Context-Sensitive Organ-Specific Evaluation and Analysis of DECT Images

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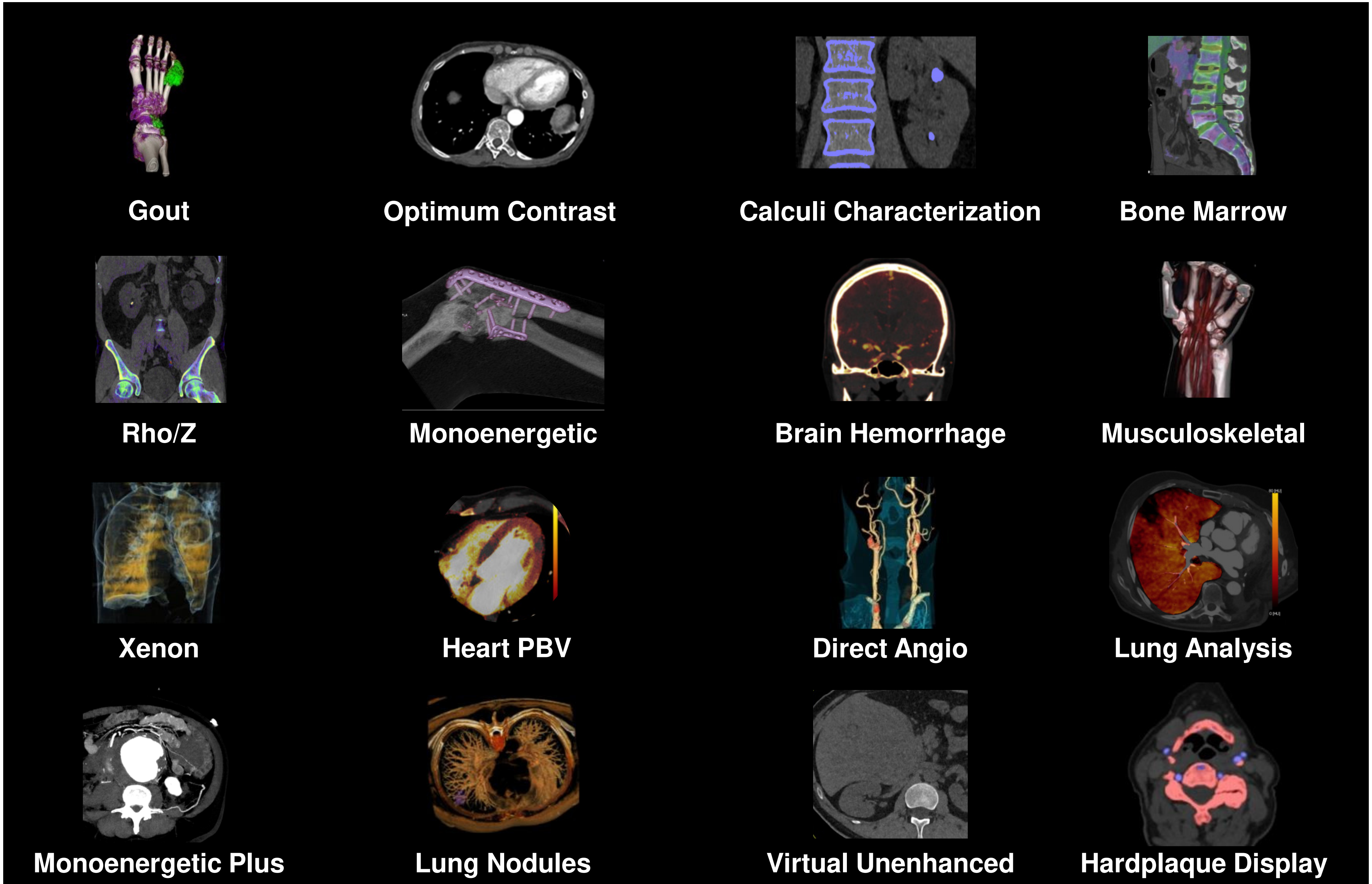
DEUTSCHES KREBSFORSCHUNGSZENTRUM IN DER HELMHOLTZ-GEMEINSCHAFT



Syngo.CT DECT application examples. Virtual unenhanced contains liver VNC, lung analysis contains lung PBV.
Courtesy of Siemens Healthineers, Forchheim, Germany

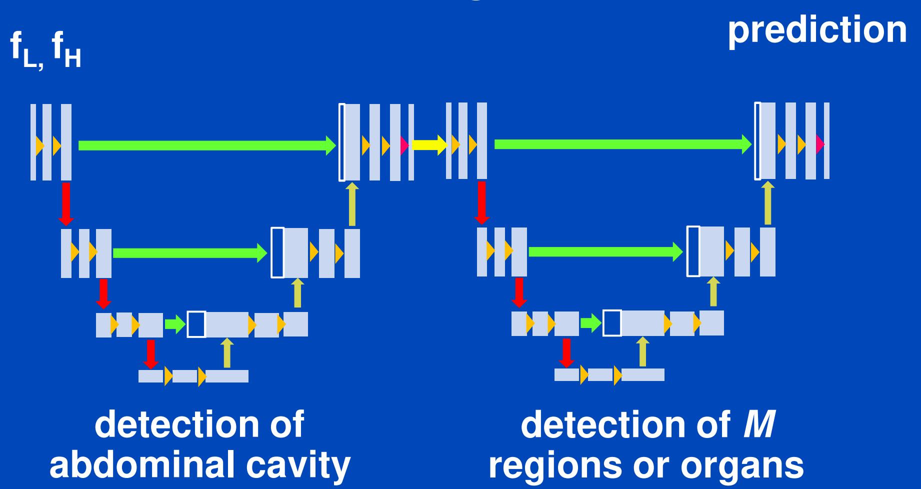

SIEMENS
CT Dual Energy
Abdomen (CA)
Application Profile
Body Bone Removal
Liver VNC
Resolution 2
Maximum HU-Value 3071
Iodine Ratio 2.24
MM Volume Compare
Findings Navigator
2:28 PM
CT
Mixing Ratio
Overlay
50%
50%
lgorithm
arameters
Material Definitions
Presets
Preproce
Optior
Low Energy [HU]
High Energy [HU]
Tissue 60
Tissue 55
Fat -110
Fat -87
Rel. CM 3.01
Iodine BHC

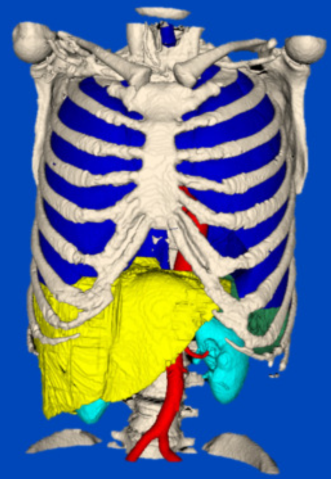
Aim

To facilitate radiologists' workflow by combining various dual energy applications into an automatic analysis tool.

Method

- Prior anatomical knowledge: 3D fully convolutional network[1]
  - Segmentation of dual energy data
  - Cascaded neural network architecture
    1. Detection of abdominal cavity
    2. Final detection of organ boundaries



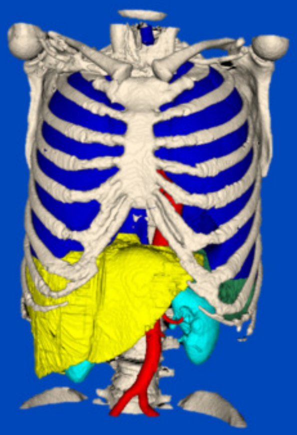


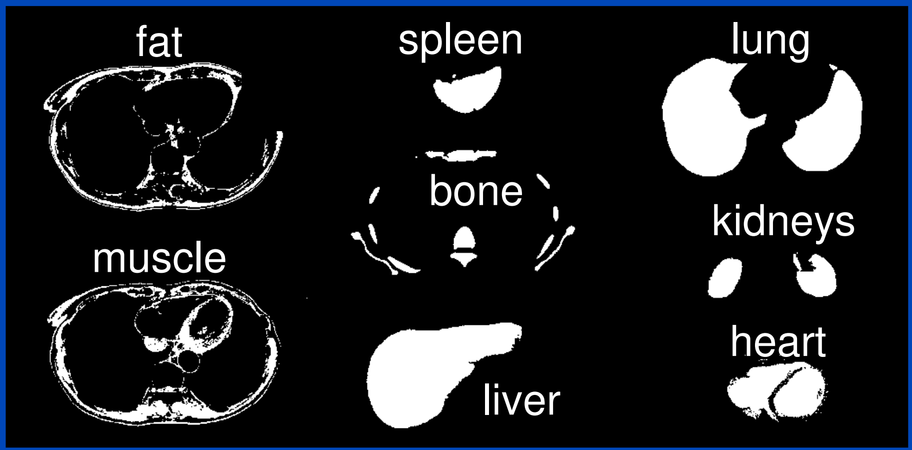
- Automatically segment **liver, kidneys, spleen, lung, bone, and aorta**.
- Thresholding remaining voxels into **muscles, fat, and vasculature**.
- Currently, manual corrections are necessary (until today).

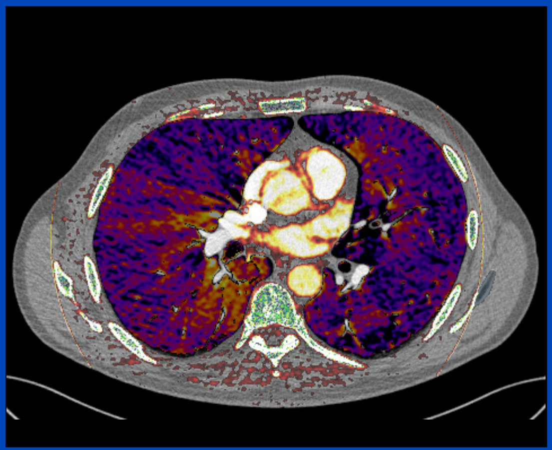
[1] S. Chen, H. Roth, S. Dorn, M. May, A. Cavallaro, M. Lell, M. Kachelrieß, H. Oda, K. Mori, and A. Maier. Towards Automatic Abdominal Multi-Organ Segmentation in Dual Energy CT using Cascaded 3D Fully Convolutional Network. *CoRR*, 2017

Method

- Segmentation delivers a binary mask for each organ.
- Use masks to allow for
  - Standardization of DE evaluation
    - Automatic placement and evaluation of region-of-interests (ROIs)
    - Automatic patient-specific calibration
  - Automation
    - Automatic selection of DE application for specific organs
    - Simultaneous DE evaluation of varying applications



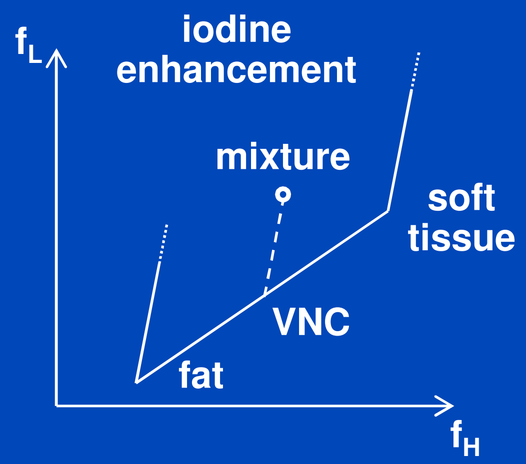




Dual Energy Evaluation Methods

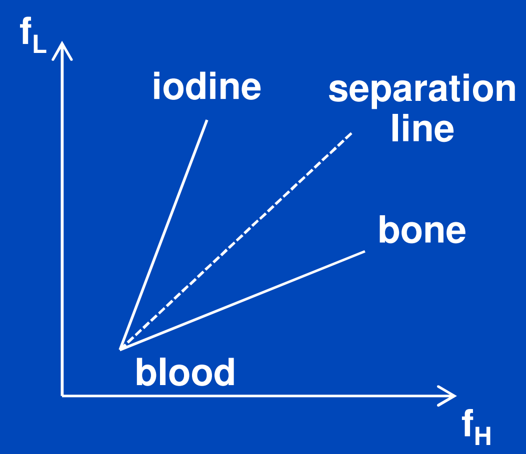
Most of the DE applications rely on two basic strategies (Siemens Syngo.Via):

Material decomposition



- LiverVNC, virtual unenhanced
- Lung perfused blood volume
- …

Material classification



- Body bone removal
- Kidney stone discrimination
- …

Dual Energy Evaluation Methods

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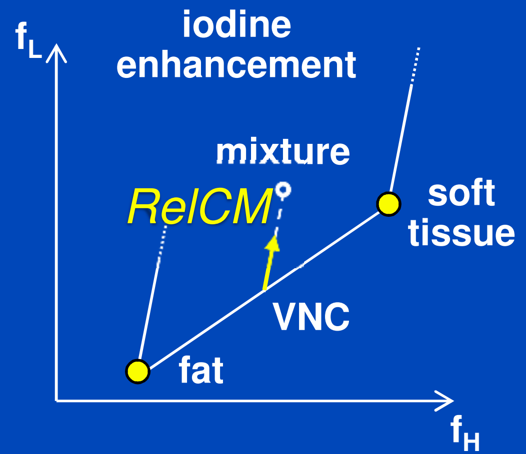
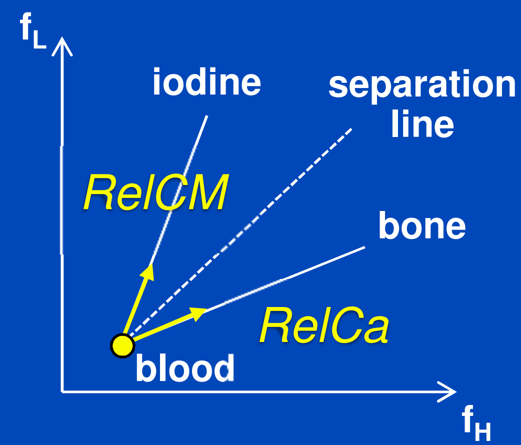
Material decomposition



Material classification



- **Calibration of reference points (fat, soft tissue, blood etc.) and relative contrasts of iodine and calcium (*RelCM, RelCa*) needed.**
  - **Manually placed region-of-interests (ROIs)**

Relative Contrast

- **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**

$$RelCM = \frac{CT_1(E_{\mathrm{L}}) - CT_2(E_{\mathrm{L}})}{CT_1(E_{\mathrm{H}}) - CT_2(E_{\mathrm{H}})} = \frac{CT_{\mathrm{I}}(E_{\mathrm{L}}) - CT_{\mathrm{W}}(E_{\mathrm{L}})}{CT_{\mathrm{I}}(E_{\mathrm{H}}) - CT_{\mathrm{W}}(E_{\mathrm{H}})}$$

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

Automatic Calibration

RelCM

- Automatic evaluation of two ROIs that contain water-iodine mixtures at two energies
  - ROI in aorta
  - ROI in liver

$$RelCM = \frac{CT_1(E_\mathrm{L}) - CT_2(E_\mathrm{L})}{CT_1(E_\mathrm{H}) - CT_2(E_\mathrm{H})} = \frac{\Delta CT_\mathrm{I}(E_\mathrm{L})}{\Delta CT_\mathrm{I}(E_\mathrm{H})}$$

RelCa

- Automatic evaluation of two ROIs, one contains Ca-fat mixture and one contains fat , at two energies
  - ROI in bone
  - ROI in fat

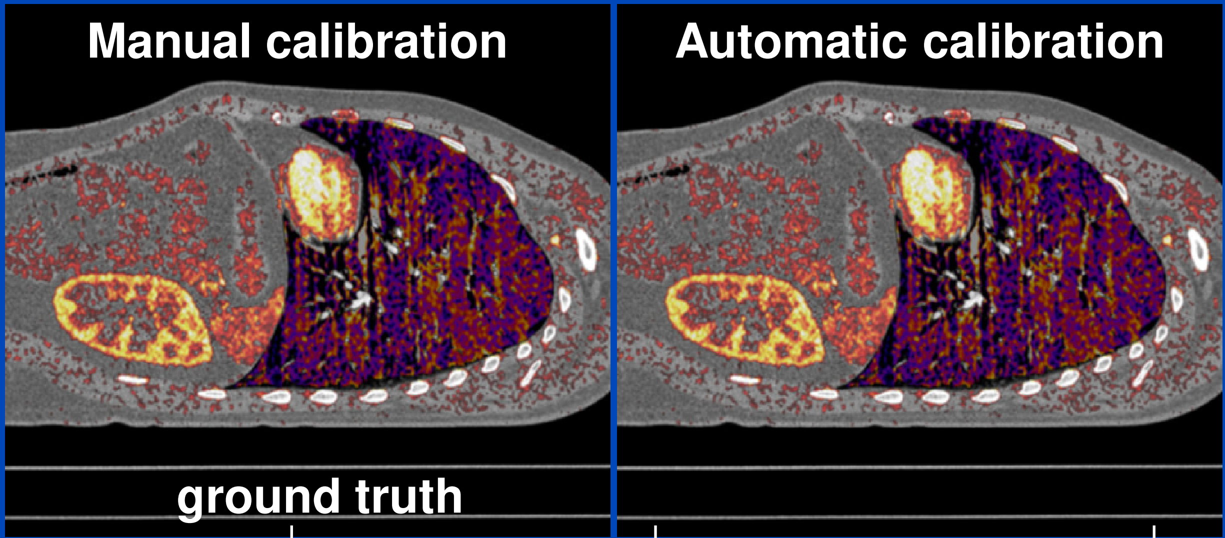
$$RelCa = \frac{CT_1(E_\mathrm{L}) - CT_2(E_\mathrm{L})}{CT_1(E_\mathrm{H}) - CT_2(E_\mathrm{H})} = \frac{\Delta CT_\mathrm{B}(E_\mathrm{L})}{\Delta CT_\mathrm{B}(E_\mathrm{H})}$$

Position of reference points in DE diagram

- Evaluation of ROIs in muscle, fat, aorta, liver, bone etc.

Manual vs. Automatic Calibration
Iodine Quantification Accuracy

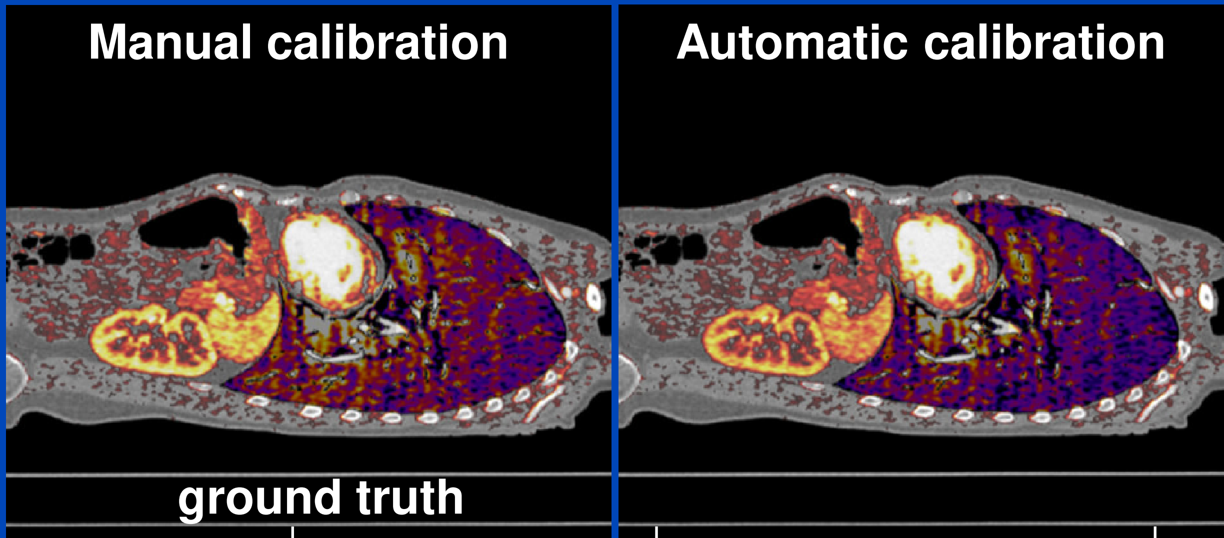
patient 008



	Ground truth	Automatic calibration	absolute error	relative error
lung	2.50 mg/mL	2.56 mg/mL	0.06 mg/mL	2.4%
heart	11.29 mg/mL	11.31 mg/mL	0.02 mg/mL	0.2%
kidney	7.26 mg/mL	7.27 mg/mL	0.01 mg/mL	0.01%
spleen	2.94 mg/mL	2.94 mg/mL	0.00 mg/mL	0.00%
			mean relative error:	0.6%

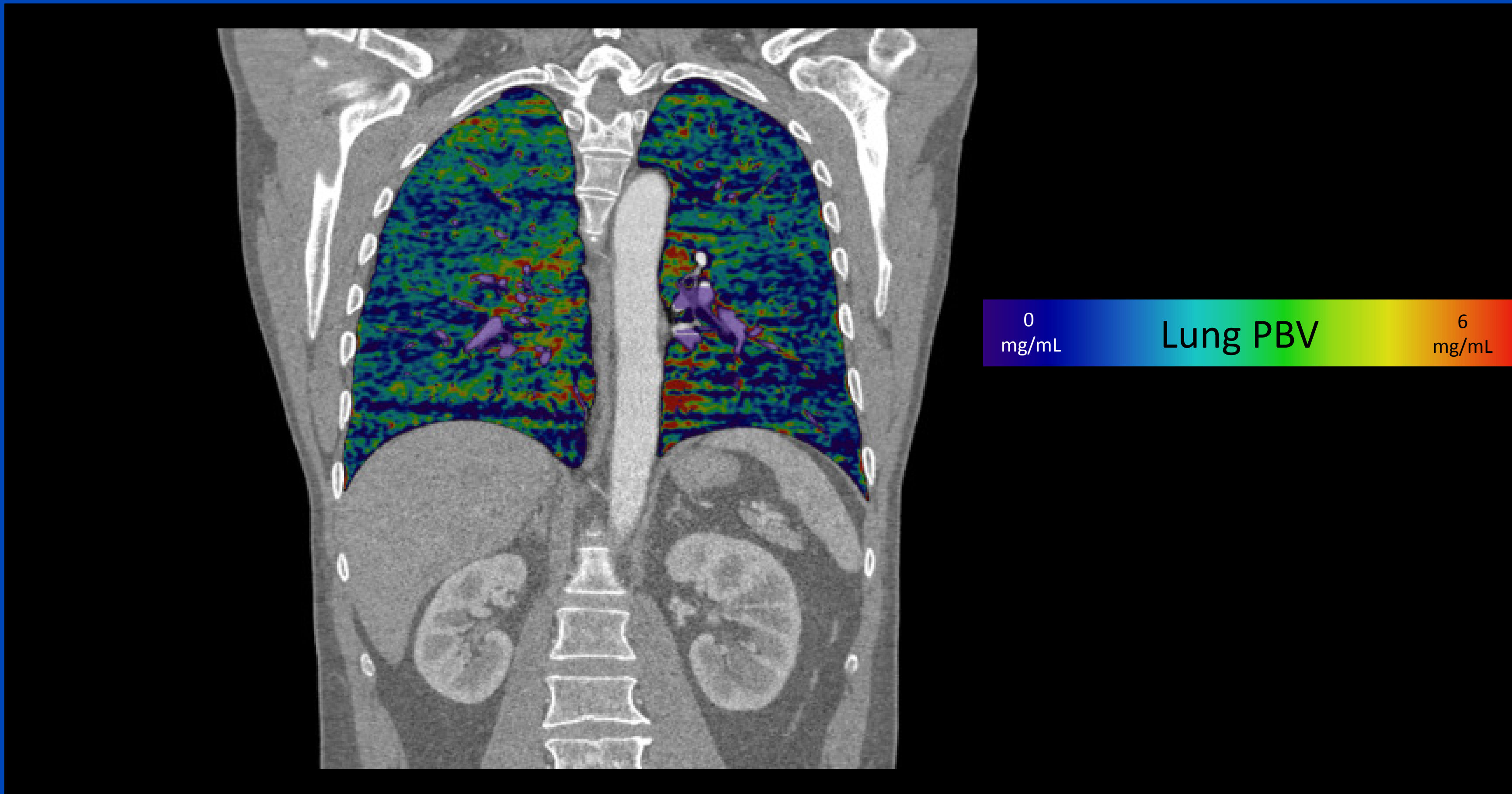
Manual vs. Automatic Calibration
Iodine Quantification Accuracy

patient 004



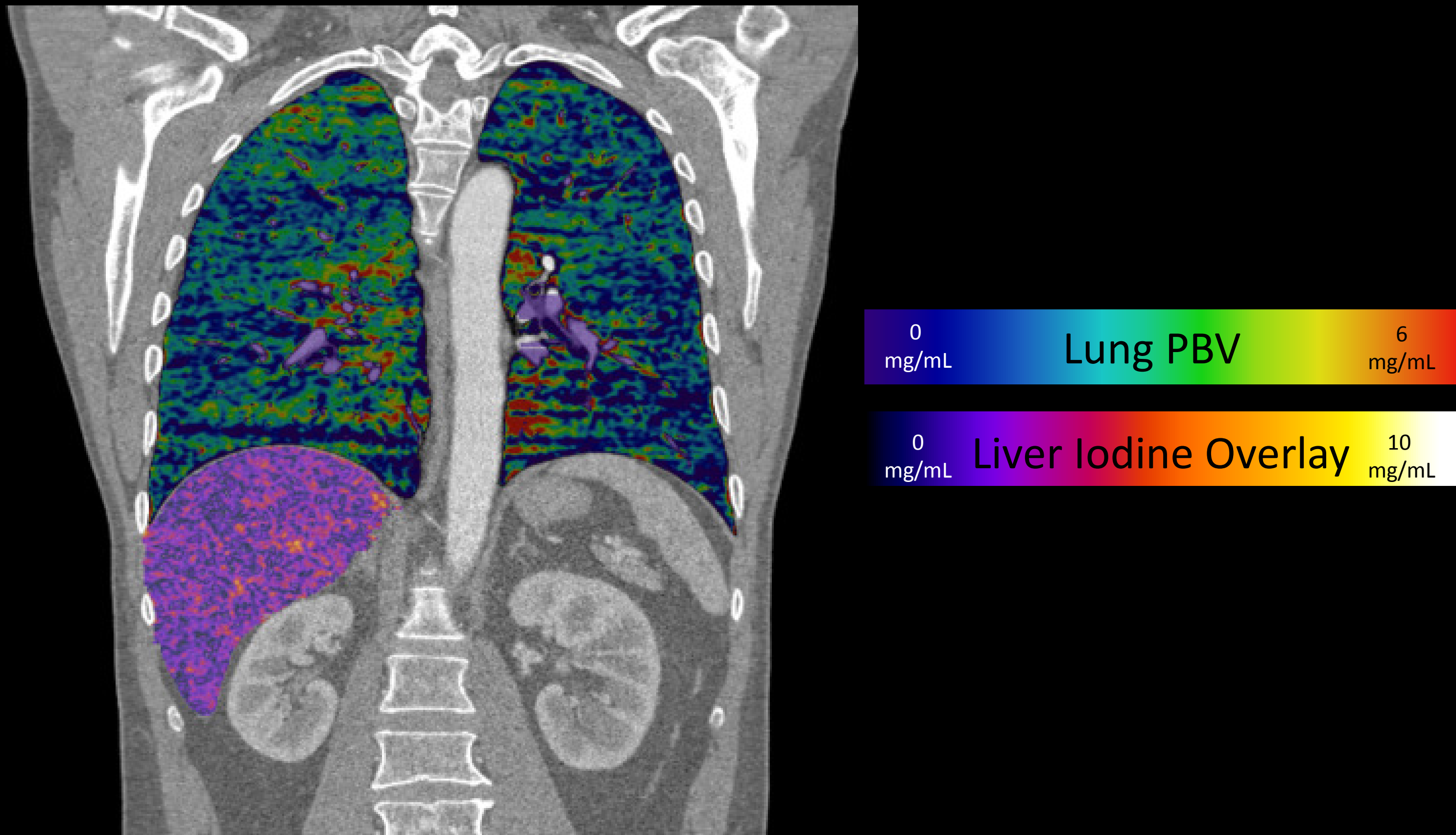
	Ground truth	Automatic calibration	absolute error	relative error
lung	1.50 mg/mL	1.62 mg/mL	0.12 mg/mL	8.0 %
heart	12.39 mg/mL	13.16 mg/mL	0.77 mg/mL	6.2 %
kidney	5.96 mg/mL	6.41 mg/mL	0.45 mg/mL	7.6 %
spleen	4.57 mg/mL	4.91 mg/mL	0.34 mg/mL	7.4 %
			mean relative error:	7.3 %

Results



C = 0 HU / W = 1000 HU

Results



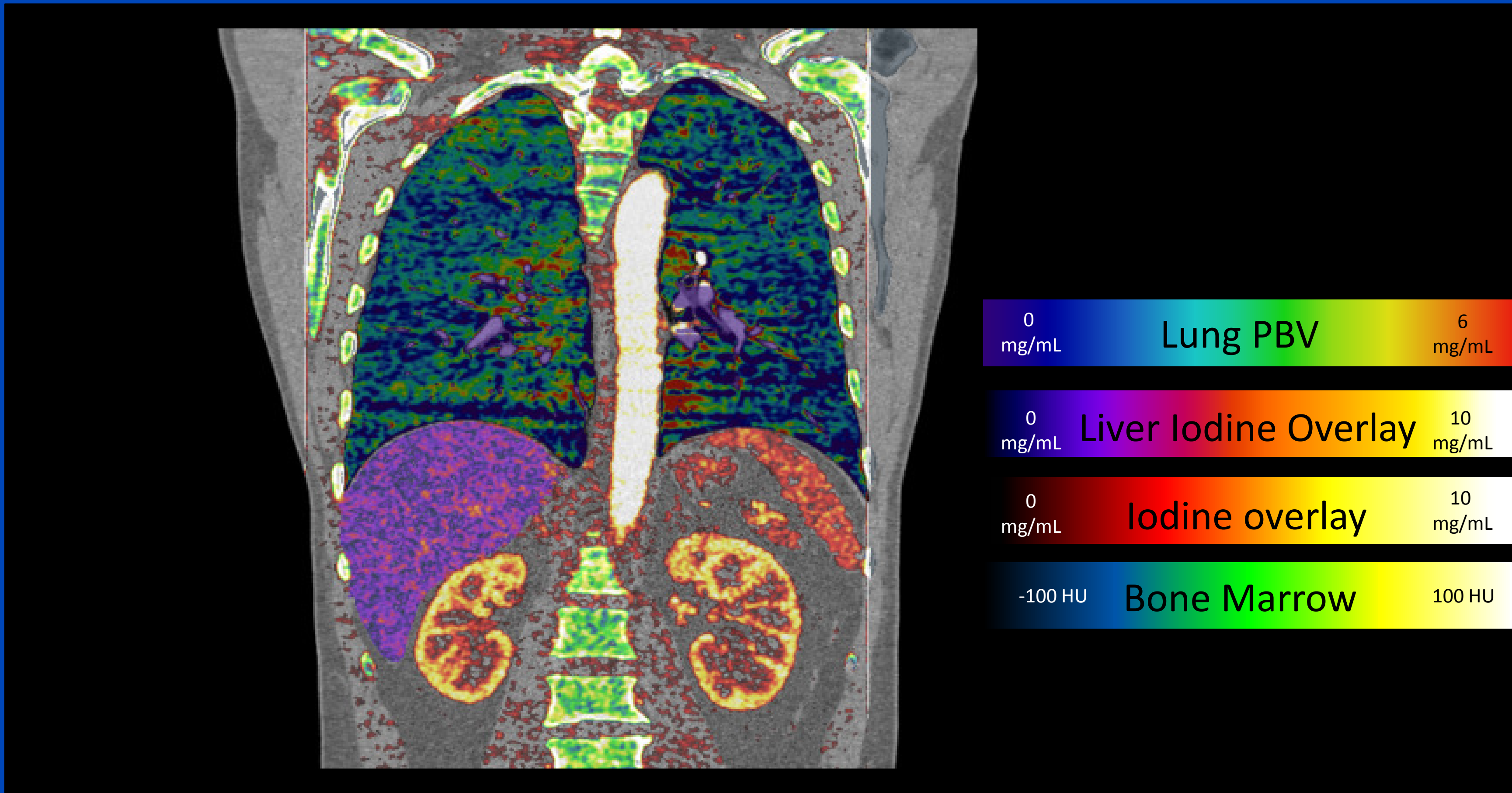
C = 0 HU / W = 1000 HU

Results

- ✓ **kidney, spleen, muscles and fat are evaluated using the same algorithm for iodine quantification**

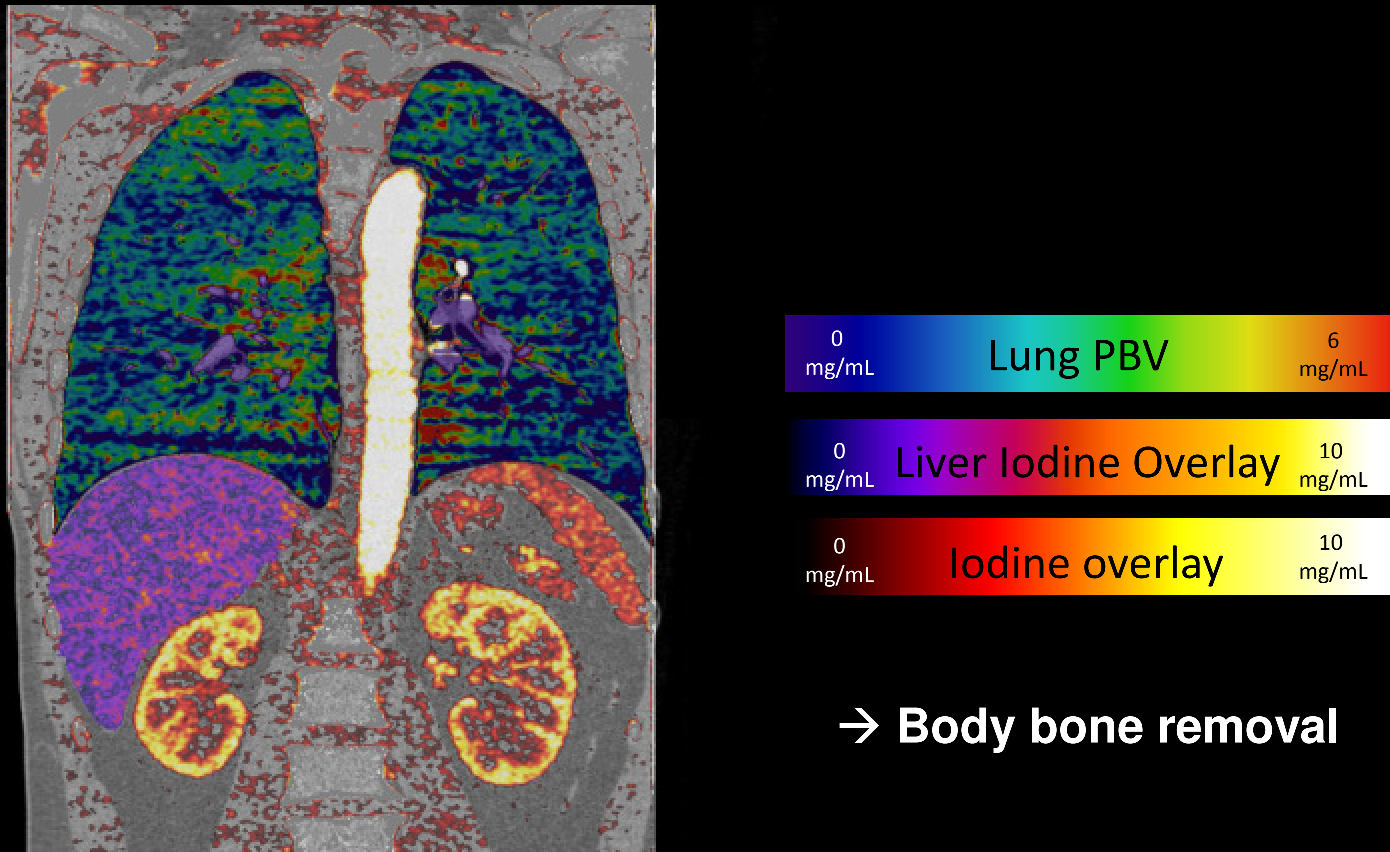
C = 0 HU / W = 1000 HU

Results



C = 0 HU / W = 1000 HU

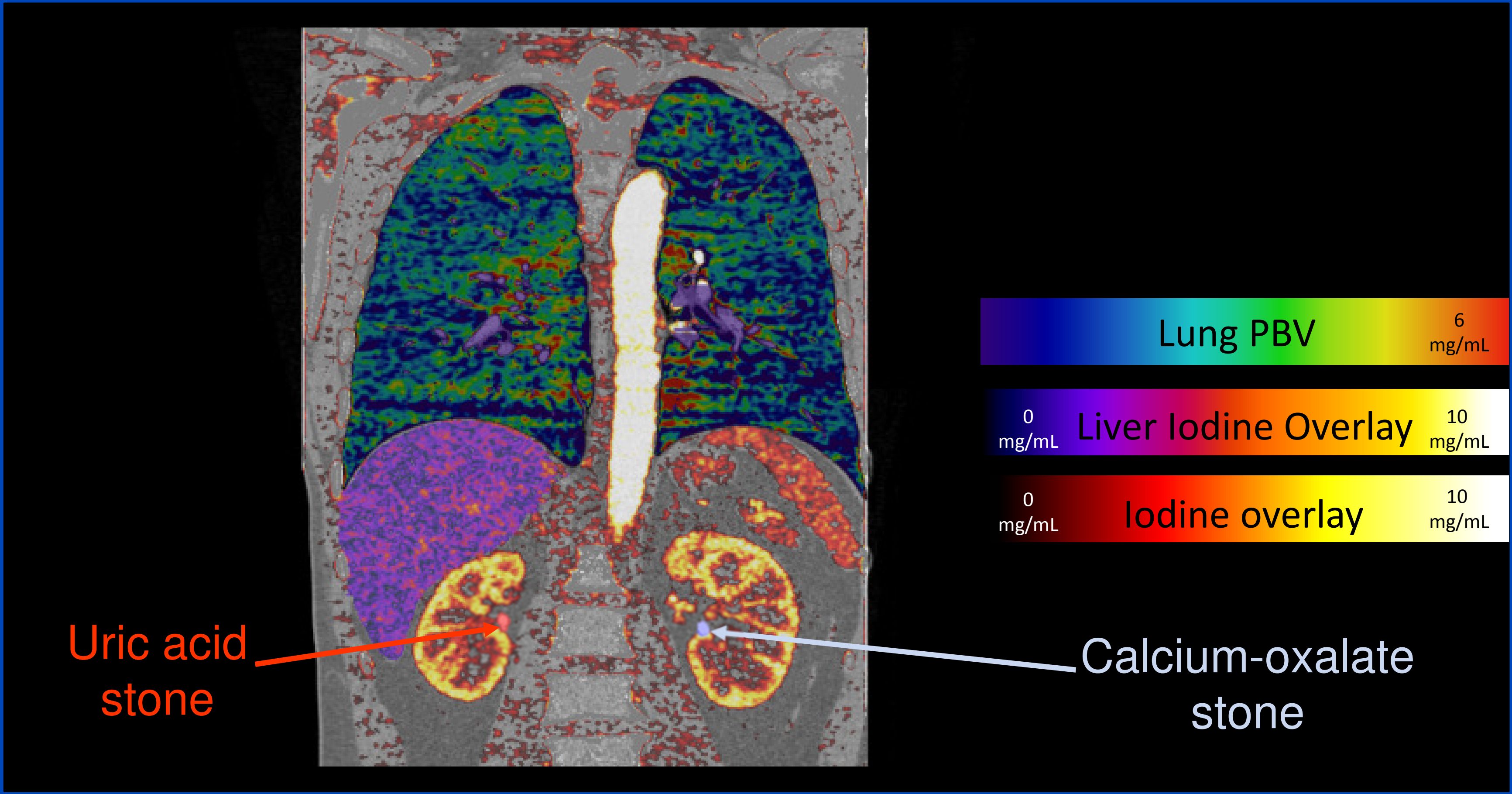
Results



→ **Body bone removal**

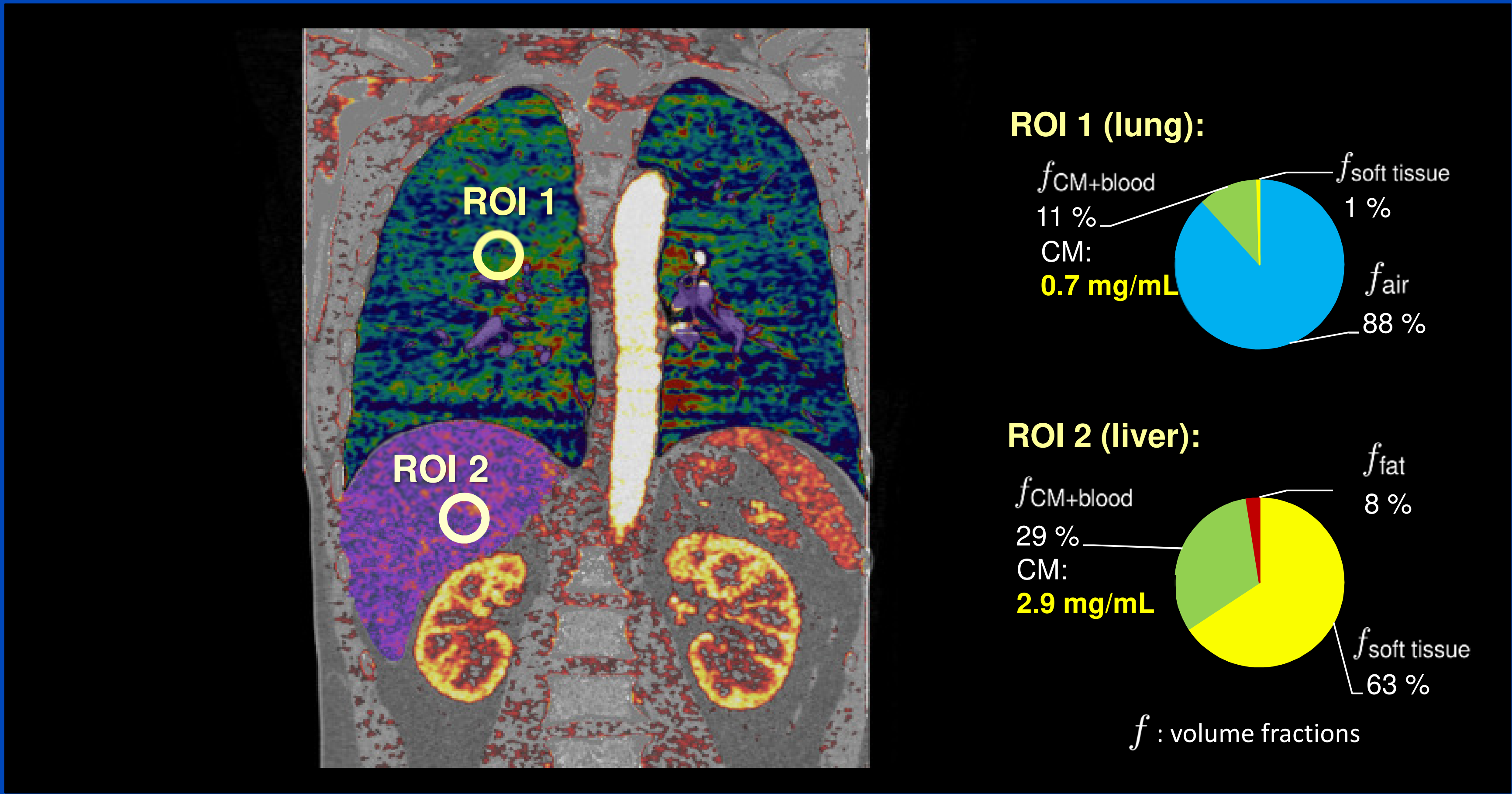
C = 0 HU / W = 1000 HU

Results



C = 0 HU / W = 1000 HU

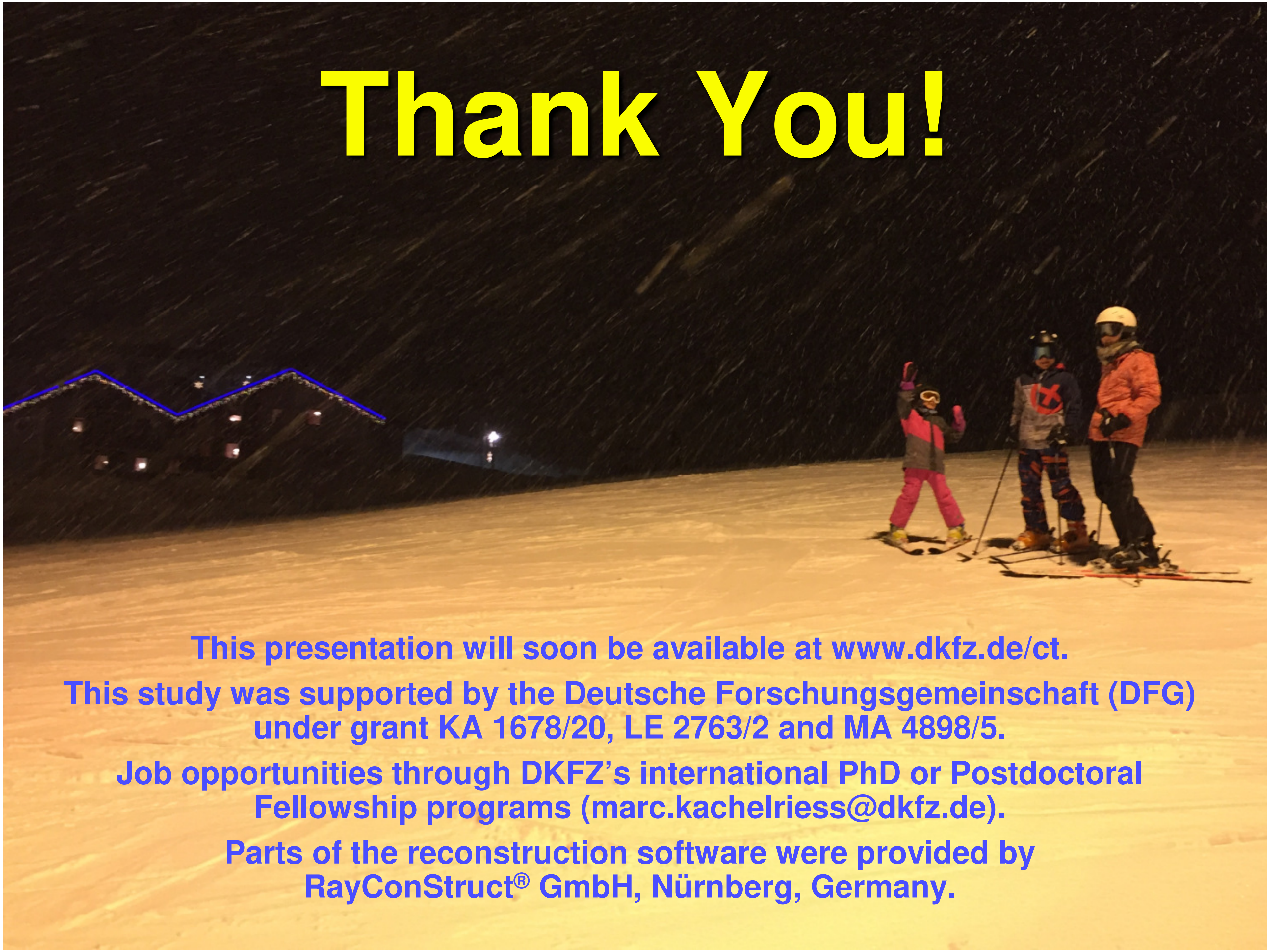
Results



C = 0 HU / W = 1000 HU

Conclusions

- Automatic patient-specific calibration potentially provides a high iodine quantification accuracy
  - Results comparable to those obtained by a user who calibrated, selected and applied the applications to various organs
- Simultaneous evaluation and combination of varying DE applications
  - Potentially, no further user-interaction is needed
- Important step towards the presentation of evermore increasingly complex information in spectral CT
- However, the automatic segmentation is still an issue.



Thank You!

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

This study was supported by the Deutsche Forschungsgemeinschaft (DFG) under grant KA 1678/20, LE 2763/2 and MA 4898/5.

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.