Do We Need Age- and Sex- Dependent Organ Weights for riskTCM or Does the Effective Dose Perform Equally Well?

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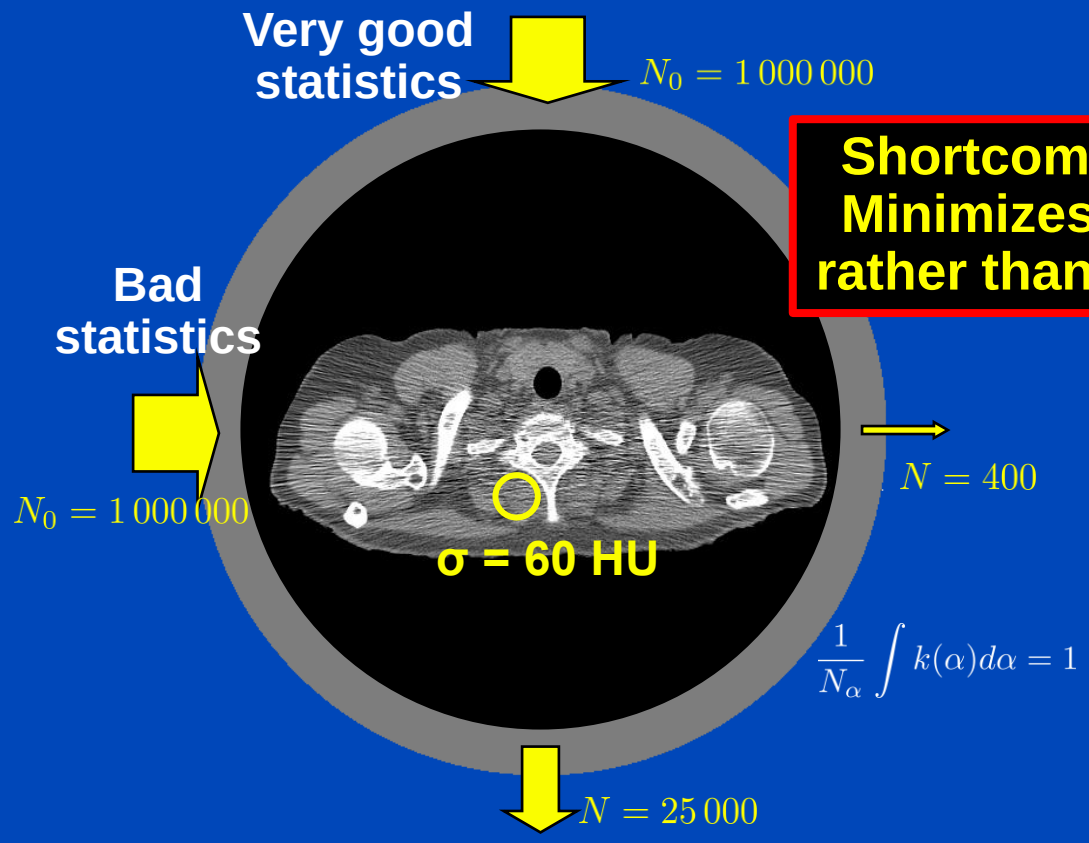
Tube Current Modulation (TCM)

noTCM

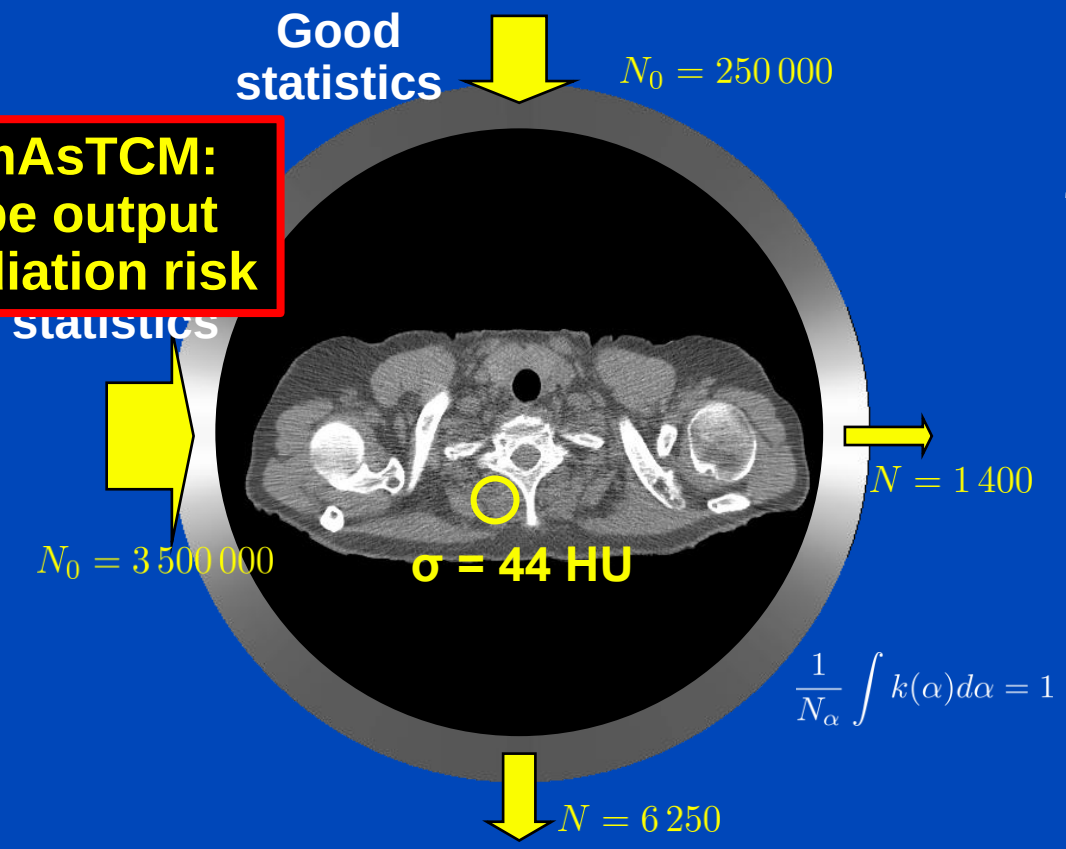
Constant tube current:
High, inhomogeneous noise



Shortcoming of mAsTCM:
Minimizes the tube output rather than the radiation risk

mAsTCM

Modulated tube current:
Lower, more homogeneous noise



M. Gies, W. A. Kalender, H. Wolf, C. Suess, and M. T. Madsen, Dose Reduction in CT by Anatomically Adapted Tube Current Modulation. I. Simulation Studies, Med. Phys. 26, 2235-2247 (1999).

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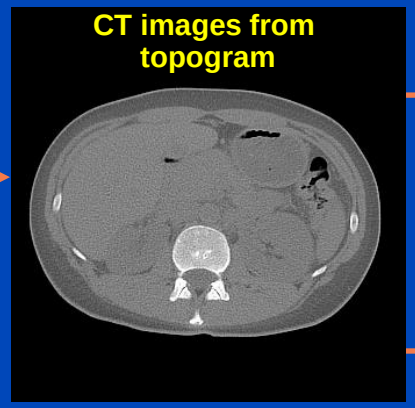
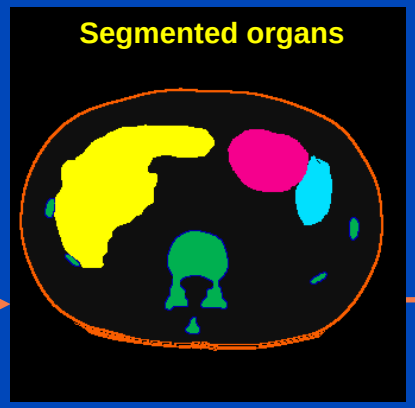
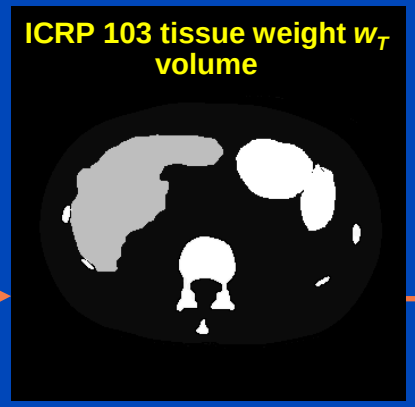
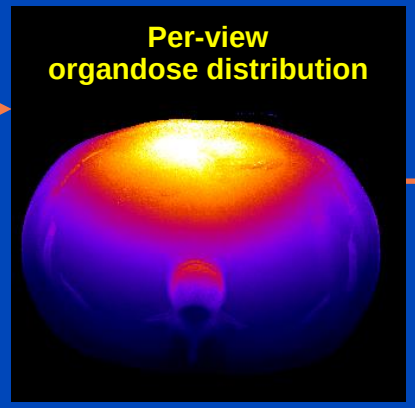
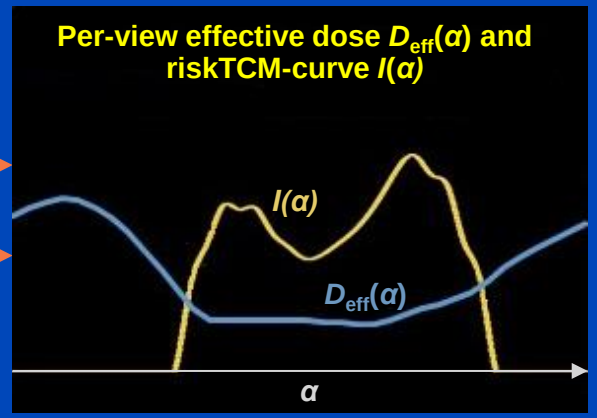
Risk-Minimizing Tube Current Modulation (riskTCM)











$$\mathrm{Risk}(\alpha) = \sum_T w_T \cdot \mathrm{OrganDose}_T(\alpha)$$

L. Klein, C. Liu, J. Steidel, L. Enzmann, M. Knaup, S. Sawall, A. Maier, M. Lell, J. Maier, and M. Kachelrieß. Patient-specific radiation risk-based tube current modulation for diagnostic CT. Med. Phys. 49(7):4391-4403, July 2022. *This paper received the Sylvia&Moses Greenfield Award for the best scientific paper on imaging in Medical Physics in 2022.*

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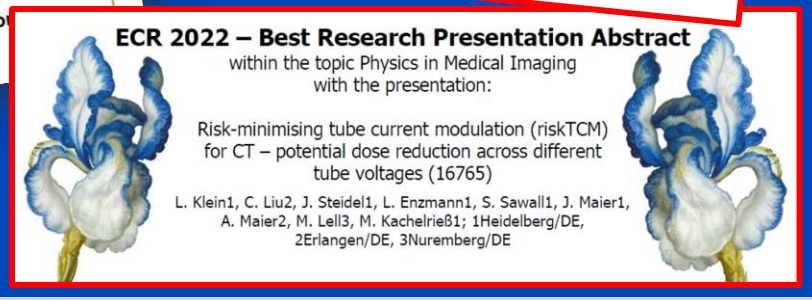
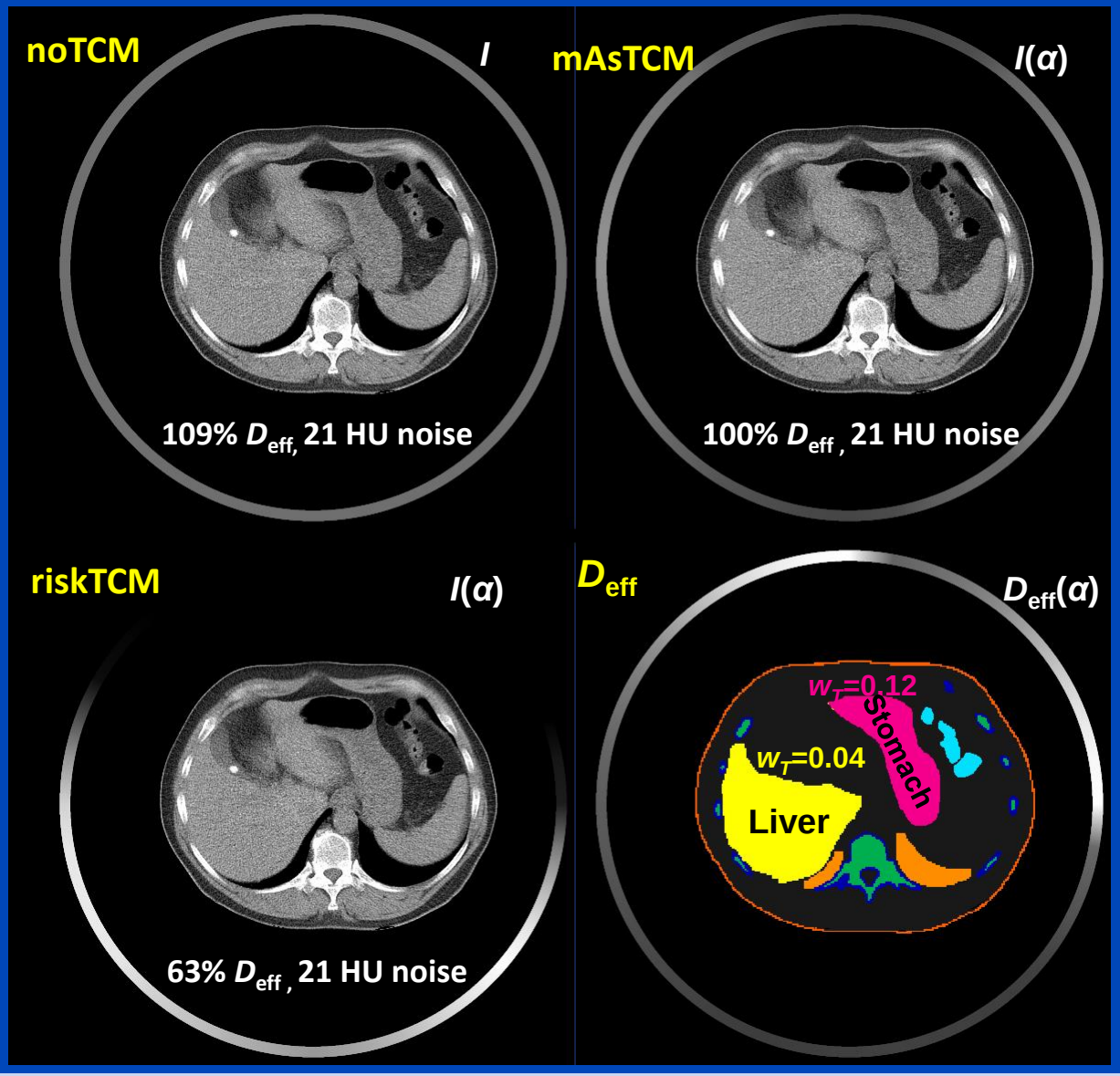
riskTCM Patient Example

At same image quality, i.e. same noise level and same spatial resolution, riskTCM reduces the effective dose between 10% and 30%, depending on the body region, compared to mAsTCM.





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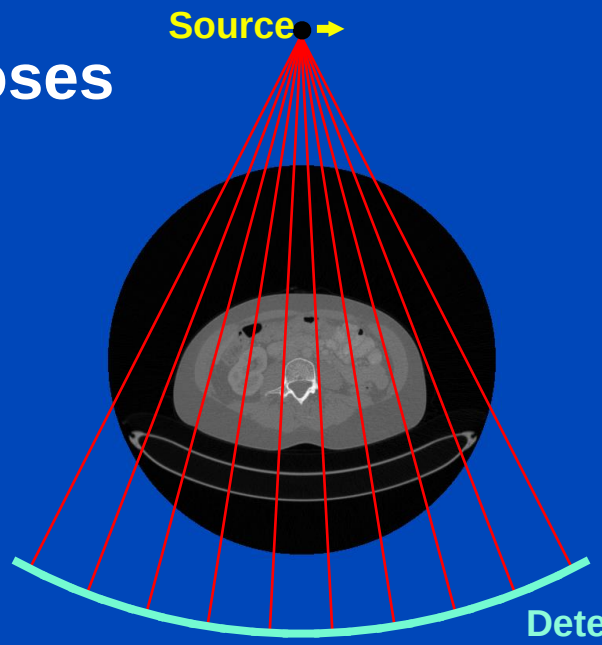
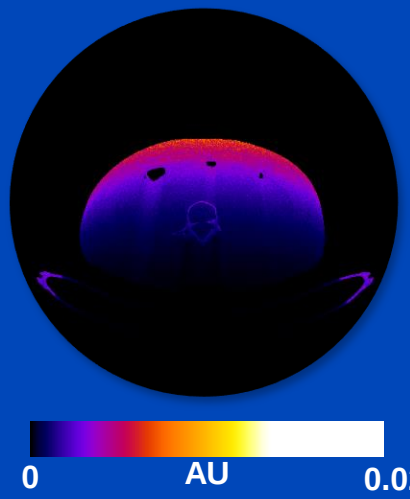
Definition Risk Measure

- **Risk: a weighted sum over the organ doses as a function of the projection angle α :**

$$\mathrm{Risk}(\alpha) = \sum_T w_T \cdot \mathrm{OrganDose}_T(\alpha)$$





How to choose weighting factors w_T for each tissue?

The Effective Dose D_{eff}: $Risk_{ICRP}$

- **Proposed by ICRP Publication 103 (2007) (International Commission on Radiological Protection)**
- **Based on LSS-Cohort data among others**
- **Normalized:** $\sum_T w_T = 1$

- **Unspecific to age and sex of the patient**

Tissue *T*	Weight w_T
Bone-marrow, colon, lung, stomach, breast, remainder	0.12
Gonads	0.08
Bladder, oesophagus, liver, thyroid	0.04
Bone surface, brain, salivary glands, skin	0.01

Charles MW. ICRP Publication 103: recommendations of the ICRP. Radiat Prot Dosim. 2007;129:500-507

Derivation Age and Sex Specific Risk Measure

- Data from BEIR: US committee for Biological Effects of Ionizing Radiation
- Atomic bomb survivors (~120000 individuals, Japan 1945)
- Dose sufficient low for stochastic radiation damage

Registration for each individual in irradiated population:

- sex
- age
- experienced dose
- location of tumor

Comparison to non-irradiated population, subtract baseline rate

Calculation of cancer risk for any population dependent on age, sex, dose

Health Risks from Exposure to Low Levels of Ionizing Radiation BEIR VII Phase 2 (2006), National Academies Press Washington, DC

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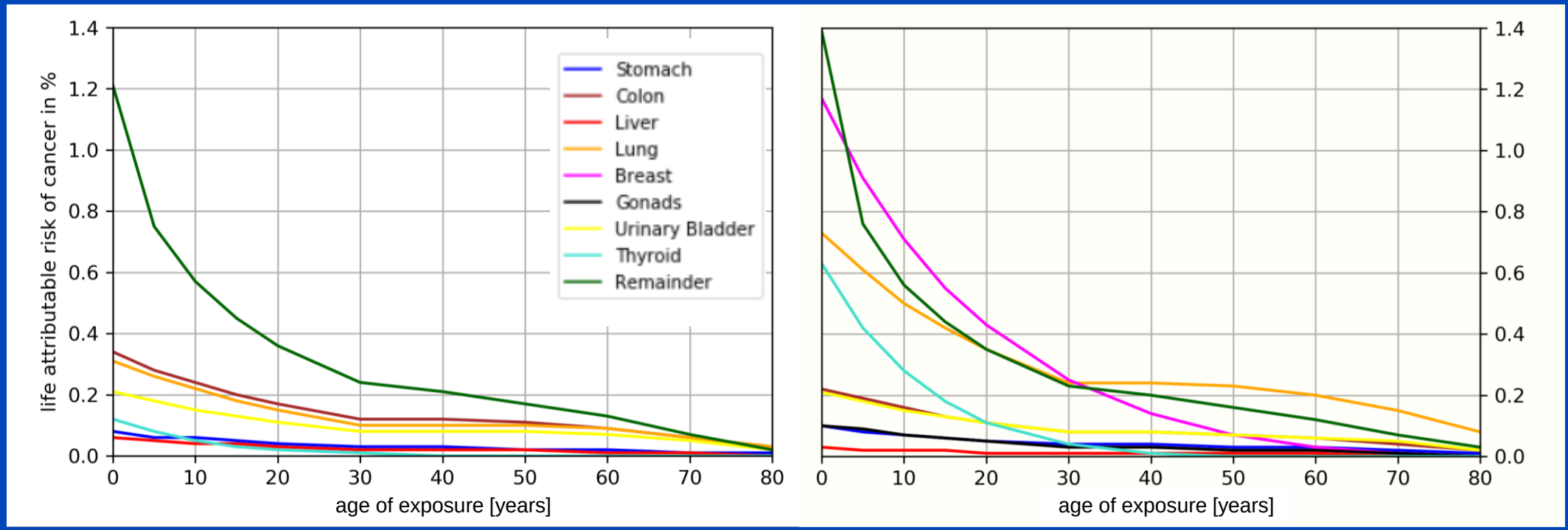
Life Attributable Risk of Cancer Incidence

Probabilities to develop location-specific cancer after irradiation of 100 mGy. These were calculated for population living in the US in the year 2000.



Male **Female**

Health Risks from Exposure to Low Levels of Ionizing Radiation BEIR VII Phase 2 (2006), National Academies Press Washington, DC

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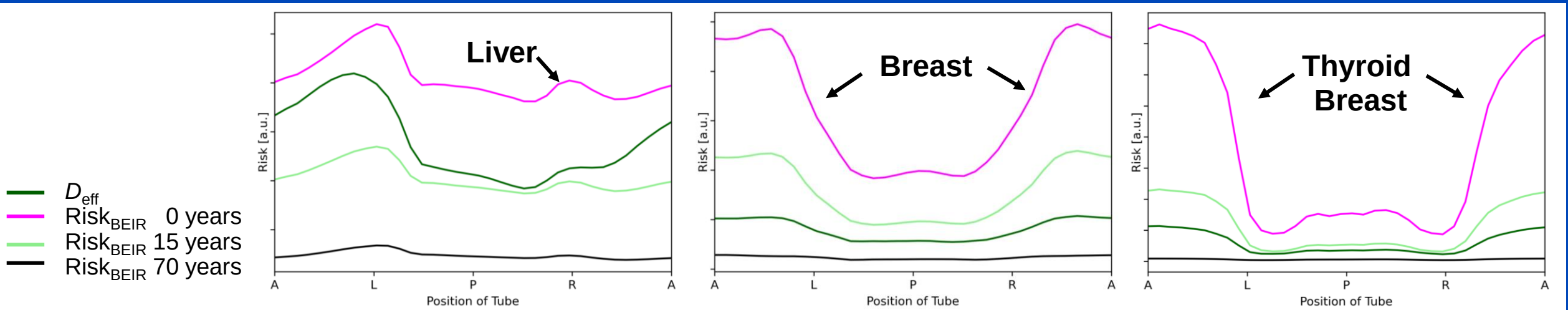
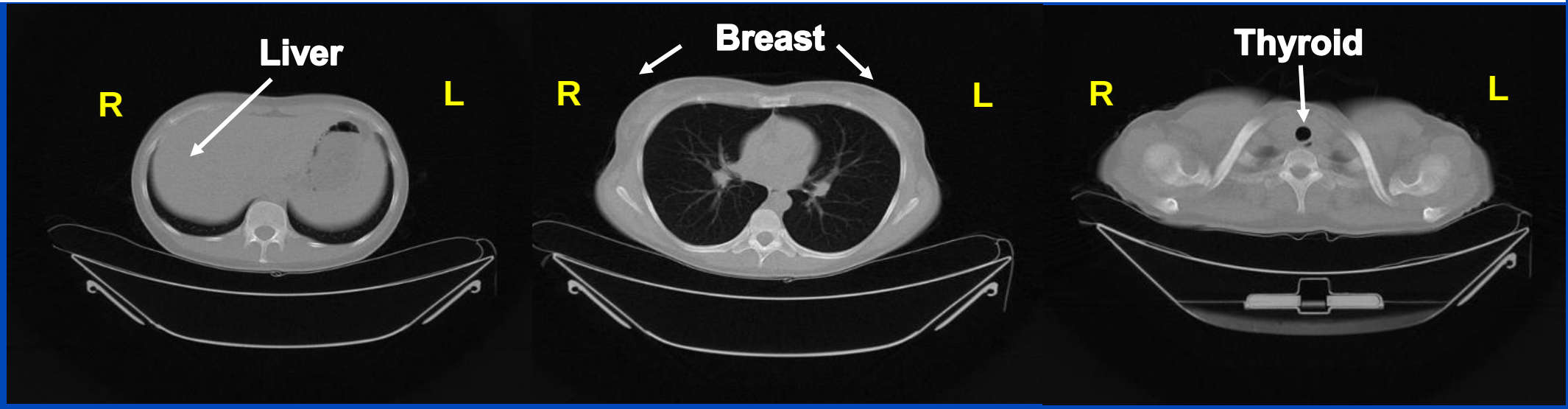
Risk Curves Female Patient

Upper Abdomen

Thorax

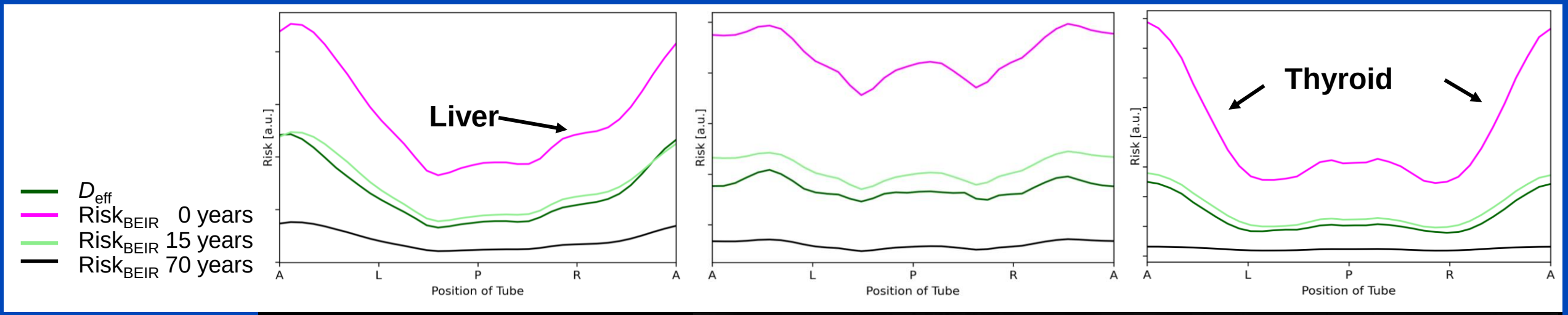
Shoulder

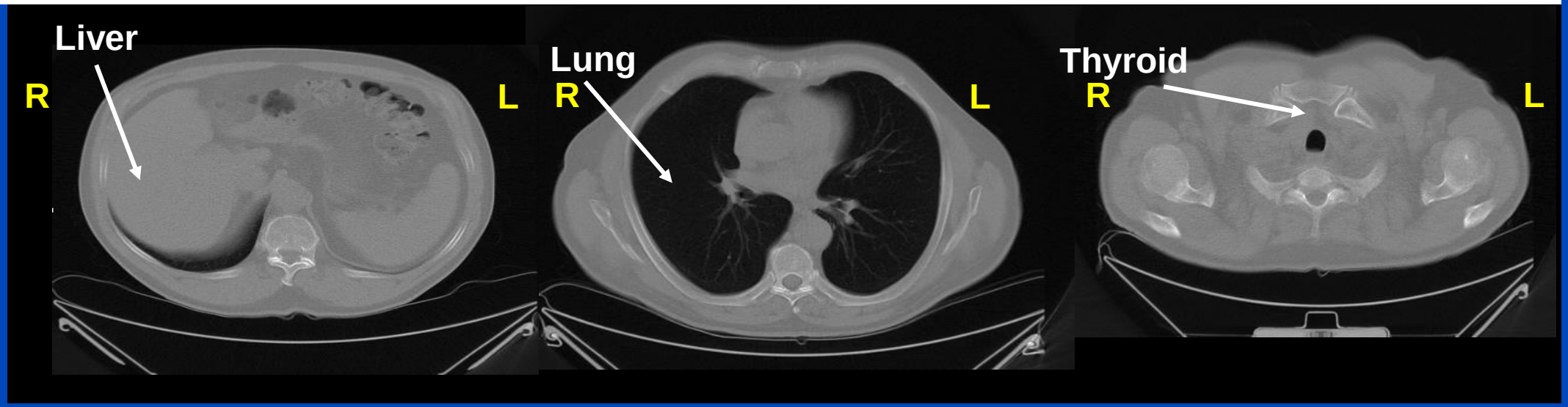




S. Klubertz, E. Baader, and M. Kachelrieß. Do we need age- and sex-dependent organ weights for the risk-specific tube current modulation (riskTCM) in diagnostic CT? Physica Medica 125S1:S69, 2024. *This work received the Young Investigator Award of the ECMP 2024.*

Risk Curves Male Patient





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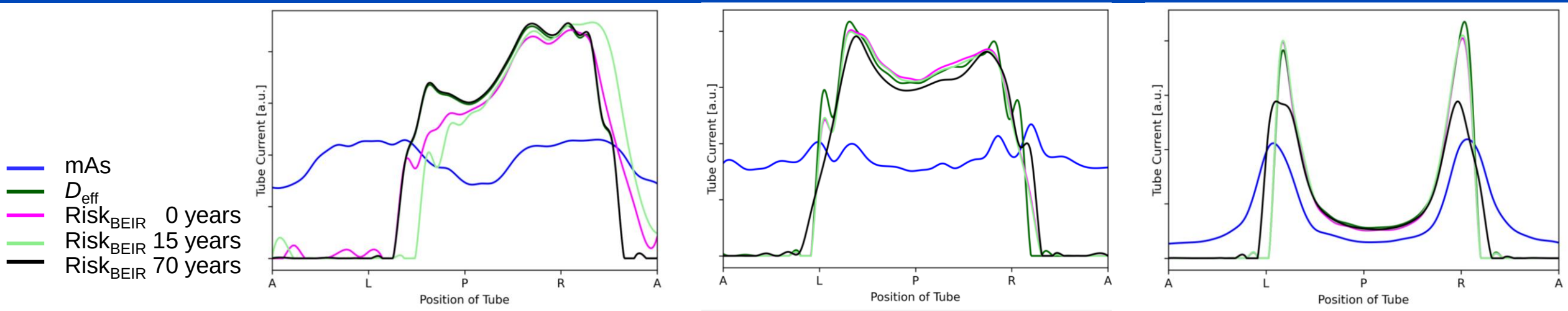
Comparison riskTCM – Female Patient



RelDose	Upper Abdomen	Thorax	Shoulder
age 0 years	1.0115	1.0003	0.9577
age 15 years	1.0079	0.9886	0.9823
age 70 years	0.9909	0.9842	0.9787

$$\text{RelDose} = \frac{\text{Risk}_{\text{BEIR}}}{\text{Risk}_{\text{ICRP}}} = \frac{\sum_{\alpha} \text{Risk}_{\text{BEIR}}(\alpha) \cdot I_{\text{BEIR}}(\alpha)}{\sum_{\alpha} \text{Risk}_{\text{BEIR}}(\alpha) \cdot I_{\text{ICRP}}(\alpha)} \approx 1$$

All TCMs are at constant image quality, i.e. same noise and spatial resolution.

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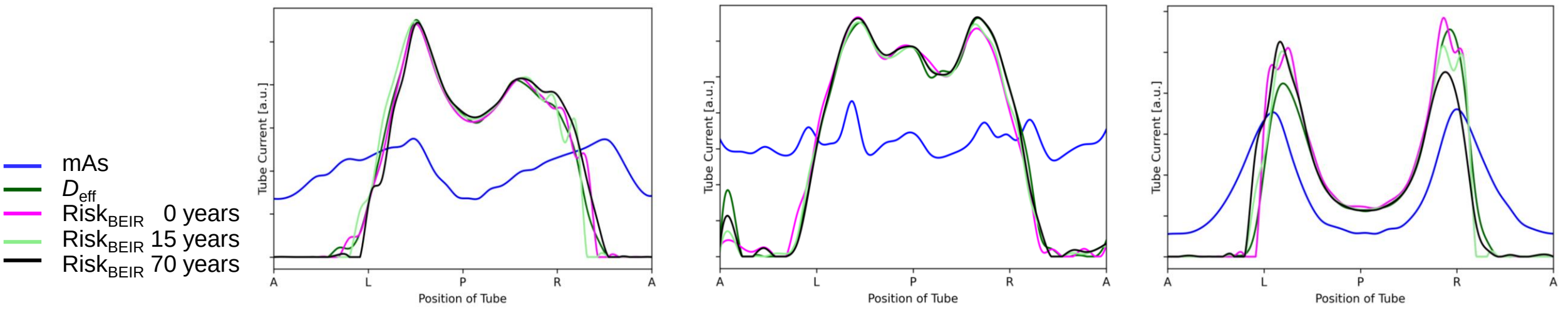
Comparison riskTCM – Male Patient



RelDose	Upper Abdomen	Thorax	Shoulder
age 0 years	1.0030	0.9886	1.0427
age 15 years	1.0059	0.9754	1.0121
age 70 years	1.0065	1.0032	1.0142

$$\text{RelDose} = \frac{\text{Risk}_{\text{BEIR}}}{\text{Risk}_{\text{ICRP}}} = \frac{\sum_{\alpha} \text{Risk}_{\text{BEIR}}(\alpha) \cdot I_{\text{BEIR}}(\alpha)}{\sum_{\alpha} \text{Risk}_{\text{BEIR}}(\alpha) \cdot I_{\text{ICRP}}(\alpha)} \approx 1$$

All TCMs are at constant image quality, i.e. same noise and spatial resolution.

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Conclusions

- Although risk significantly decreases with age the relative values of the organ risks nearly remains the same.
- Thus, there are only minor deviations in the resulting riskTCM curves between the D_{eff} model and the age-specific risk model.
- When implementing riskTCM on a CT scanner it appears to be sufficient to use D_{eff} as a risk model.

DGMP
Deutsche Gesellschaft für Medizinische Physik e.V.

Die Deutsche Gesellschaft für Medizinische Physik e.V.

verleiht im Rahmen des 5. European Congress` of Medical Physics vom 11. bis 14. September 2024 in München

Sophia Klubertz

den

Young Investigator Award

für die Arbeit

Do We Need Age- and Sex-Dependent Organ Weights for the Risk-Specific Tube Current Modulation (riskTCM) in Diagnostic CT?

14. September 2024

Prof. Dr. Martin Fiebich
Präsident der DGMP

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Thank You!

- This presentation will soon be available at www.dkfz.de/ct.
- Job opportunities through DKFZ's international PhD or Postdoctoral Fellowship programs (marc.kachelriess@dkfz.de).
- Parts of the reconstruction software were provided by RayConStruct® GmbH, Nürnberg, Germany.