

ICRP

Computational Phantoms of Children and Pregnant Females

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INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

Contents

- Background
- Computational human phantoms for children
- Computational human phantoms for pregnant females

Background

How to estimate protection quantities

External Exposure

Physical quantities



Dose coefficients



Equivalent dose and Effective dose

Internal Exposure

Intake of radionuclide



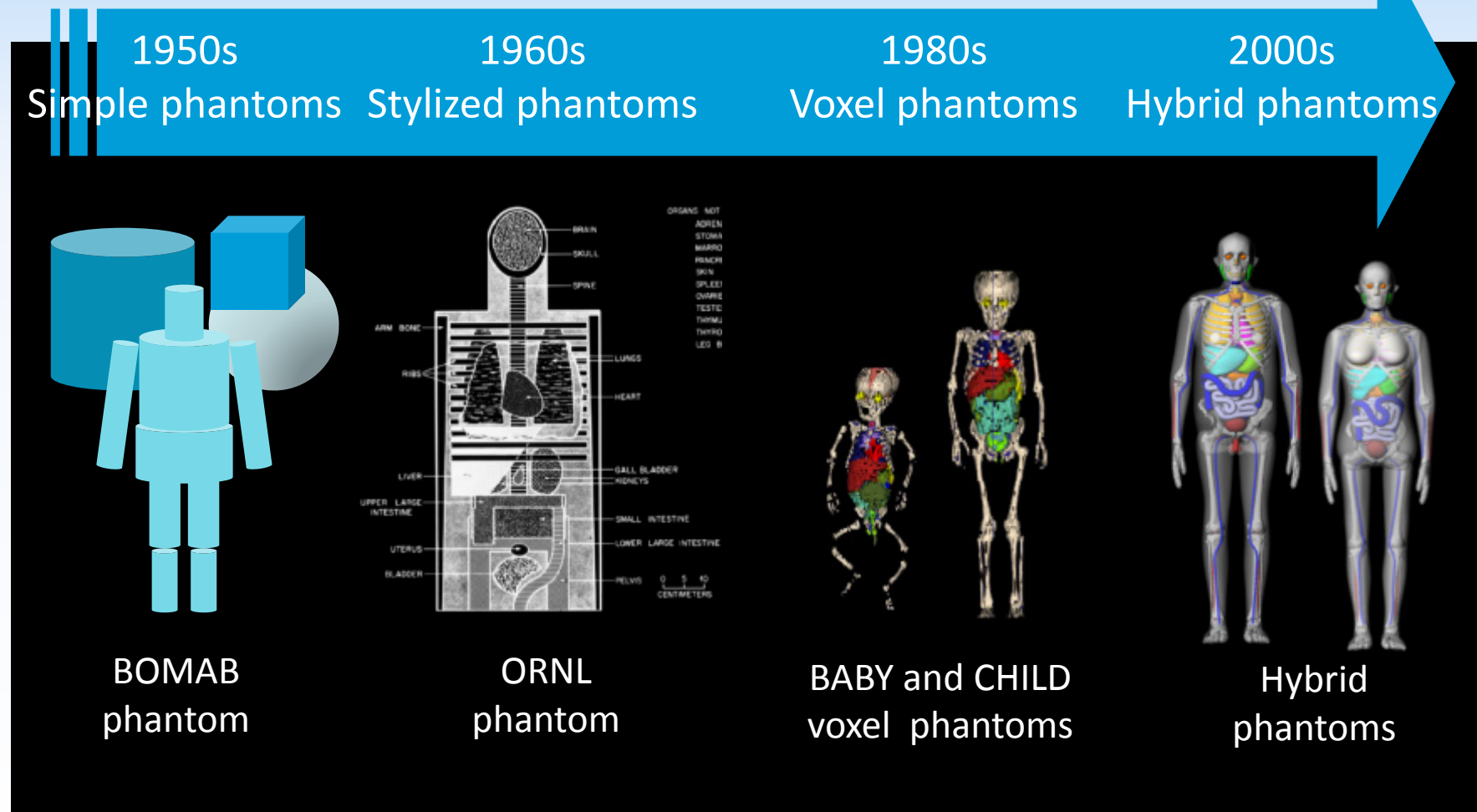
Dose coefficients



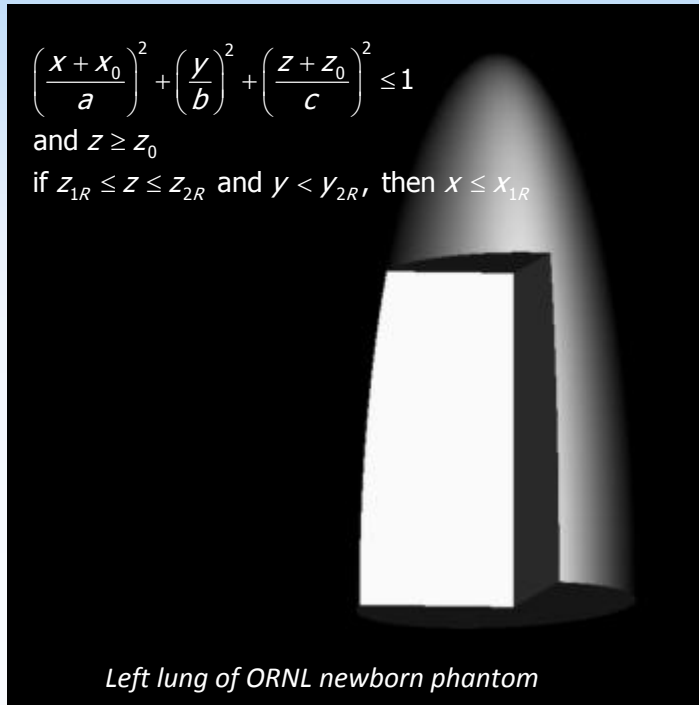
Equivalent dose and Effective dose

Evolution of Computational Human Phantoms

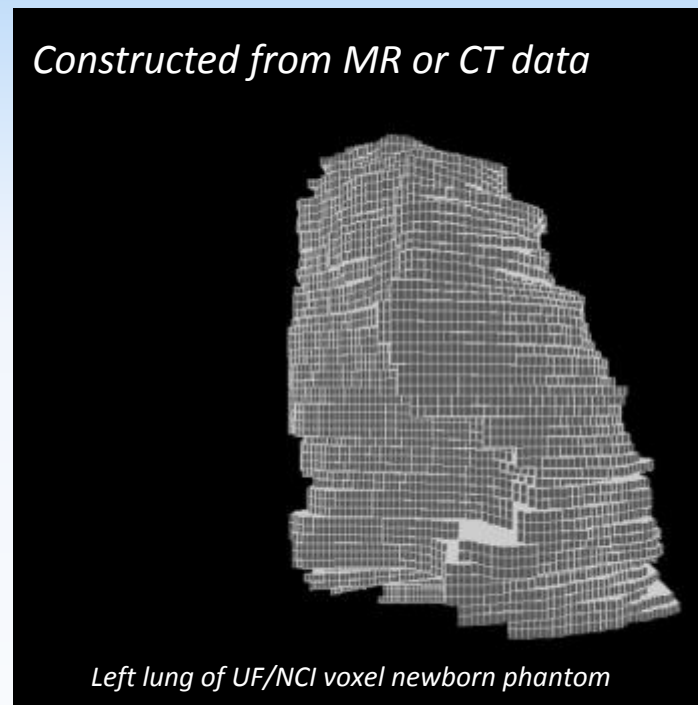
More accurate anatomy



First vs. Second generation phantoms

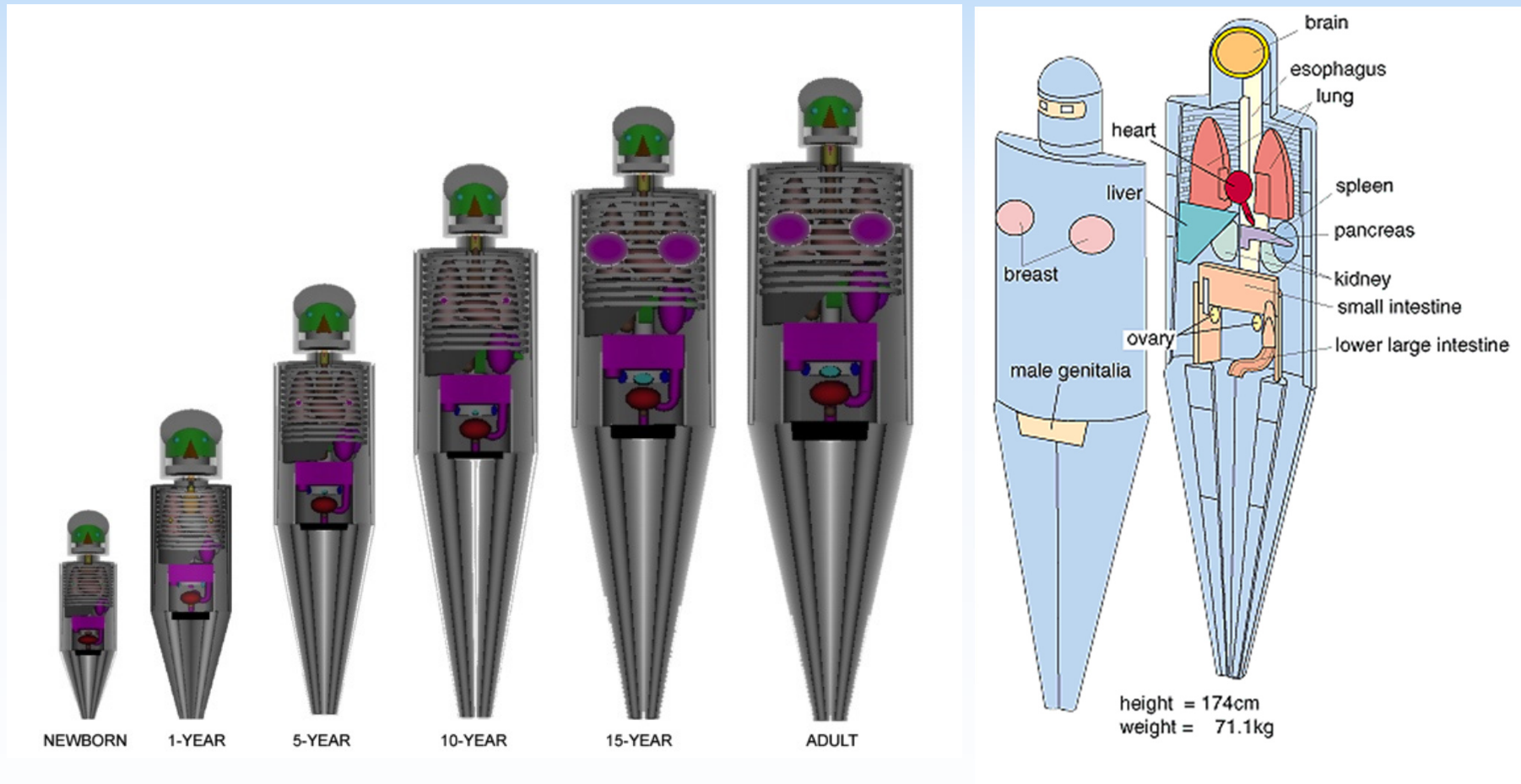


Stylized (mathematical)
phantom
Since 1960s



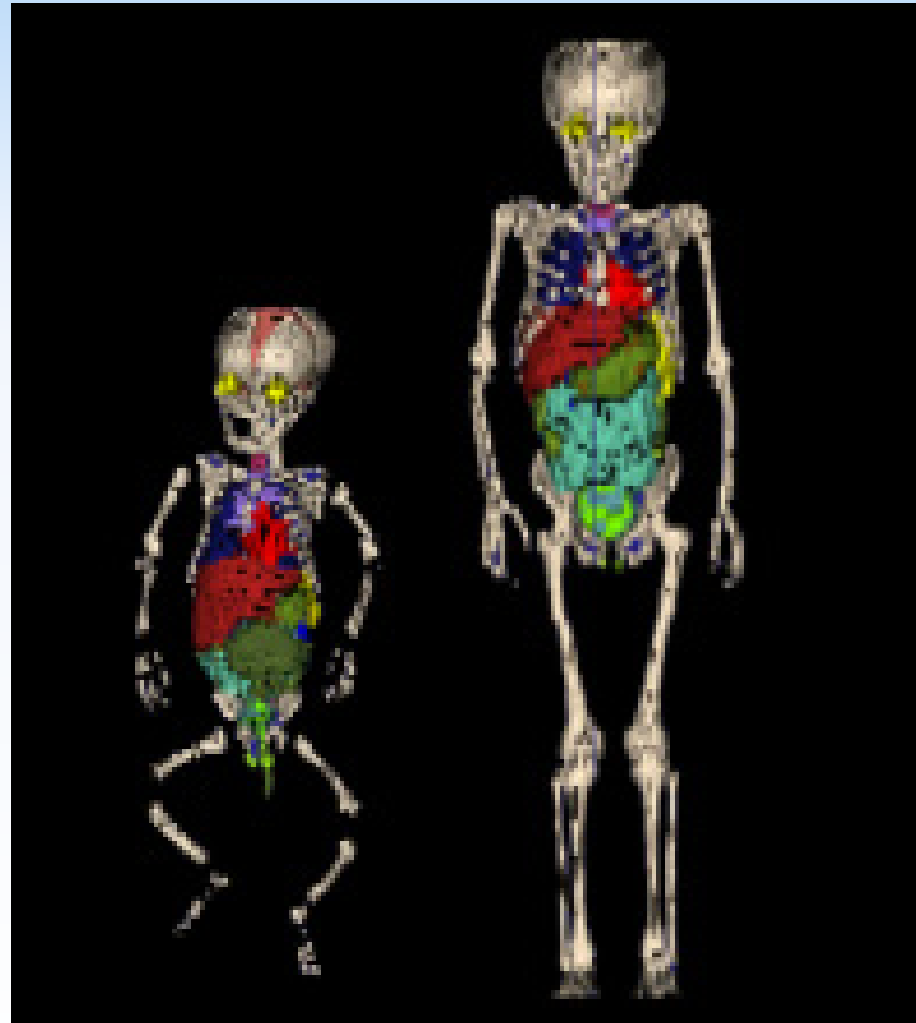
Voxel (tomographic)
phantom
Since 1980s

ORNL Stylized Phantom Series*

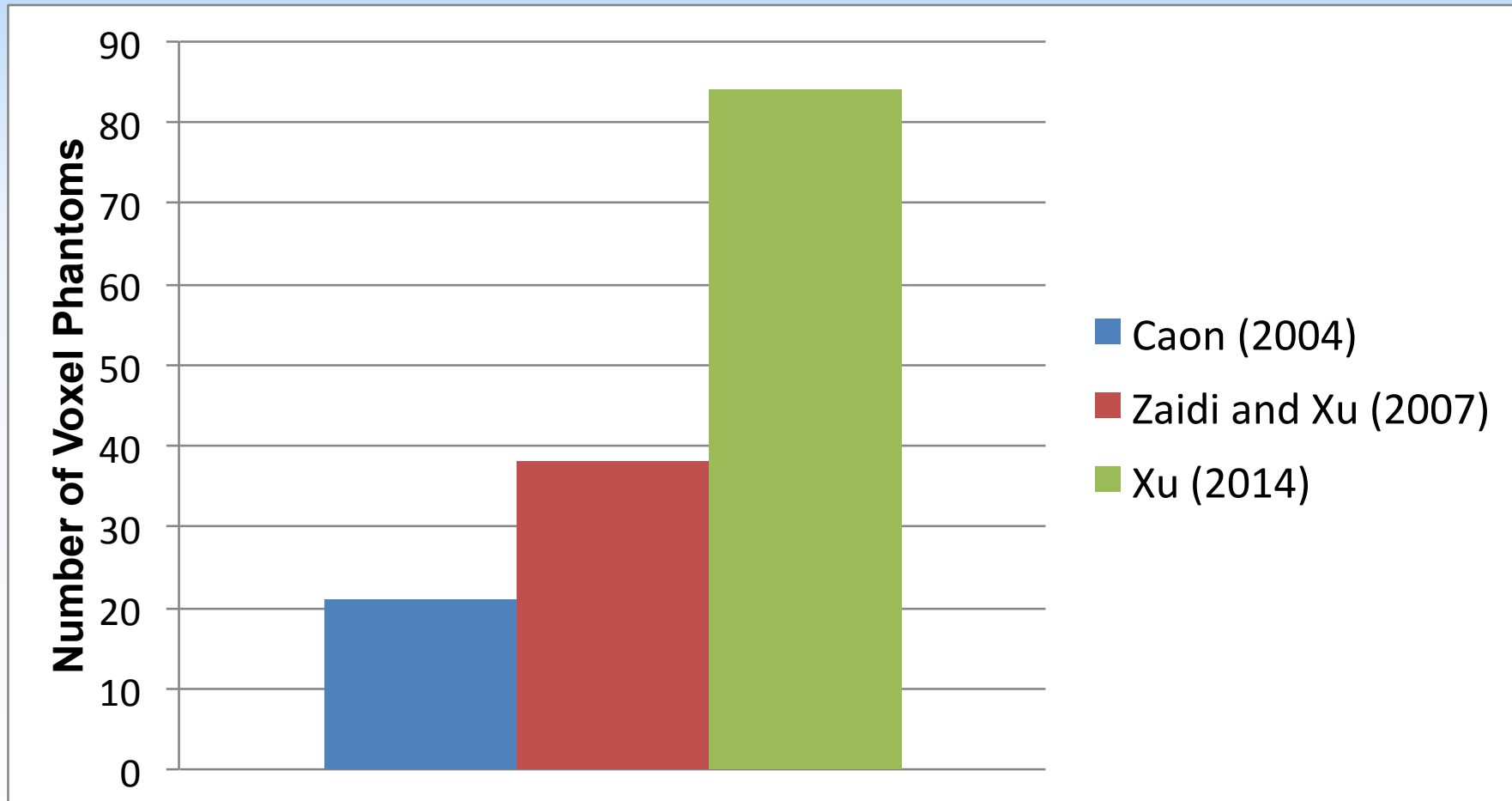


First Voxel Phantoms*

2-month BABY (left) and
7-year CHILD (right)
pediatric voxel phantoms



Status of Voxel Phantoms*

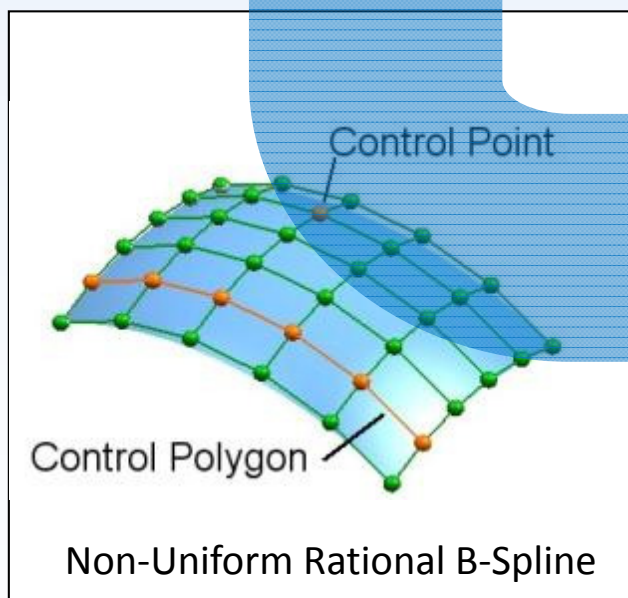


Computational Human Phantoms of Children

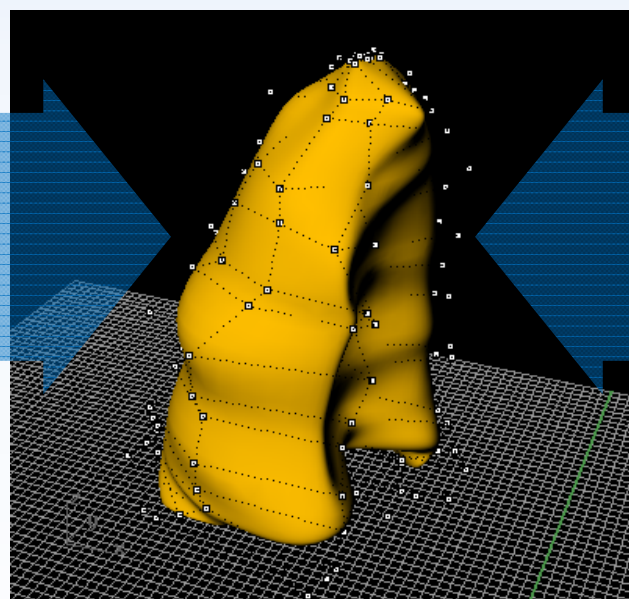
Third generation phantoms: Hybrid Phantom

Stylized phantom

Mathematical Flexibility
(NURBS surface)

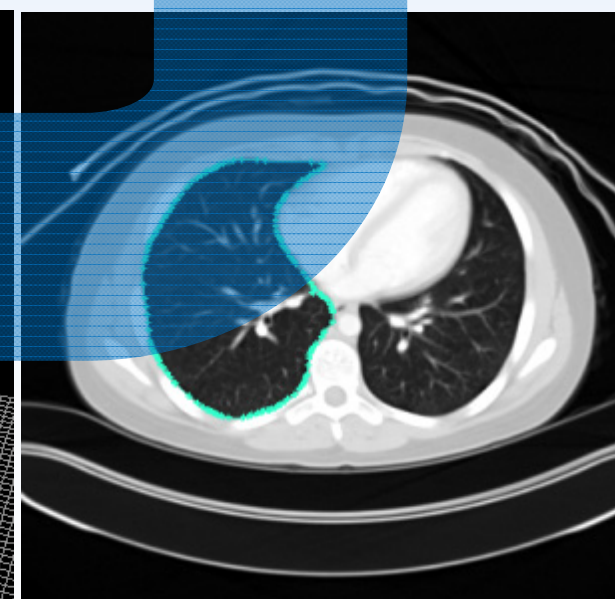


Hybrid approach



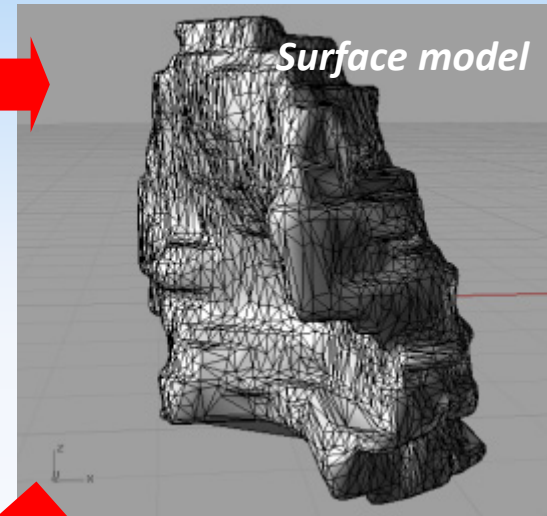
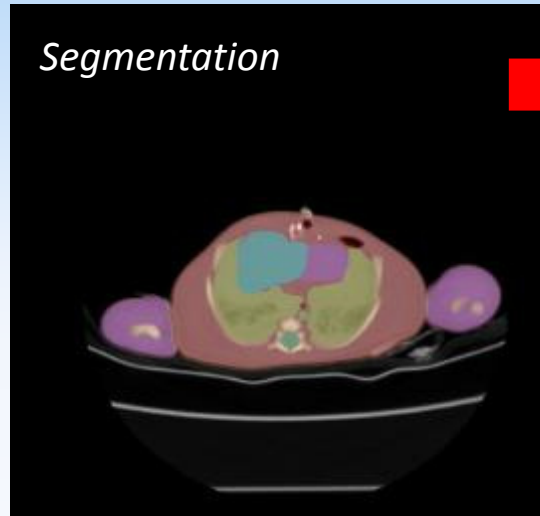
Voxel phantom

Anatomical Realism
(CT images of patient)



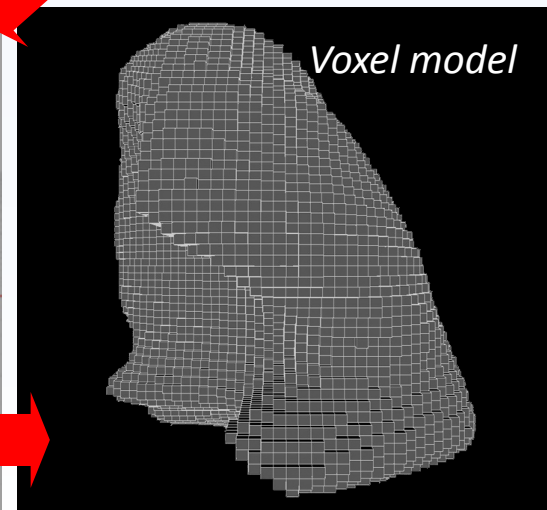
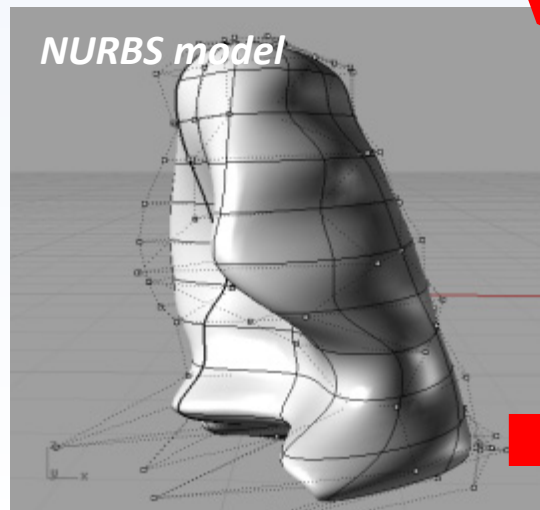
Procedure to develop hybrid phantom

Contour organs from CT images of real patients



Build surface models from organ contours

Smoother and more flexible than surface models



Convert to voxel models for Monte Carlo calculations

Reference data incorporated

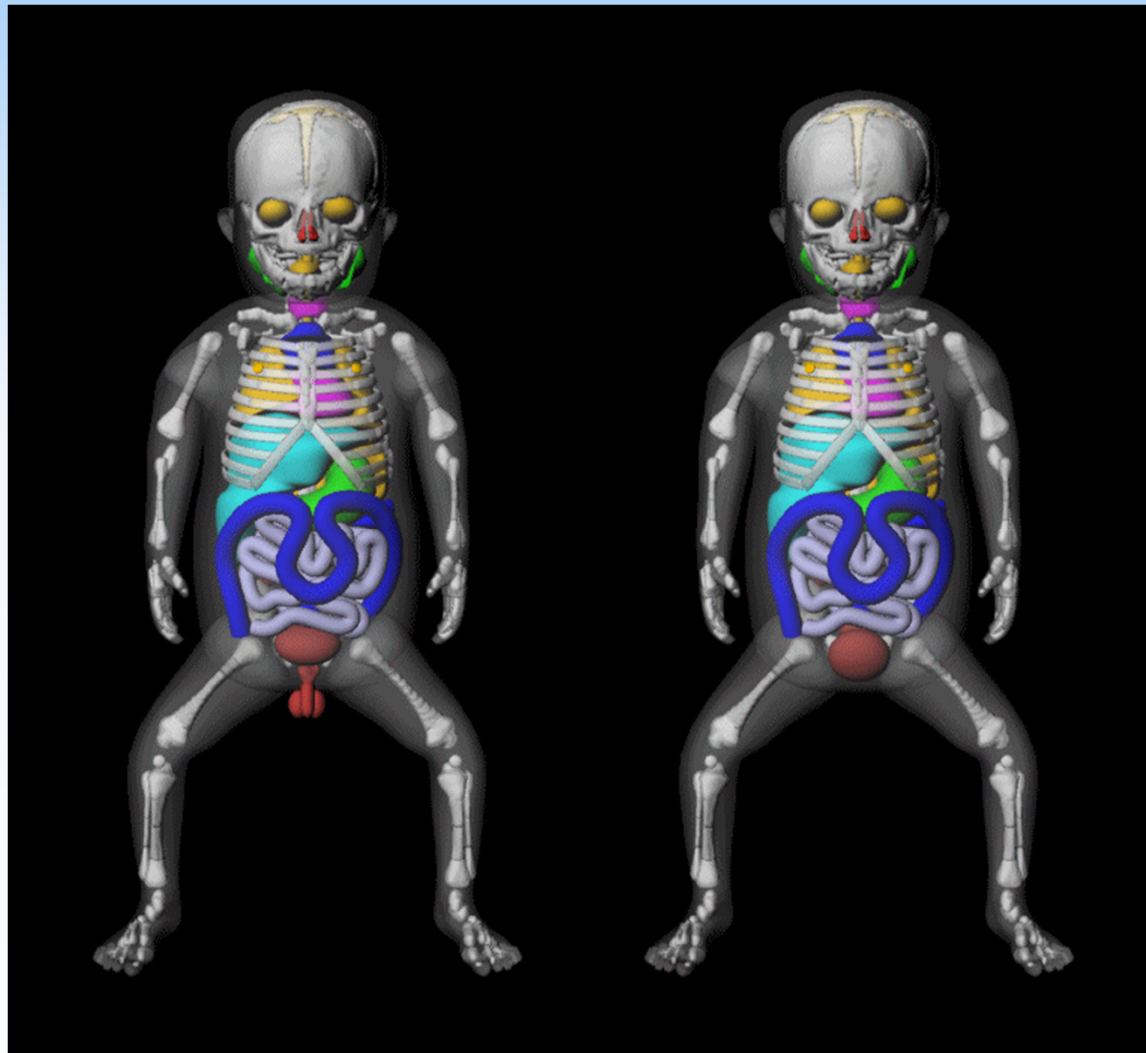
Reference organ volume
(ICRP Publication 89)

Reference organ composition
(ICRU 46 & ICRP 89)

Reference gastro-intestine
(ICRP Publication 100)

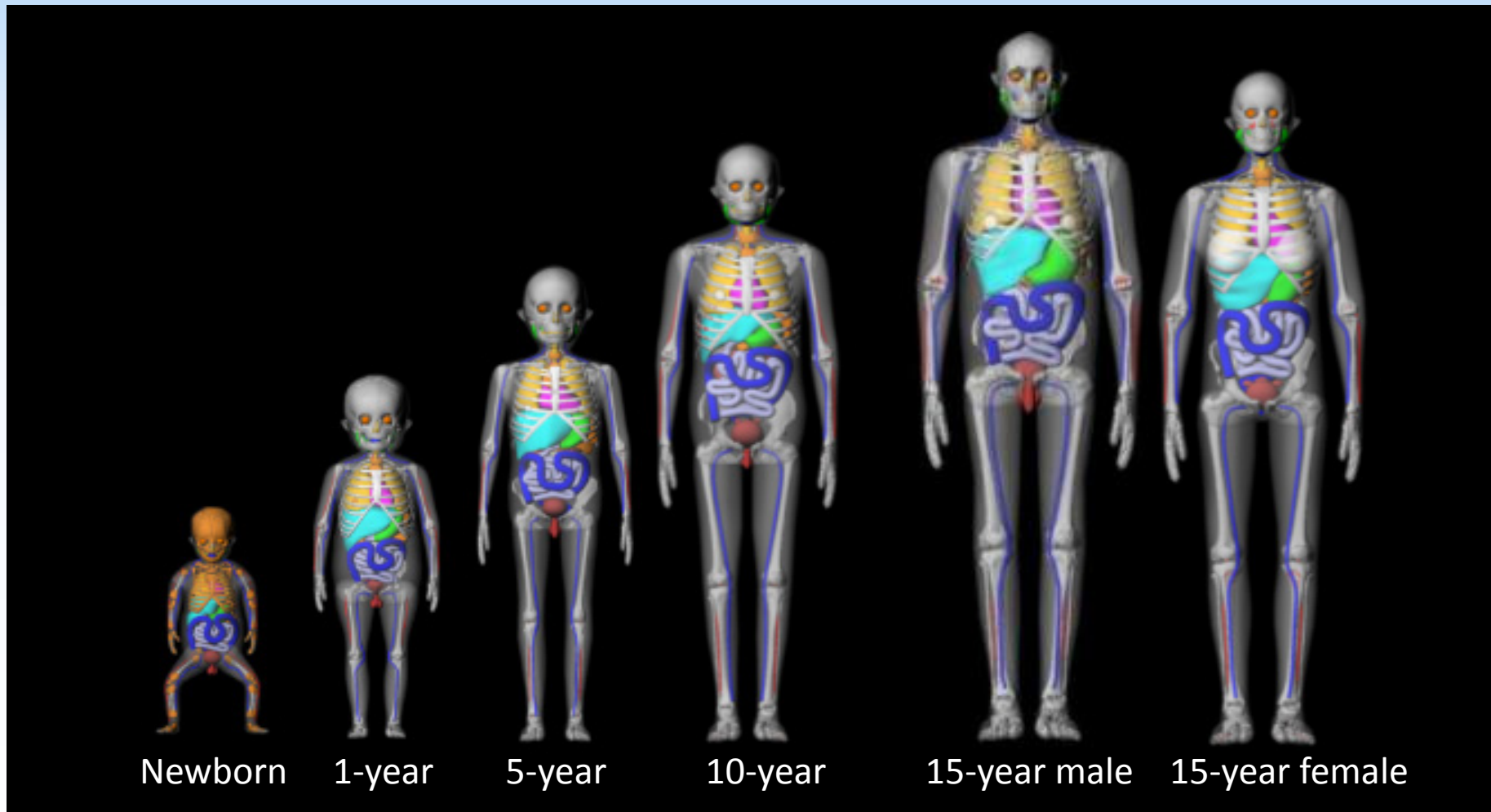
Reference anthropometry
(CDC NHANES data)

First newborn hybrid phantoms*

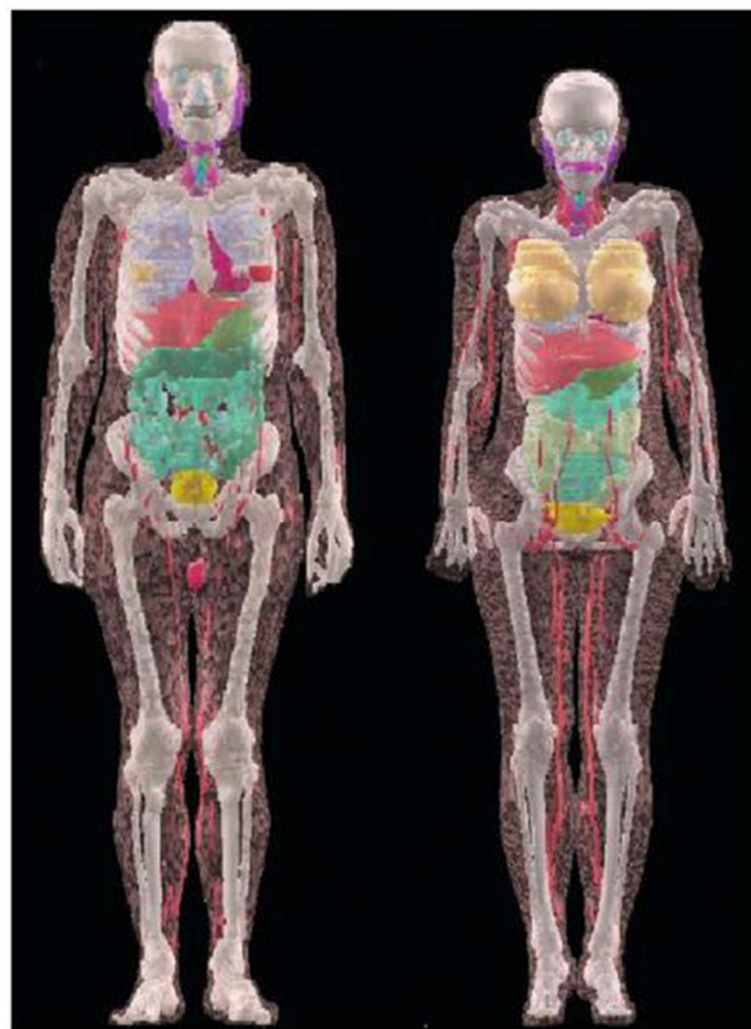


UF/NCI hybrid male (left) and female (right)
newborn phantoms

UF/NCI Hybrid Phantoms for Children (2006-2013)



ICRP Adult Reference Phantoms*



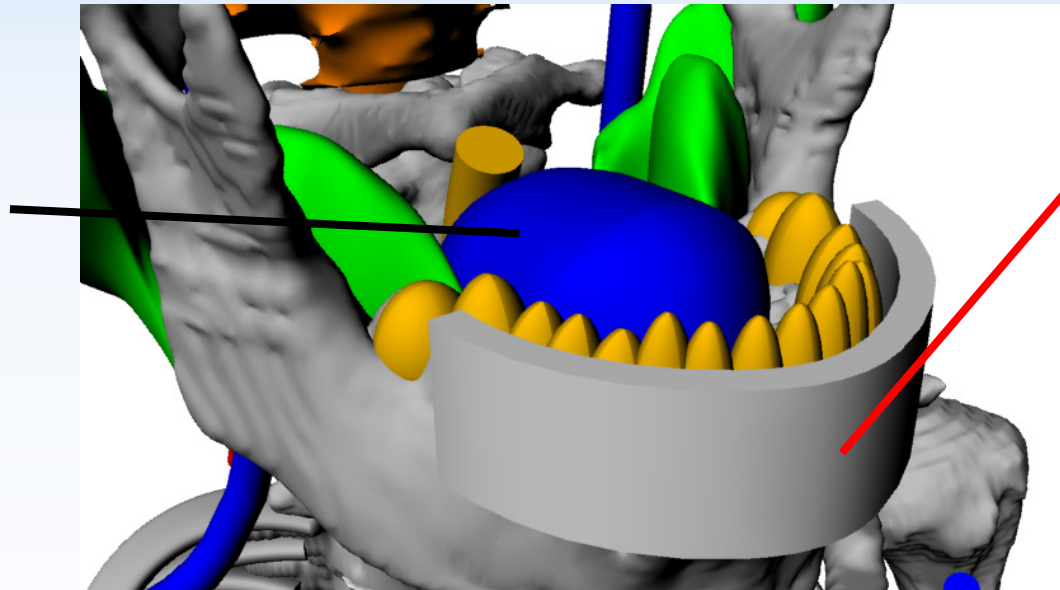
- Developed from Golem (male) and Laura (female) adult phantoms.
- ICRP Committee II Task Group DOCAL**
- External dose conversion coefficients (ICRP 116)
- Internal dose coefficients (coming soon)

ICRP Pediatric Phantoms

- ICRP Committee II Task Group CPRT*
- Adopt UF/NCI pediatric phantoms as a template
- Additional modeling
 - Oral mucosa, lips and cheeks
 - Breast: glandular + adipose
 - Lung blood
 - Ureters
 - Lymphatic node model
 - Skeletal muscle model

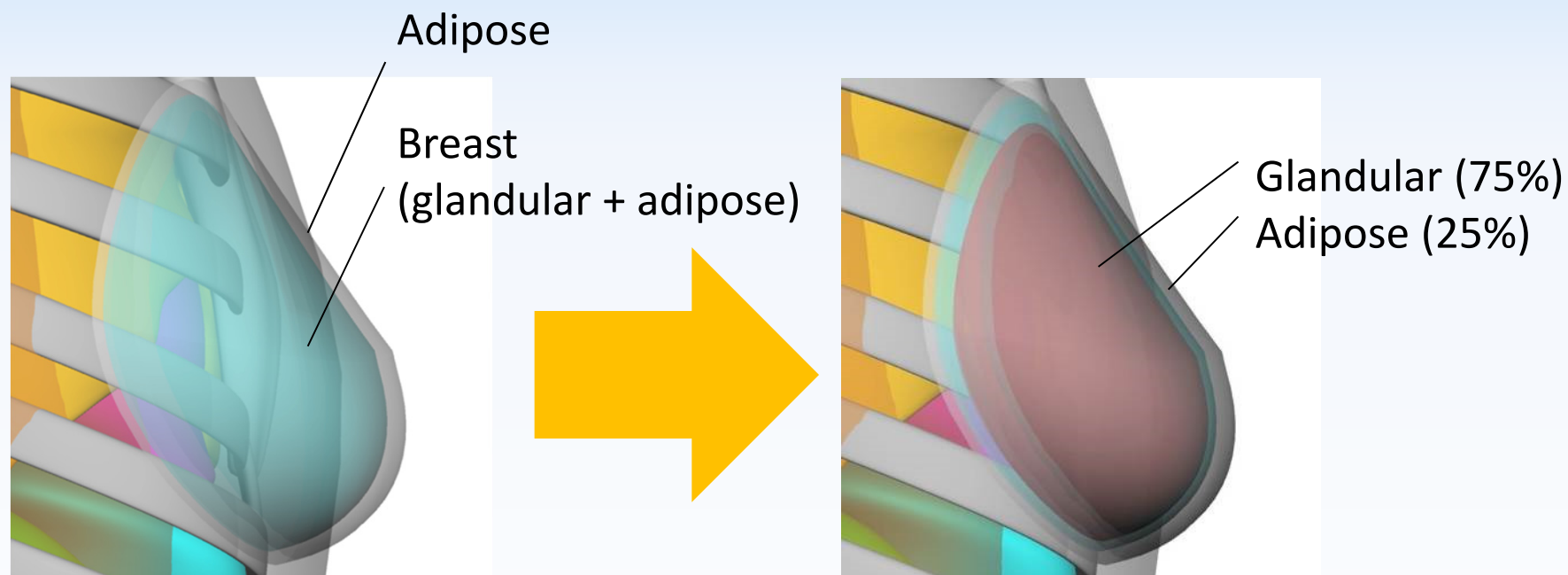
Oral mucosa, lips and cheeks ICRP pediatric phantoms

Oral
mucosa
layer
(tongue)

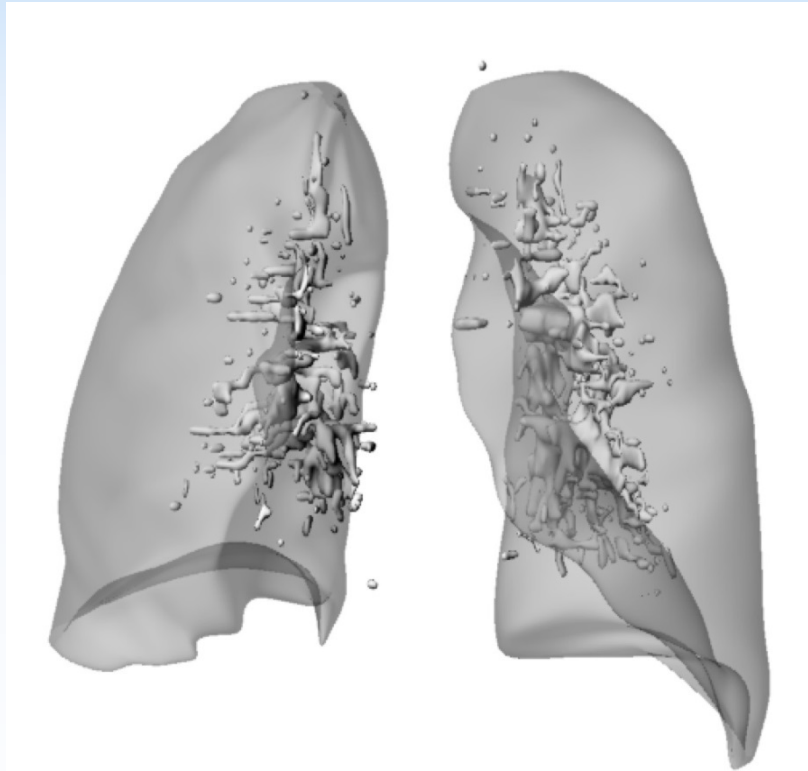


Oral
mucosa
layer
(lips and
cheeks)

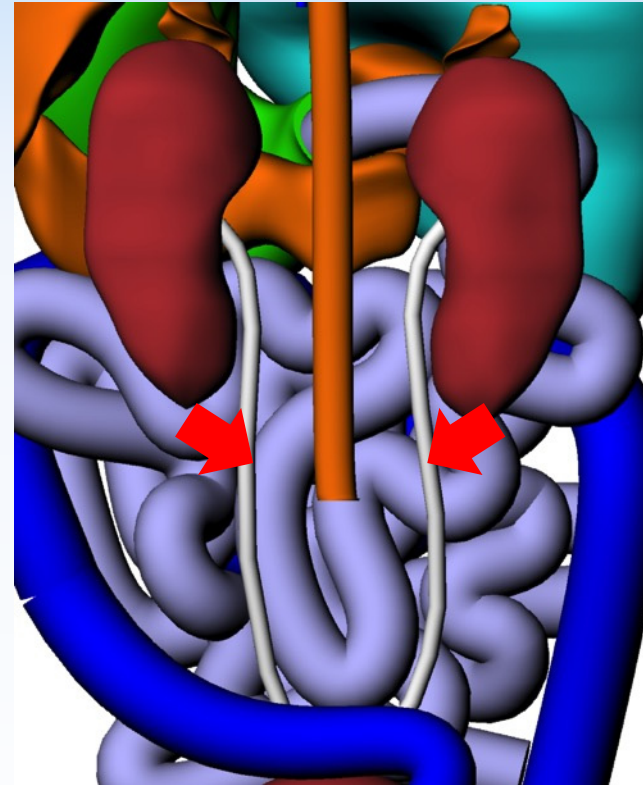
Breast model ICRP 15-year-old female



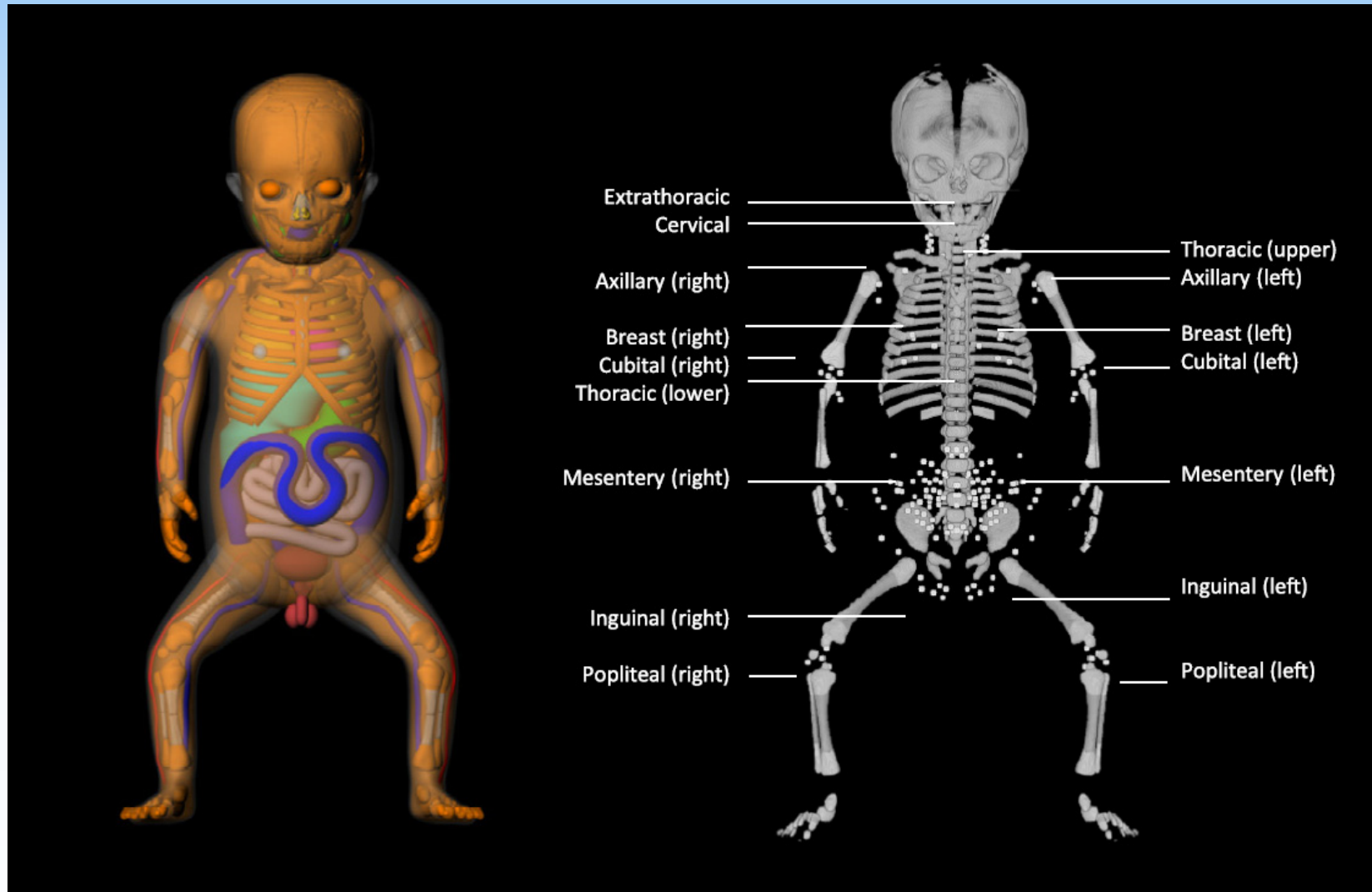
Lung blood and ureters



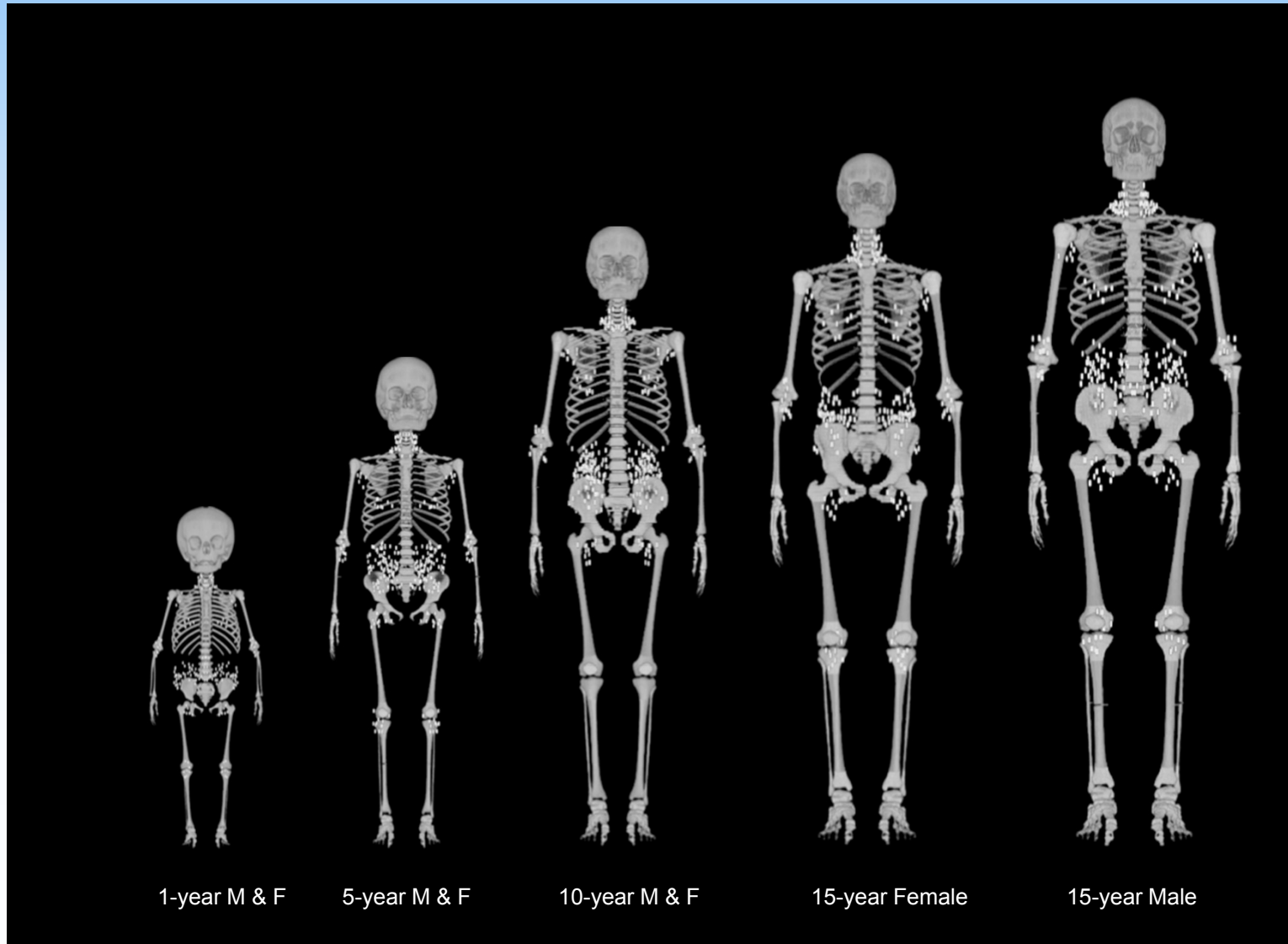
Lung model in the ICRP
15-yo female phantom



Ureter model in the ICRP
15-yo male phantom



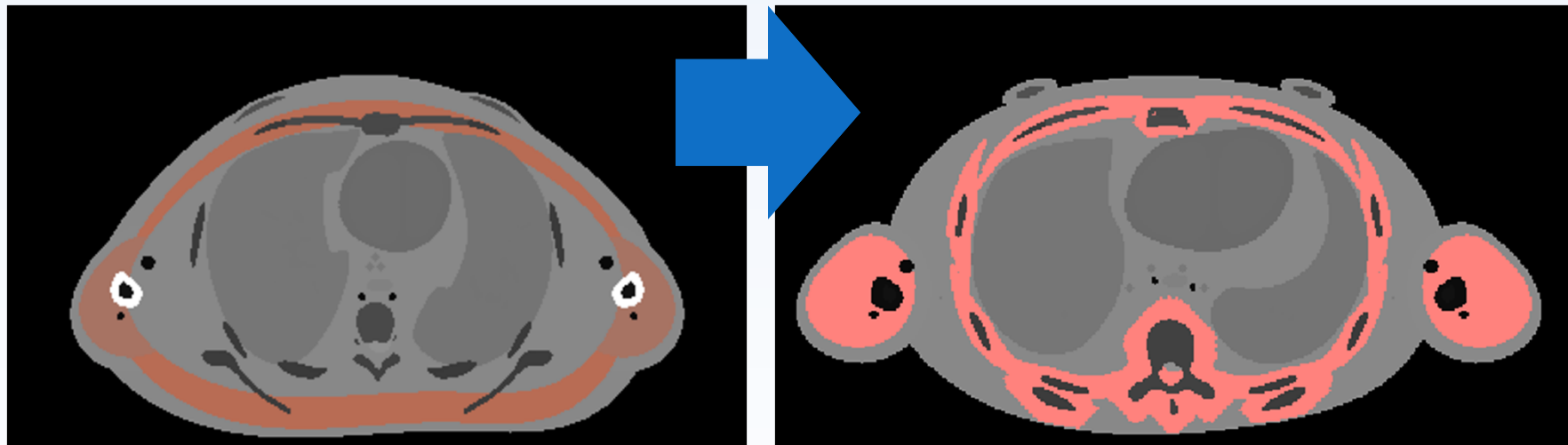
Lymph nodes computationally generated for the newborn male phantom in 16 different cluster sites



Lymph nodes generated for the ICRP pediatric phantoms

Skeletal muscle model

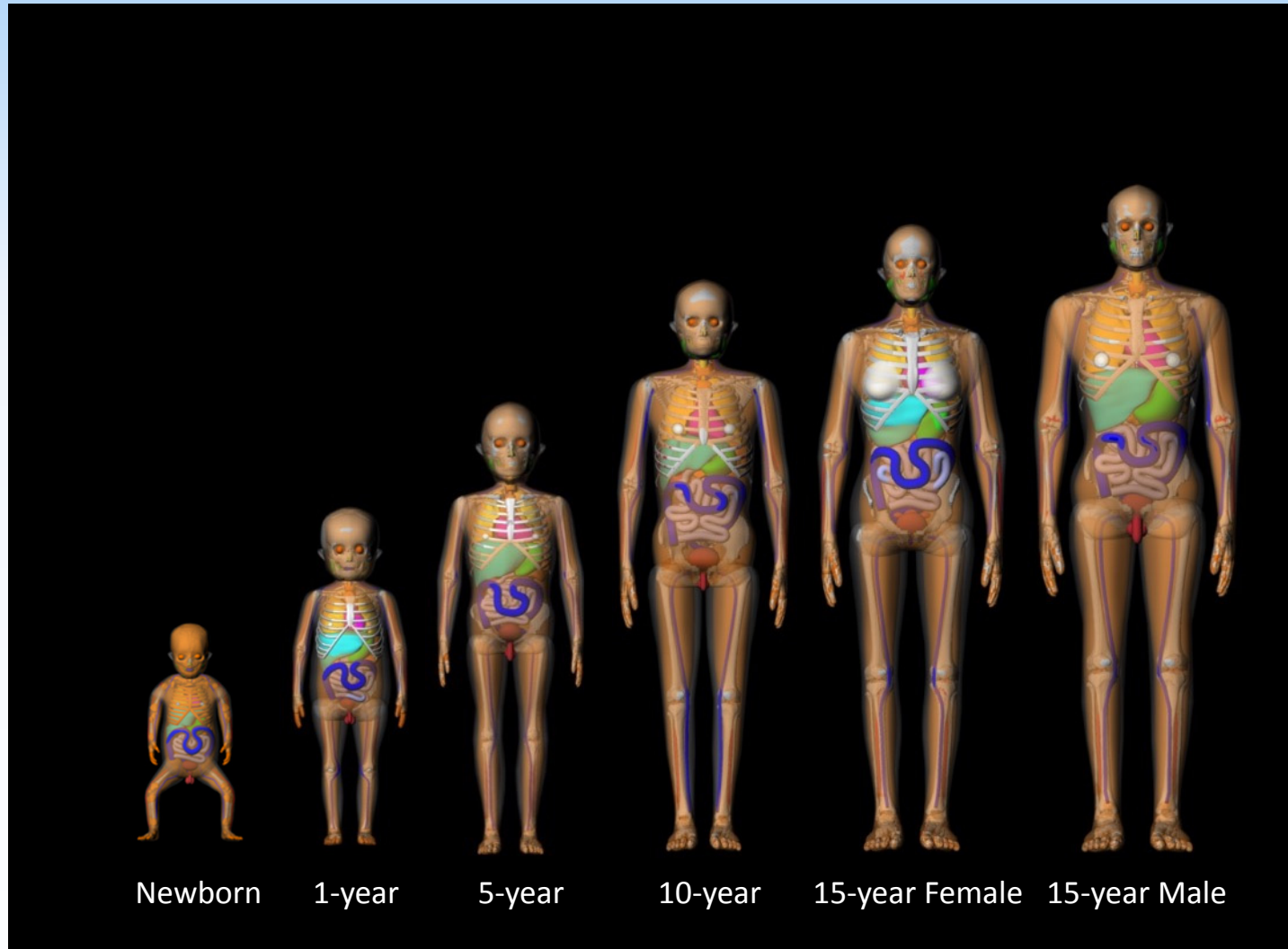
Revise simplified muscle model in UF/NCI phantoms using an in-house MATLAB script which grows muscle layers around skeleton (Stepusin et al. at UF)



Original muscle model in the UF/NCI phantoms

New muscle model in the ICRP pediatric phantoms

ICRP Pediatric Phantoms



Ongoing ICRP tasks

- Beta version tested by the TG members
- Internal dose coefficients (Task Group CPRT*)
- ICRP Publication XXX for the pediatric phantoms + internal dose coefficients.
- Environmental dose coefficients for public (Task Group ENVIR**)

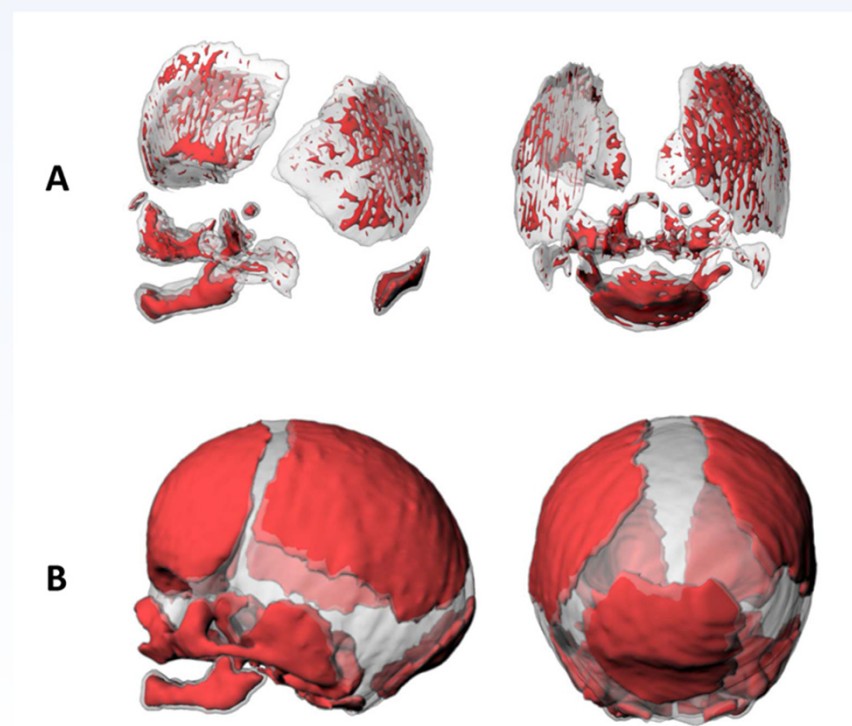
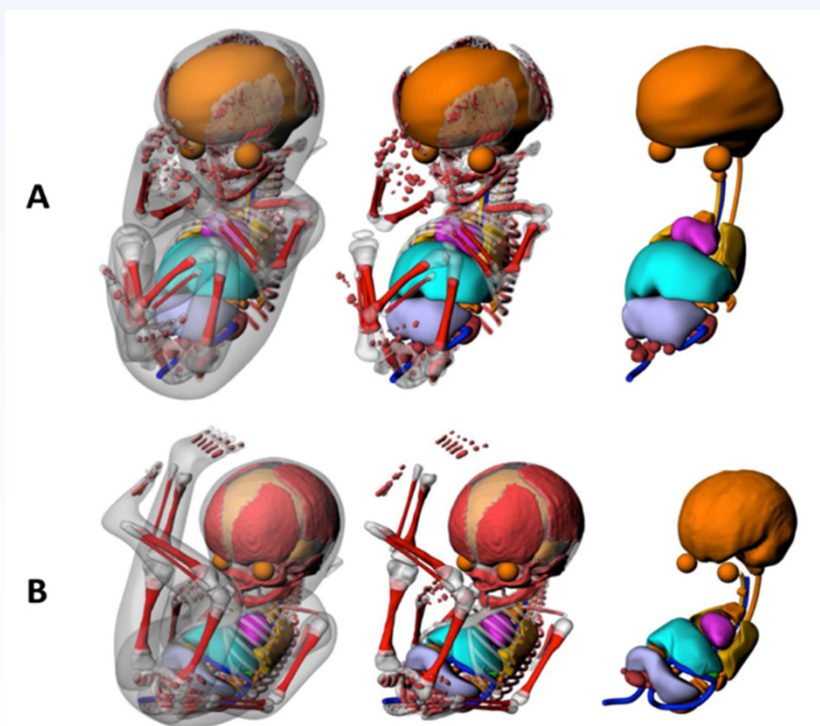
*CPRT: Computational Phantom and Radiation Transport

**ENVIR: Environmental Dosimetry

Computational Human Phantoms of Pregnant Females

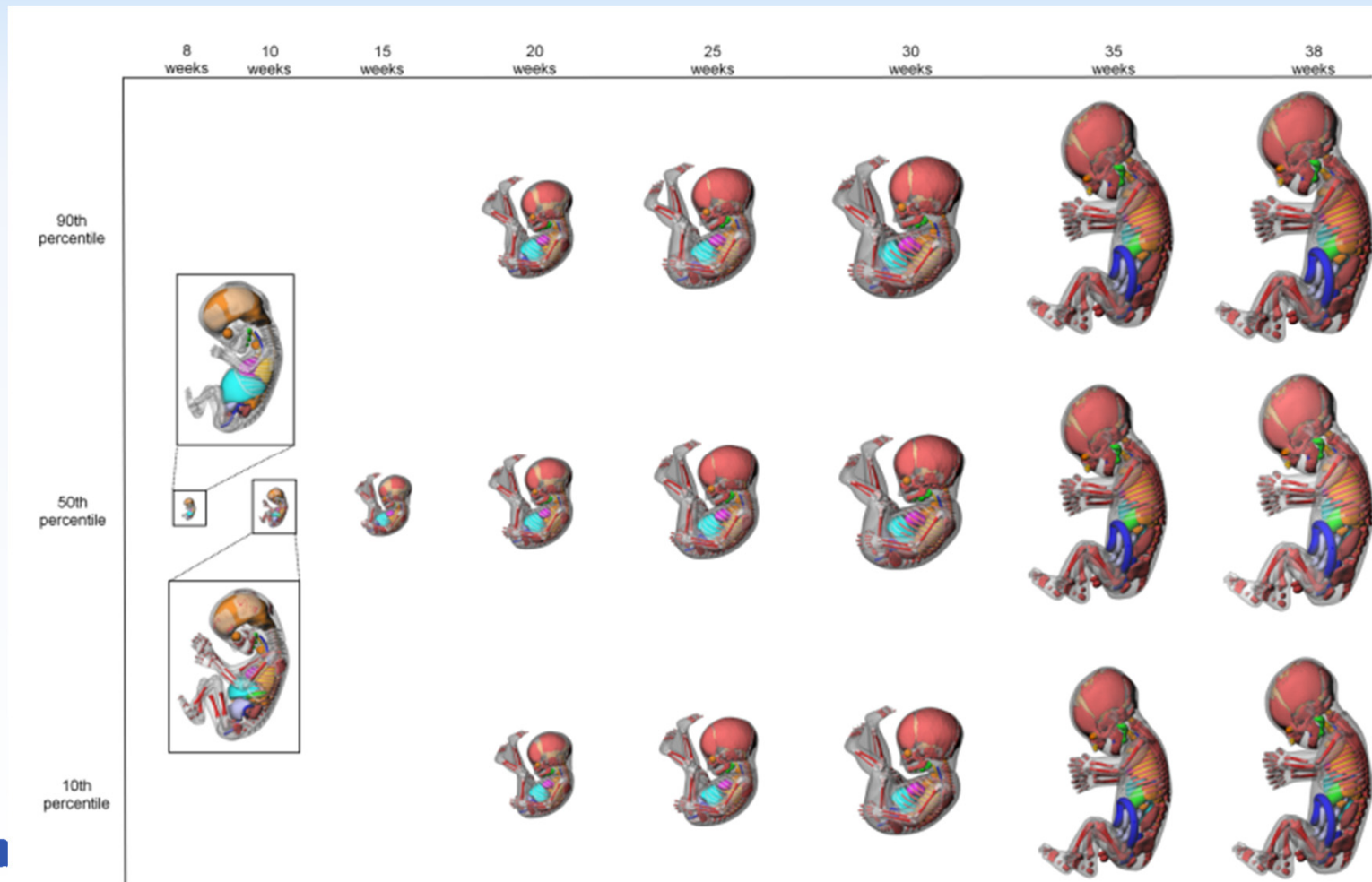
UF Series of Fetal and Pregnant Female Phantoms

- Developed to support epidemiological studies of childhood cancer following in-utero exposure at the Mayak Pu Production Facility and the villages along the Techa River in the 1950s.
- Originally based on segmented CT, MR, and NMR microscopy images of specimens at 11.5 and 22 weeks post-conception.



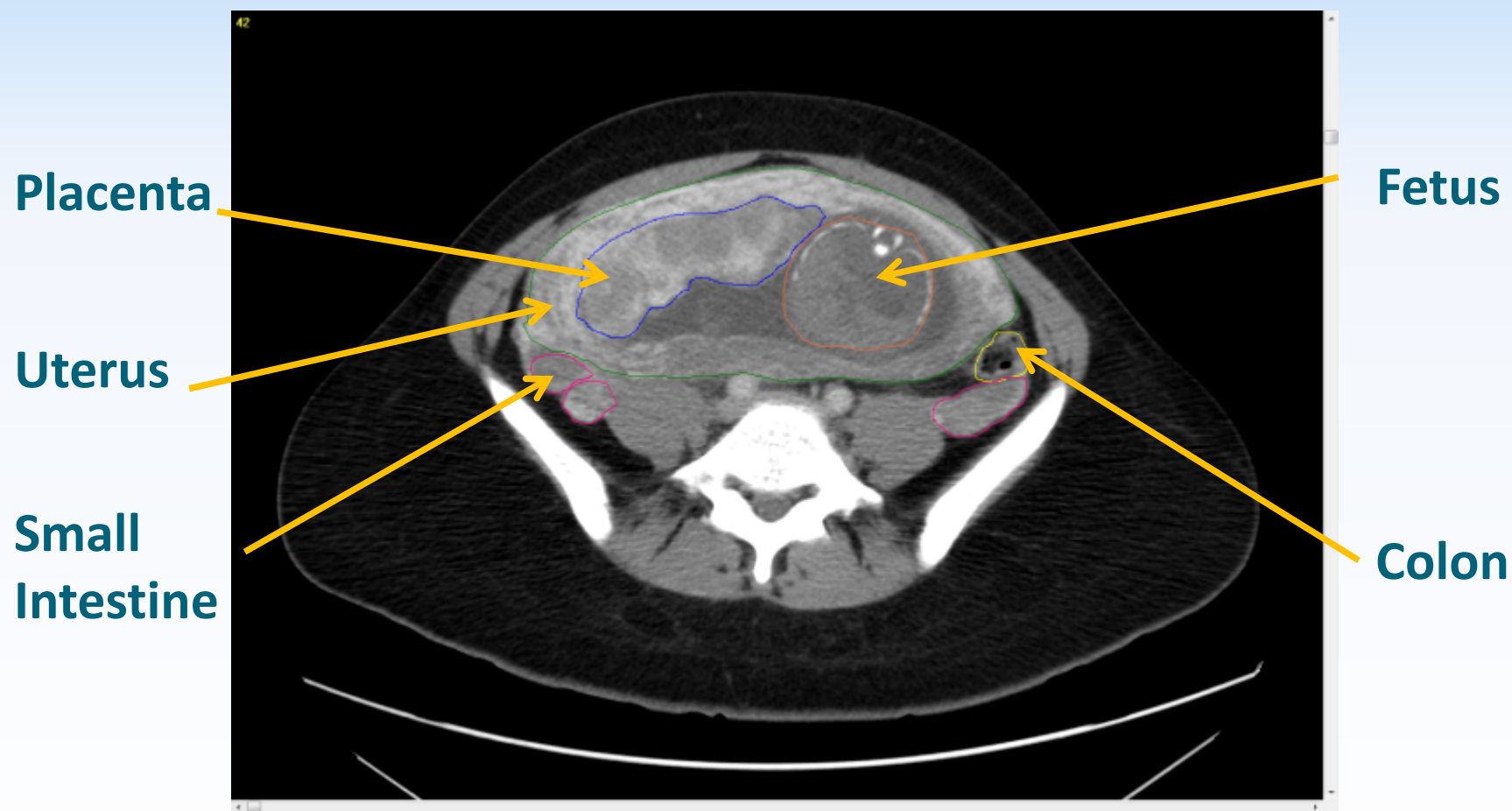
UF Series of Fetal and Pregnant Female Phantoms

These specimen-specific models were volumetrically rescaled to create a set of reference models at 8 weeks to 38 weeks post-conception.



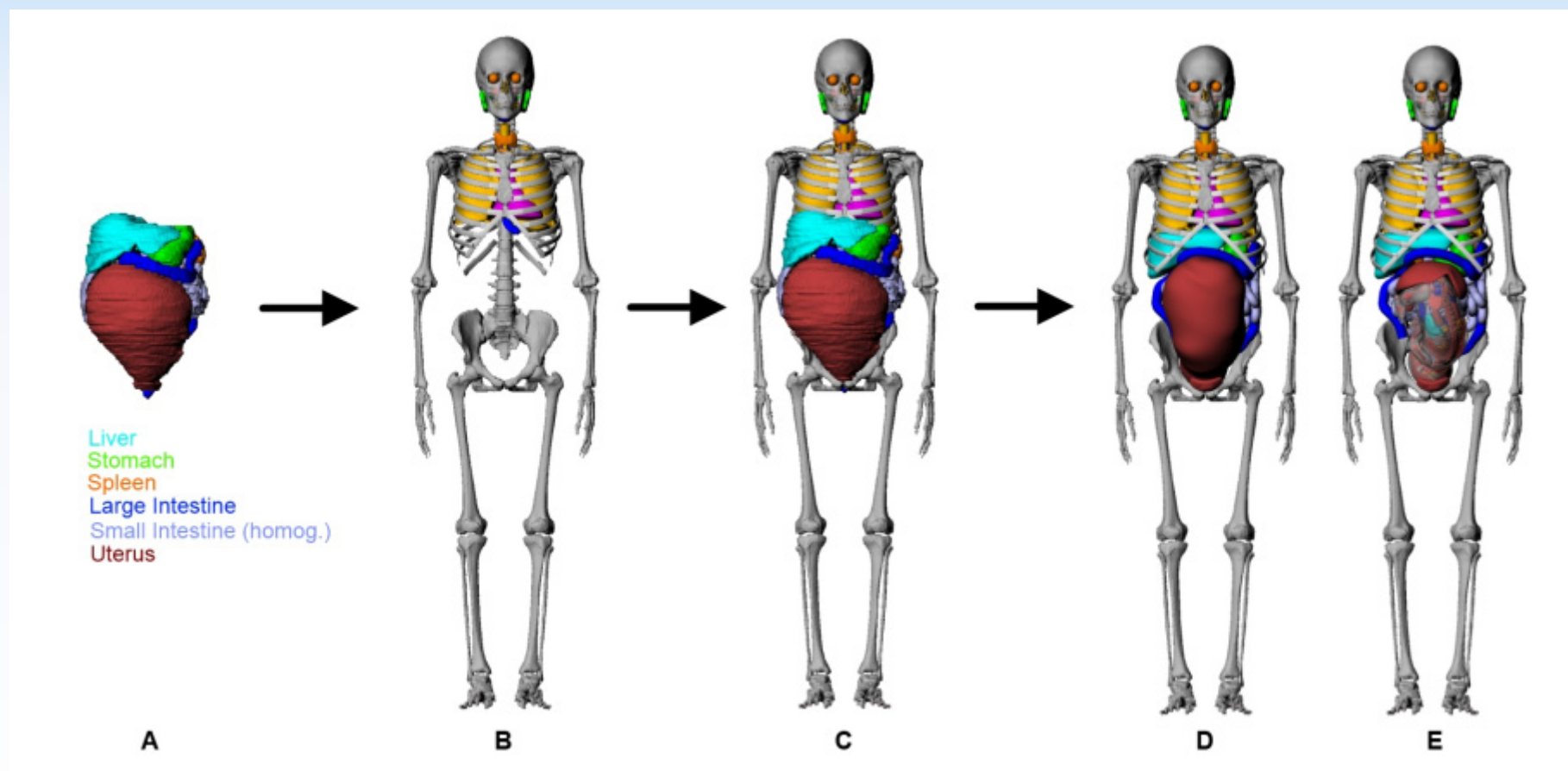
UF Series of Fetal and Pregnant Female Phantoms

Next, CT images of the abdominal region of pregnant females with fetuses of equivalent volume were segmented.

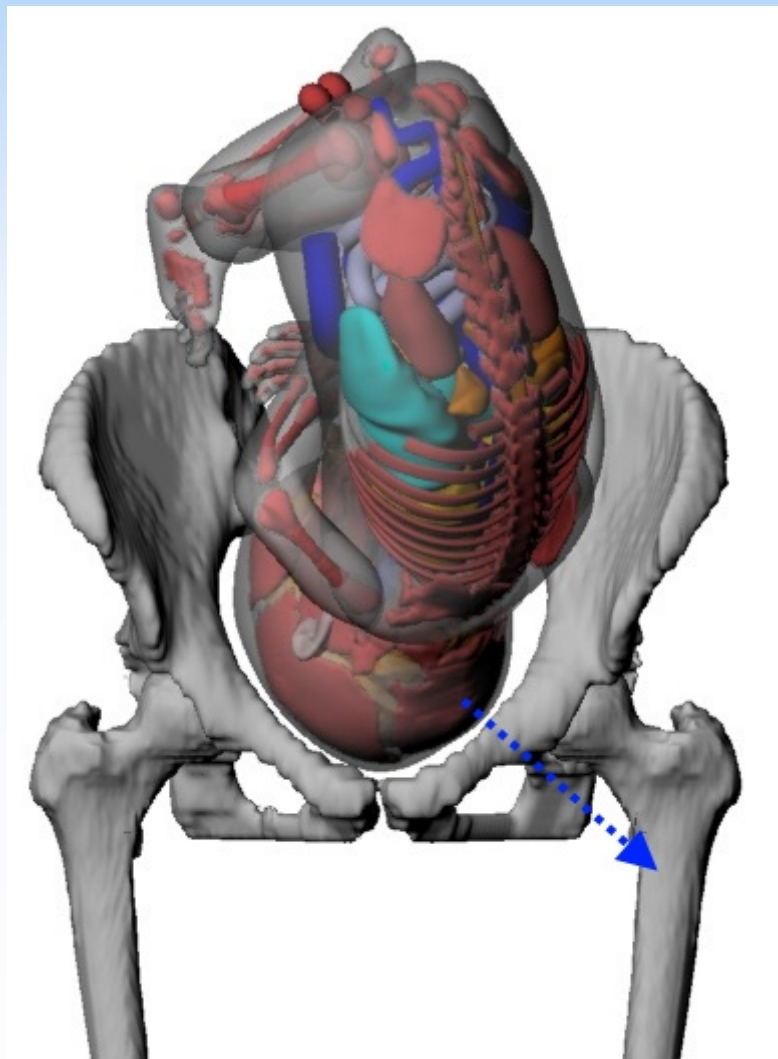


UF Series of Fetal and Pregnant Female Phantoms

The CT-segmented anatomy was inserted into the UF/NCI adult female phantom and re-sized to ICRP reference masses. The appropriate fetal model was then inserted at a nominal fetal orientation and uterine position.

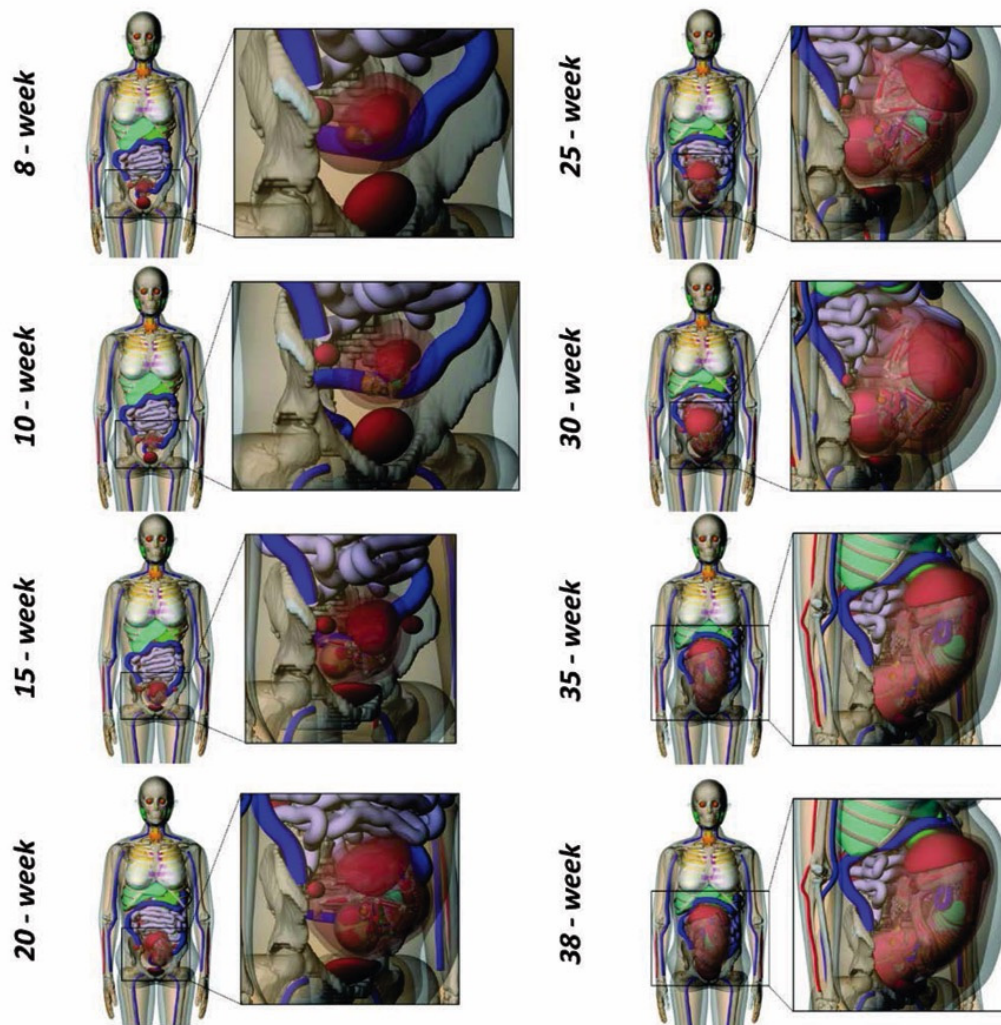


UF Series of Fetal and Pregnant Female Phantoms



- Reference Position Assumed
- Approximate left occiput anterior (LOA) fetal orientation in 38-week UF pregnant female phantom
- However, other positions (e.g., breech) can be easily modeled

UF Series of Fetal and Pregnant Female Phantoms



Voxel forms of these models are adopted by ICRP for future publication of

- Specific Absorbed Fractions
- Biokinetic Models
- Dose Coefficients for Fetal Organ Dosimetry

Thank you for your attention



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