Motion Vector Field Estimation and Motion–Compensated Reconstruction for Flat Detector Cone–Beam CT Scans of Breathing Patients

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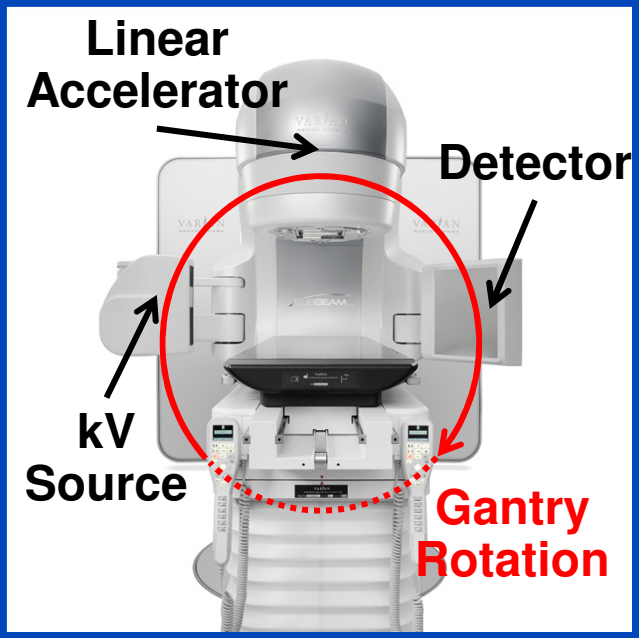
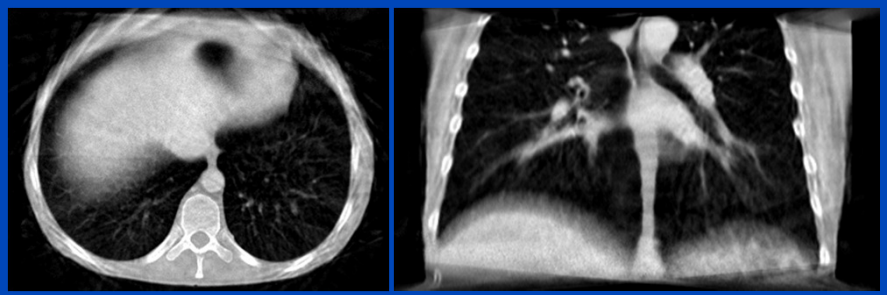
FAU VARIAN medical systems dkfz.

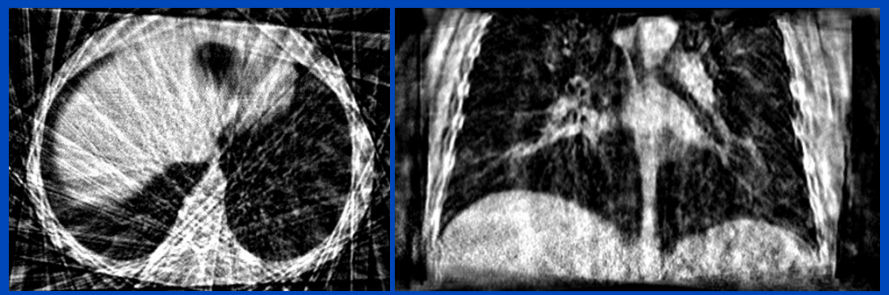
4D Cone–Beam CT (4DCBCT) on Slowly Rotating CBCT Devices



- CBCT imaging unit (kV source and flat panel detector) mounted on the gantry of a linear particle accelerator (LINAC) treatment system
- Comes with a maximum gantry rotation speed of 6° per second
- Much slower than clinical CT devices (60 s/360° versus 0.3 s/360°)
- Cycle of respiratory motion usually in the magnitude of 2 – 5 seconds, i.e. 10 – 30 respirations per scan
- Artifacts in 3DCBCT and conventional 4DCBCT



3DCBCT ⇒ Motion artifacts



Conventional 4DCBCT ⇒ Angular sampling artifacts

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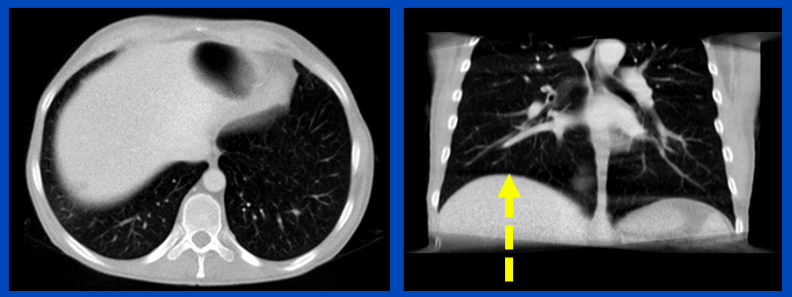
Aim

Provide high quality respiratory–correlated 4D volumes from on–board CBCT scans without using dedicated acquisition techniques or knowledge from prior planning scans.

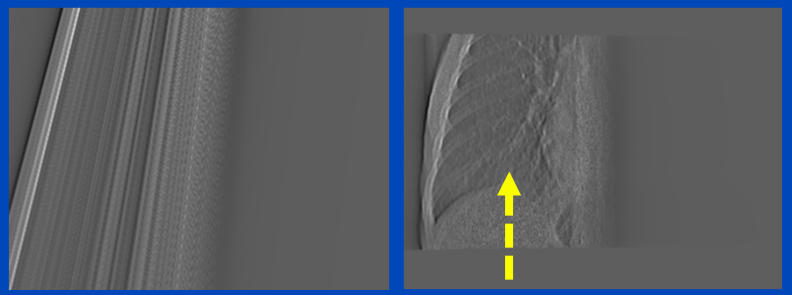
Motion Compensation (MoCo)

- **Combine benefits**
  - High temporal resolution of conventional 4DCBCT
  - Low noise level from 3DCBCT
- **Use ALL projection data**
  - For each single 3D volume of a 4D data set
  - Compensate for motion using motion vector fields (MVF)
  - MVF are estimated based on conventional 4DCBCT images
- **Backproject then warp [1]**
  - Backprojection of projection data along straight lines
  - Then warp with respect to MVF

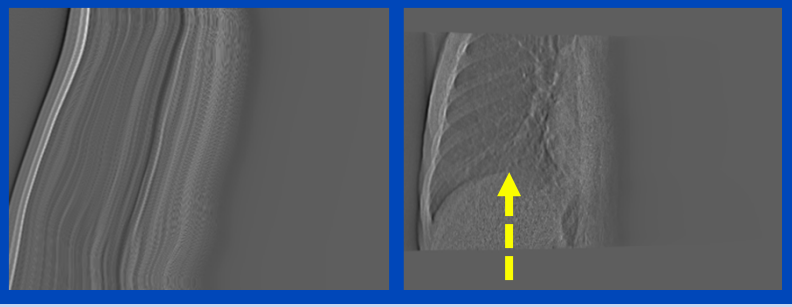
Ground truth in phase 1



Backprojection on (straight) acquisition lines of one projection acquired in phase 2



Backprojection wraped to phase 1



[1] Li et al., "*Motion correction for improved target localization with on–board cone–beam computed tomography*," Phys. Med. Biol., vol. 51, no. 2, pp. 253–267, Feb. 2006.

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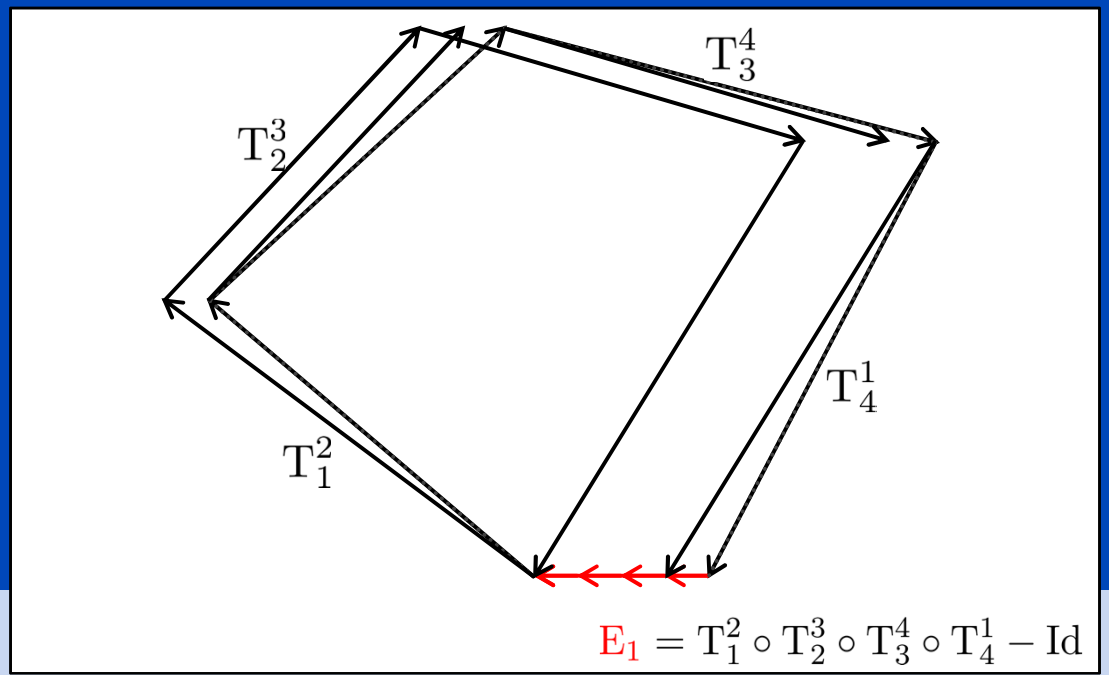
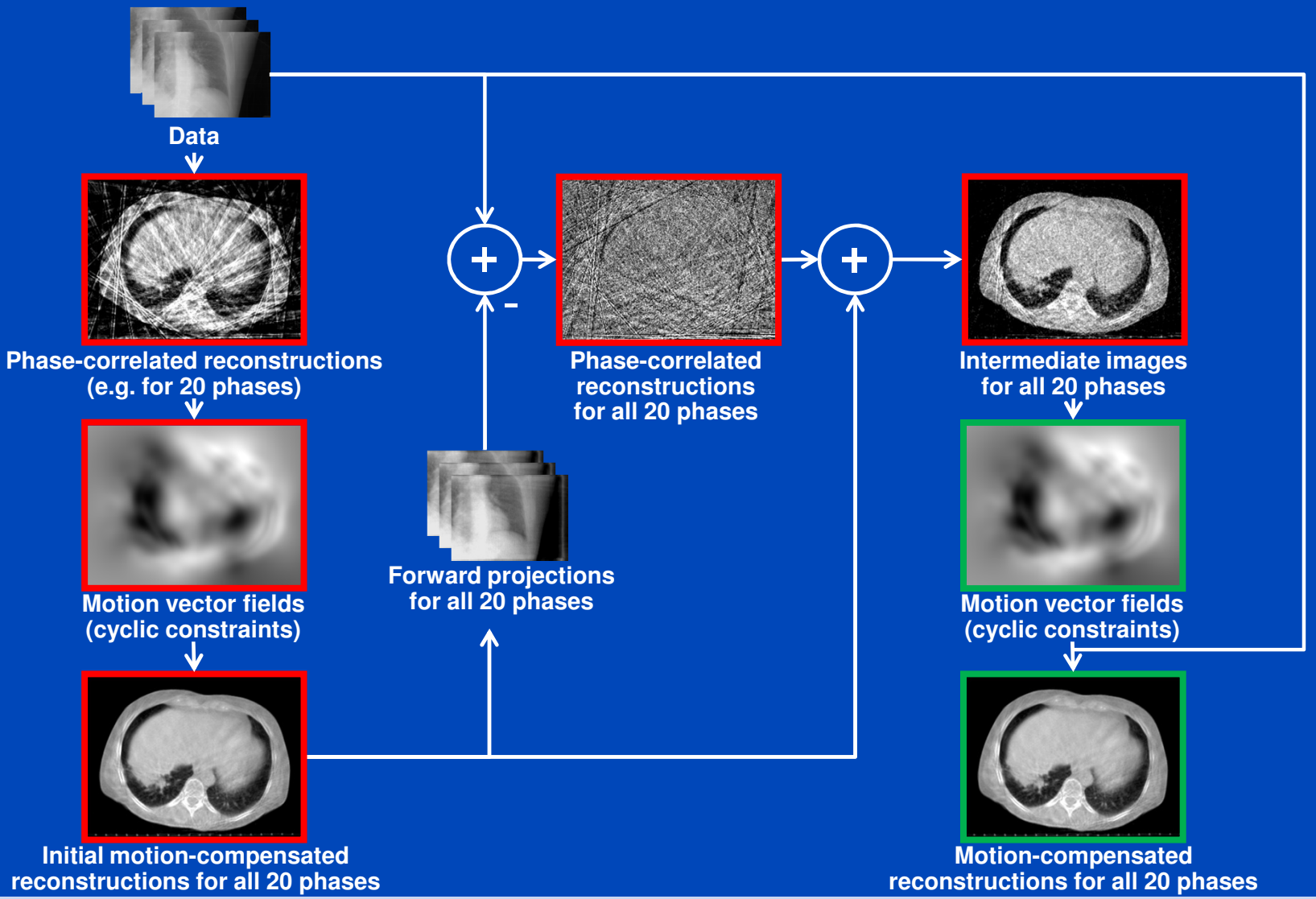
A Cyclic Registration with Temporal Constraints

- Initial guess of MVF T_j^{j+1} between adjacent phases[1]
  - Using a spatial registration algorithm
- Add temporal constraint
  - Cyclic form of breathing motion patterns ⇒ Error estimate E
  - Minimization by applying the error estimate on the estimated vector fields



Iterative Motion Estimation



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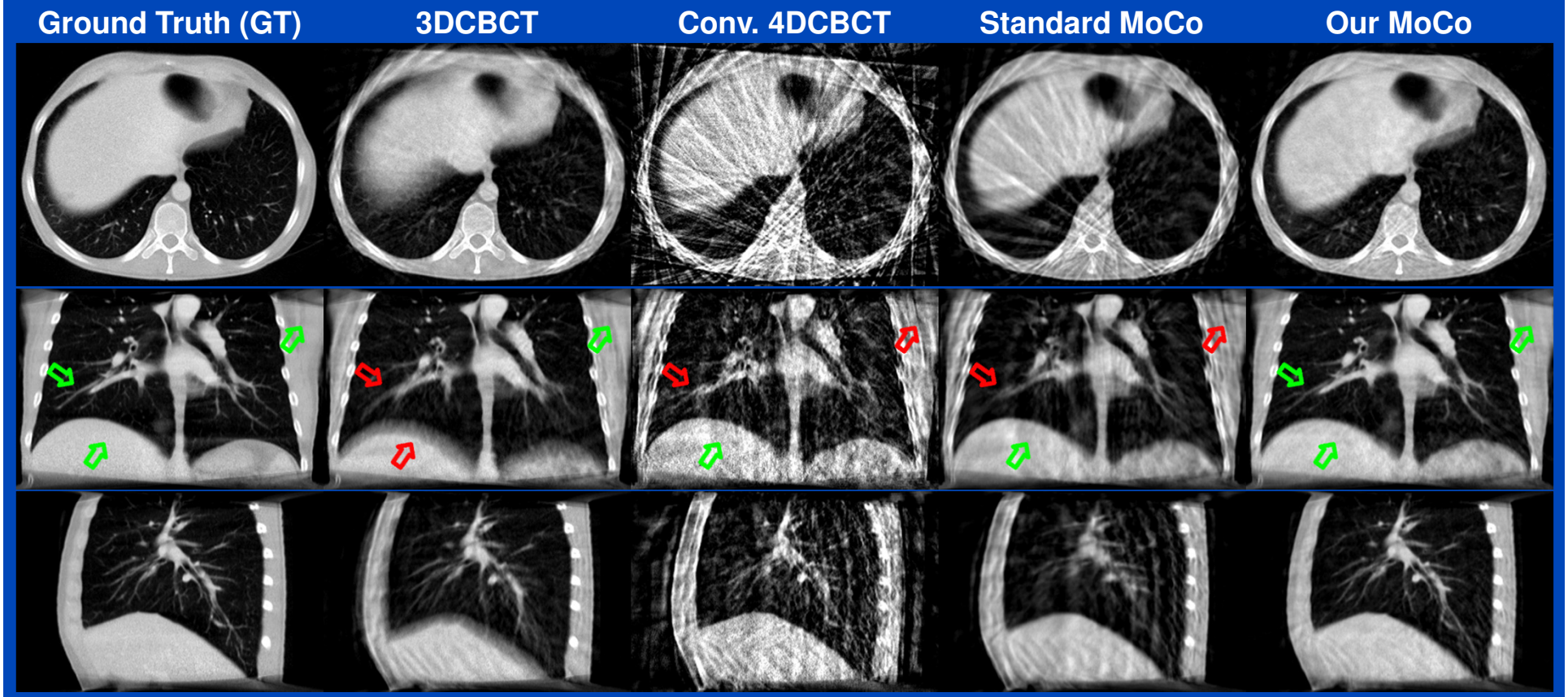
Results for Simulated Data



- Clinical CT data of a patient thorax deformed with respect to realistic vector fields to simulate breathing

C = –200 HU, W = 1400 HU

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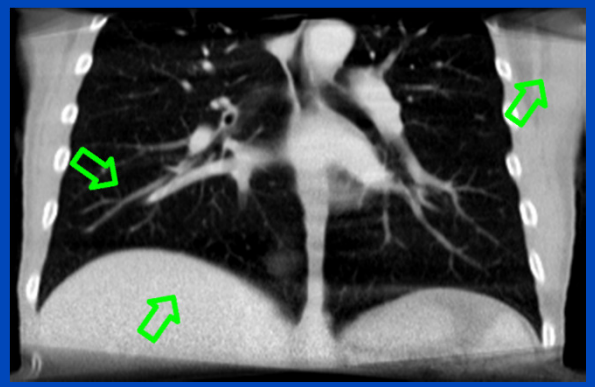
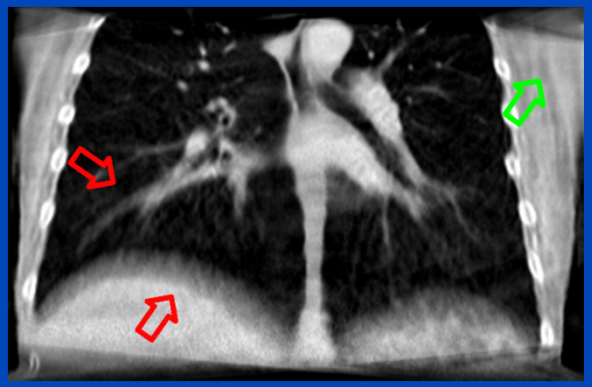
Results for Simulated Data

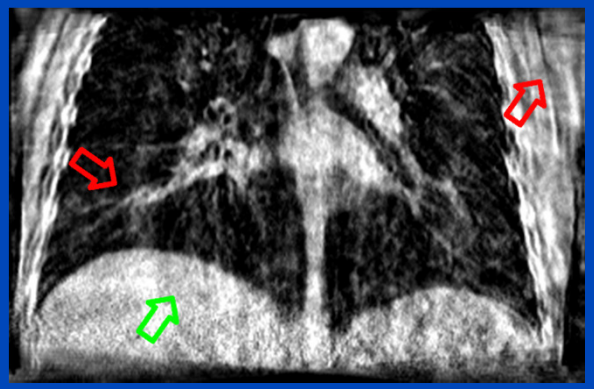
Ground Truth (GT)



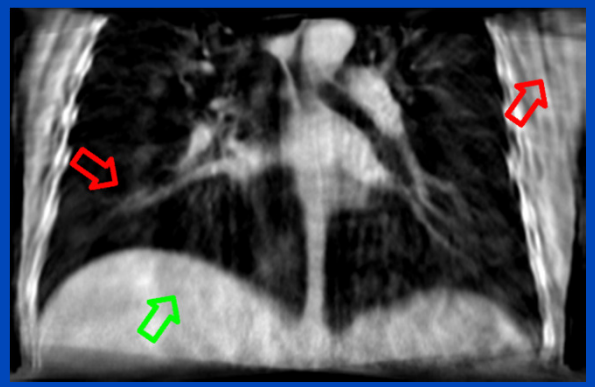
3DCBCT



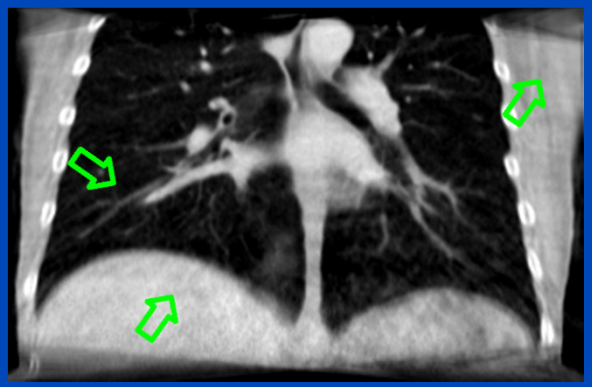
Conventional 4DCBCT



Standard MoCo



Our MoCo



Our MoCo:
Motion–compensated image reconstruction applying MVFs from our iterative motion estimation based on a cyclic registration with temporal constraints

- **High temporal and high spatial resolution**
- **Low noise level and visibility of lung details**

C = –200 HU, W = 1400 HU

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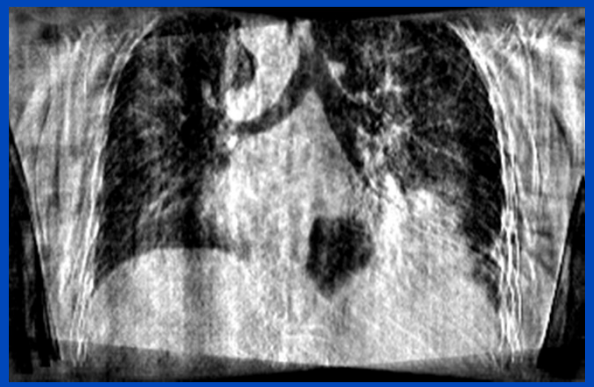
Results for Patient Data

Ground Truth (GT)

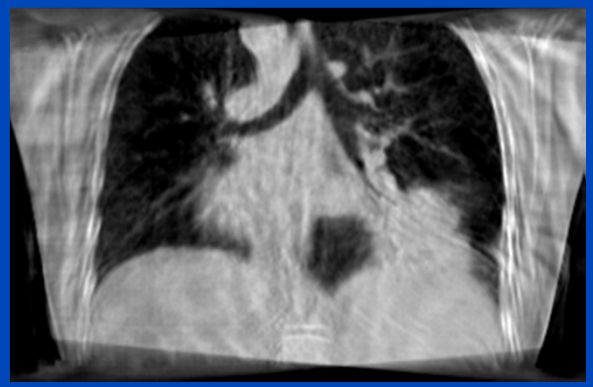
Not Available

3DCBCT

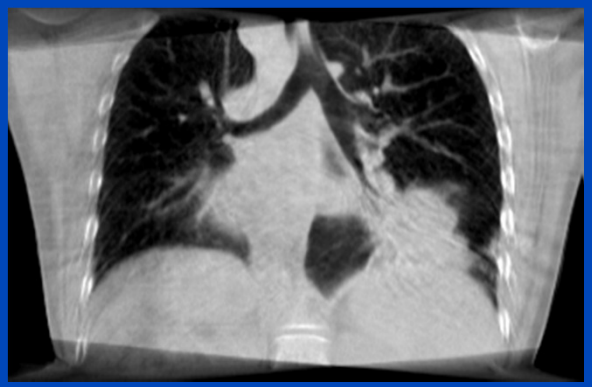
Conventional 4DCBCT



Standard MoCo



Our MoCo



Our MoCo:
Motion–compensated image reconstruction applying MVFs from our iterative motion estimation based on a cyclic registration with temporal constraints

- **Similar impressions as with the simulated data**

C = –200 HU, W = 1400 HU

Acquired with an On–Board Imager®
Varian Medical Systems, Palo Alto, CA

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Summary

- Iterative motion estimation using a cyclic registration with temporal constraints
  - Allows for estimation of motion vector fields from conventional 4DCBCT images
  - Decreased sensitivity to angular sampling artifacts
  - No dedicated acquisition technique required
  - No knowledge required from prior scans like planning CTs
- Motion–compensated image reconstruction applying these motion vector fields
  - Combine benefits of 3DCBCT and 4DCBCT
    - » High spatial and high temporal resolution
    - » Low image noise
  - Visibility of lung details

Thank You!

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