Iodine Quantification Accuracy in Dual Source Dual Energy CT Using Default Parameters vs. Patient-Specific Calibrations

Sabrina Dorn[1,2], Stefan Sawall[1,2], Joscha Maier[1,2], and Marc Kachelrieß[1,2]

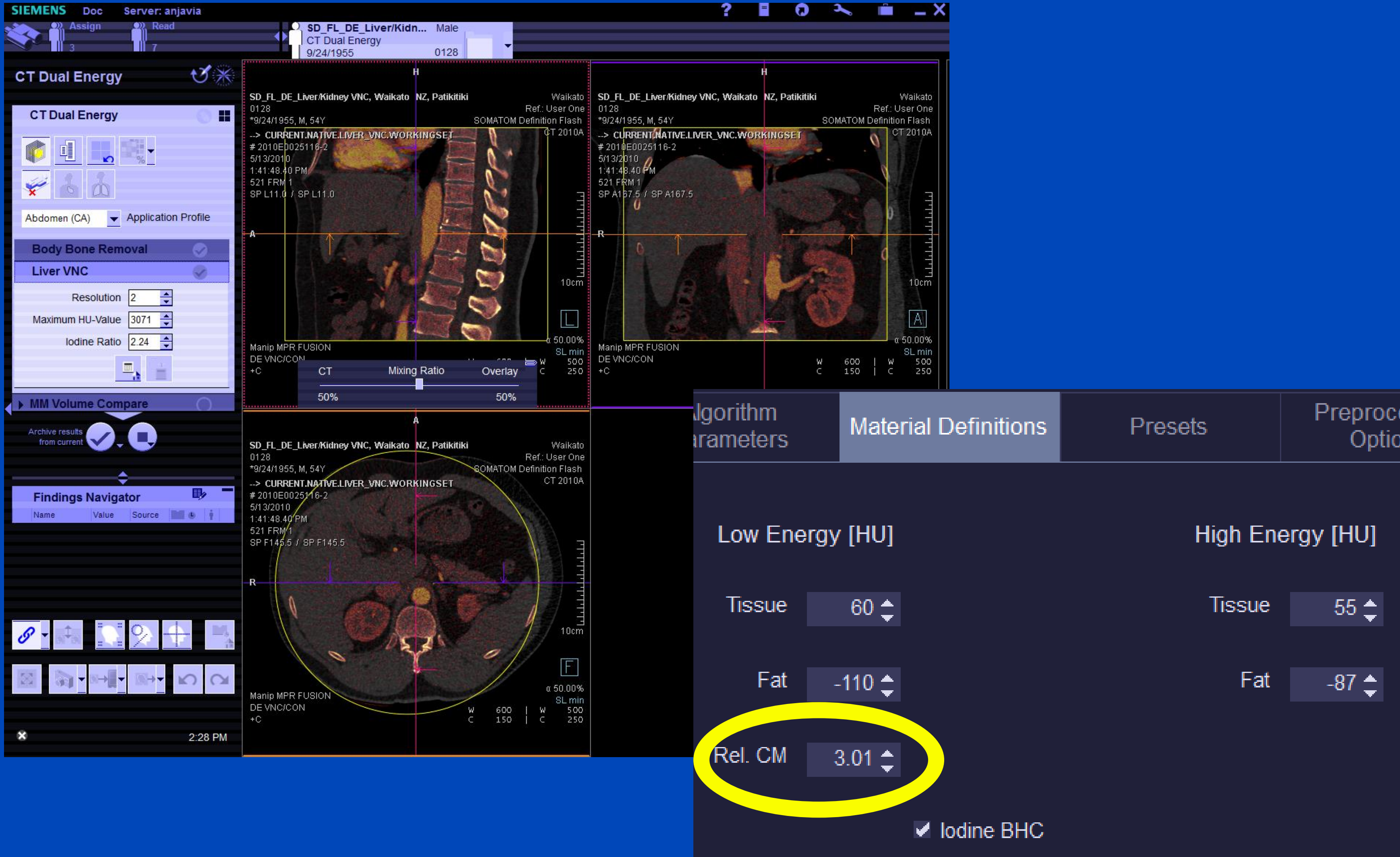
[1]German Cancer Research Center (DKFZ), Heidelberg, Germany
[2]University of Heidelberg, Germany

DECT-based Material Decomposition

- **Detection, visualization and quantification of iodine**
  → Computation of a „virtual“ unenhanced image and an iodine image
  → Visualization and quantification of the local iodine uptake in tissue as a measure of the local blood supply

Standard image Virtual unenhanced image Iodine image

Courtesy of Klinikum Großhadern, LMU München



- **Calibration required because the spectral behavior depends on the patient size in image-based DECT.**
- **Basically, RelCM evaluates the ratio or the difference of CT numbers.**
- **The relative contrast media ratio (RelCM) is calibrated by default.**

Material Mixtures

- **Two water-iodine mixtures of unknown mixing ratio**

$$CT_1(E) = (1 - w_1)CT_{\mathrm{W}}(E) + w_1 CT_{\mathrm{I}}(E) = w_1 CT_{\mathrm{I}}(E)$$
$$CT_2(E) = (1 - w_2)CT_{\mathrm{W}}(E) + w_2 CT_{\mathrm{I}}(E) = w_2 CT_{\mathrm{I}}(E)$$

- **Their relative contrast is independent of the mixing ratio**

$$\frac{CT_1(E_{80\,\mathrm{kV}}) - CT_2(E_{80\,\mathrm{kV}})}{CT_1(E_{140\,\mathrm{kV}}) - CT_2(E_{140\,\mathrm{kV}})} = \frac{CT_{\mathrm{I}}(E_{80\,\mathrm{kV}})}{CT_{\mathrm{I}}(E_{140\,\mathrm{kV}})}$$

- **Hence, it can be used to calibrate DECT.**

Aim

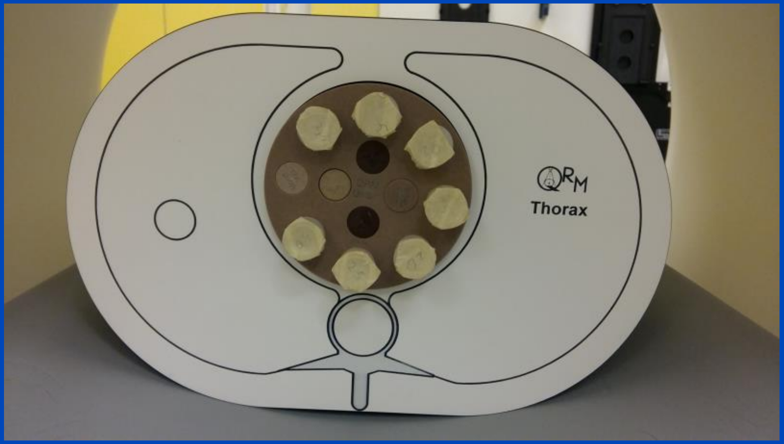
To evaluate the influence of the calibration of the relative contrast media ratio (RelCM) on iodine quantification accuracy in dual source dual energy CT (DS-DECT).

Calibration can be done either using default parameters or patient-specific evaluations.

Materials & Methods

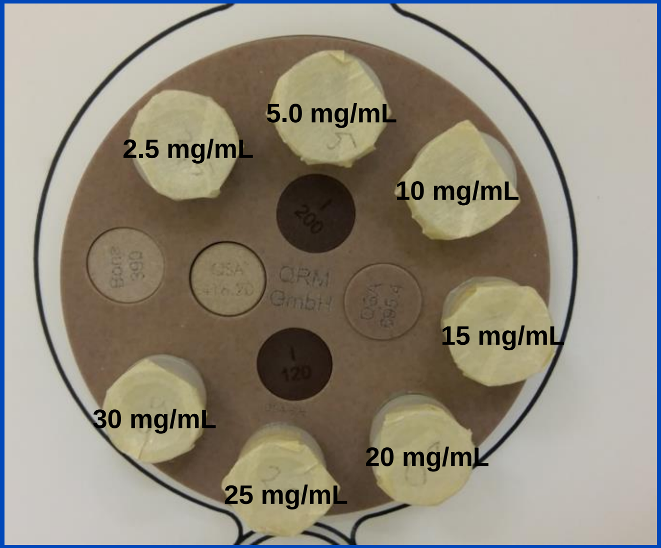
Phantoms

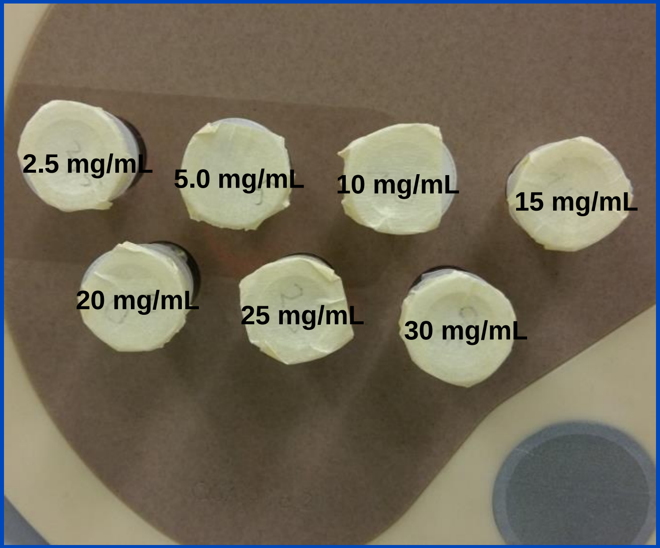
- **Anthropomorphic thorax and liver phantom**
- **Three different phantom sizes**
  - **Small** (200 × 300 mm)
  - **Medium** (250 × 350 mm)
  - **Large** (300 × 400 mm)



Materials & Methods
Phantoms

- Vials filled with varying iodine concentration ranging from 2.5 to 30 mg/mL



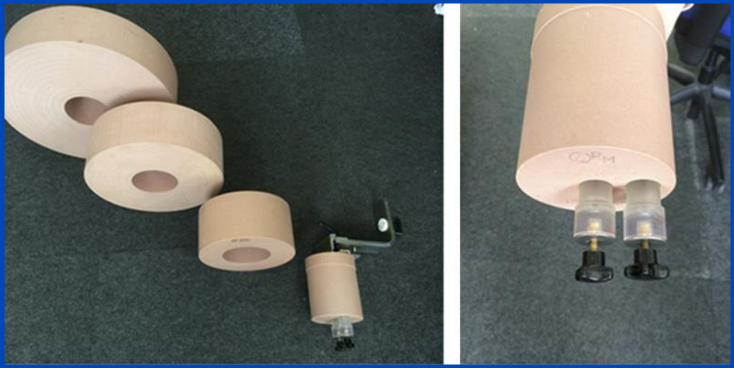


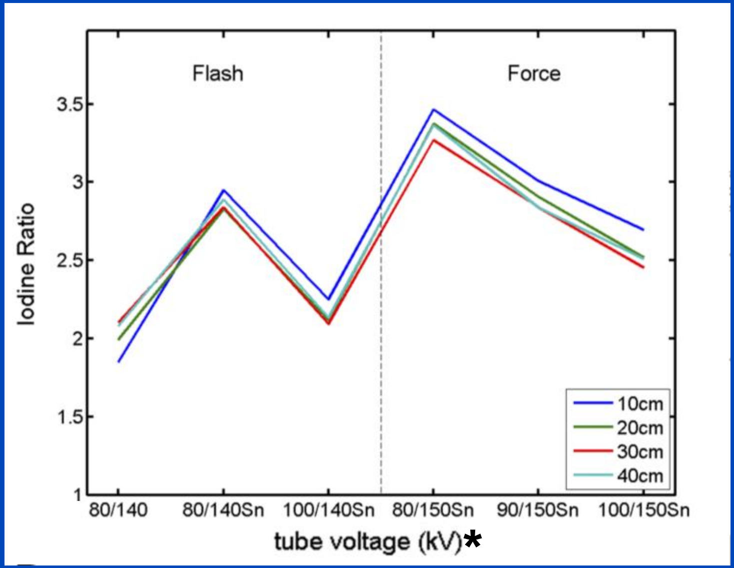
- Dual source dual energy acquisition (SOMATOM Definition Flash, Siemens Healthineers AG, Erlangen, Germany)
  - 80 kV (low energy) and 140 kV (high energy) with additional 0.4 mm tin prefiltration

Materials & Methods
RelCM Calibration

- **Default calibration**
  - **RelCM calibration based on measurements**
  - **For each tube voltage combination, one RelCM value is preset by default**
  - **RelCM is a measure of spectral separation**

Tube voltage combination	RelCM
80 kV / 140 kV + 0.4 mm Sn	**3.01**
100 kV / 140 kV + 0.4 mm Sn	2.24
70 kV / 150 kV + 0.6 mm Sn	4.13
80 kV / 150 kV + 0.6 mm Sn	3.46
90 kV / 150 kV + 0.6 mm Sn	3.01
100 kV / 150 kV + 0.6 mm Sn	2.64





*B. Krauss, K. Grant, B. Schmidt, T. Flohr. The Importance of Spectral Separation An Assessment of Dual-Energy Spectral Separation for Quantitative Ability and Dose Efficiency. Investigative Radiology, 50 (2), 2015

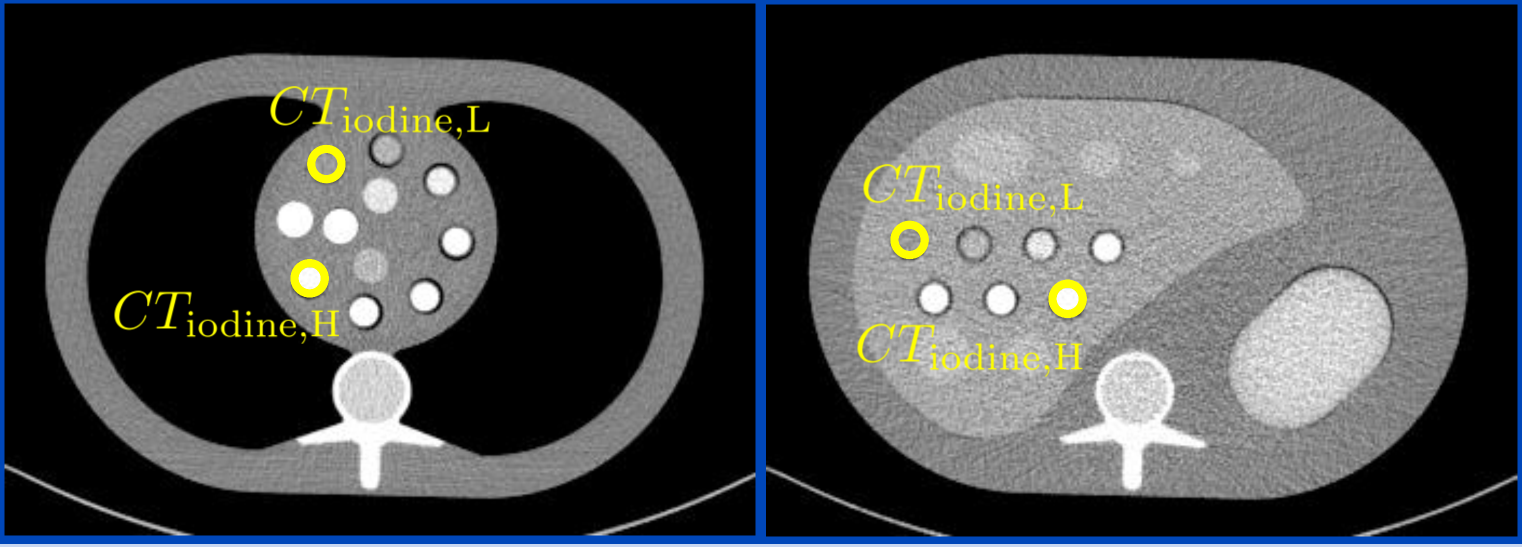
dkfz.

Materials & Methods

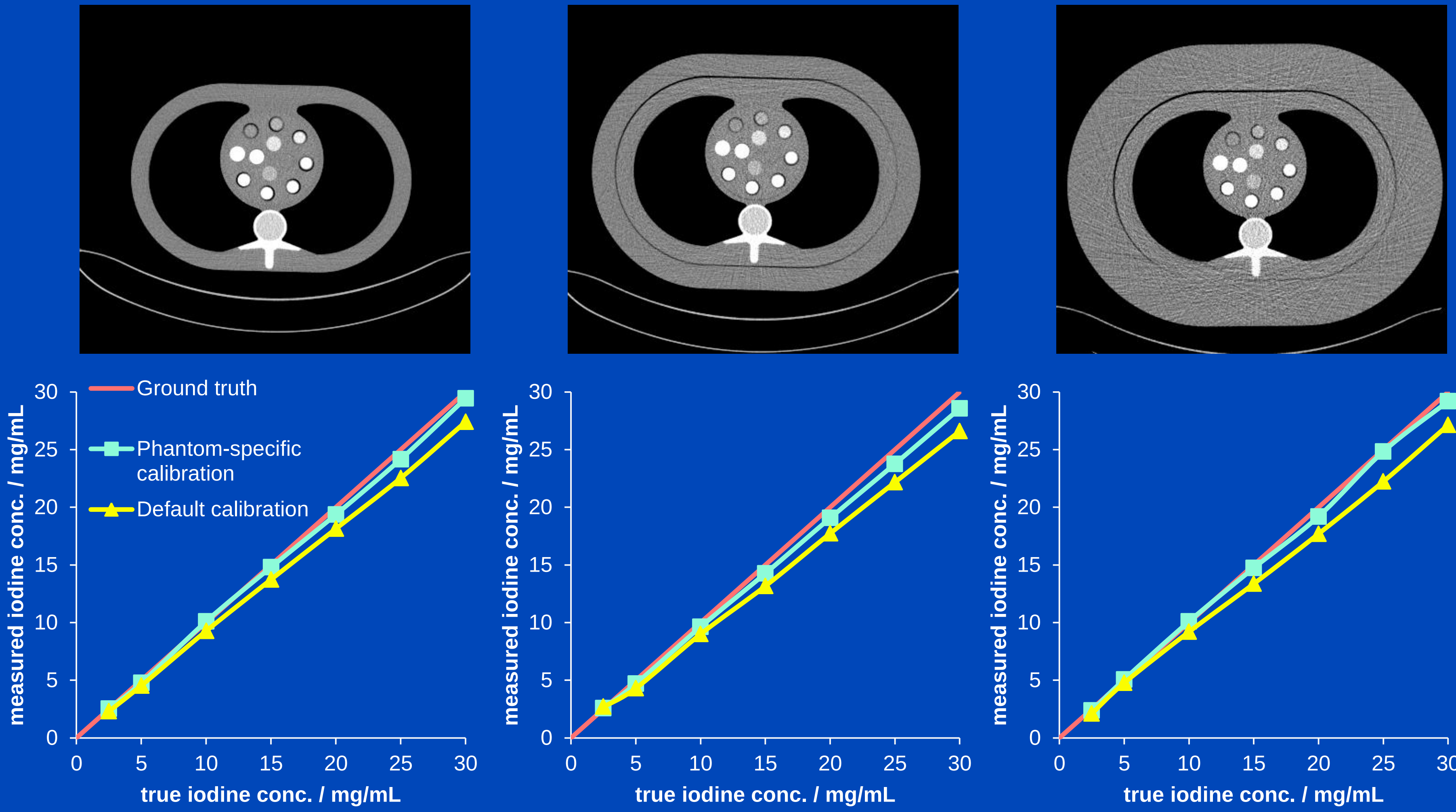
RelCM Calibration

- **Patient-specific calibration**
  - Evaluation of ROI containing lowest possible iodine concentration and ROI containing highest possible concentration
  - The ratio of the iodine contrast at low and high energy determines the relative contrast media ratio

$$\mathrm{RelCM} = \frac{CT_{\mathrm{iodine,H}}(E_{80\,\mathrm{kV}}) - CT_{\mathrm{iodine,L}}(E_{80\,\mathrm{kV}})}{CT_{\mathrm{iodine,H}}(E_{140\,\mathrm{kV}}) - CT_{\mathrm{iodine,L}}(E_{140\,\mathrm{kV}})}$$

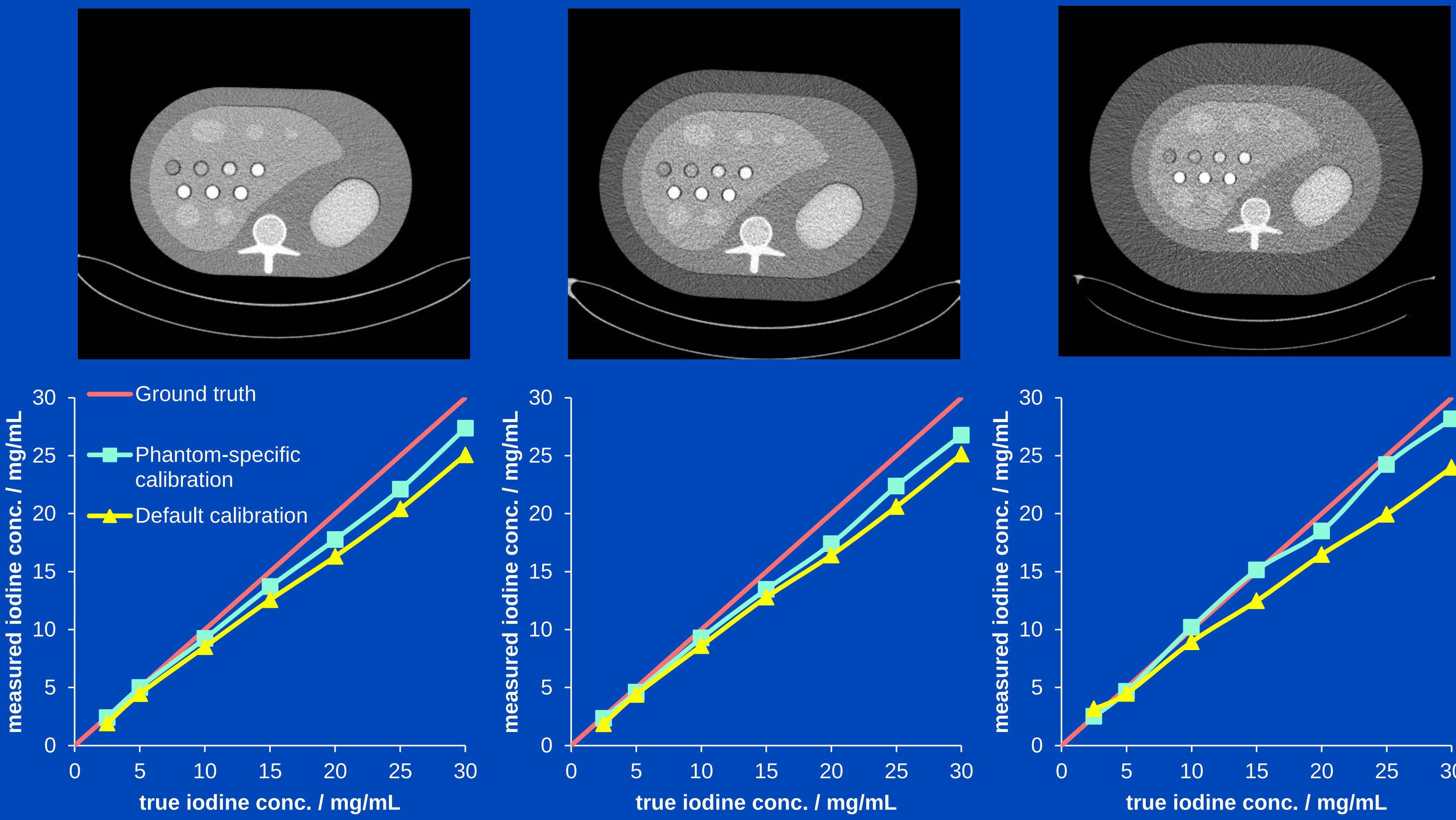


Iodine Quantification Accuracy



→Material decomposition and iodine quantification is performed using Syngo.CT Dual Energy (Siemens Healthineers AG, Erlangen, Germany)

Iodine Quantification Accuracy



→Material decomposition and iodine quantification is performed using Syngo.CT Dual Energy (Siemens Healthineers AG, Erlangen, Germany)

dkfz.

Results

Influence of Patient-specific Calibration on Relative Contrast Ratio

	Liver Phantom		Thorax Phantom	
	RelCM	Reduction	RelCM	Reduction
Default	3.01	0.0 %	3.01	0.0 %
Small	2.86	5.0 %	2.80	7.0 %
Medium	2.91	3.3 %	2.81	6.7 %
Large	2.67	11.3 %	2.76	8.3 %
	Mean	**6.5 %**	Mean	**7.3 %**

- **Phantom-specific calibrations result in lower RelCM values.**

dkfz.

Results

Quantitative Evaluation of Iodine Quantification Accuracy

- **Accuracy improvement factor**

$$AIF = \frac{\epsilon_{\text{default}} - \epsilon_{\text{patient}}}{\epsilon_{\text{default}}}$$

	Liver Phantom			Thorax Phantom		
	Mean relative error		*AIF*	*Mean relative error*		*AIF*
	e_{default}	e_{PS}		e_{default}	e_{PS}	
Small	16.9 %	7.4 %	56.3 %	8.7 %	2.4 %	72.9 %
Medium	16.8 %	9.9 %	41.4 %	11.2 %	4.5 %	59.6 %
Large	13.7 %	7.6 %	44.8 %	10.2 %	2.4 %	76.6 %
		Mean	**47.5 %**		Mean	**69.7 %**

dkfz.

Conclusions

- **Default parameter is a trade-off between iodine quantification accuracy and degrading effects.**
- **Phantom-specific calibrations result in lower RelCM values but better and more accurate iodine concentrations, since it accounts for beam hardening, scatter and actual object size.**
- **Patient-specific calibration on patient data can improve iodine quantification accuracy in clinical routine.**

Thank You!

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