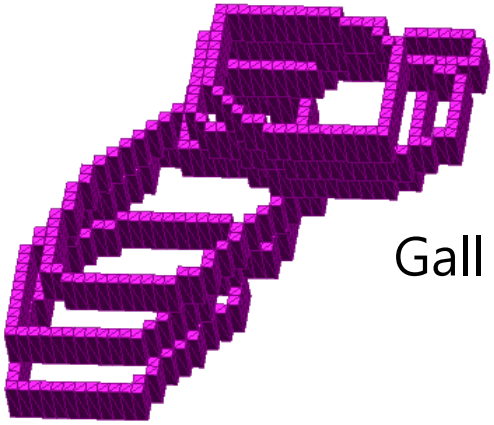
Adult male VRCP
(2.137 × 2.137 × 8 mm^3)



Urinary bladder

Stomach



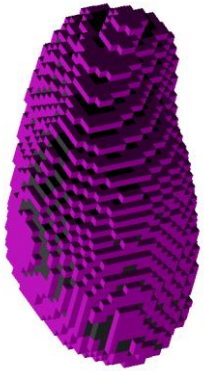


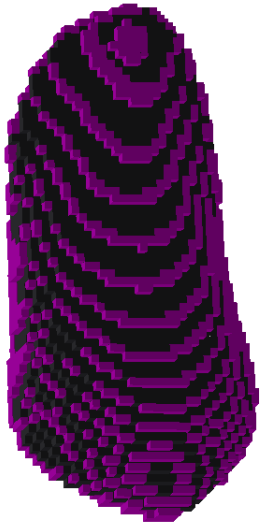
Gall bladder

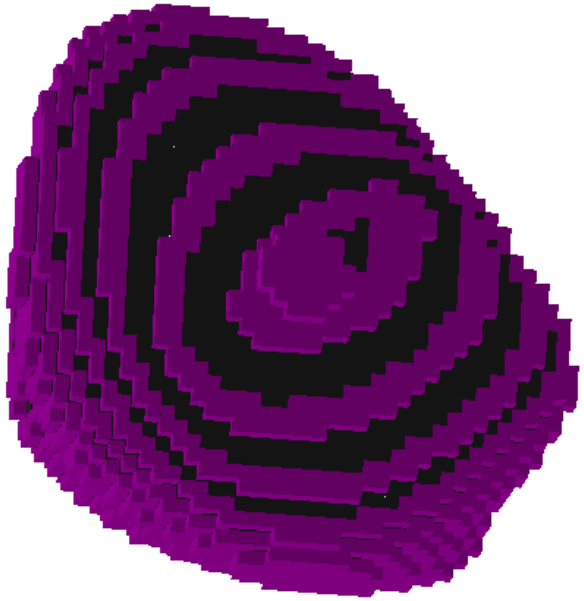
"***Discontinuous***"

VRCP Limitations (Hollow Organs)

Gall bladder







1-year-male VRCP (0.663 × 0.663 × 1.4 mm^3)

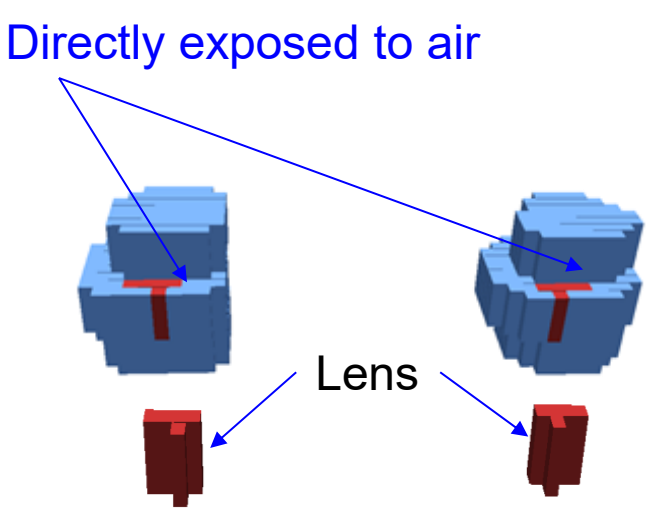
5-year-male VRCP (0.85 × 0.85 × 1.928 mm^3)

15-year-male VRCP (1.2 × 1.2 × 2.828 mm^3)

"***Discontinuous***"

VRCP Limitations (Eye Lens)

- The lenses of the eyes are directly exposed to air, which is anatomically incorrect, resulting in significant overestimation in lens dose calculation for weakly-penetrating radiations.



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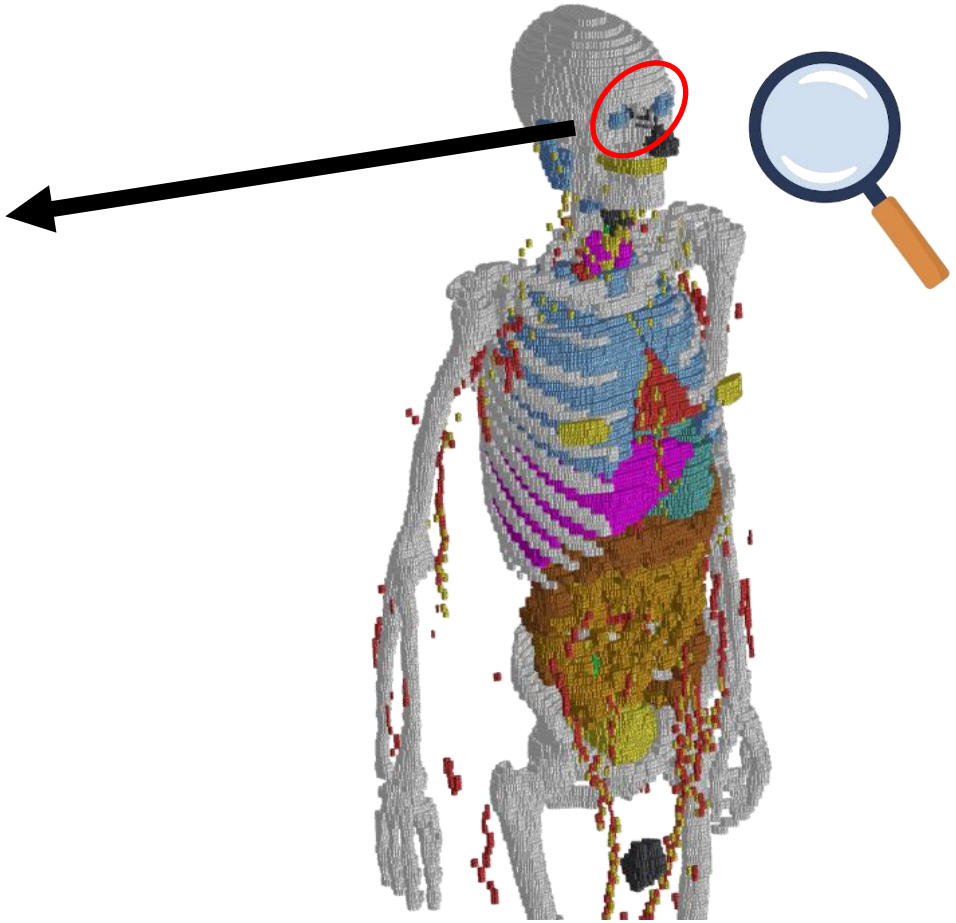

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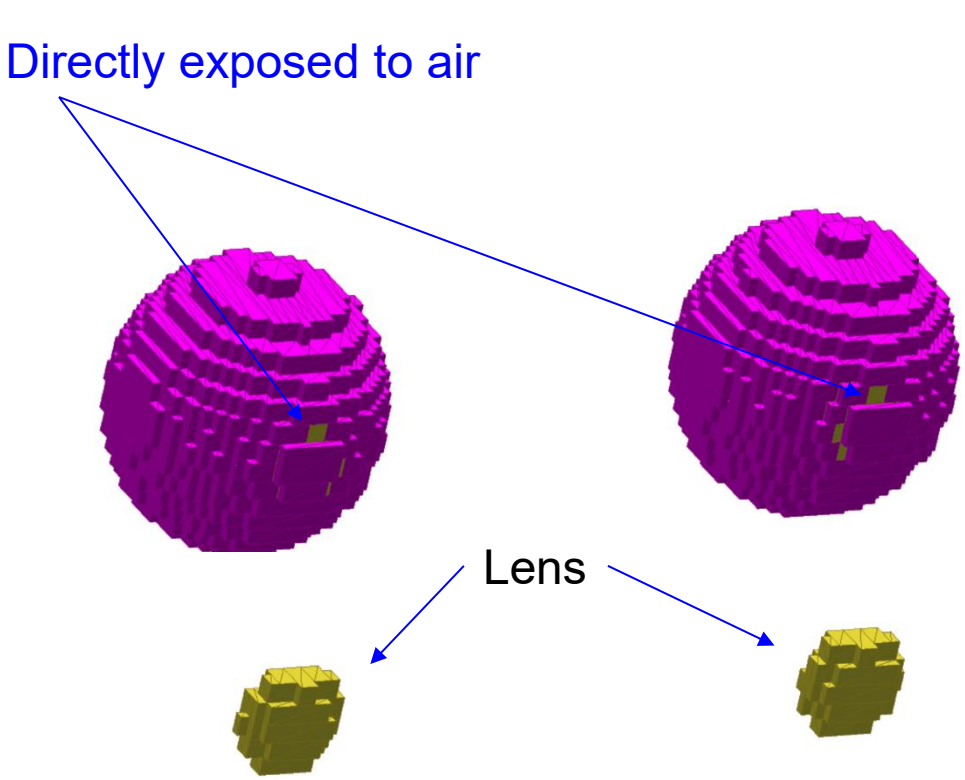
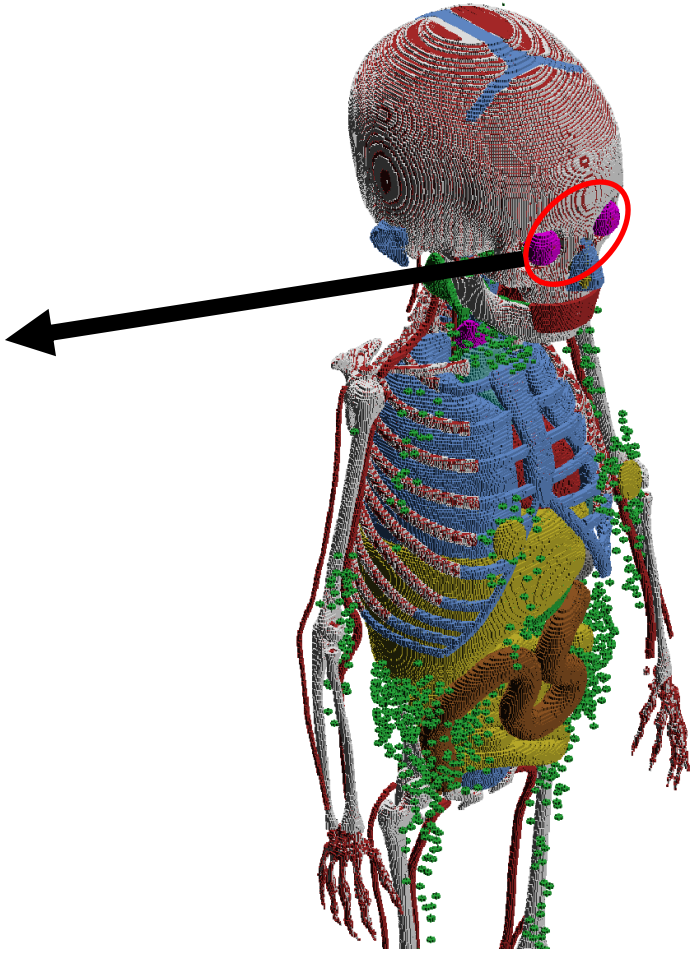
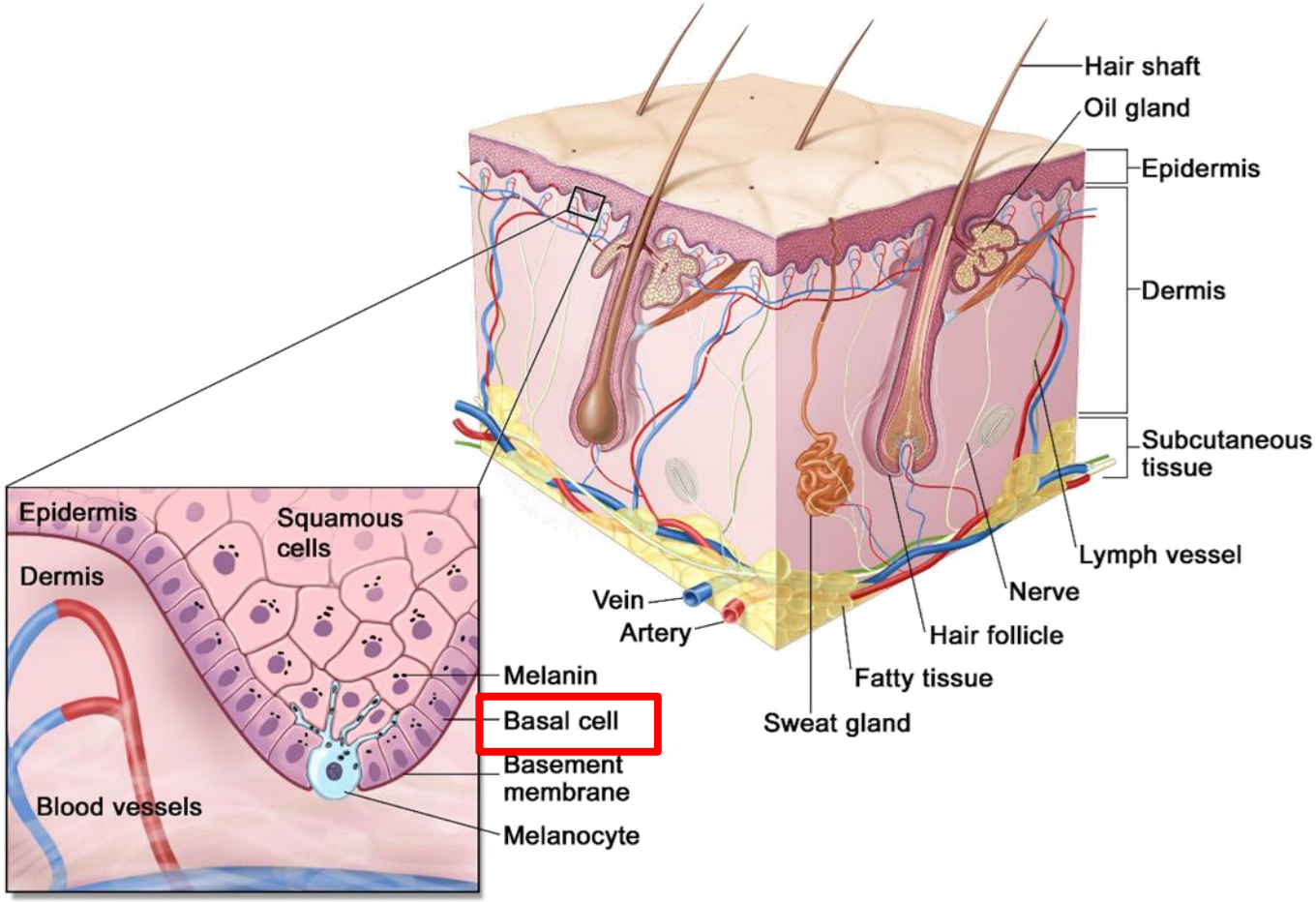


1-year-female VRCP



1-year-female VRCP

VRCP Limitations (Micron-thick target, Skin)

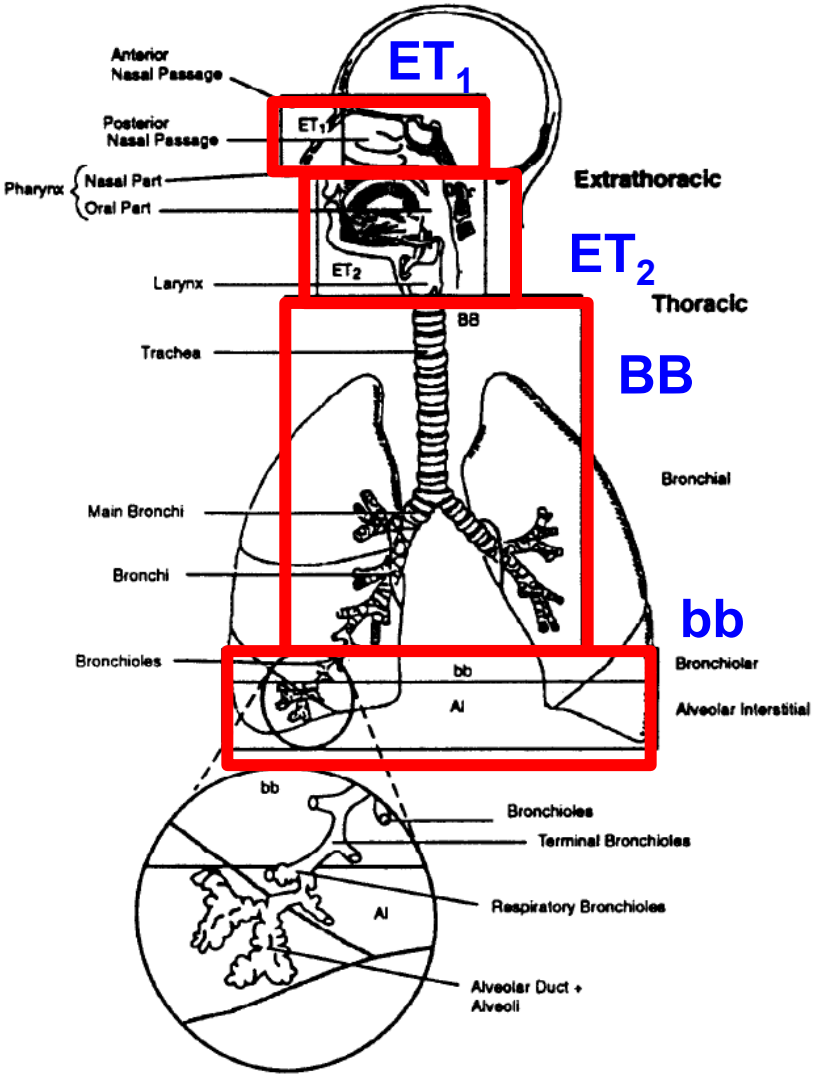


Radiosensitive basal cell layer

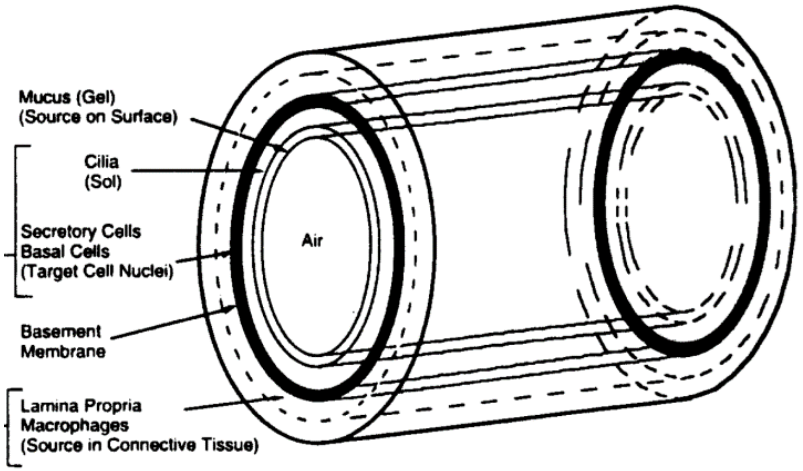
- **"50-µm"** thickness (≥ 15-year)
- **"60-µm"** thickness (≤ 10-year)

Voxel resolutions: 0.66 – 8.00 mm

VRCP Limitations (Micron-thick target, Respiratory)



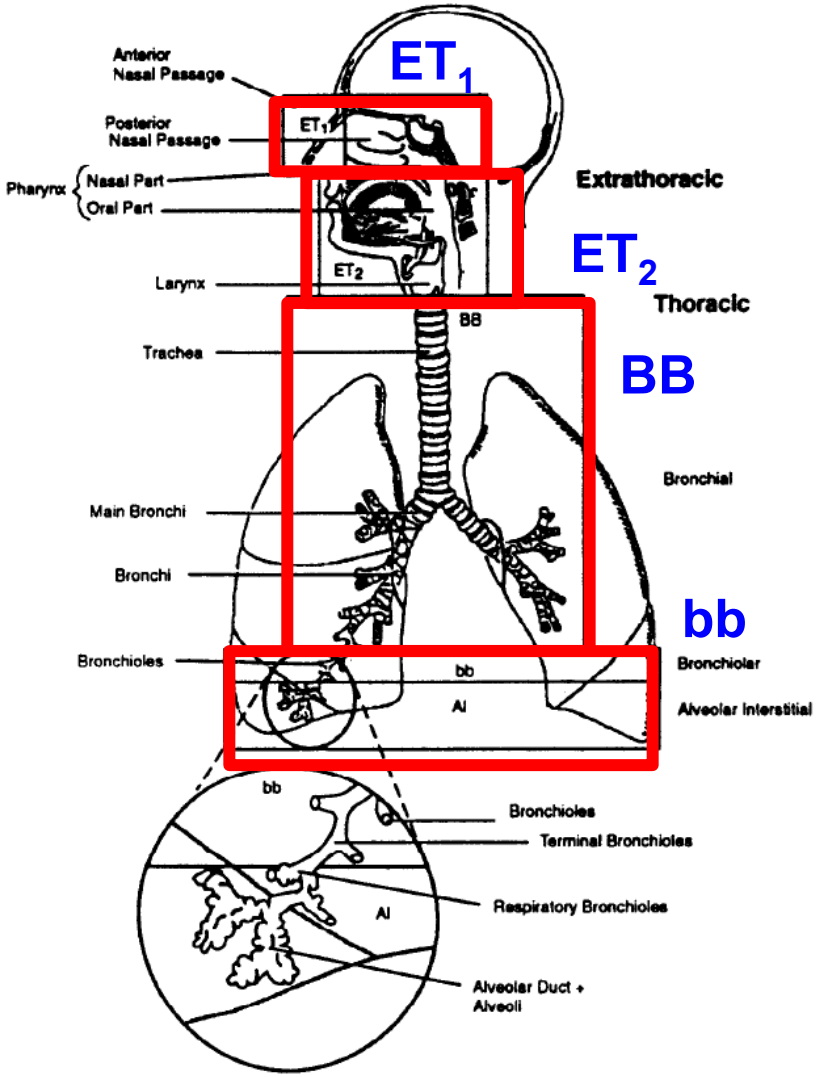
Human Respiratory Tract Model (ICRP 66, 1994)



"8-15-μm" thickness **radiosensitive** cell layer

Voxel resolutions: 0.66 – 8.00 mm

VRCP Limitations (Micron-thick target, Respiratory)



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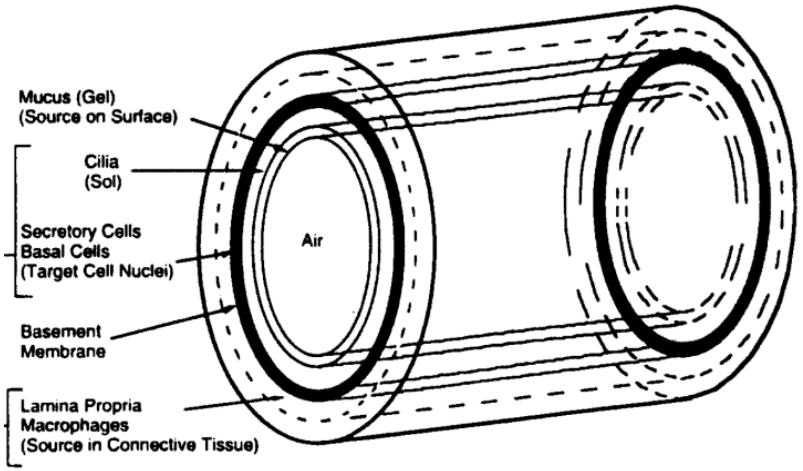
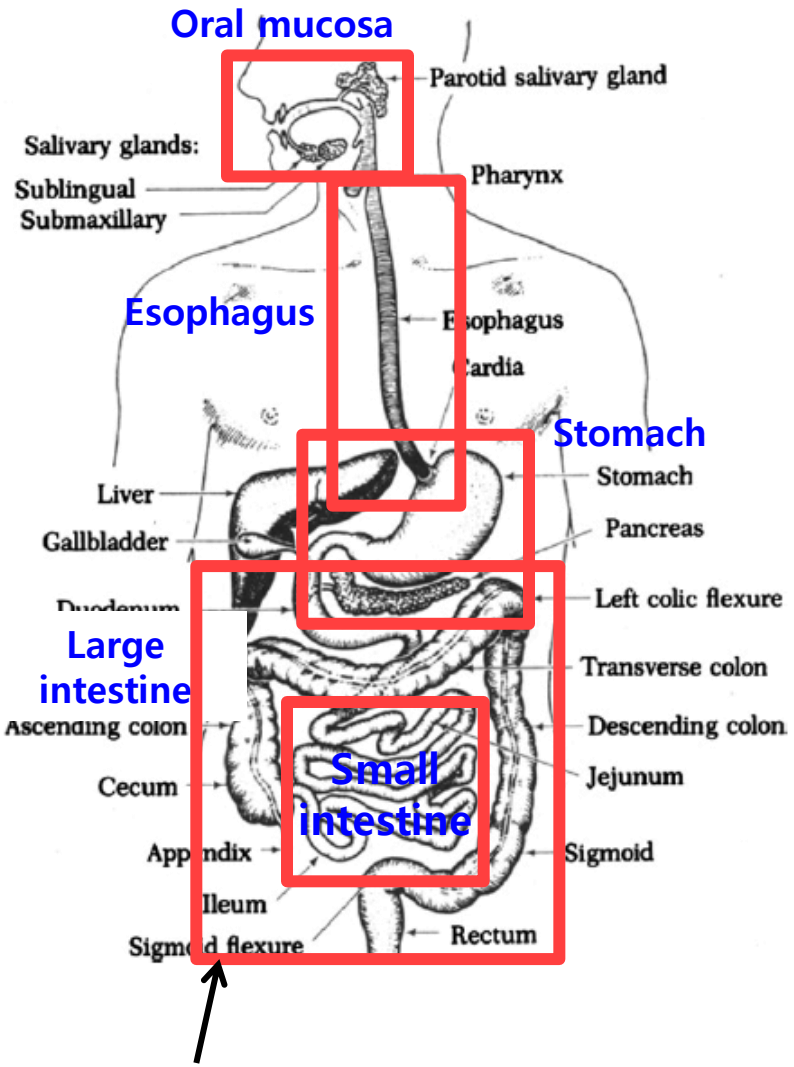


"8-15-μm" thickness **radiosensitive** cell layer

24 "additional" stylized models used for adult and paediatric SAF calculations

Voxel resolutions: 0.66 – 8.00 mm

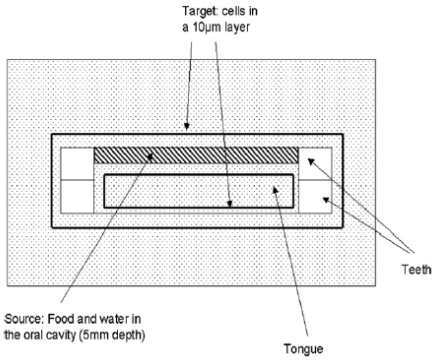
VRCP Limitations (Micron-thick target, Alimentary)

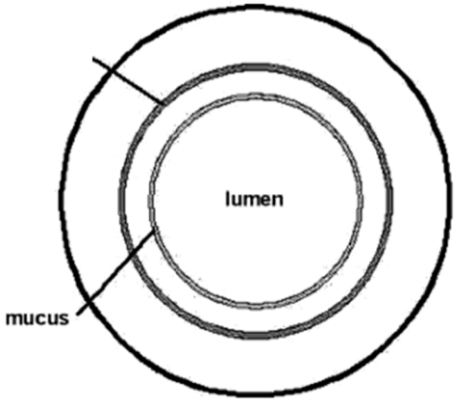


Note: 3 different stylized phantoms are used for large intestine.

Human Alimentary Tract Model (ICRP 100, 2006)

"10-40-μm" thickness **radiosensitive** cell layers





42 "additional" stylized models used for adult and paediatric SAF calculations

Voxel resolutions: 0.66 – 8.00 mm

Other Limitations

- The VRCPs were matched to the reference organ masses ***exclusive of blood content***.
  - Organs smaller than usual (i.e., by 3-20%)
  - Some neighboring organs not in contact
- These phantoms are ***not deformable***.
- Some spongiosa is not fully covered by cortical bone.
- Some cartilage is included in spongiosa.
- The sacrum of the female phantom does not have cortical bone.
- The distribution of lymphatic nodes in the phantoms are not symmetric.
- Some tissue masses do not match the ICRP-89 data

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Advances in Phantom Technology

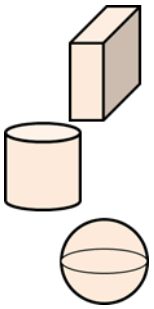
1950s~1960s	1st Generation (1960s~)	2nd Generation (1980s~)	3rd Generation (2000s~)	4th Generation (2010s~)
Simplified	Stylized (Equations)	Voxel (Volume Mesh)	NURBS/Polygon Mesh (Surface Mesh)	Tetrahedron (Volume Mesh)

To represent the human anatomy more realistic and precise

Advances in Phantom Technology

1950s~1960s

Simplified



Advances in Phantom Technology

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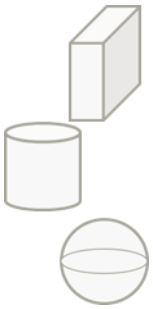
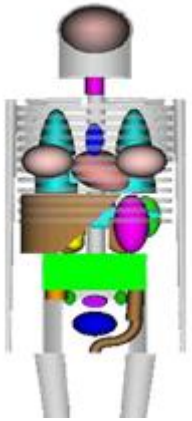
Simplified



1st Generation
(1960s~)

Stylized (Equations)

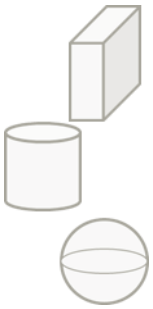


MIRD5, ORNL ADAM/EVA, KMIRD, ...

Advances in Phantom Technology

1950s~1960s

Simplified



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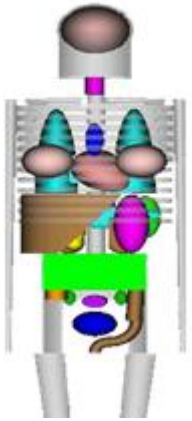


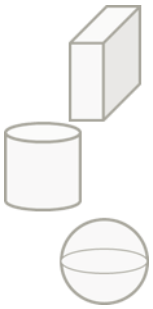
MIRD5, ORNL ADAM/EVA, KMIRD, …

- Specific organs

Advances in Phantom Technology

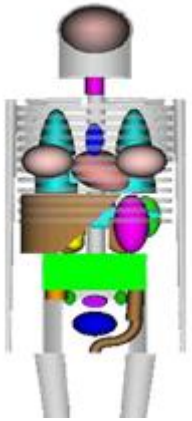
1950s~1960s

Simplified



1st Generation
(1960s~)

Stylized (Equations)

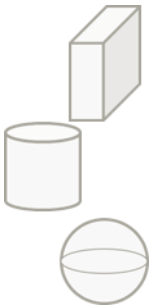


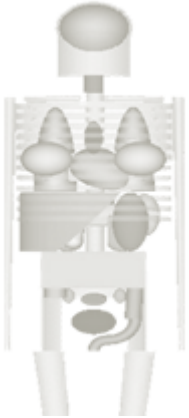
MIRD5, ORNL ADAM/EVA, KMIRD, …

- Specific organs
- Not realistic

Advances in Phantom Technology

1950s~1960s	1st Generation (1960s~)	2nd Generation (1980s~)
Simplified	Stylized (Equations)	**Voxel (Volume Mesh)**





MIRD5, ORNL ADAM/EVA, KMIRD, …

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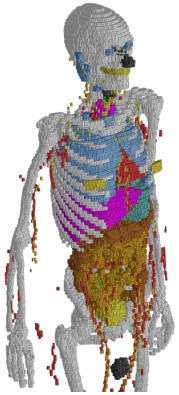
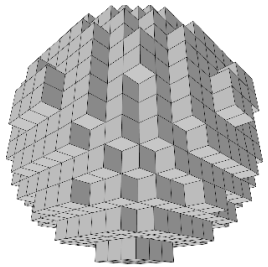


ICRP 110, VIP-MAN, HDRKs, …



Voxel

Advances in Phantom Technology

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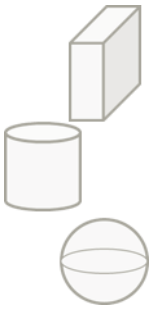
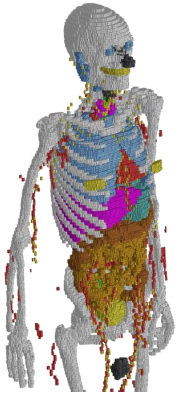
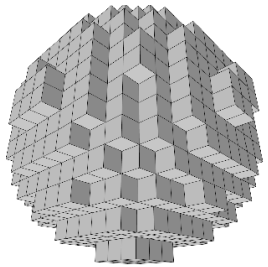
Simplified	Stylized (Equations)	**Voxel (Volume Mesh)**







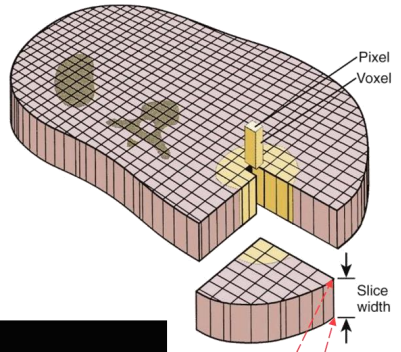
Voxel

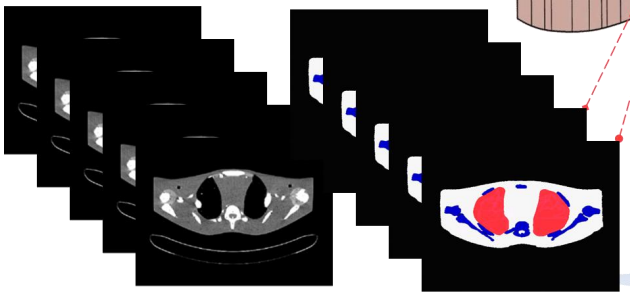
MIRD5, ORNL ADAM/EVA, KMIRD, ...

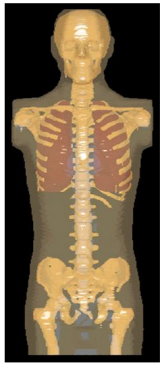
- Specific organs
- Not realistic

ICRP 110, VIP-MAN, HDRKs, ...

- **Realistic than stylized**



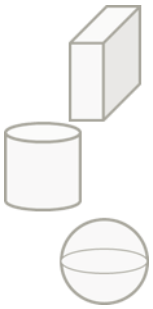




Voxel model

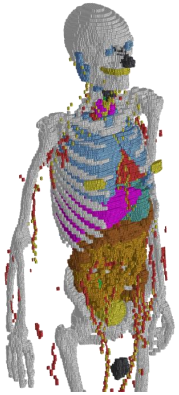
Advances in Phantom Technology

1950s~1960s	1st Generation (1960s~)	2nd Generation (1980s~)
Simplified	Stylized (Equations)	**Voxel (Volume Mesh)**



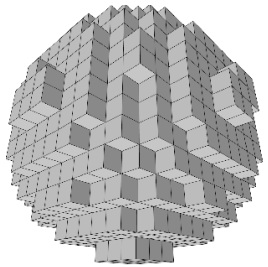
MIRD5, ORNL ADAM/EVA, KMIRD, …

- Specific organs
- Not realistic



ICRP 110, VIP-MAN, HDRKs, …

- **Realistic than stylized**
- **Limited voxel resolutions (millimeter scale)**

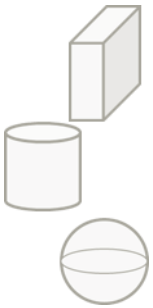


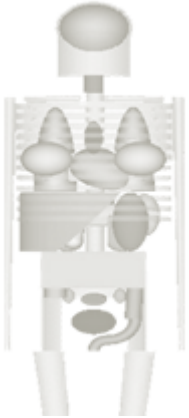
Voxel

- **Difficult to define thin/tiny organs**
  - Holes in the skin and hollow organs
  - Difficult to define micron-thick radiosensitive target regions
    - Skin: 50- or 60-μm-thick target layer
    - HATM/HRTM: 8−40-μm-thick target layer
    - Eye lens: 400 μm on average

Advances in Phantom Technology

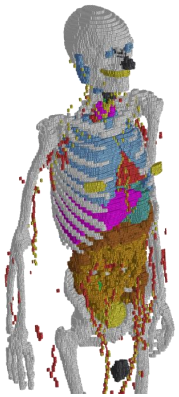
1950s~1960s	1st Generation (1960s~)	2nd Generation (1980s~)
Simplified	Stylized (Equations)	**Voxel (Volume Mesh)**





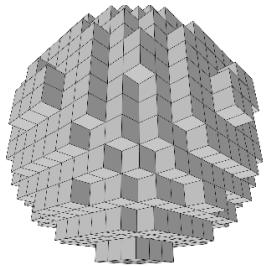
MIRD5, ORNL ADAM/EVA, KMIRD, ...

- Specific organs
- Not realistic



ICRP 110, VIP-MAN, HDRKs, ...

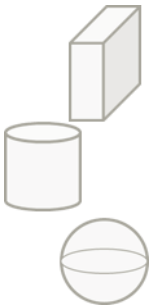
- **Realistic than stylized**
- **Limited voxel resolutions (millimeter scale)**
- **Not deformable**
- **Stair-stepped**



Voxel

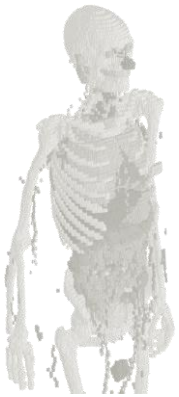
Advances in Phantom Technology

1950s~1960s	1st Generation (1960s~)	2nd Generation (1980s~)	3rd Generation (2000s~)
Simplified	Stylized (Equations)	Voxel (Volume Mesh)	NURBS/Polygon Mesh (Surface Mesh)



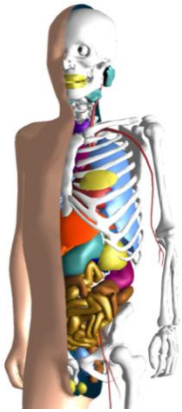
MIRD5, ORNL ADAM/EVA, KMIRD, …

- Specific organs
- Deformable
- Not realistic



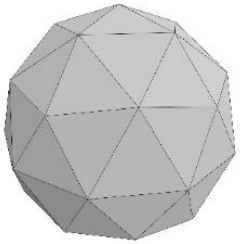
ICRP 110, VIP-MAN, HDRKs, …

- Realistic than stylized
- Limited voxel resolutions (millimeter scale)
- Not deformable
- Stair-stepped



PSRKs, UF Family, RPI-AM,AF 4D XCAT, …

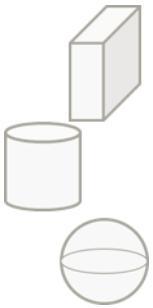
NURBS



Polygon Mesh

Advances in Phantom Technology

1950s~1960s	1st Generation (1960s~)	2nd Generation (1980s~)	3rd Generation (2000s~)
Simplified	Stylized (Equations)	Voxel (Volume Mesh)	**NURBS/Polygon Mesh (Surface Mesh)**

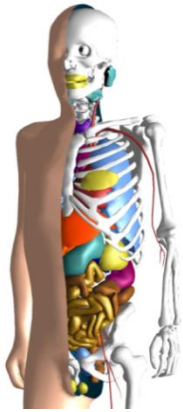


MIRD5, ORNL ADAM/EVA, KMIRD, …

- Specific organs
- Deformable
- Not realistic

ICRP 110, VIP-MAN, HDRKs, …

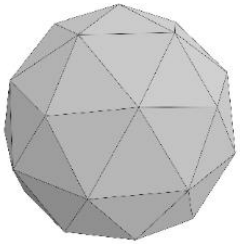
- Realistic than stylized
- Limited voxel resolutions (millimeter scale)
- Not deformable
- Stair-stepped



PSRKs, UF Family, RPI-AM,AF 4D XCAT, …

- **Smooth boundary**

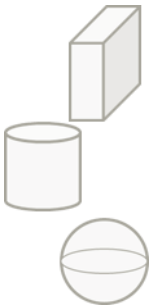
NURBS

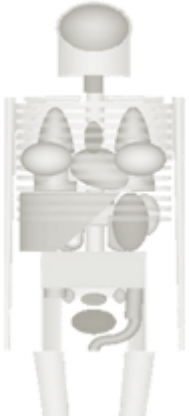


Polygon Mesh

Advances in Phantom Technology

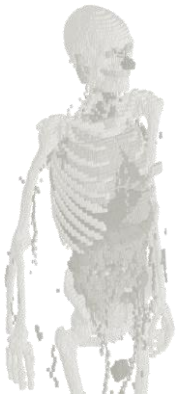
1950s~1960s	1st Generation (1960s~)	2nd Generation (1980s~)	3rd Generation (2000s~)
Simplified	Stylized (Equations)	Voxel (Volume Mesh)	**NURBS/Polygon Mesh (Surface Mesh)**





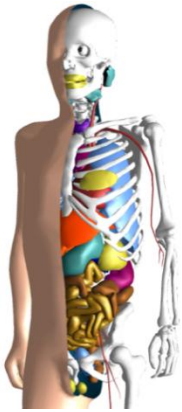
MIRD5, ORNL ADAM/EVA, KMIRD, ...

- Specific organs
- Deformable
- Not realistic



ICRP 110, VIP-MAN, HDRKs, ...

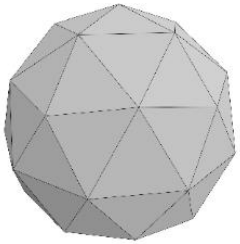
- Realistic than stylized
- Limited voxel resolutions (millimeter scale)
- Not deformable
- Stair-stepped



PSRKs, UF Family, RPI-AM,AF 4D XCAT, ...

- **Smooth boundary**
- **Thin/small structures**

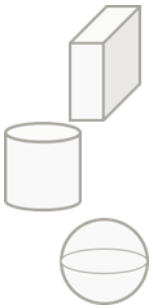
NURBS



Polygon Mesh

Advances in Phantom Technology

1950s~1960s	1st Generation (1960s~)	2nd Generation (1980s~)	3rd Generation (2000s~)
Simplified	Stylized (Equations)	Voxel (Volume Mesh)	NURBS/Polygon Mesh (Surface Mesh)



MIRD5, ORNL ADAM/EVA, KMIRD, …

- Specific organs
- Deformable
- Not realistic

ICRP 110, VIP-MAN, HDRKs, …

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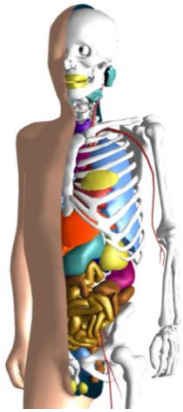
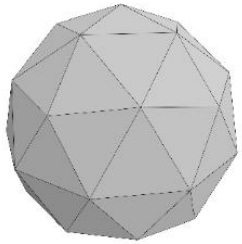


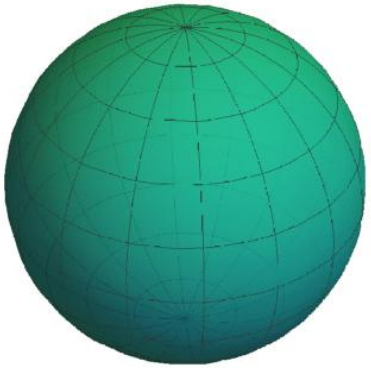
PSRKs, UF Family, RPI-AM,AF 4D XCAT, …

- **Smooth boundary**
- **Thin/small structures**
- **Deformable**

NURBS

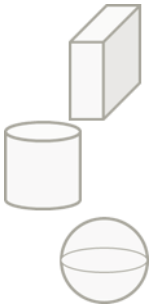


Polygon Mesh



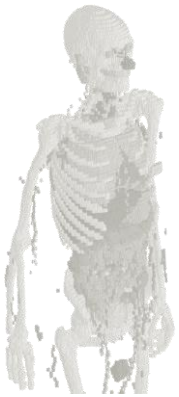
Advances in Phantom Technology

1950s~1960s	1st Generation (1960s~)	2nd Generation (1980s~)	3rd Generation (2000s~)
Simplified	Stylized (Equations)	Voxel (Volume Mesh)	NURBS/Polygon Mesh (Surface Mesh)



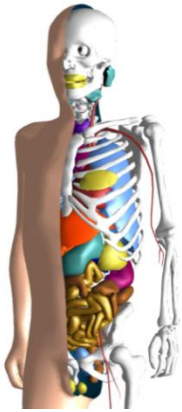
MIRD5, ORNL ADAM/EVA, KMIRD, …

- Specific organs
- Deformable
- Not realistic



ICRP 110, VIP-MAN, HDRKs, …

- Realistic than stylized
- Limited voxel resolutions (millimeter scale)
- Not deformable
- Stair-stepped

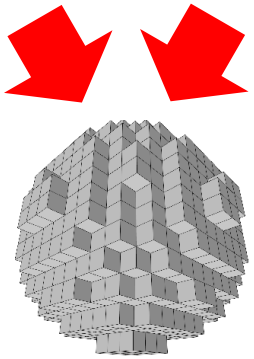


PSRKs, UF Family, RPI-AM,AF 4D XCAT, …

- **Smooth boundary**
- **Thin/small structures**
- **Deformable**
- **Voxelized for MC**

NURBS

Polygon Mesh

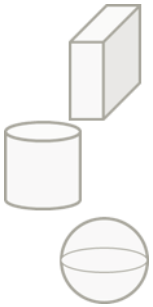


Voxel

Monte Carlo codes

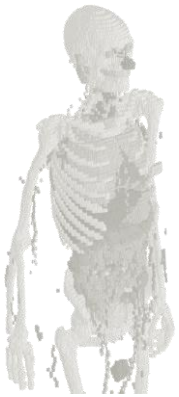
Advances in Phantom Technology

1950s~1960s	1st Generation (1960s~)	2nd Generation (1980s~)	3rd Generation (2000s~)
Simplified	Stylized (Equations)	Voxel (Volume Mesh)	NURBS/Polygon Mesh (Surface Mesh)



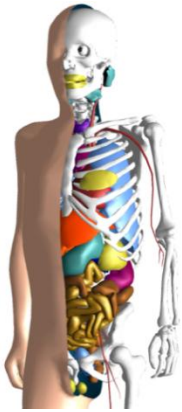
MIRD5, ORNL ADAM/EVA, KMIRD, …

- Specific organs
- Deformable
- Not realistic



ICRP 110, VIP-MAN, HDRKs, …

- Realistic than stylized
- Limited voxel resolutions (millimeter scale)
- Not deformable
- Stair-stepped

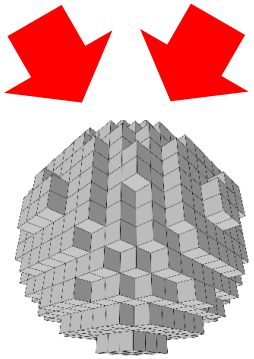


PSRKs, UF Family, RPI-AM,AF 4D XCAT, …

- ~~Smooth boundary~~
- ~~Thin/small structures~~
- ~~Deformable~~
- Voxelized for MC

NURBS

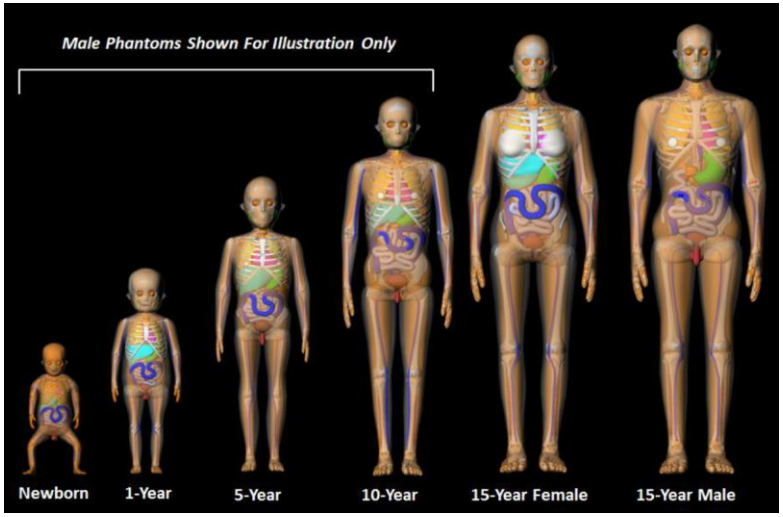
Polygon Mesh



Voxel

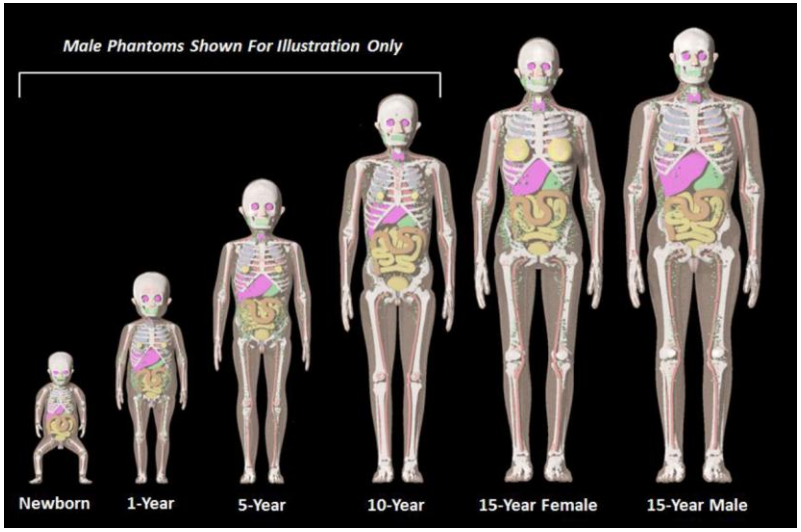
Monte Carlo codes

Advances in Phantom Technology



UF/NCI pediatric phantoms

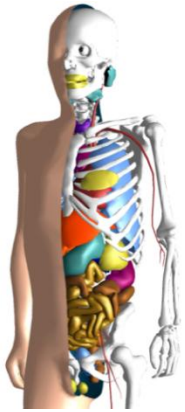
Voxelized



Pediatric VRCPs (ICRP 143, 2020)

3rd Generation (2000s~)

NURBS/Polygon Mesh (Surface Mesh)

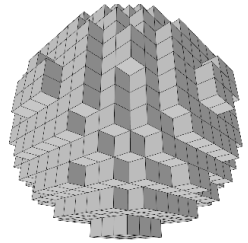


NURBS

Polygon Mesh

PSRKs,
UF Family,
RPI-AM,AF
4D XCAT, ...

- ~~Smooth boundary~~
- ~~Thin/small structures~~
- ~~Deformable~~
- **Voxelized for MC**



Voxel

Monte Carlo codes

Advances in Phantom Technology

IOP PUBLISHING PHYSICS IN MEDICINE AND BIOLOGY
Phys. Med. Biol. **56** (2011) 3137–3161 doi:10.1088/0031-9155/56/10/016

A polygon-surface reference Korean male phantom (PSRK-Man) and its direct implementation in Geant4 Monte Carlo simulation

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[2] Department of Nuclear and Radiological Engineering, University of Florida, Gainesville, FL 32611, USA
[3] Korea Institute of Nuclear Safety, 19 Guseong-dong, Yuseong-gu, Daejeon 305-600, Korea
[4] Department of Physical Therapy, Kyungbuk College, Hyucheon 2-dong, Yeongju-si, Gyeongbuk 750-712, Korea

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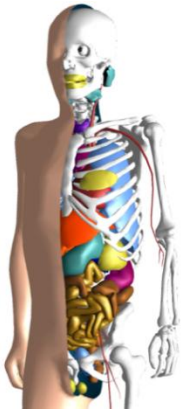
Abstract
Even though the hybrid phantom embodies both the anatomic reality of voxel phantoms and the deformability of stylized phantoms, it must be voxelized to be used in a Monte Carlo code for dose calculation or some imaging simulation, which incurs the inherent limitations of voxel phantoms. In the present study, a voxel phantom named VKH-Man (Visible Korean Human-Man), was converted to a polygon-surface phantom (PSRK-Man, Polygon-Surface Reference Korean-Man), which was then adjusted to the Reference Korean data. Subsequently, the PSRK-Man polygon phantom was directly, without any voxelization process, implemented in the Geant4 Monte Carlo code for dose calculations. The calculated dose values and computation time

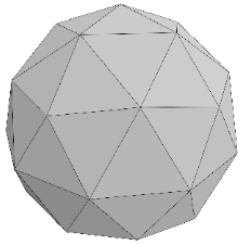
Kim et al., PMB 2011

3rd Generation (2000s~)

NURBS/Polygon Mesh (Surface Mesh)



NURBS



Polygon Mesh

PSRKs,
UF Family,
RPI-AM,AF
4D XCAT, …

- **Smooth boundary**
- **Thin/small structures**
- **Deformable**
- Voxelized for MC

Direct (Voxelized X)

Monte Carlo codes

Advances in Phantom Technology

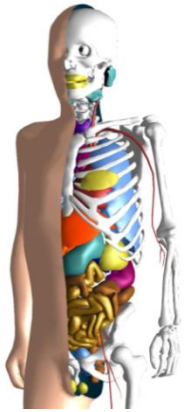
Photon energy (MeV)	Computation time (hh:mm:ss)		Ratio
	Polygon mesh phantom (a)	Voxelized phantom (b)	(a/b)
0.015	65:17:33	0:42:31	92.1
0.03	73:54:04	0:54:37	81.2
0.05	86:10:14	1:09:42	74.2
0.08	95:42:08	1:20:42	71.2
0.2	101:16:00	1:35:56	63.3
0.4	99:40:11	1:43:52	57.6
0.8	98:56:25	1:49:11	54.4
2	96:12:04	2:15:43	42.5
8	99:16:57	2:59:14	33.2
10	100:13:50	3:11:47	31.4

Kim et al., PMB 2011

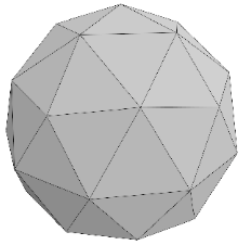
30-90 times slower
(Voxel >> Polygon)

3rd Generation (2000s~)

NURBS/Polygon Mesh (Surface Mesh)



NURBS



Polygon Mesh

PSRKs,
UF Family,
RPI-AM,AF
4D XCAT, ...

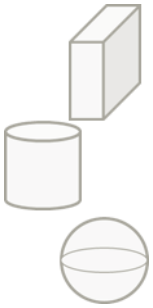
- **Smooth boundary**
- **Thin/small structures**
- **Deformable**
- Voxelized for MC
- **Slow MC calc.**

Direct (Voxelized X)

Monte Carlo codes

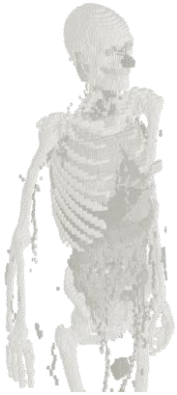
Advances in Phantom Technology

1950s~1960s	1st Generation (1960s~)	2nd Generation (1980s~)	3rd Generation (2000s~)
Simplified	Stylized (Equations)	Voxel (Volume Mesh)	**NURBS/Polygon Mesh (Surface Mesh)**



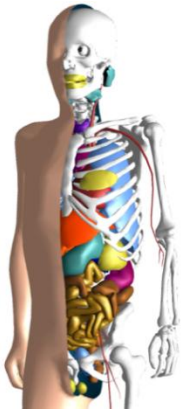
MIRD5, ORNL ADAM/EVA, KMIRD, …

- Specific organs
- Deformable
- Not realistic



ICRP 110, VIP-MAN, HDRKs, …

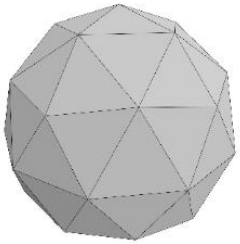
- Realistic than stylized
- Limited voxel resolutions (millimeter scale)
- Not deformable
- Stair-stepped



PSRKs, UF Family, RPI-AM,AF 4D XCAT, …

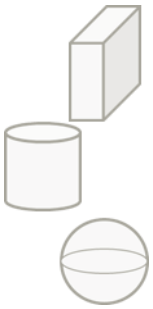
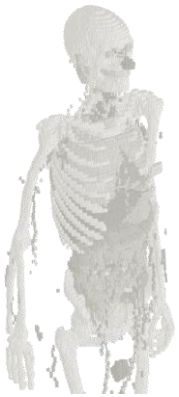
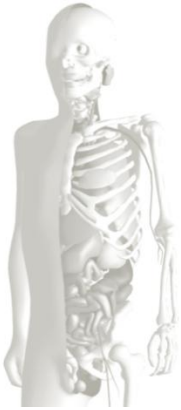
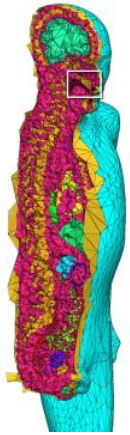
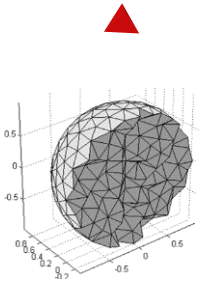
- **Smooth boundary**
- **Thin/small structures**
- **Deformable**
- **Voxelized for MC**
- **Slow MC calc.**
- **No sub-organ density variation**

NURBS



Polygon Mesh

Advances in Phantom Technology

1950s~1960s	1st Generation (1960s~)	2nd Generation (1980s~)	3rd Generation (2000s~)	4th Generation (2010s~)
Simplified	Stylized (Equations)	Voxel (Volume Mesh)	NURBS/Polygon Mesh (Surface Mesh)	**Tetrahedron (Volume Mesh)**
				 
MIRD5, ADAM/EVA, KMIRD, ...	ICRP 110, VIP-MAN, HDRKs, ...	PSRKs, UF Family, RPI-AM,AF 4D XCAT, ...		**THRKs, MRCPs, MRKPs**
• Specific organs • Deformable • Not realistic	• Realistic than stylized • Limited voxel resolutions (millimeter scale) • Not deformable • Stair-stepped	• Smooth boundary • Thin/small structures • Deformable • Voxelized for MC • Slow MC calc. • No sub-organ density variation		

Advances in Phantom Technology

IOP Publishing | Institute of Physics and Engineering in Medicine
Physics in Medicine and Biology
Phys. Med. Biol. **59** (2014) 3173–3185
doi:10.1088/0031-9155/59/12/3173

Tetrahedral-mesh-based computational human phantom for fast Monte Carlo dose calculations

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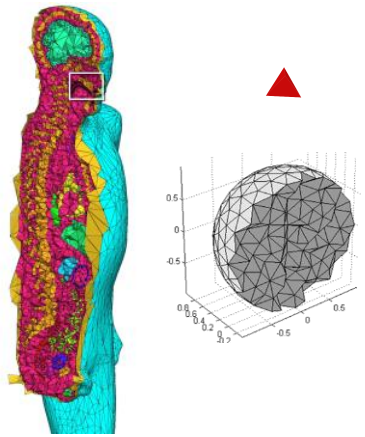
Abstract

Although polygonal-surface computational human phantoms can address several critical limitations of conventional voxel phantoms, their Monte Carlo simulation speeds are much slower than those of voxel phantoms. In this study, we sought to overcome this problem by developing a new type of computational human phantom, a tetrahedral mesh phantom, by converting

Yeom et al., PMB 2014

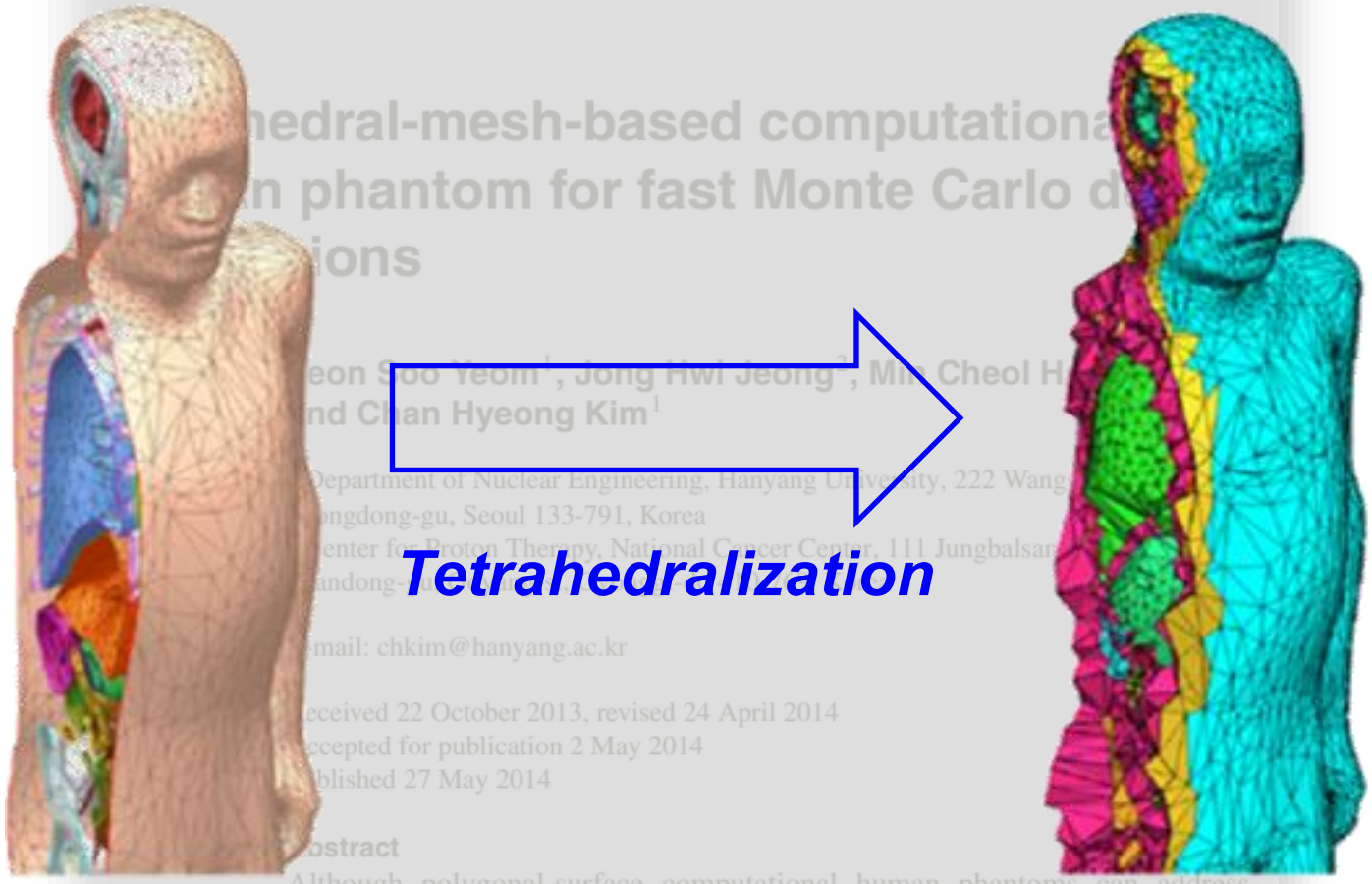
4th Generation (2010s~)

Tetrahedron (Volume Mesh)



THRKs, MRCPs, MRKPs

Advances in Phantom Technology

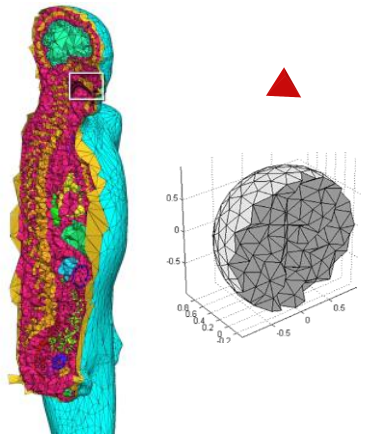


Polygon

Tetrahedron

4th Generation
(2010s~)

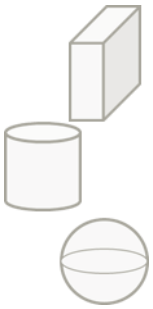
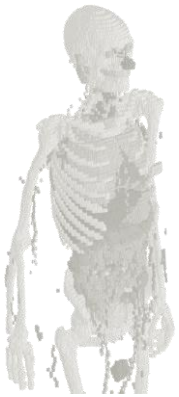
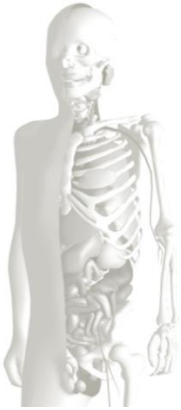
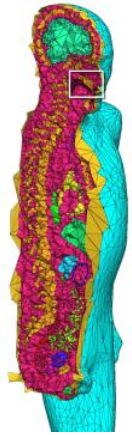
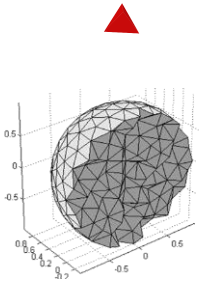
Tetrahedron
(Volume Mesh)



THRKs,
MRCPs,
MRKPs

Yeom et al., PMB 2014

Advances in Phantom Technology

1950s~1960s	1st Generation (1960s~)	2nd Generation (1980s~)	3rd Generation (2000s~)	4th Generation (2010s~)
Simplified	Stylized (Equations)	Voxel (Volume Mesh)	NURBS/Polygon Mesh (Surface Mesh)	**Tetrahedron (Volume Mesh)**
				 
MIRD5, ADAM/EVA, KMIRD, ...	ICRP 110, VIP-MAN, HDRKs, ...	PSRKs, UF Family, RPI-AM,AF 4D XCAT, ...	THRKs, MRCPs, MRKPs	
• Specific organs • Deformable • Not realistic	• Realistic than stylized • Limited voxel resolutions (millimeter scale) • Not deformable • Stair-stepped	• Smooth boundary • Thin/small structures • Deformable • Voxelized for MC • Slow MC calc. • No sub-organ density variation	• **Smooth boundary** • **Thin/small structures** • **Deformable**	

Advances in Phantom Technology

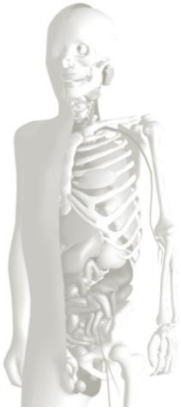
Energy (MeV)	Computation time (hh:mm:ss)		Ratio
	Polygon mesh phantom (a)	Tetrahedralized phantom (b)	(a/b)
0.015	65:17:33	0:15:45	**248.7**
0.03	73:54:04	0:18:46	236.3
0.05	86:10:14	0:31:41	163.2
0.08	95:42:08	0:35:31	161.7
0.2	101:16:00	0:52:17	116.2
0.4	99:40:11	1:01:56	96.6
0.8	98:56:25	1:05:03	91.3
2	96:12:04	1:22:19	70.1
8	99:16:57	2:00:26	49.5
10	100:13:50	2:12:00	45.6

Yeom et al., PMB 2014

40-250 times faster
(Tetrahedron >> Polygon)

3rd Generation (2000s~)

NURBS/Polygon Mesh (Surface Mesh)

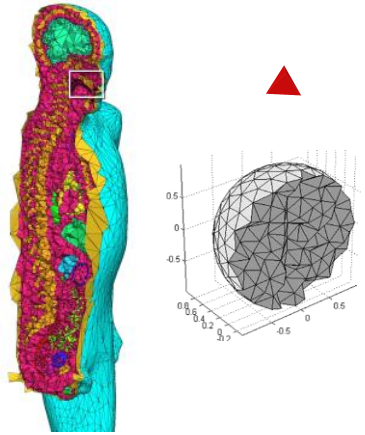


PSRKs,
UF Family,
RPI-AM,AF
4D XCAT, ...

- Smooth boundary
- Thin/small structures
- Deformable
- Voxelized for MC
- Slow MC calc.
- No sub-organ density variation

4th Generation (2010s~)

Tetrahedron (Volume Mesh)



**THRKs,
MRCPs,
MRKPs**

- **Smooth boundary**
- **Thin/small structures**
- **Deformable**
- **Fast MC calc. (no voxelization)**

Advances in Phantom Technology

Energy (MeV)	Computation time (hh:mm:ss)		Ratio
	Polygon mesh phantom (a)	Tetrahedralized phantom (b)	(a/b)
0.015	65:17:33	0:15:45	**248.7**
0.03	73:54:04	0:18:46	236.3
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2	96:12:04	1:22:19	70.1
8	99:16:57	2:00:26	49.5
10	100:13:50	2:12:00	45.6

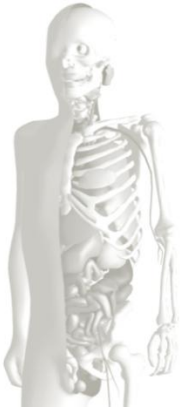
Yeom et al., PMB 2014

Comparable or even faster than voxel phantoms!!!

40-250 times faster
(Tetrahedron >> Polygon)

3rd Generation (2000s~)

NURBS/Polygon Mesh (Surface Mesh)

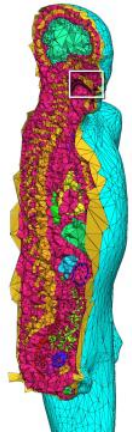


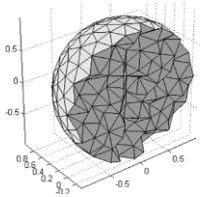
PSRKs,
UF Family,
RPI-AM,AF
4D XCAT, ...

- Smooth boundary
- Thin/small structures
- Deformable
- Voxelized for MC
- Slow MC calc.
- No sub-organ density variation

4th Generation (2010s~)

Tetrahedron (Volume Mesh)

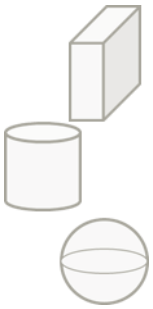
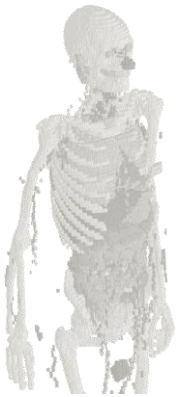
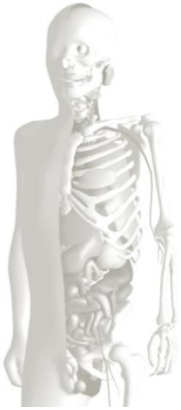
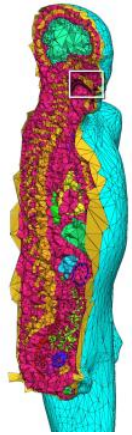
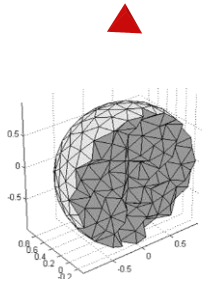




THRKs,
MRCPs,
MRKPs

- **Smooth boundary**
- **Thin/small structures**
- **Deformable**
- **Fast MC calc. (no voxelization)**

Advances in Phantom Technology

1950s~1960s	1st Generation (1960s~)	2nd Generation (1980s~)	3rd Generation (2000s~)	4th Generation (2010s~)
Simplified	Stylized (Equations)	Voxel (Volume Mesh)	NURBS/Polygon Mesh (Surface Mesh)	**Tetrahedron (Volume Mesh)**
				 
MIRD5, ADAM/EVA, KMIRD, ...	ICRP 110, VIP-MAN, HDRKs, ...	PSRKs, UF Family, RPI-AM,AF 4D XCAT, ...	THRKs, MRCPs, MRKPs	
• Specific organs • Deformable • Not realistic	• Realistic than stylized • Limited voxel resolutions (millimeter scale) • Not deformable • Stair-stepped	• Smooth boundary • Thin/small structures • Deformable • Voxelized for MC • Slow MC calc. • No sub-organ density variation	• **Smooth boundary** • **Thin/small structures** • **Deformable** • **Fast MC calc. (no voxelization)** • **Sub-organ density variation**	

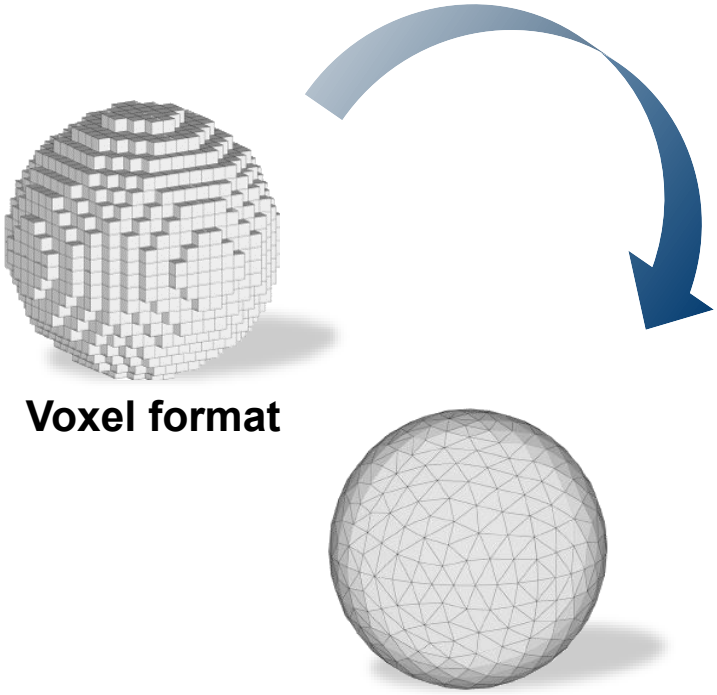
Advances in Phantom Technology

	2nd Gen	3rd Gen	**4th Gen**
	Voxel	Surface (voxelized in MC)	**Tetrahedron**
Surface smoothness	X	O (X)	O
Small and thin structure	X	O (X)	O
Computation speed	O	X (O)	O
Deformation	X	O	O

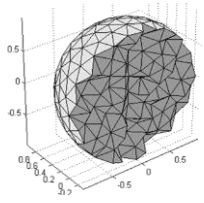
VRCP Limitations Discussed in C2 Meeting, 2013

(Abu Dhabi, UAE October 2013)

- The committee decided to convert the voxel-type reference computational phantoms into a high-quality mesh format to address these problems of the voxel phantoms.
- The new phantoms will replace the current voxel-type reference phantoms from the next general recommendations.



Tetrahedron



ICRP Task Group 103 (2016)

- Main Commission
- Scientific Secretariat
- Committee 1
  Radiation Effects
- Committee 2
  Doses from Radiation Exposure
- Committee 3
  Protection in Medicine
- Committee 4
  Application of the Commission권
  Recommendations
- Committee 5
  Protection of the Environment
- Emeritus Members
- Full ICRP Membership List
- ICRP and Fukushima
- Formal Relations with other
  Organisations
- ICRP Funding

You are here: ICRP Activities > Task Group 103

Task Group 103
Mesh-type Reference Computational Phantoms (MRCP)

The mandate for this Task Group - Mesh-type Reference Computational Phantoms (MRCP) - will be focused on converting the current voxel-type reference computational phantoms into a high-quality mesh format to address the limitations of the voxel-type phantoms in some dose coefficient calculations.
Specific work will include:

1. development of mesh-type ICRP reference computational phantoms which have all source and target tissues including the details of the eyes and skin and the thin target tissues (10-300 micron) of the alimentary and respiratory tract organs,
2. use of these mesh-type phantoms to calculate external and internal dose coefficients to estimate the uncertainties of the current reference dose coefficients, especially for the dose coefficients calculated with stylized phantoms (eye lenses, skin, and alimentary and respiratory tract organs) for weekly penetrating radiations, and
3. demonstration of phantom posture change and related dose coefficient calculations.

Chair

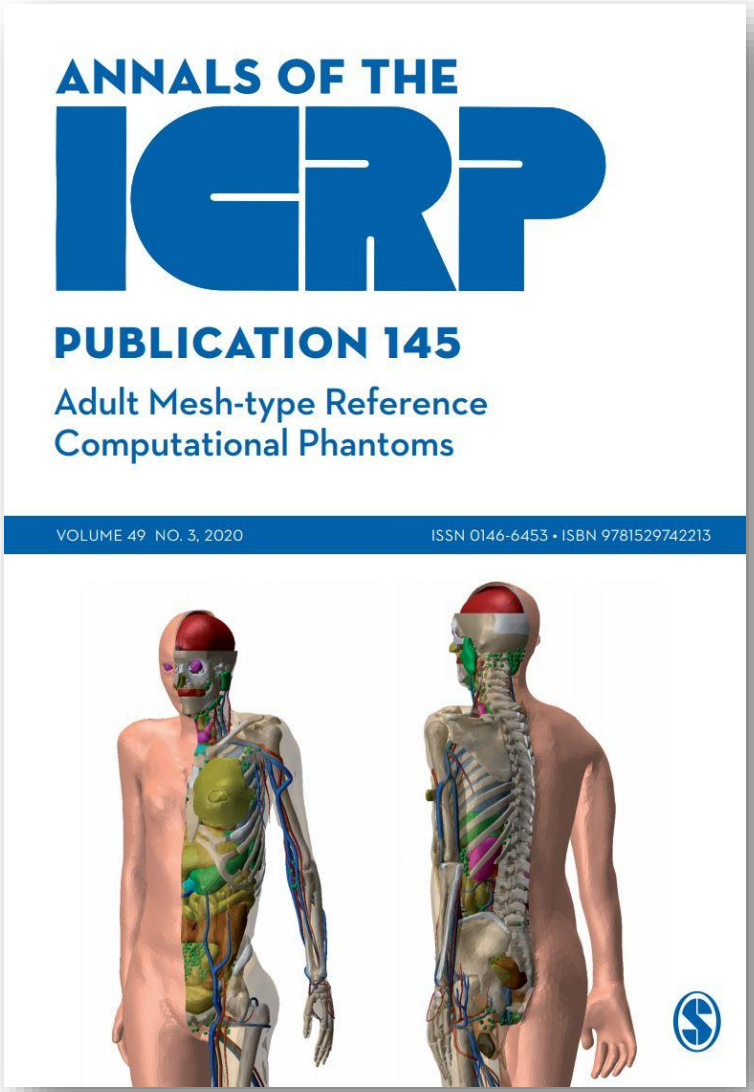
Prof Chan Hyeong Kim

Membership of TG 103

- Chan Hyeong Kim (Hanyang Univ., Korea) - *Chair*
- Yeon Soo Yeom (Yonsei Univ., Korea, ICRP C2)
- Chansoo Choi (Univ. of Florid, U.S.A)
- Bangho Shin (Univ. of Florid, U.S.A)
- Maria Zankl (BfS, Germany)
- Nina Petoussi-Henss (BfS, Germany)
- Wesley Bolch (Univ. of Florid, U.S.A)
- Choonsik Lee (NCI, U.S.A, ICRP C2)
- Keith Eckerman (ORNL, U.S.A)
- Riu Qiu (Tsinghua Univ., China)
- Bum Sun Chung (Yonsei Univ., Korea) – M.D./anatomist
- Haegin Han (NCI, U.S.A)
- Derek Jokisch (Francis Marion Univ., U.S.A, ICRP C2)
- Tat Thang Nguyen (Hanoi Institute of Technology, Vietnam)
- Suhyeon Kim (Hanyang Univ., Korea)

Achievements of TG 103

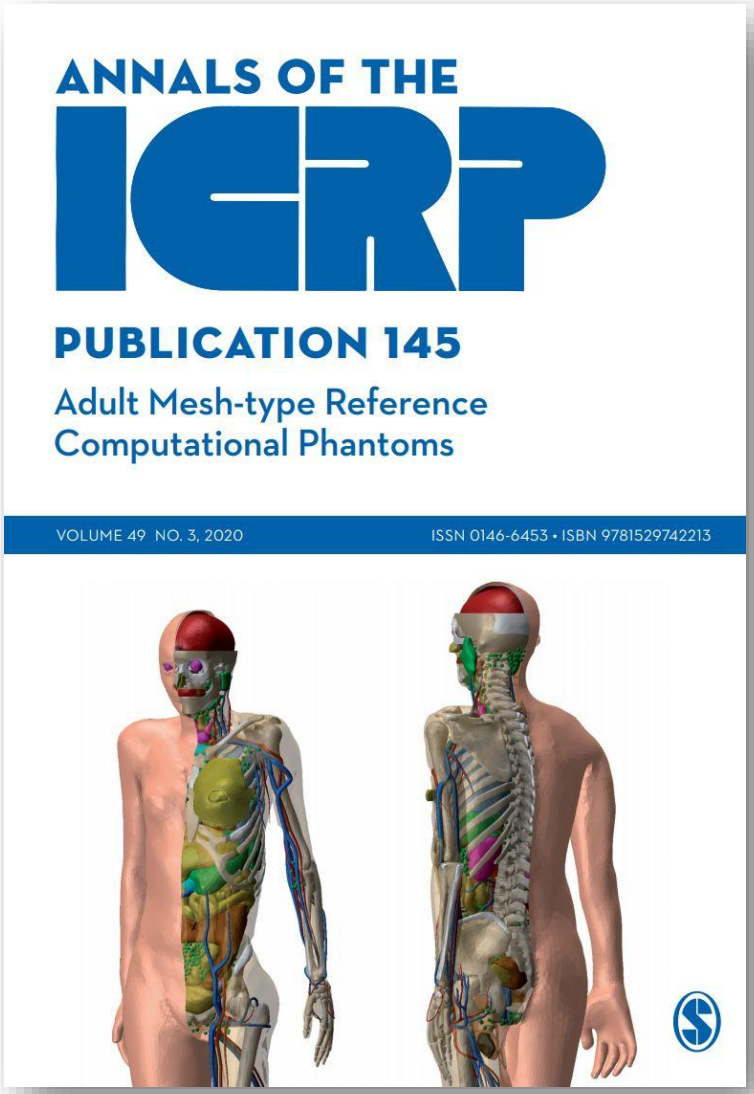
Adult MRCPs



ICRP Publication 145 (2020)

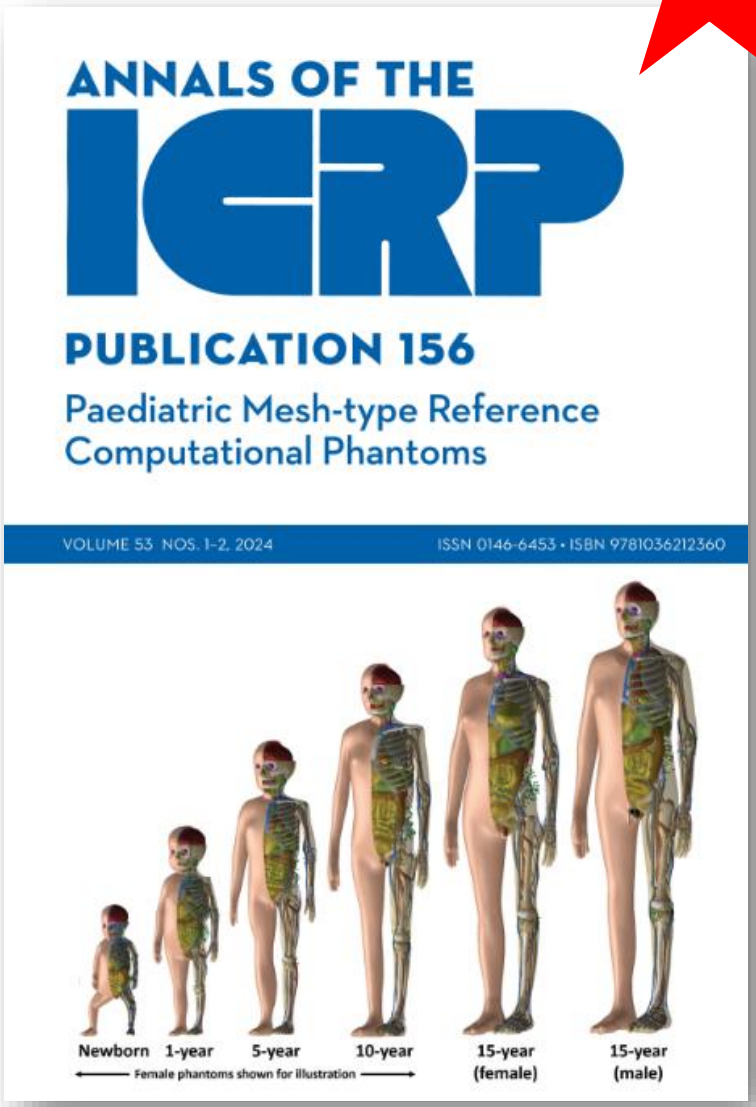
Achievements of TG 103

Adult MRCPs



ICRP Publication 145 (2020)

Paediatric MRCPs



ICRP Publication 156 (2024)

Main Points – ICRP 156 (2024)

- This publication presents paediatric mesh-type reference computational phantoms (MRCPs) representing the reference male and female at 0 (i.e. newborn), 1, 5, 10, and 15 years of age, which are counterparts of the paediatric voxel-type reference computational phantoms in *Publication 143* (ICRP, 2020a) developed based on computed tomography images of real people.

- The paediatric MRCPs were constructed by converting the *Publication 143* voxel phantoms (ICRP, 2020a) to a high-quality mesh format, assimilating the supplementary stylised models used in conjunction with the voxel phantoms to overcome limitations of voxel geometry, and adding tissue layers that are considered to contain cells at risk of radiogenic cancer.

- The paediatric MRCPs include all the necessary source and target tissues defined by the ICRP system for effective dose calculations, including the micrometre-thick source and target layers of the alimentary and respiratory tracts, skin, and urinary bladder, as well as dose calculations for the lens of the eye.

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Main Points – ICRP 156 (2024)

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3. Conversion of the paediatric voxel-type reference computational phantoms to mesh format
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ICRP Publication 156

Paediatric Mesh-type Reference Computational Phantoms

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Authors on behalf of ICRP

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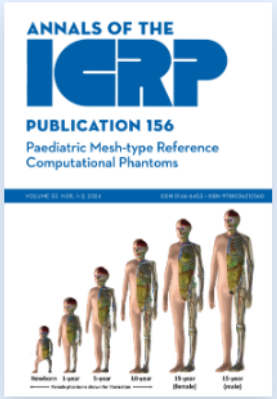
Abstract - Following the issuance of the 2007 Recommendations in Publication 103, the Commission released the adult (male and female) and paediatric (newborn, 1-, 5-, 10-, and 15-year-old male and female) reference computational phantoms in Publications 110 and 143, respectively, for use in effective dose calculations. These phantoms are voxel models represented in the form of a three-dimensional array of cuboidal voxels, which were constructed from computed tomography images of people and adjusted to be consistent with the reference anatomical parameters given in Publication 89. The voxel phantoms provide anatomical improvements over the mathematical-equation-based stylised phantoms used for the previous dose coefficient (DC) calculations prior to the 2007 Recommendations. Nevertheless, the voxel phantoms, due to the nature of voxel geometry and finite voxel resolutions, have limitations in representing small and thin organs and tissues, necessitating additional supplementary stylised models such as those defined for the respiratory tract airways, the alimentary tract organ walls and stem cell layers, the lens of the eye, and the skin basal layer. To address the limitations of the voxel phantoms, Task Group 103 was charged with developing mesh-type reference computational phantoms (MRCPs) by converting the voxel phantoms into a high-quality/fidelity mesh format with anatomical improvements for the complex organs and tissues which were not represented fully in the voxel phantoms. MRCPs for the adult male and female were then developed and released recently in Publication 145. Following the release of the adult MRCPs, the current publication describes the construction of the paediatric MRCPs, the counterparts of the Publication 143 voxel phantoms. The paediatric MRCPs, like the adult MRCPs, were developed to have all the source and target tissues required for calculation of effective dose, including the micrometre-scale regions, assimilating the supplementary stylised models. These phantoms can be used directly in general purpose Monte Carlo codes, such as Geant4, PHITS, and MCNP6, fully maintaining the high fidelity of the mesh geometry in Monte Carlo dose calculations. To investigate the impact of the paediatric MRCPs, the DCs of organ dose and effective dose and specific absorbed fractions (SAFs) for some selected external and internal exposures were calculated and compared with the values calculated using the Publication 143 phantoms, the Publication 66 and 100 mathematical models for the respiratory and alimentary tracts, and the reference values of Publication 155. While some differences in the DCs and SAFs were observed for anatomically improved organs and weakly penetrating radiations, they were found to be fairly similar, indicating that the reference DCs obtained from the Publication 143 voxel phantoms for both external and internal exposures remain valid in the current ICRP dosimetry system. The Publication 143 voxel phantoms remain the primary ICRP/International Commission on Radiation Units and Measurements reference models for the calculation of reference DCs based on Publication 103 methodology. The paediatric MRCPs will be used for all calculations of reference DCs following the next set of ICRP general recommendations, and provide a resource for wider use in radiological protection applications.



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