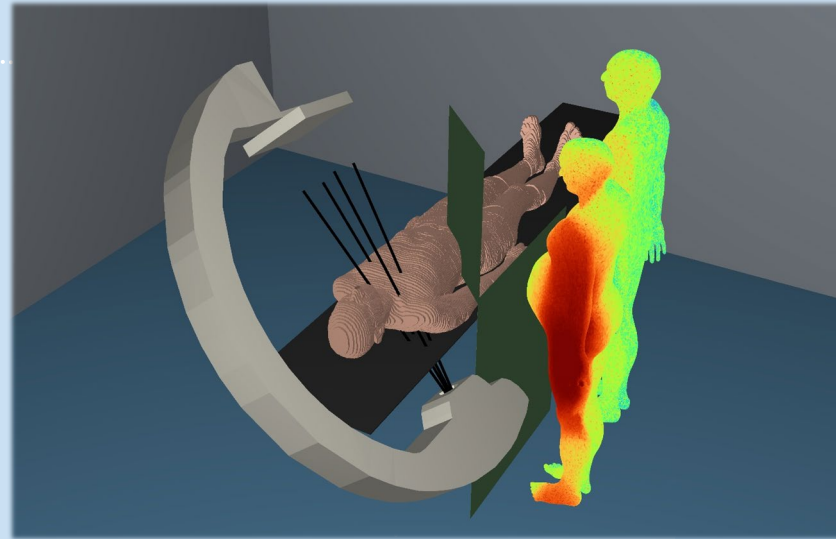


Towards modelling of fetus doses for workers in x-ray image guided interventional labs



Erlend Andersen
25.08.2025

Respect • Professional excellence • Accessibility • Commitment

Risks of fetal irradiation

Table 4. Probability of bearing healthy children as a function of radiation dose

Effect	Gestation age [week]	Threshold dose [mGy]
Death	2-7	200-500
	7-21	>500
	21-	>1000
Malformation	3-11	100
CNS damage	8-25	100

Absorbed dose to conceptus, mGy, above natural background	Probability that child will have <i>no</i> malformation, %	Probability that child will <i>not</i> develop cancer (age 0-19), % ¹⁾
0	97	99.7
0.5	97	99.7
1.0	97	99.7
2.5	97	99.7
5	97	99.7
10	97	99.6
50	97	99.4
100	(close to 97) ²⁾	99.1

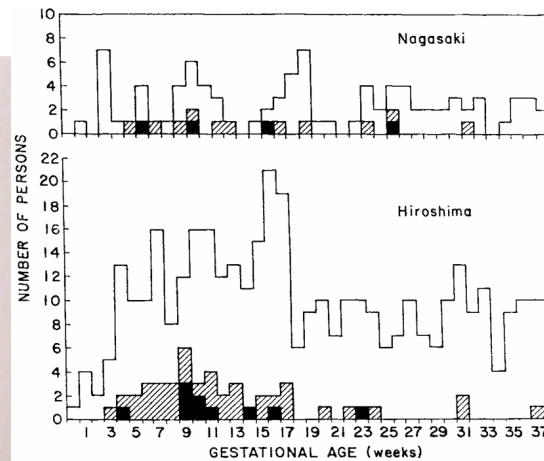
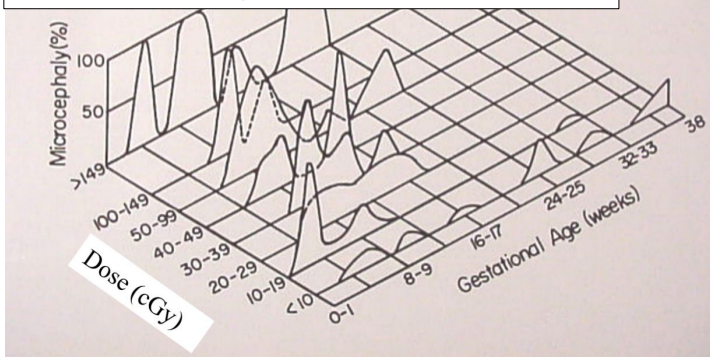
¹⁾ Rounded values. Radiation risk for fatal cancer conservatively assumed to be 0.6% per 100 mGy fetal dose, corresponding to about 1/17,000 per mGy, and a linear dose-response relationship. Many epidemiological studies suggest that the risk may be lower than that assumed here. Background risk of childhood cancer calculated from NCI-SEER (1994).

²⁾ Although the exact risk in humans is uncertain, animal data suggest that malformations due to radiation are not likely at doses less than 100–200 mGy. Above this malformations would only be observed if exposure were between the 3rd and 25th weeks of gestation. The risk of malformation is low at 100–200 mGy but will increase with increasing dose. Decreased IQ and possible retardation are only detectable when foetal doses exceed 100 mGy during the 8th to 25th weeks of gestation.

Small head size after atomic irradiation

R W Miller, J J Mulvihill

PMID: 996782 DOI: 10.1002/tera.1420140311

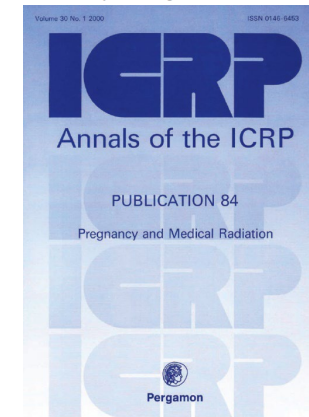


Small head circumference among persons exposed in utero to the atomic bomb, according to gestational age.

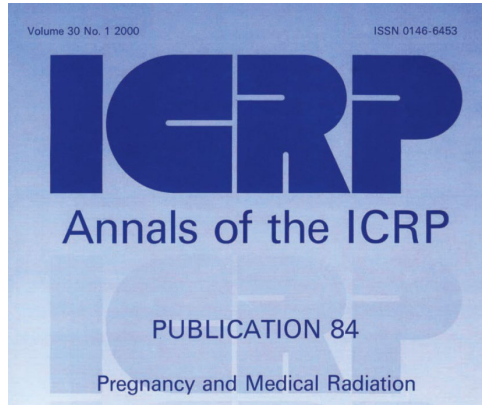
Normal intelligence and head size □; small head size with normal intelligence ▨; small head size with mental retardation ■.

SMALL HEAD SIZE AFTER IN-UTERO EXPOSURE TO ATOMIC RADIATION

ROBERT W. MILLER WILLIAM J. BLOT*
 Epidemiology Branch, National Cancer Institute, Bethesda, Maryland, U.S.A., and Atomic Bomb Casualty Commission, Hiroshima, Japan



Risks of fetal irradiation



Dose limits for the fetus are broadly comparable with those for the general public. This is reasonable since while the mother may have chosen to be a radiation worker, the unborn child has not made such a decision.

Regulatory fetal dose limits

Most of Europe: 1mGy during gestation period.

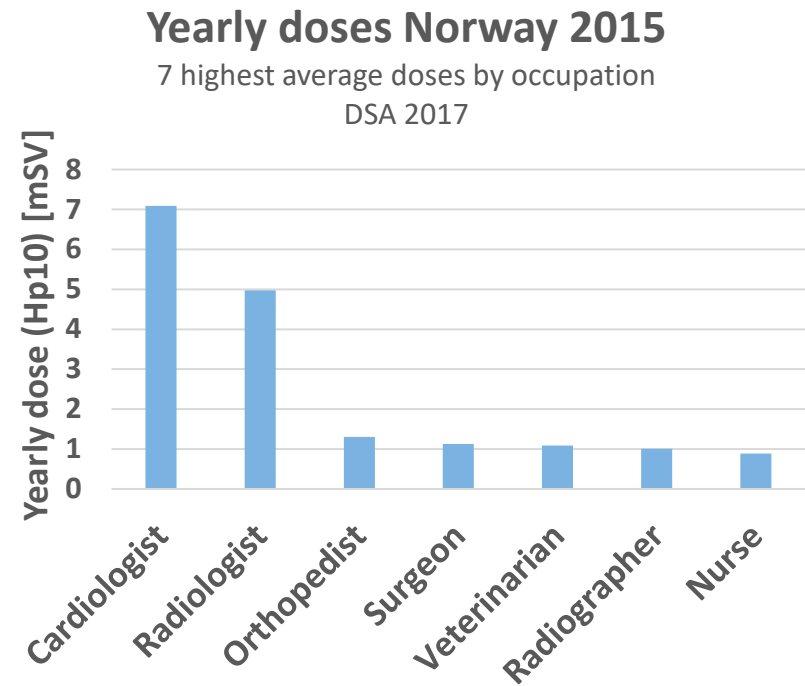
United States: 0.5mGy per month.

Regulatory radiation worker dose limits

Most of Europe: 20mSv per year

United States: 50mSv per year.

What fetus doses to expect for radiation workers at hospitals?

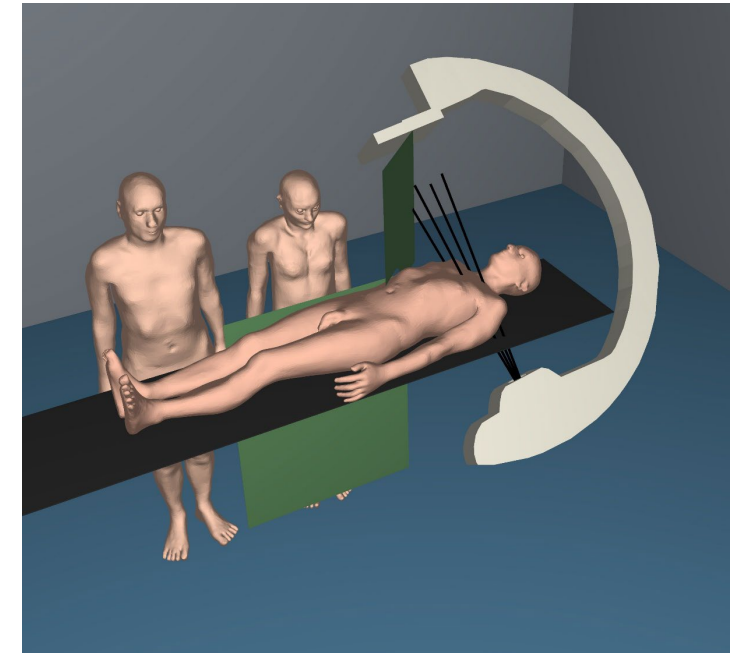


ORIGINAL ARTICLE



Efficacy and User Experience of a Novel X-Ray Shield on Operator Radiation Exposure During Cardiac Catheterization: A Randomized Controlled Trial

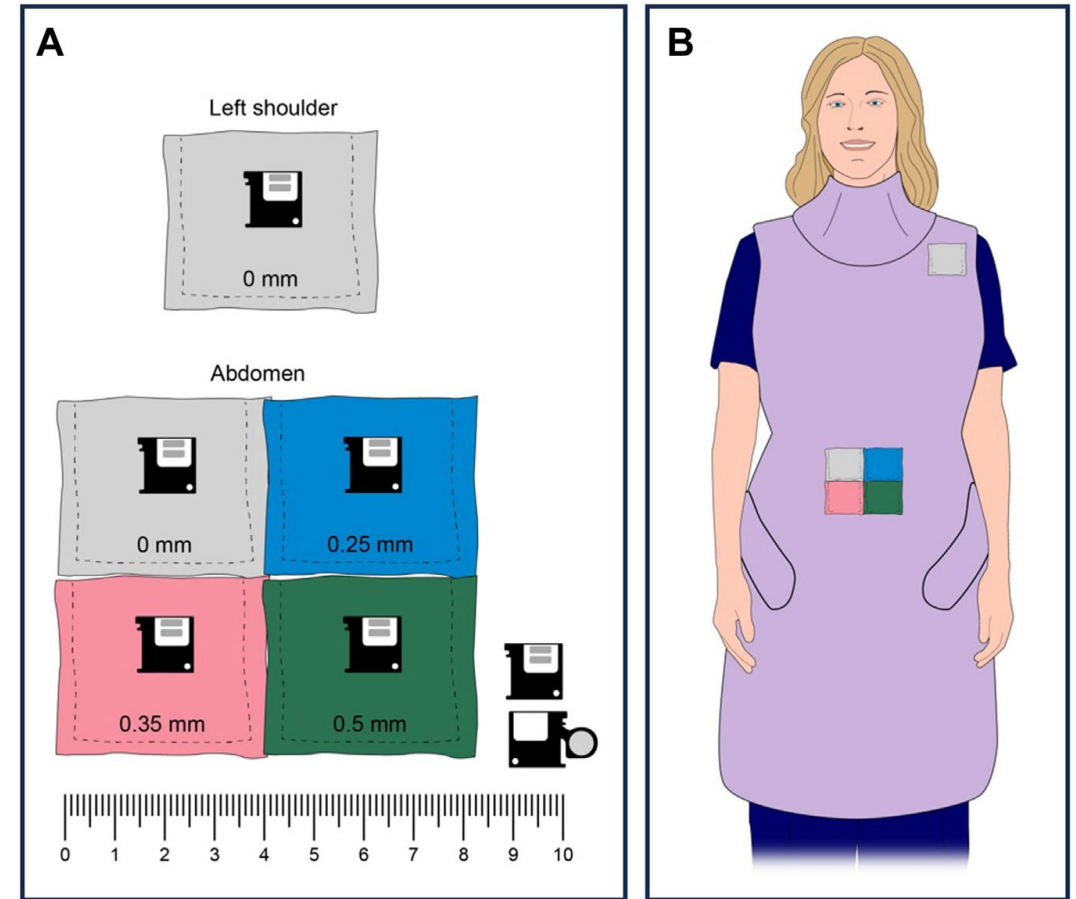
Cedric Davidsen, MD, Kristian Ytre-Hauge, PhD, Andreas Tefre Samneøy, PhD, Kjetil Vikenes, MD, PhD, Patrizio Lancellotti, MD, PhD, Vegard Tuseth, MD, PhD



What fetus doses to expect for radiation workers at hospitals?

How to estimate fetus dose

**Worst case fetus dose estimation:
Skin entrance dose at waist level**
We can't measure inside people



Original Research

Radiation Exposure and Protection for (Assumed) Pregnant Interventional Cardiologists and Electrophysiologists

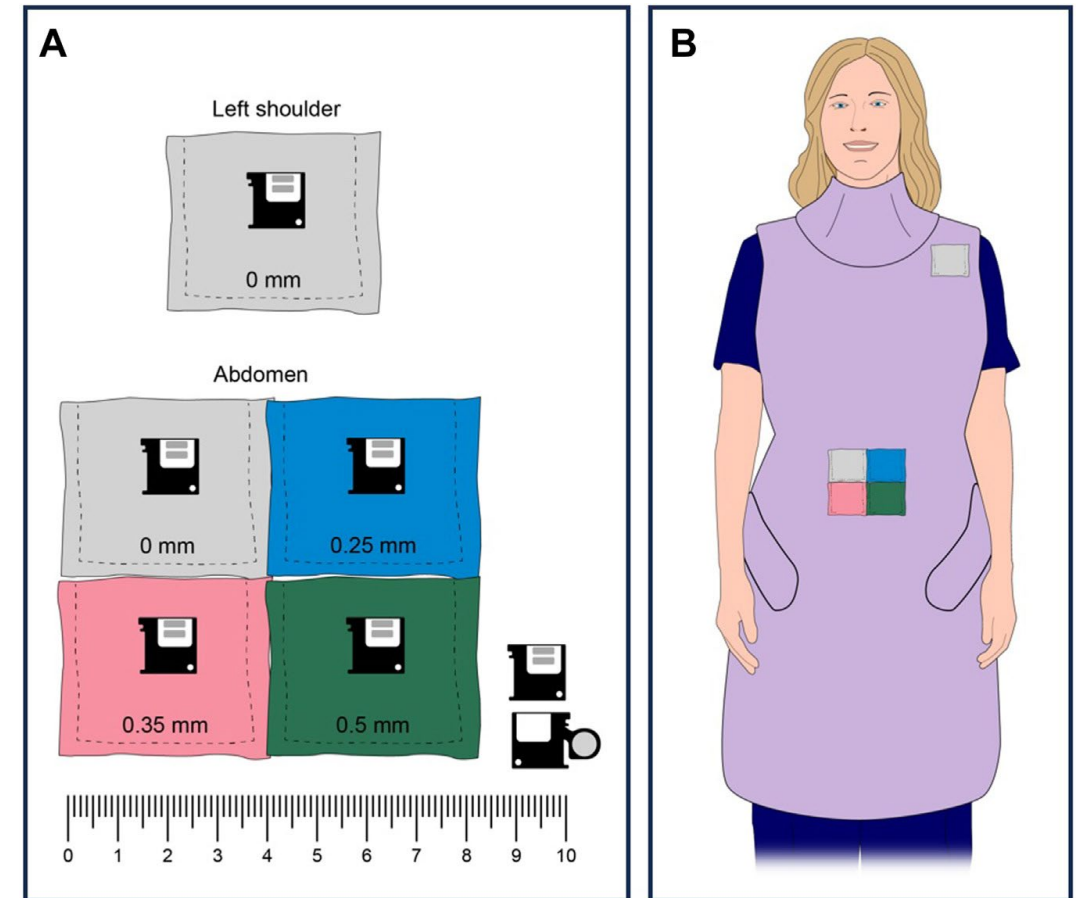
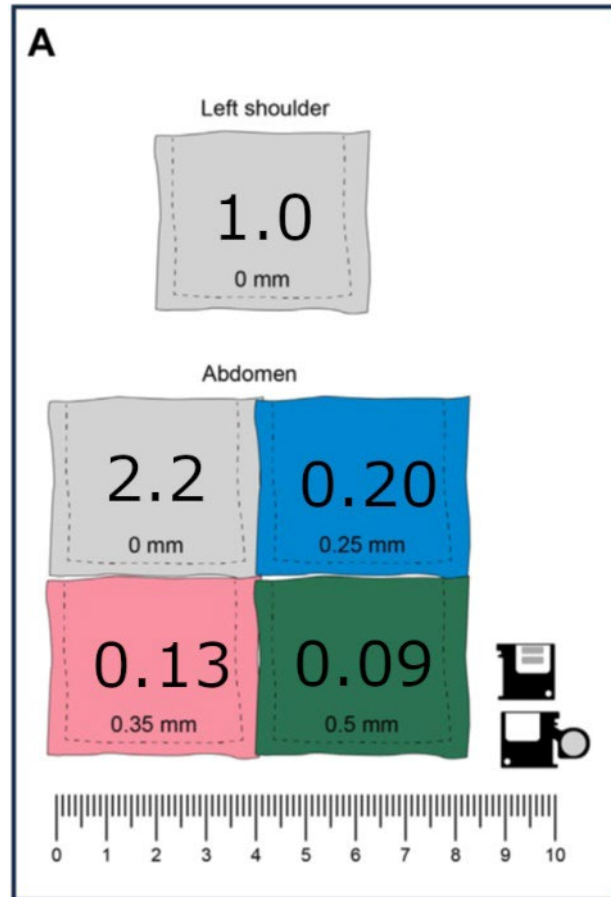
Kenneth A. Fetterly, PhD^{a,*}, Beth A. Schueler, PhD^b, Jelena M. Mihailovic, PhD^b,
Jake H. Fiedler, RRPT^c, Glenn M. Sturchio, PhD^c, Allison Cabalka, MD^a,
Patricia J.M. Best, MD^a, Rajiv Gulati, MD, PhD^a, Mayra Guerrero, MD^a

^a Department of Cardiovascular Medicine, Mayo Clinic, Rochester, Minnesota; ^b Department of Radiology, Mayo Clinic, Rochester, Minnesota; ^c Division of Radiation Safety, Mayo Clinic, Rochester, Minnesota

What fetus doses to expect for radiation workers at hospitals?

Ratio

$$\frac{\text{Waist dose}}{\text{Left shoulder dose}}$$



Original Research

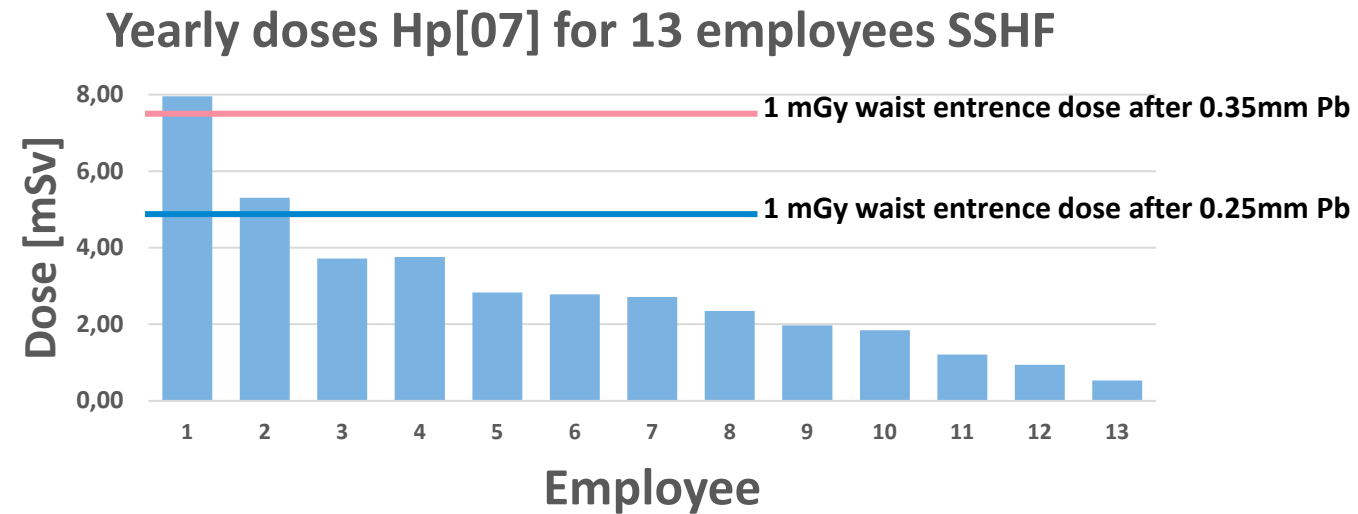
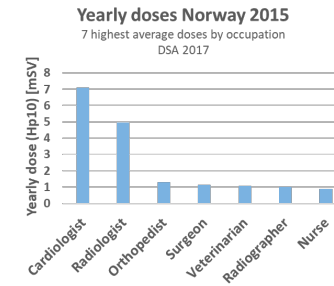
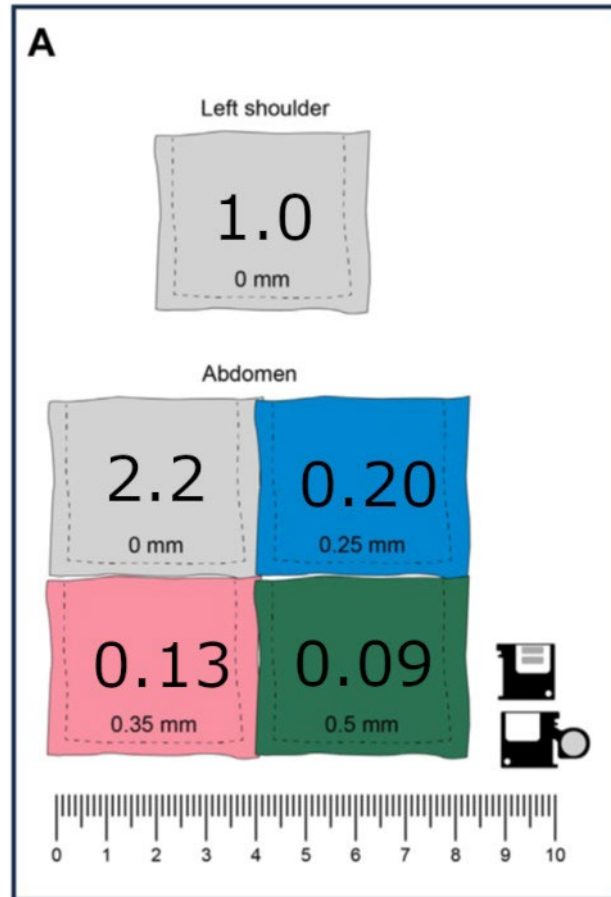
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^a Department of Cardiovascular Medicine, Mayo Clinic, Rochester, Minnesota; ^b Department of Radiology, Mayo Clinic, Rochester, Minnesota; ^c Division of Radiation Safety, Mayo Clinic, Rochester, Minnesota

What fetus doses to expect for radiation workers at hospitals?

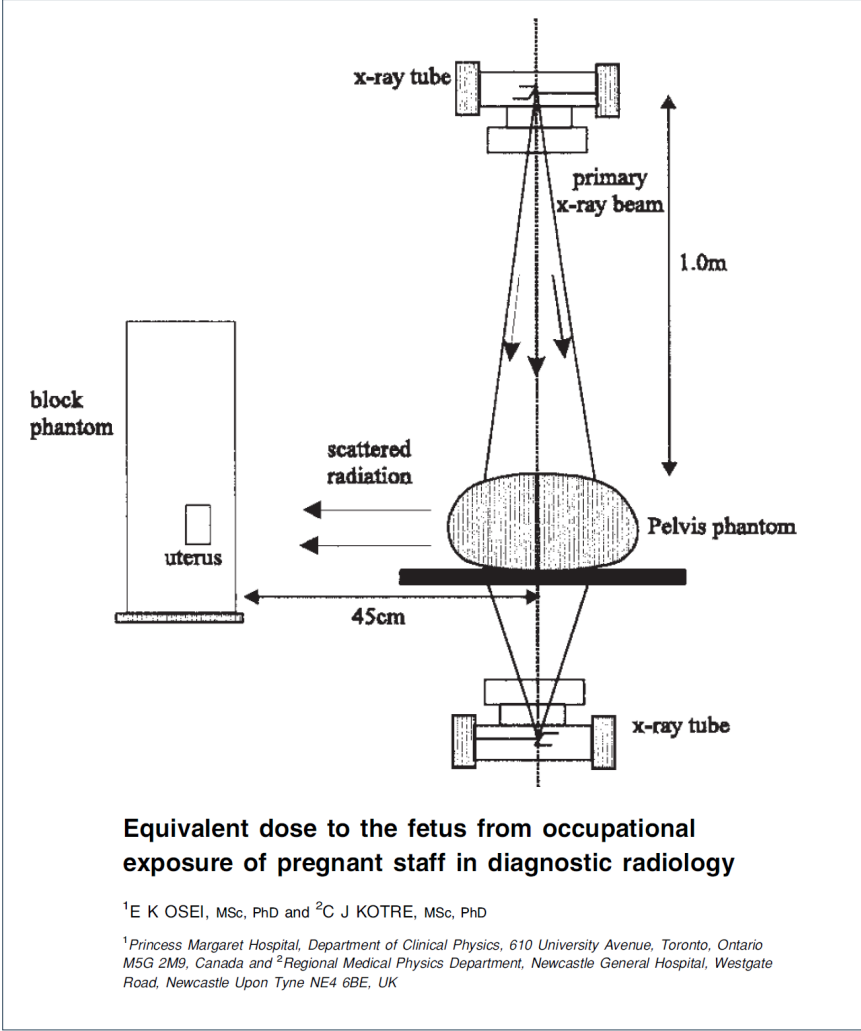
Waist dose
Left shoulder dose



Can we do better and should we do better?

We can't measure inside people
 There is a lack of methods to estimate fetus doses in a radiation environment

Concerns about radiation hazards during pregnancy is one of reasons for women avoiding a career in interventional cardiology [survey studies]



(b) Ratio between the equivalent dose to the uterus and the entrance dose

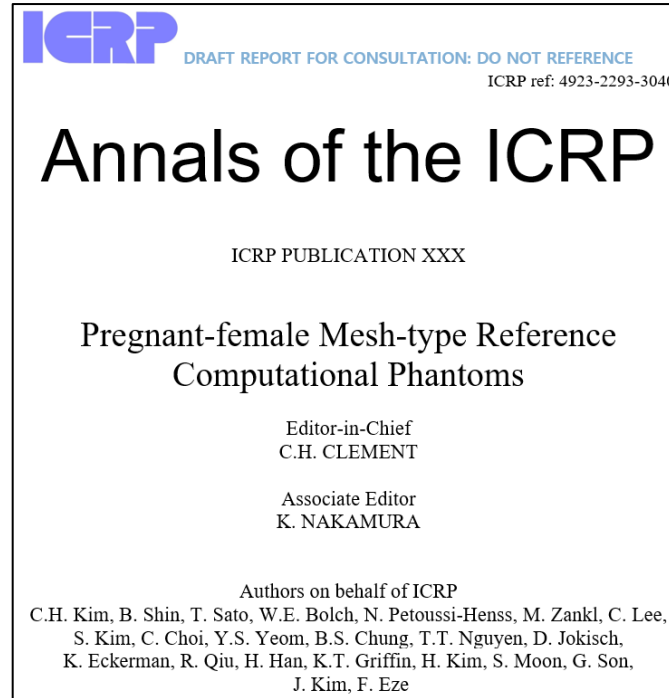
Lead thickness (mm)	Tube potential (kVp) ^a		
	61	74	85
0.05	0.25	0.29	0.32
0.10	0.28	0.31	0.34
0.15	0.30	0.33	0.36
0.20	0.31	0.35	0.37
0.25	0.34	0.36	0.37
0.30	0.35	0.36	0.37
0.33	0.35	0.36	0.38
0.35	0.35	0.36	0.39

Can we do better and should we do better?

We can't measure inside people

There is a lack of methods to estimate fetus doses in a radiation environment

Concerns about radiation hazards during pregnancy is one of reasons for women avoiding a career in interventional cardiology [survey studies]

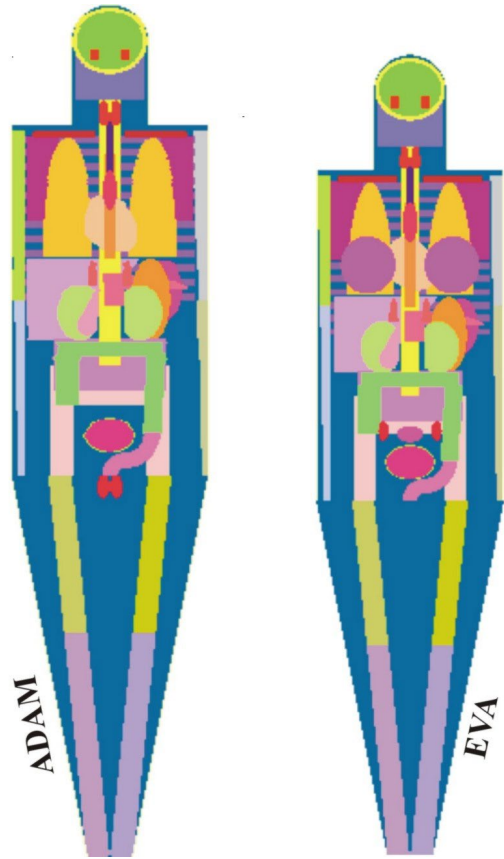


Phantoms for radiation transport simulations and dose calculations

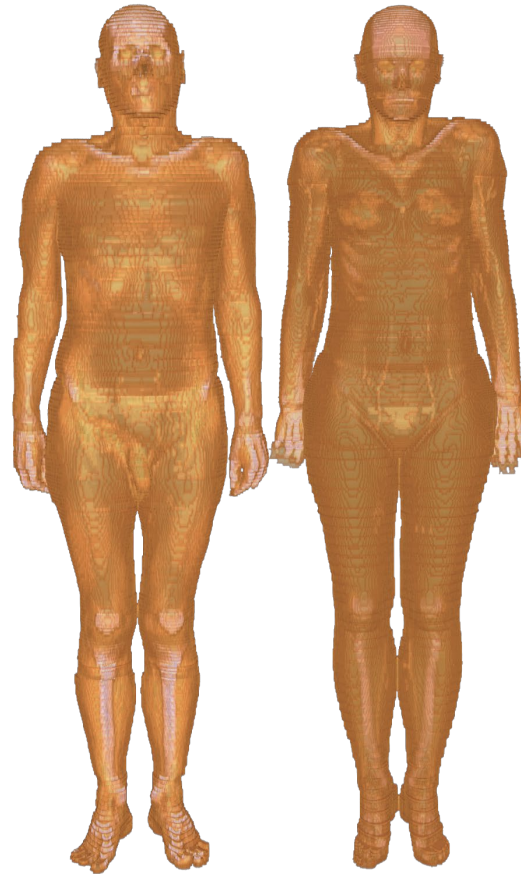


A history of phantoms for radioprotection

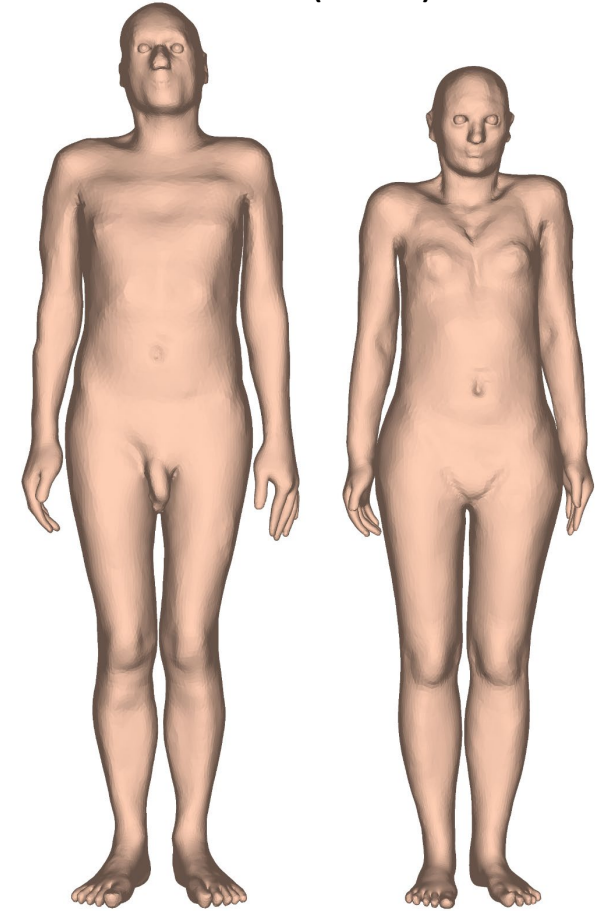
Adam and Eva
(1990)



ICRP/ICRU Reference voxel models
(2009)



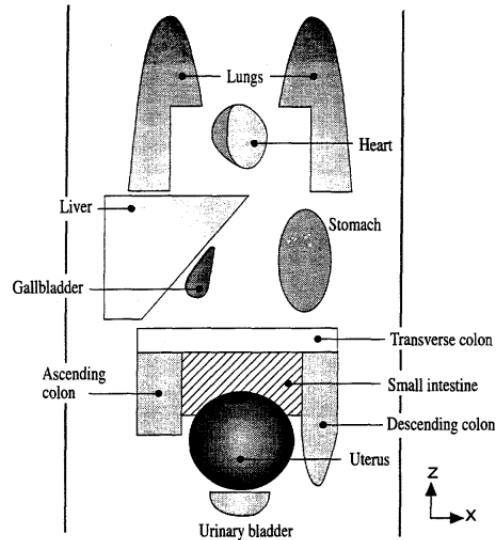
ICRP Reference mesh models
(2020)



Kramer R., Zankl M., Williams G., Drexler G., The Calculation of Dose from External Photon Exposures Using Reference Human Phantoms and Monte Carlo Methods. Part I: The Male (ADAM) and Female (EVA) Adult Mathematical Phantoms. GSF-Report S-885, Reprint July 1999, Institut für Strahlenschutz, GSF-Forschungszentrum für Umwelt und Gesundheit, Neuherberg-München, 1982.

A history of phantoms for radioprotection

Pregnant mathematical phantom (1995)



Pregnant voxel phantom (2008)

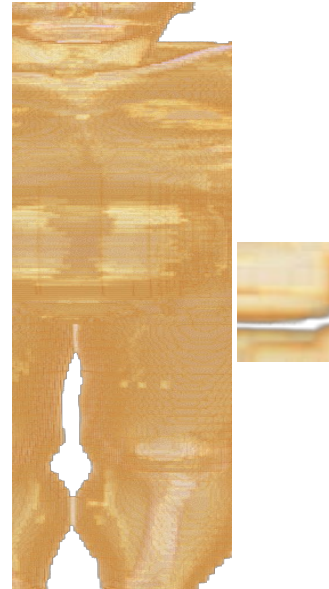


Fig. 3.4. Artist's rendition of organs in the 3-month model, as viewed from the front of the body (A-P projection). Not drawn to scale.

Mathematical Models
and Specific Absorbed Fractions of
Photon Energy in the Nonpregnant
Adult Female and at the End of
Each Trimester of Pregnancy

M. G. Stabin
E. E. Watson
M. Cristy
J. C. Flynn
K. F. Eckerman
J. L. Davis
D. Marshall
M. K. Gehlen

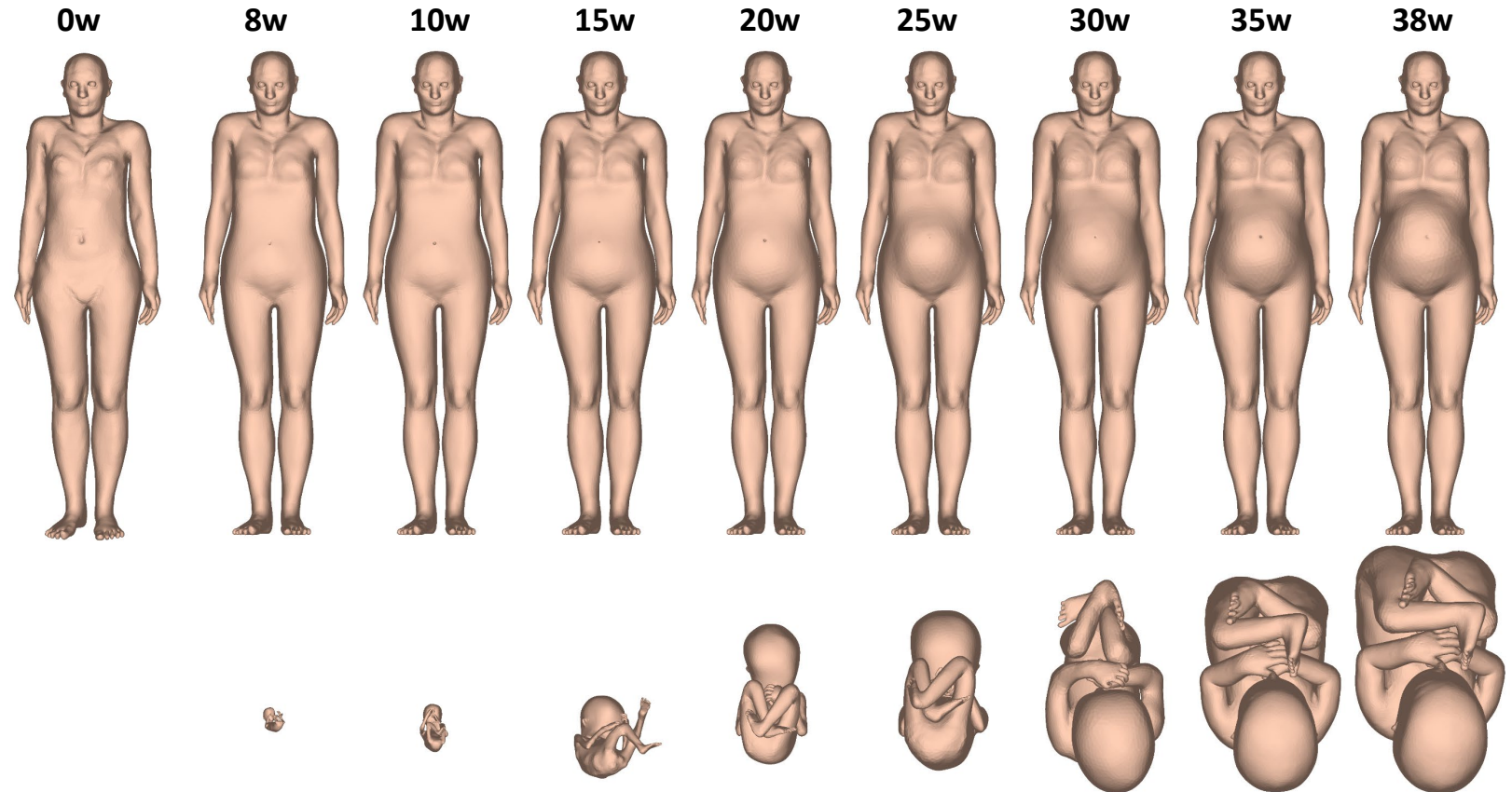
Janine Becker, Maria Zankl, Ute Fill,
Christoph Hoeschen

Katja — the 24th week of virtual pregnancy for
dosimetric calculations

Heinrich-Zentrum München, German Research Center for Environmental Health,
Neuherberg, Germany
e-mail: janine.becker@heinz-muenchen.de

A history of phantoms for radioprotection

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



ICRP DRAFT REPORT FOR CONSULTATION: DO NOT REFERENCE
ICRP ref: 4923-2293-3040

Annals of the ICRP

ICRP PUBLICATION XXX

Pregnant-female Mesh-type Reference Computational Phantoms

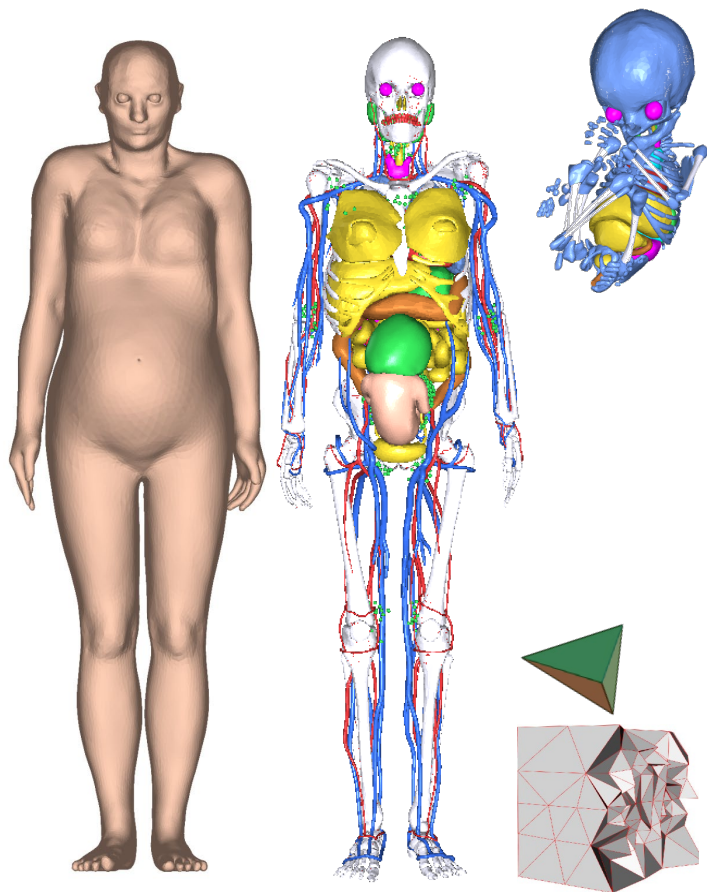
Editor-in-Chief
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K. NAKAMURA

Authors on behalf of ICRP

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J. Kim, F. Eze

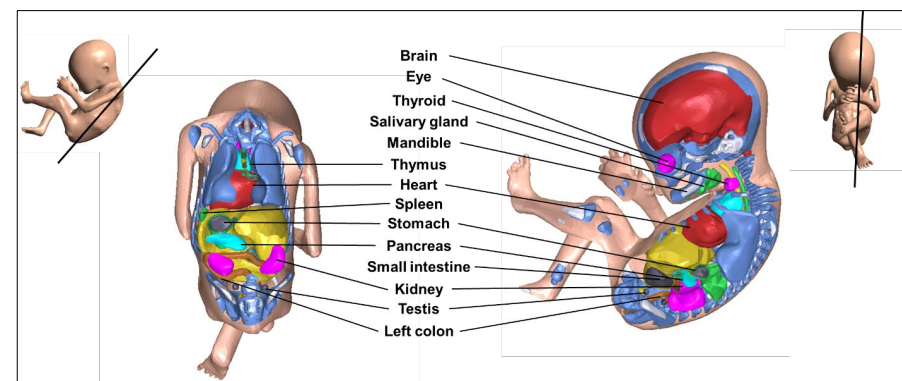
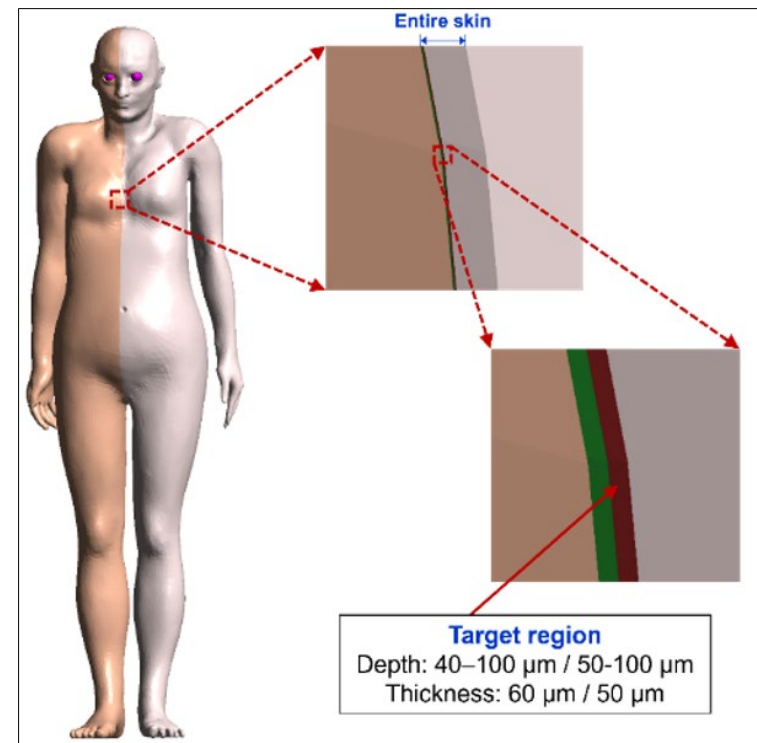
Pregnant mesh phantoms



Detailed model of anatomy and atomic composition

- 10-17 million tetrahedra
- 374 different organs

Planned to be published April 2025



We have the tools

Project on scattered radiation in interventional labs

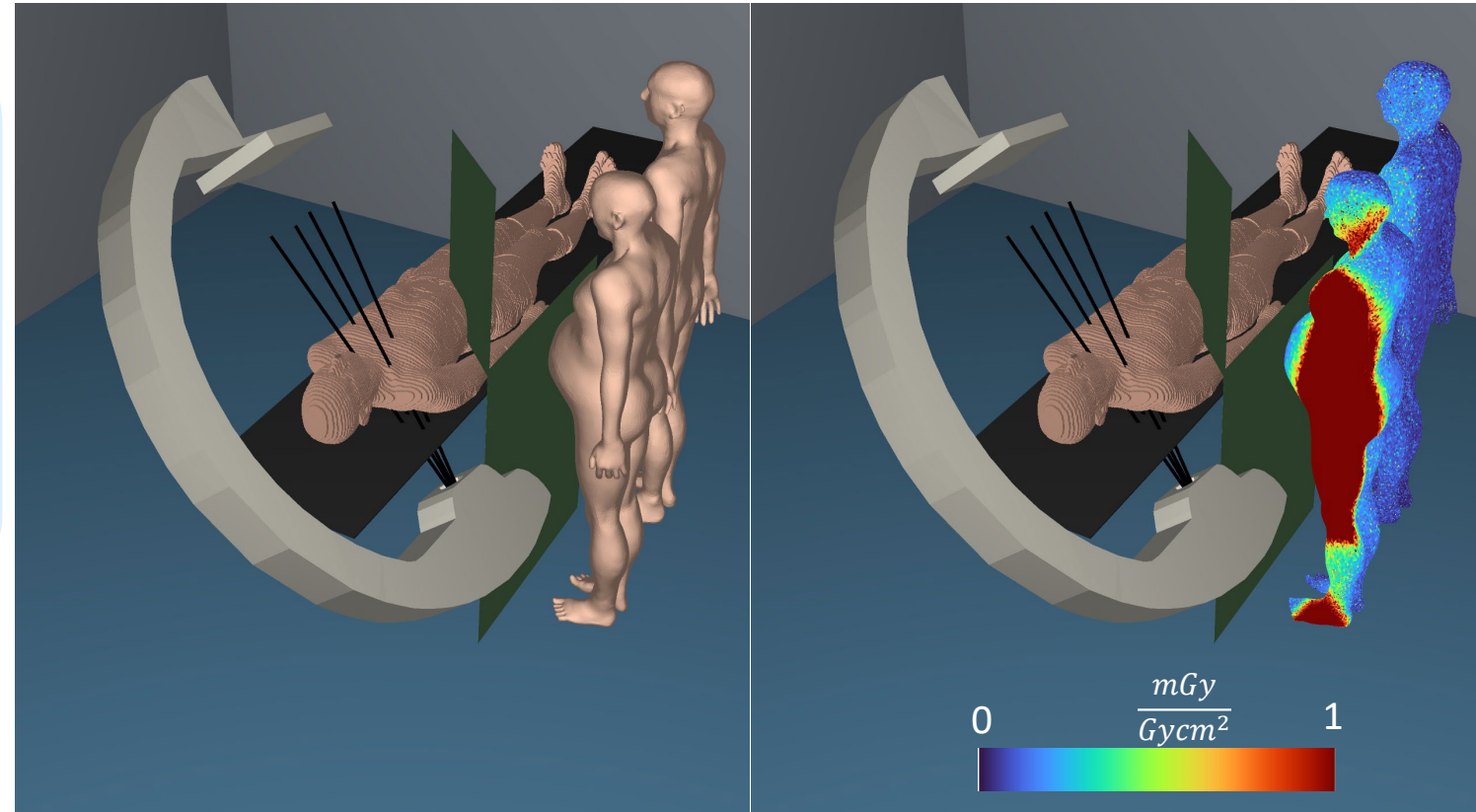
Main goals

- Benchmark radioprotection setups in silico
- Enable safe reduction of personal radiation protection equipment
- **Develop methodology for fetus dose estimation for radiation workers**

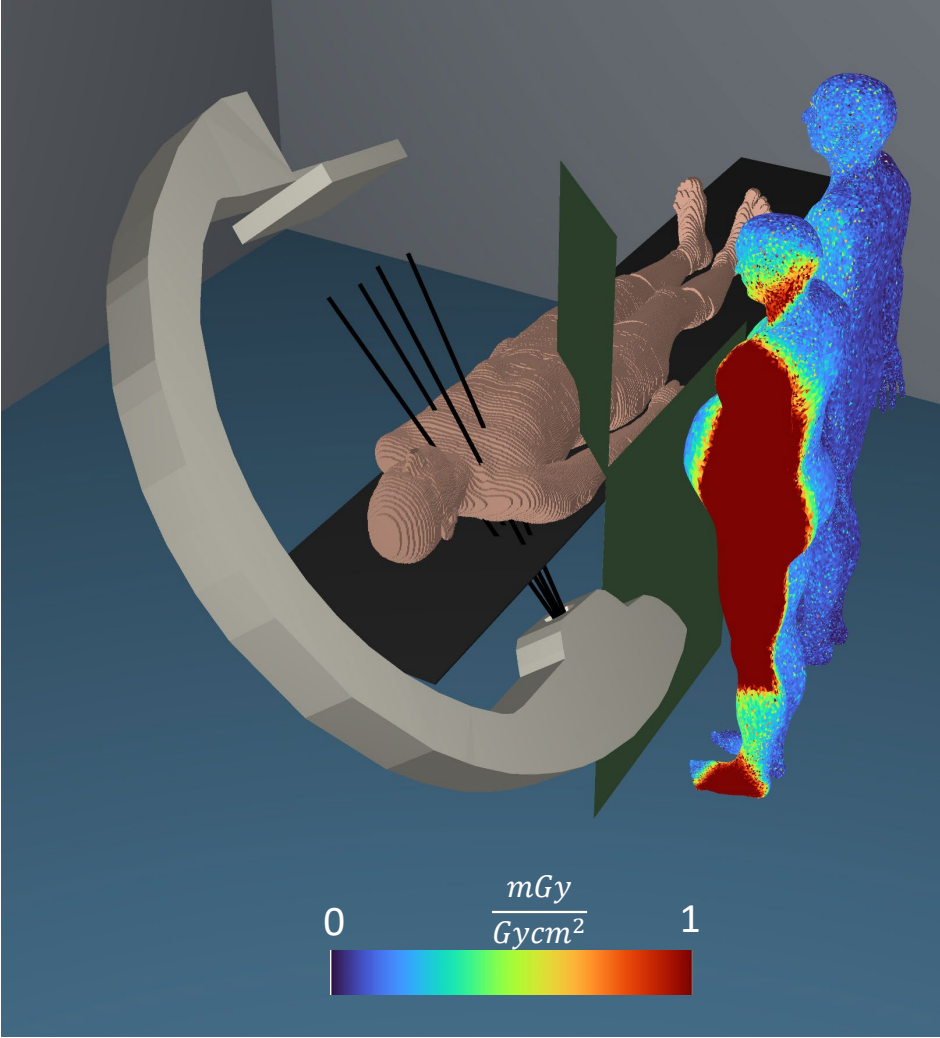
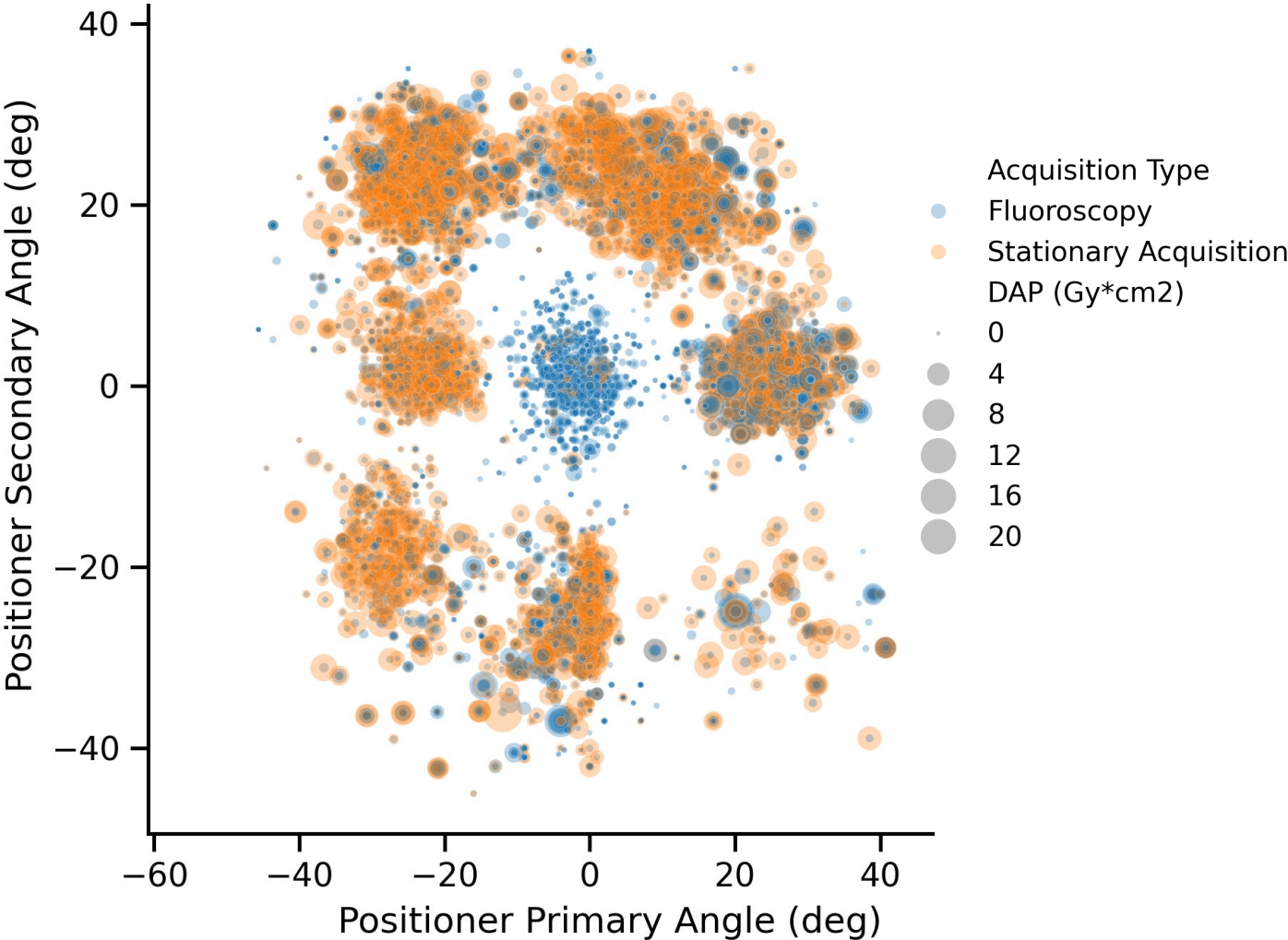
 SØRLANDET SYKEHUS

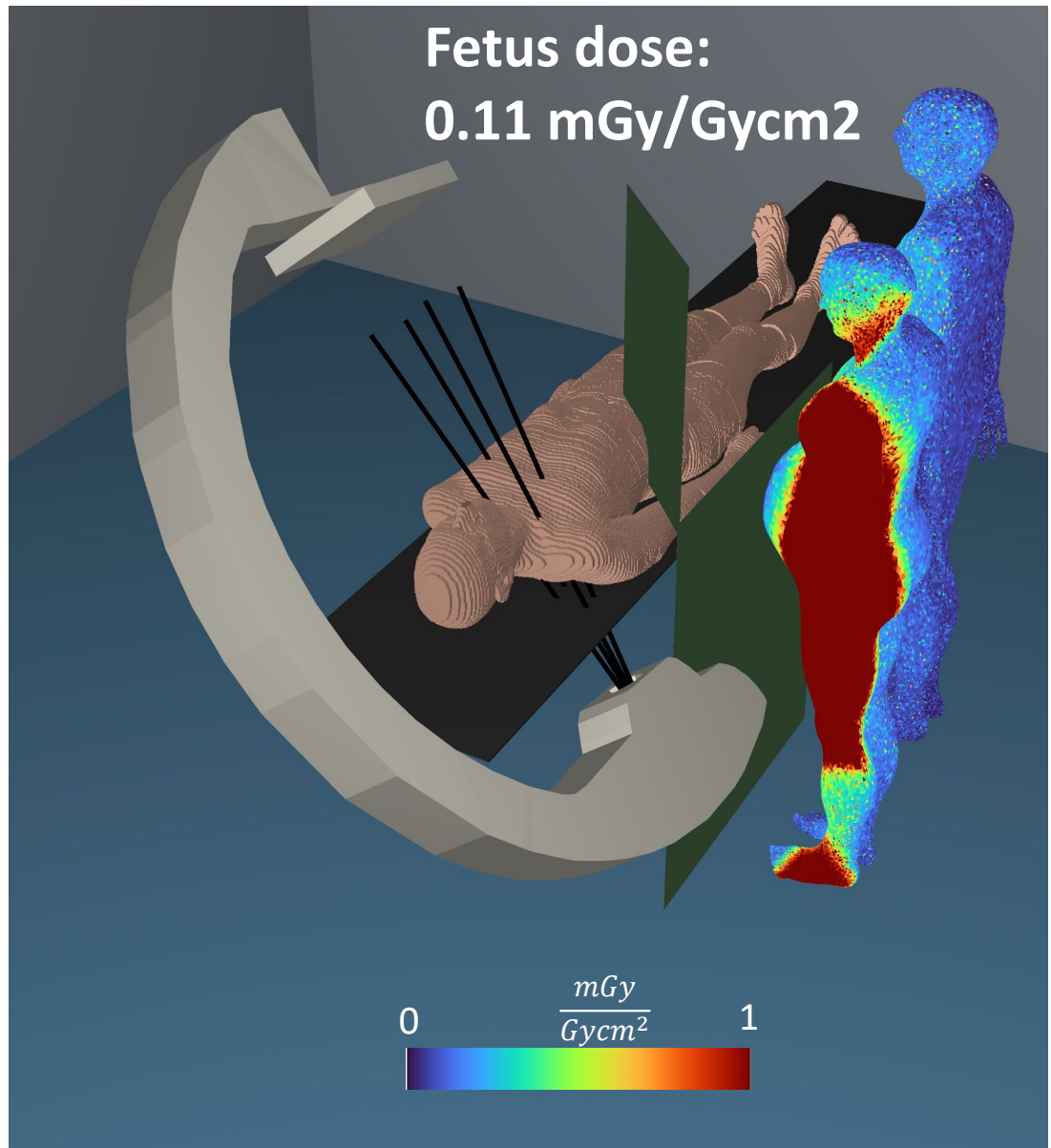
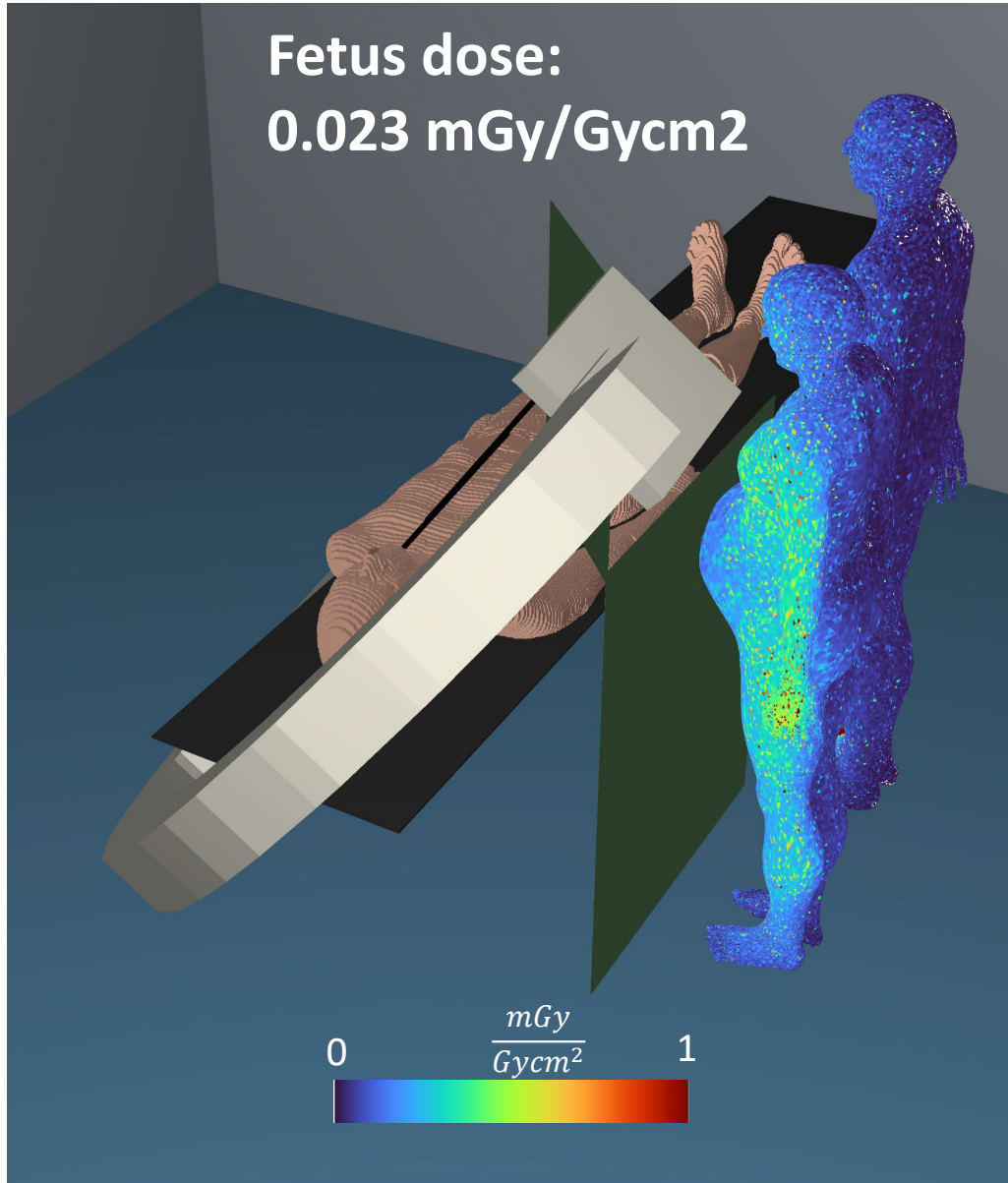
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 HELSE BERGEN
Haukeland universitetssjukehus



One year of exposures for one employee

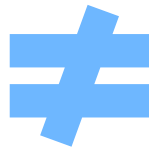




Summary

- Pregnant workers can perform fluoroscopy procedures
- The radiation protection community will get new tools for fetus dose estimation (thanks to ICRP and TG103)

Make sure radiation workers **are** safe



Make sure radiation workers **feel** safe

