Beyond Iodine: Dose Reduction Potential with Patient-Specific Prefiltration in Hafnium-Enhanced CT Scans with EI and PC Detectors

Jörg Steidel, Laura Klein, Joscha Maier, Stefan Sawall, and Marc Kachelrieß

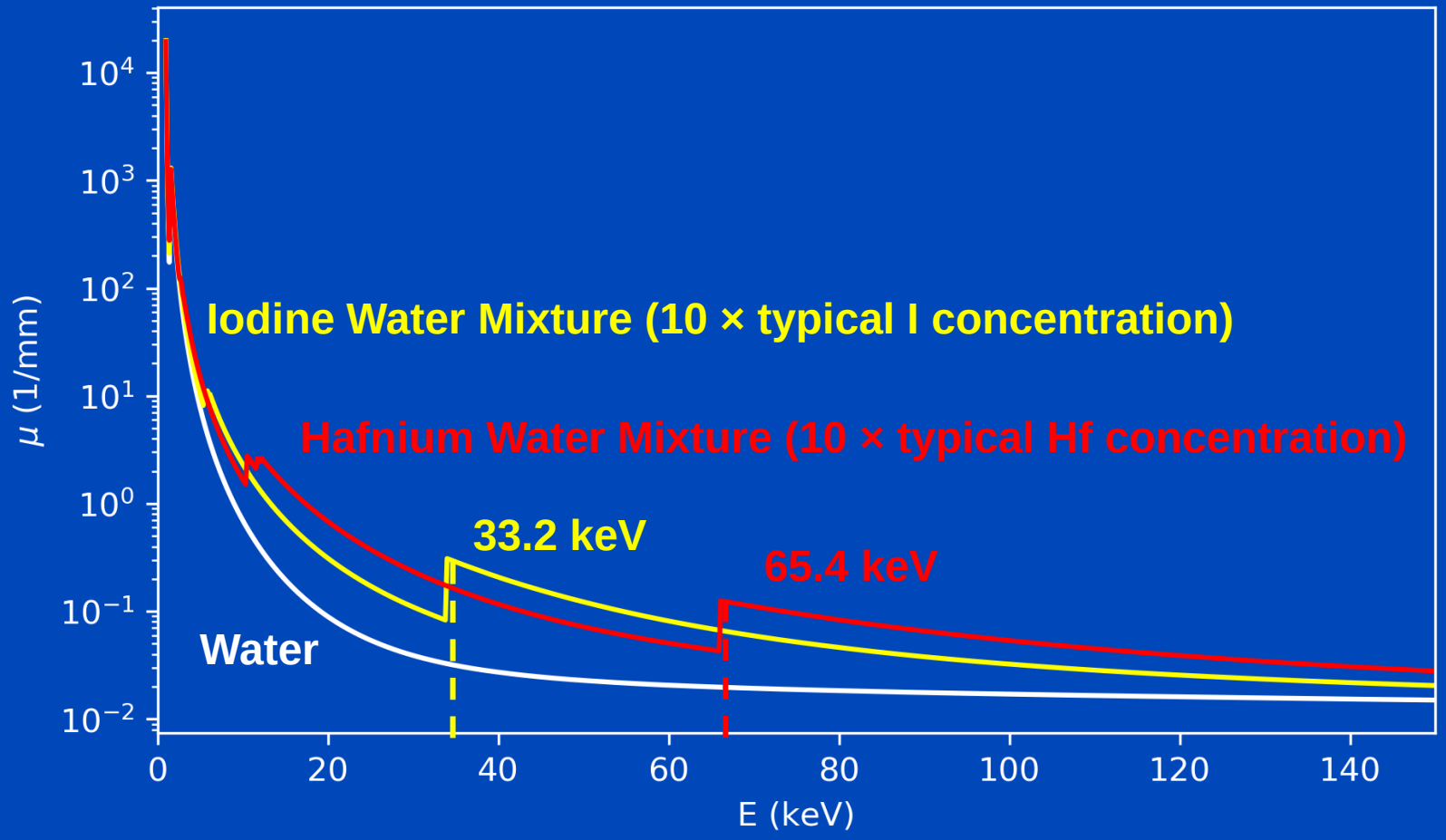
German Cancer Research Center (DKFZ)
Heidelberg, Germany
www.dkfz.de/ct

dkfz. DEUTSCHES KREBSFORSCHUNGSZENTRUM IN DER HELMHOLTZ-GEMEINSCHAFT

Aim

To assess the dose reduction potential of patient-specific copper prefiltration for CT scans enhanced with iodine and hafnium.

Linear Attenuation Coefficients Hafnium vs. Iodine



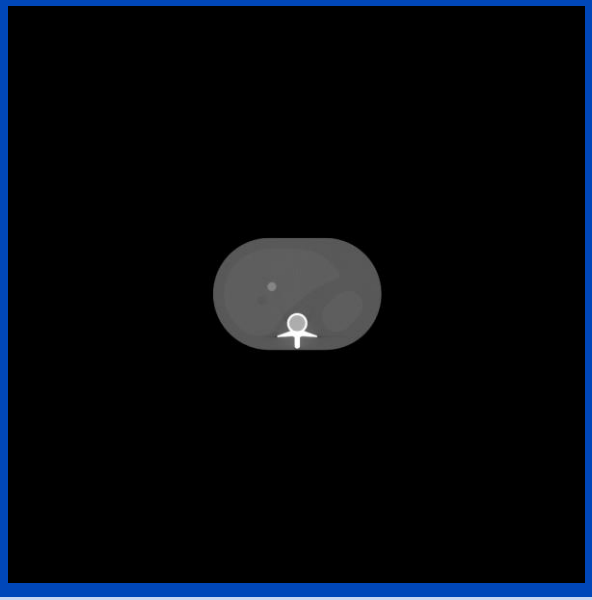
Typical Values for Current CT Systems

- Tube voltage range: 70 – 150 kV
- Maximum tube current time product: 1000 mAs (assuming 1 s exposure per z-position)
- Tube current modulation switched on

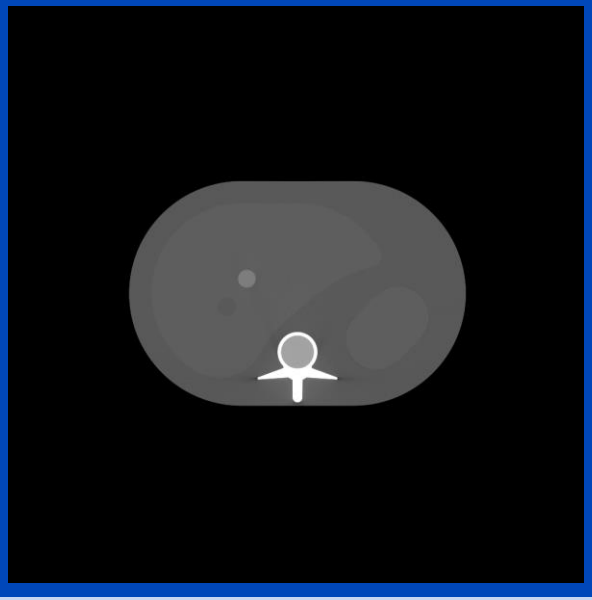
Simulations

- Prefilter material: copper
- Prefilter thickness: 0.0 – 5.0 mm in steps of 0.1 mm
- Tube voltage: 40 – 150 kV in steps of 5 kV
- Energy integrating (EI) and photon counting (PC) detector
- Three abdomen phantoms

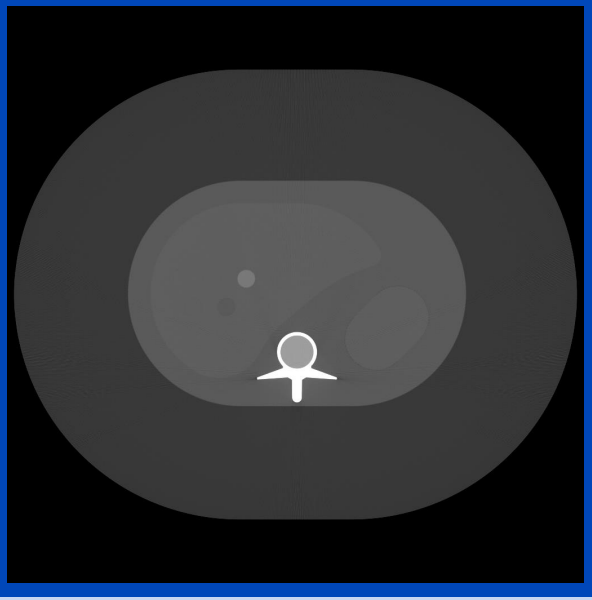
Child (15 × 10 cm)



Adult (30 × 20 cm)



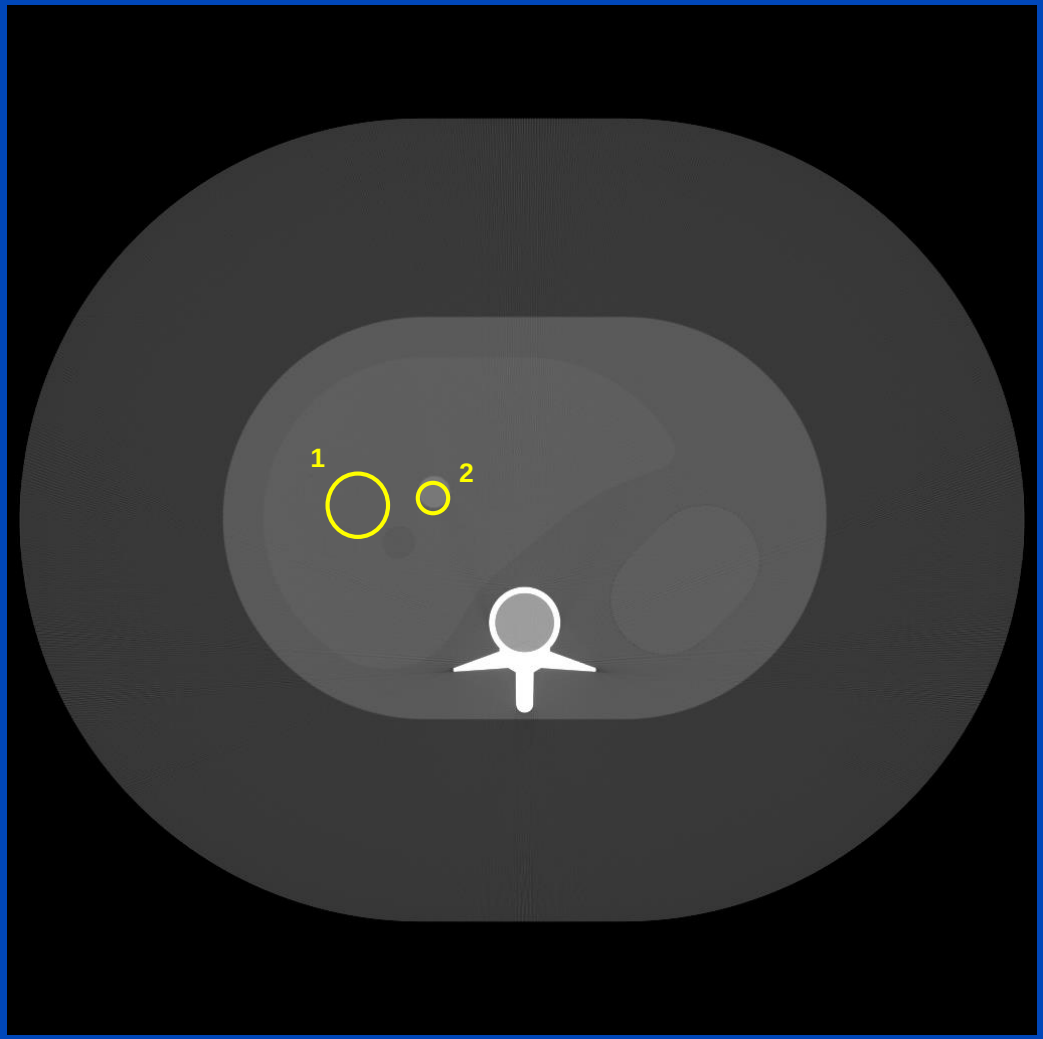
Obese (50 × 40 cm)



C = 200 HU, *W* = 1000 HU, *U* = 100 kV, no prefilter

dkfz.

Image Quality Assessment



C = 200 HU, *W* = 1000 HU, *U* = 100 kV, no prefilter

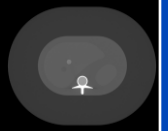
$$\mathrm{CNRD} = \frac{|\mu_1 - \mu_2|}{\sqrt{\sigma_1^2 + \sigma_2^2}\sqrt{D}}$$

- **Regions of interest**
  1. **Liver**
  2. **Iodine/hafnium insert**
- **Dose: Monte Carlo simulations of a 32 cm CTDI phantom**

J. Steidel, J. Maier, S. Sawall, M. Kachelrieß et al. Dose Reduction Potential in Diagnostic Single Energy CT through Patient-Specific Prefilters and a Wider Range of Tube Voltages. Med. Phys. (in press).

dkfz.

Dose Reduction by Patient-Specific Copper Prefilters

		Child (15 cm × 10 cm) 	Adult (30 cm × 20 cm) 	Obese (50 cm × 40 cm) 
EI	Basis	0.0 mm, 50 mAs, 70 kV Iodine contrast	0.0 mm, 120 mAs, 90 kV Iodine contrast	0.0 mm, 720 mAs, 120 kV Iodine contrast
	Iodine Contrast	0.4 mm, 1000 mAs, 50 kV **57%**	0.2 mm, 1000 mAs, 65 kV **49%**	0.0 mm, 1000 mAs, 105 kV **39%**
	Iodine Contrast (≥70 kV)	0.1 mm, 70 mAs, 70 kV **3%**	0.1 mm, 1000 mAs, 70 kV **40%**	0.0 mm, 1000 mAs, 105 kV **39%**
	Hafnium Contrast	3.3 mm, 1000 mAs, 85 kV **43%**	2.3 mm, 1000 mAs, 95 kV **79%**	0.3 mm, 1000 mAs, 120 kV **83%**
PC	Basis	0.0 mm, 50 mAs, 70 kV Iodine contrast	0.0 mm, 120 mAs, 90 kV Iodine contrast	0.0 mm, 720 mAs, 120 kV Iodine contrast
	Iodine Contrast	0.4 mm, 1000 mAs, 50 kV **41%**	0.2 mm, 1000 mAs, 65 kV **25%**	0.0 mm, 1000 mAs, 105 kV **8%**
	Iodine Contrast (≥70 kV)	0.1 mm, 70 mAs, 70 kV **2%**	0.3 mm, 1000 mAs, 70 kV **24%**	0.0 mm, 1000 mAs, 105 kV **8%**
	Hafnium Contrast	3.3 mm, 1000 mAs, 85 kV **26%**	2.3 mm, 1000 mAs, 95 kV **68%**	0.3 mm, 1000 mAs, 120 kV **74%**

Conclusions

- Significant dose reduction with hafnium contrast for adult and obese patients
- Iodine contrast is only advantageous for the child phantom if a tube voltage of 50 kV was available
- Cu filter with thickness range of 0.0 – 3.3 mm required
- Fine gradations to optimally adapt to the patient (e.g. 0.3 mm steps)

Element	Z	K-Edge
Iodine	53	33.2 keV
Gadolinium	64	50.2 keV
Ytterbium	70	61.3 keV
Hafnium	72	65.4 keV
Tungsten	74	69.5 keV
Bismuth	83	90.5 keV

Thank You!

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

Job opportunities through DKFZ's international PhD or Postdoctoral Fellowship programs (www.dkfz.de) or directly through Prof. Dr. Marc Kachelrieß (marc.kachelriess@dkfz.de).

Parts of the reconstruction software were provided by RayConStruct® GmbH, Nürnberg, Germany.