Tube Current and Tube Voltage Modulation in CT to Minimize the Patient's Radiation Risk

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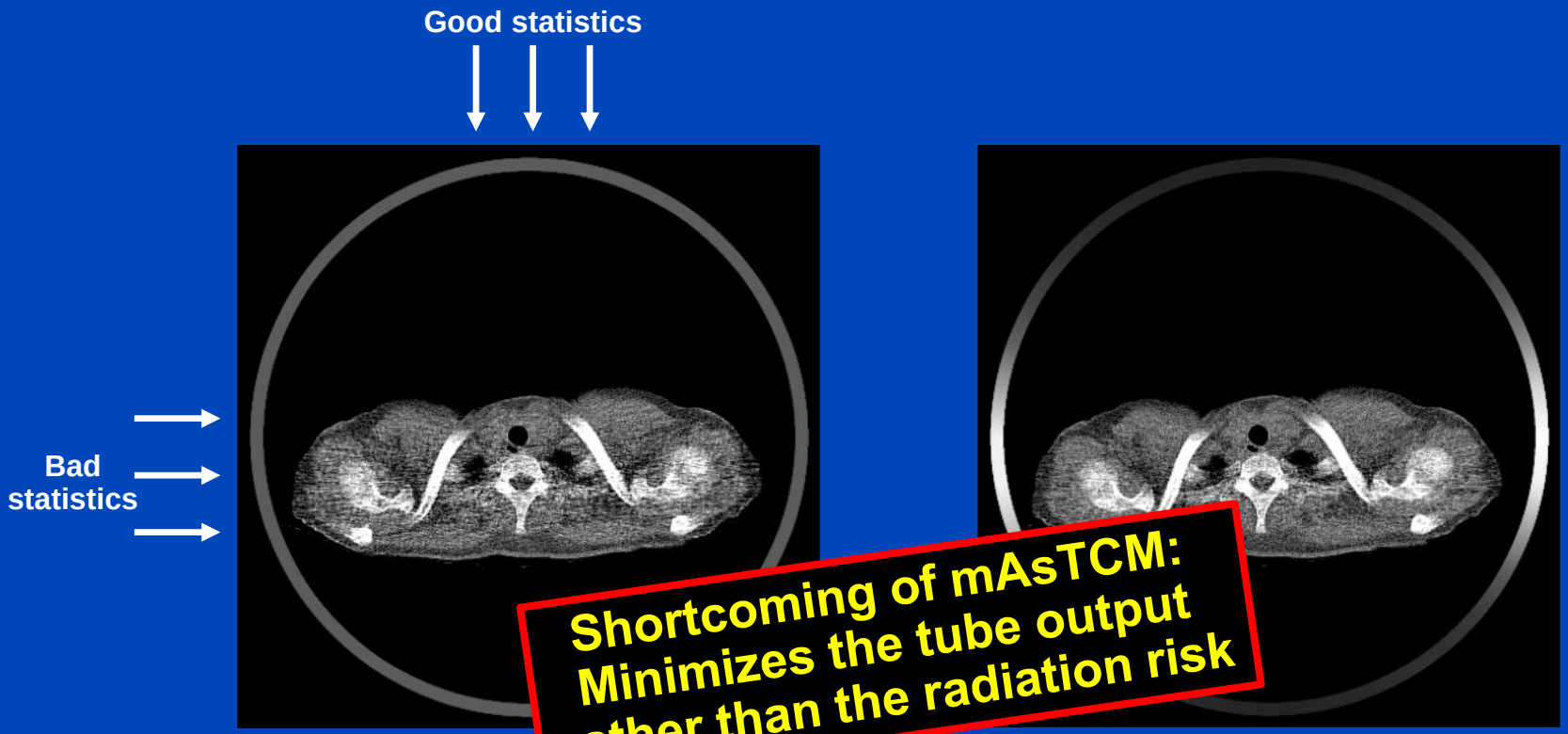
TCM Minimizing the mAs-Product (mAsTCM)



[1]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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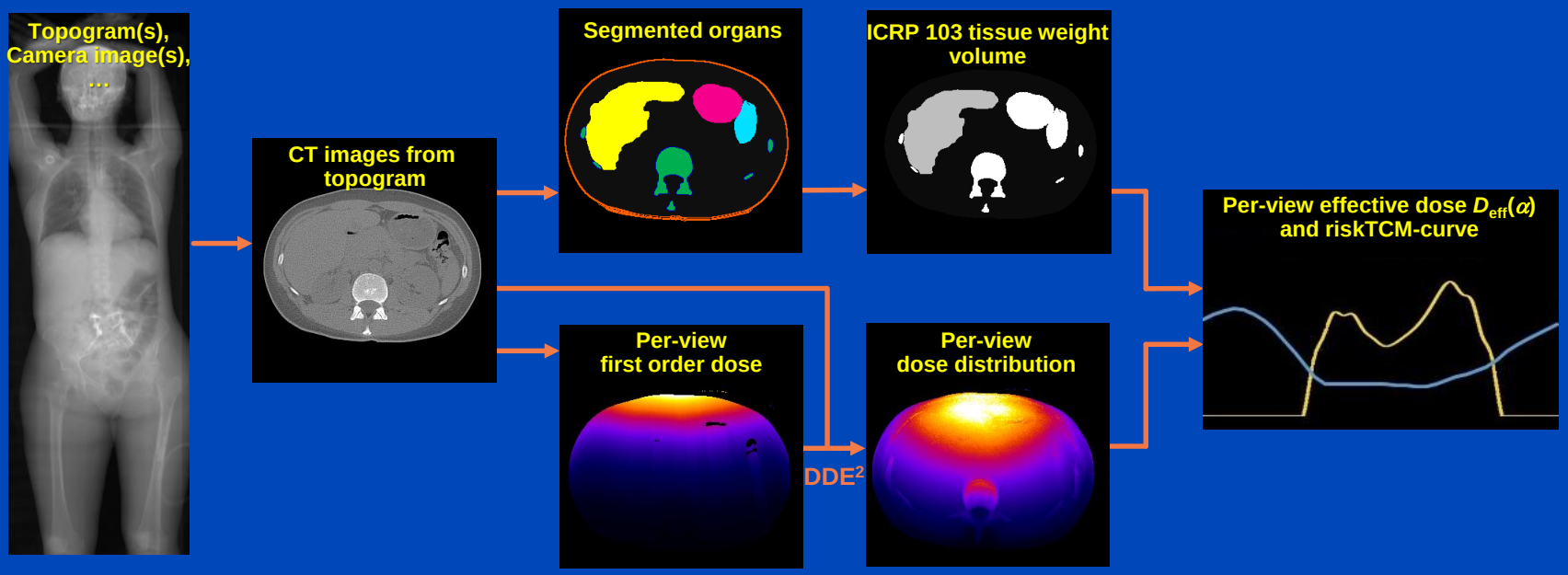
TCM Minimizing the Radiation Risk (riskTCM[1])

Basic workflow



[1]L. Klein, M. Kachelrieß et al. Patient-specific radiation risk-based tube current modulation. Med. Phys. 49(7):4391-4403, July 2022.

[2]J. Maier, M. Kachelrieß et al. Real-time estimation of patient-specific dose distributions using the deep dose estimation (DDE). Med. Phys. 49(4):2259-2269, April 2022.

Aim

- Today's state-of-art tube current modulation (mAsTCM) minimizes the mAs product.
- Our previously proposed risk-specific TCM (riskTCM[1]) minimizes the patient risk.
- None of these methods optimizes the photons' energy distribution governed by the tube voltage.
- Therefore, we propose a combined tube current and tube voltage modulation minimizing the patient risk (riskTCTVM).

mAsTCM = optimized for the x-ray tube, good for the patient

riskTCM = optimized for the patient, better for the patient

riskTCTVM = optimized for the patient, much better for the patient?

[1]L. Klein, M. Kachelrieß et al. Patient-specific radiation risk-based tube current modulation. Med. Phys. 49(7):4391-4403, July 2022.

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Methods

- Simulation study
- Minimization of effective dose D_{eff} at constant noise level
- Modulation of tube current and voltage
- Voltage range: 70 kV to 150 kV
- X-ray spectra: Tucker spectra attenuated by intrinsic filtration and bowtie filter
- Apply water precorrection for scanners with tube voltage modulation[1]
- Here: unenhanced scans only

[1]L. Ritschl, F. Bergner, C. Fleischmann, and M. Kachelrieß. Water calibration for CT scanners with tube voltage modulation. Phys. Med. Biol. 55:4107-4117, July 2010.

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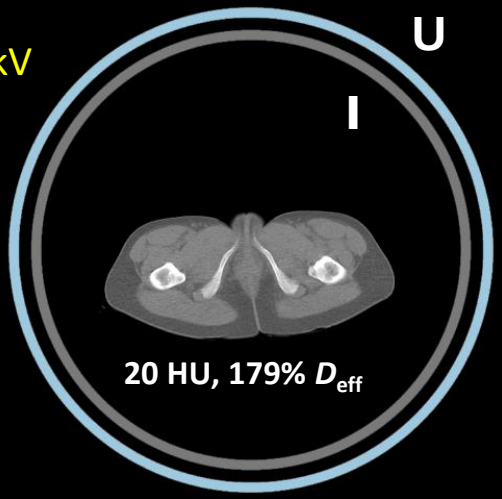
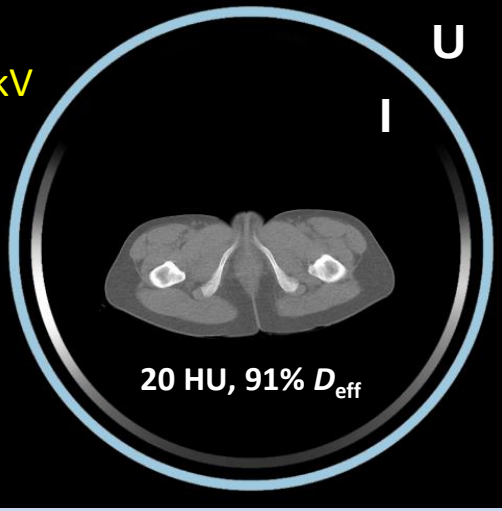
Risk Minimizing Tube Current & Tube Voltage Modulation (riskTCTVM)

noTCM
U = 120 kV

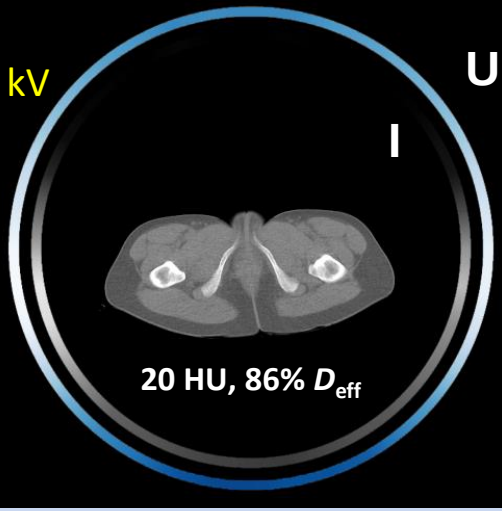


mAsTCM
U = 120 kV

riskTCM
U = 120 kV



riskTCTVM
U = 70…150 kV



D_{eff} values of noTCM, riskTCM and riskTCTVM relative to mAsTCM. *C* = 40 HU, *W* = 900 HU

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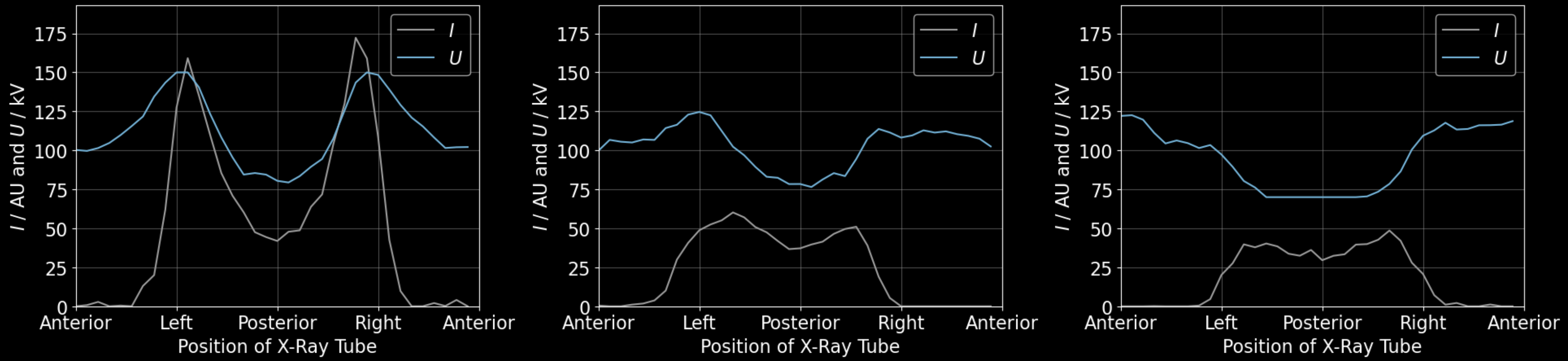
Risk Minimizing Tube Current & Tube Voltage Modulation (riskTCTVM)



D_{eff} values of riskTCTVM and riskTCM relative to mAsTCM. C = 40 HU, W = 900 HU

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Conclusions

- The tube voltage range chosen by riskTCTVM depends on the anatomical region. For some regions, riskTCTVM uses the full range from 70 kV to 150 kV.
- riskTCTVM yields further potential dose reductions in the order of 5 to 10% compared to riskTCM (for unenhanced scans).
- While riskTCM would require only software changes and achieves about 30% dose reduction, riskTCTVM would require x-ray generators capable of modulating the tube voltage to achieve about 5% dose reduction.
- Next steps:
  - Apply riskTCM to iodine-enhanced scans
  - Also modulate the prefilter thickness
- **Vendors should take action to implement riskTCM.**

Thank You!

This presentation will soon be available at www.dkfz.de/ct.

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Job opportunities through DKFZ's international Fellowship programs (marc.kachelriess@dkfz.de).

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