

# 4D Anatomical Constrained Motion-Compensated Reconstruction of On-Board 4D CBCT Scans

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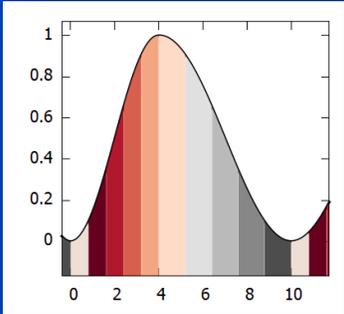
Abstract ID: CT2020-029

# Problem Statement

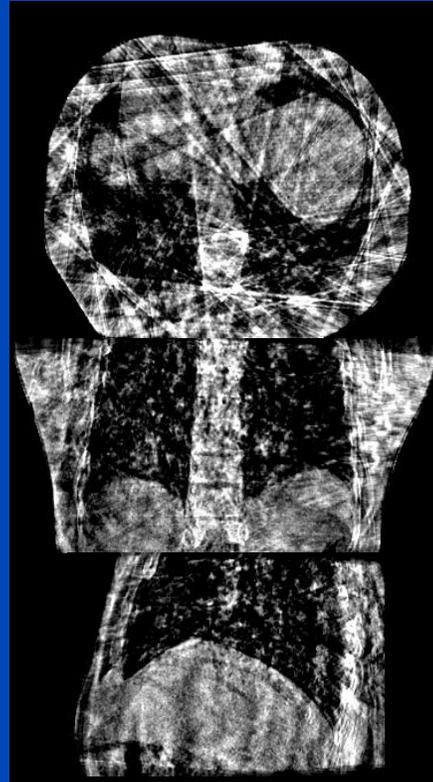
one minute CBCT  
 $\approx 20$  breathings  
 $\Rightarrow 20$  scan angles



4D FDK



sparseness  
artifacts



acMoCo<sup>1,2</sup>

remaining  
DIR artifacts



sliding interface motion

spine motion

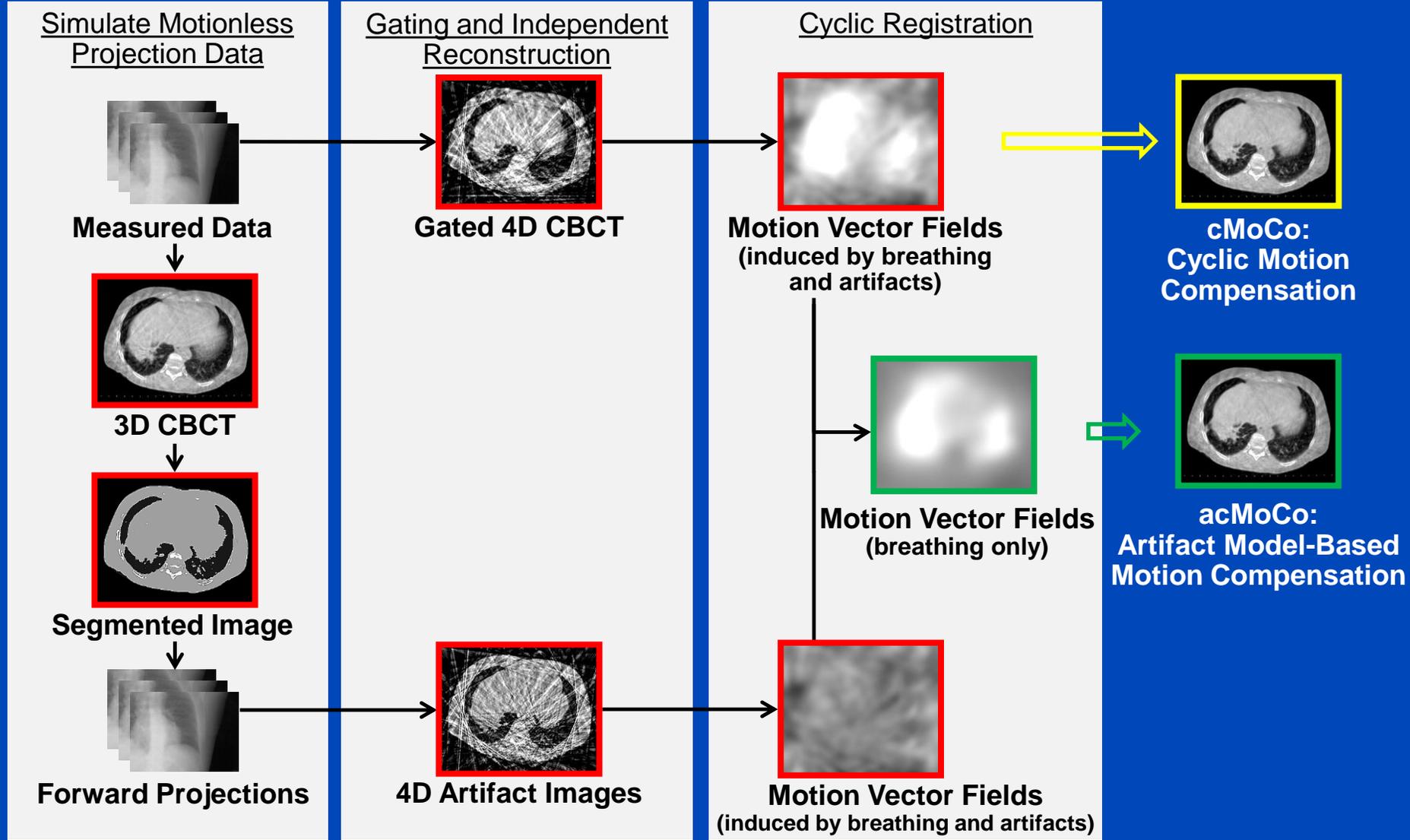
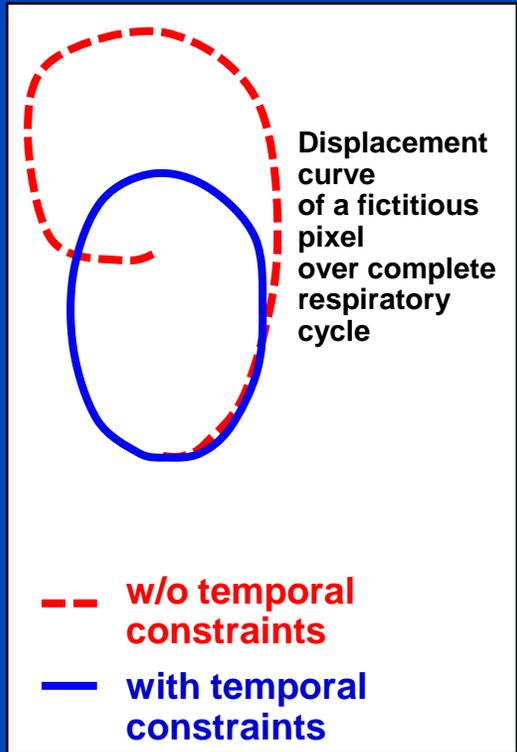
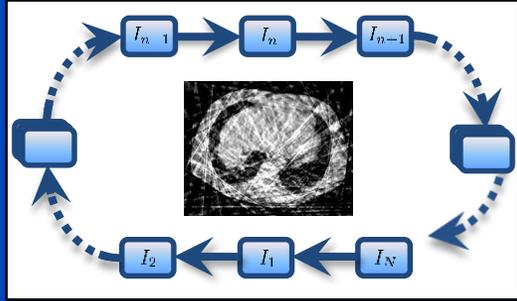
back motion

**Problems solvable with anatomical 4D regularisation  $\Rightarrow$  acacMoCo**

<sup>1</sup> Brehm, Kachelrieß et al., "Self-adapting cyclic registration for motion-compensated cone-beam CT in image-guided radiation therapy," Med. Phys. 39(12) 7603, 2012.

<sup>2</sup> Brehm, Kachelrieß et al., "Artifact-resistant motion estimation with a patient-specific artifact model for motion-compensated cone-beam CT," Med. Phys. 40(10) 101913, 2013.

# cMoCo<sup>1</sup> and acMoCo<sup>2</sup>



<sup>1</sup> Brehm, Kachelrieß et al., "Self-adapting cyclic registration for motion-compensated cone-beam CT in image-guided radiation therapy," Med. Phys. 39(12) 7603, 2012.

<sup>2</sup> Brehm, Kachelrieß et al., "Artifact-resistant motion estimation with a patient-specific artifact model for motion-compensated cone-beam CT," Med. Phys. 40(10) 101913, 2013.

# Materials and Methods

## Reconstruction:

- 512×512×210 mm<sup>3</sup>
- 8×1 min scans and 2×2 min scans
- 20 phase-gated 4D FDK images, width = 10%, increment = 5%
- Methods: 4D FDK, acMoCo, acacMoCo

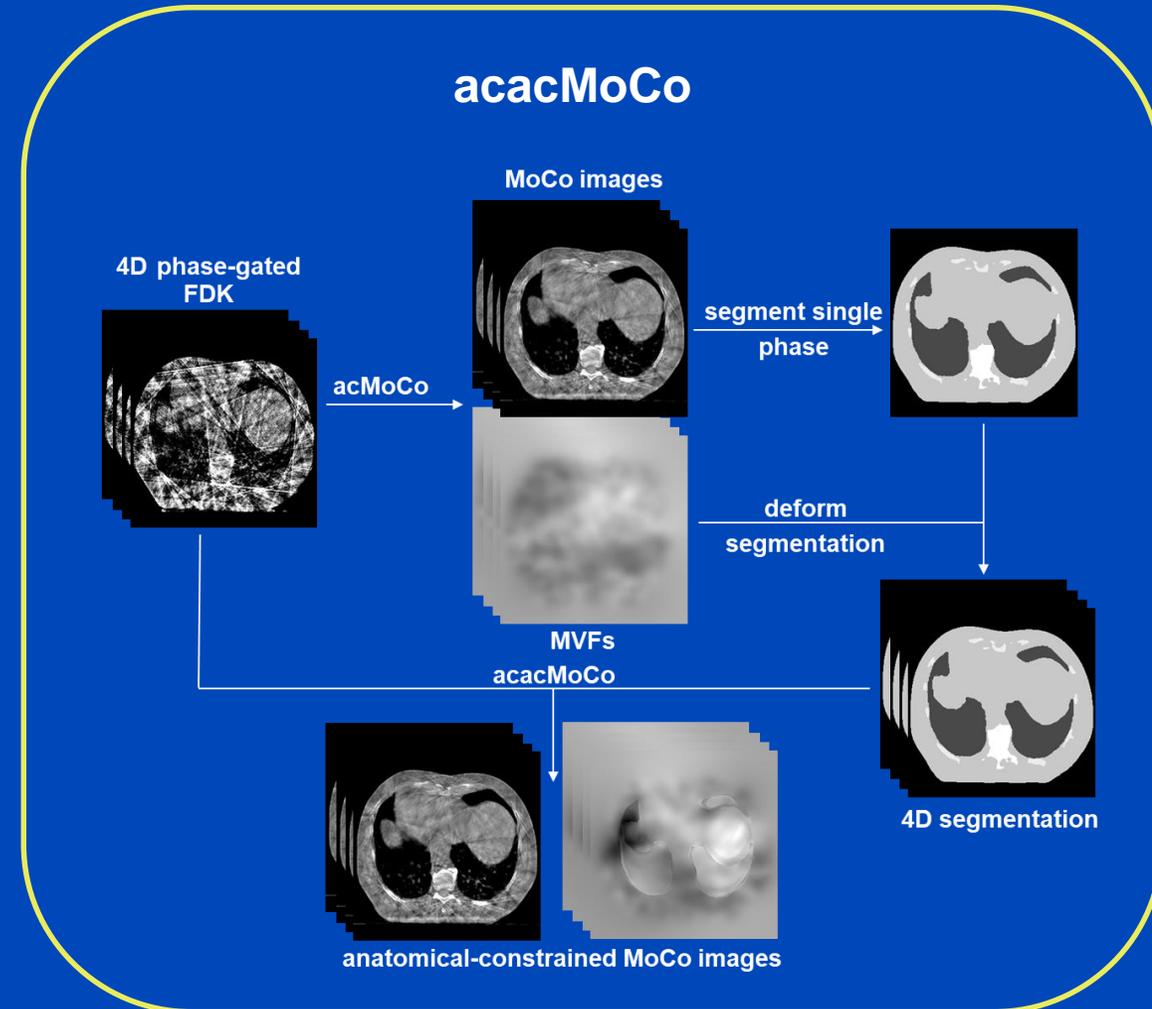
## Motion Estimation:

- Demons Algorithm
- Cyclic constraints<sup>1</sup>
- Artifact model<sup>2</sup>
- Anatomical constraints
  - Sliding Organ Motion<sup>3</sup>
  - Couch handling
  - Stationarity rules
  - Patient outline registration
- Multi-resolutions

<sup>1</sup> Brehm, Kachelrieß et al., “Self-adapting cyclic registration for motion-compensated cone-beam CT in image-guided radiation therapy,” Med. Phys. 39(12) 7603, 2012.

<sup>2</sup> Brehm, Kachelrieß et al., “Artifact-resistant motion estimation with a patient-specific artifact model for motion-compensated cone-beam CT,” Med. Phys. 40(10) 101913, 2013.

<sup>3</sup> Sauppe, Kachelrieß et al., “Sliding organ motion regularisation for motion-compensated cone-beam CT (CBCT) in image-guided radiation therapy (IGRT),” ECR 2018, B-1432.

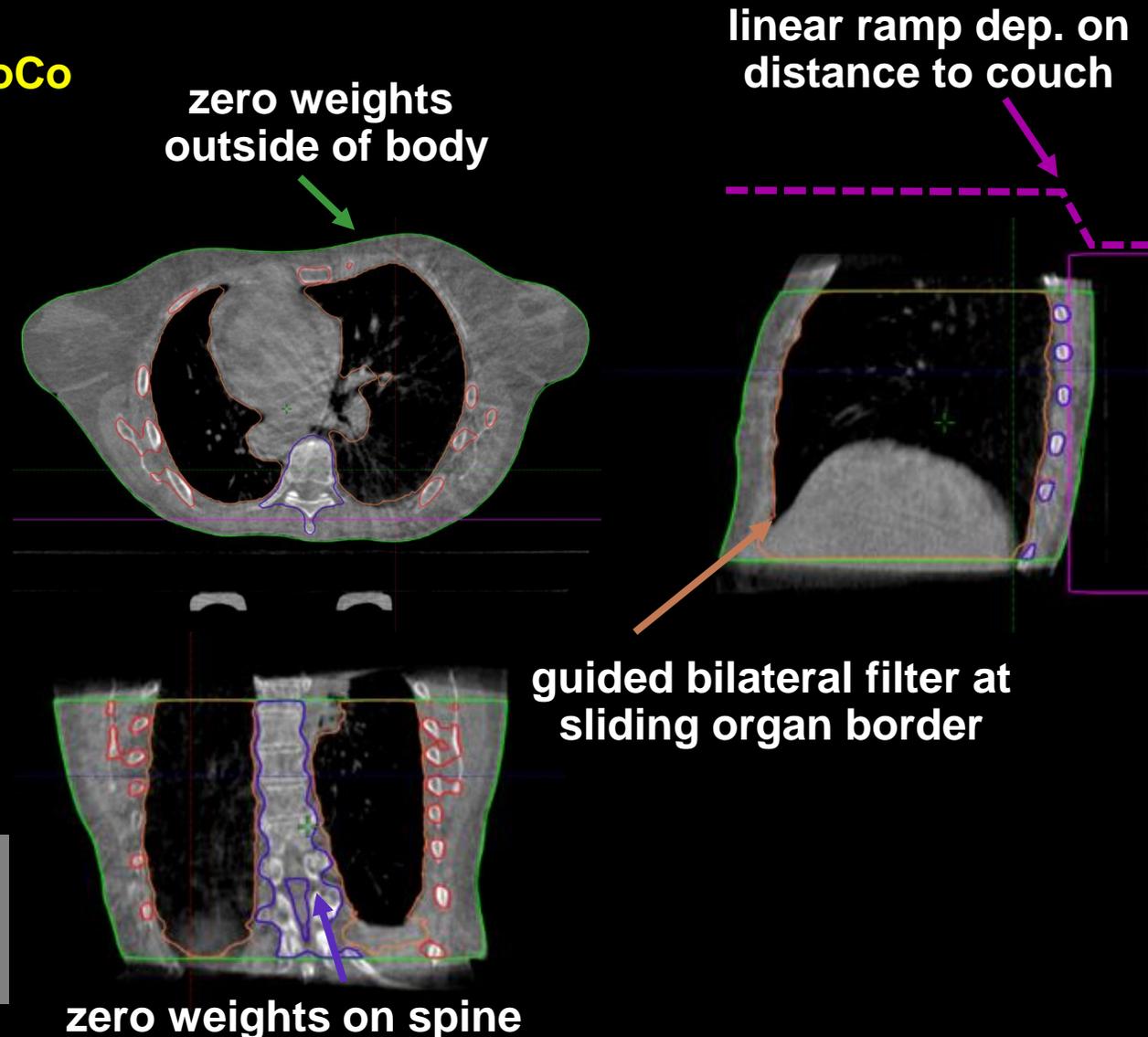
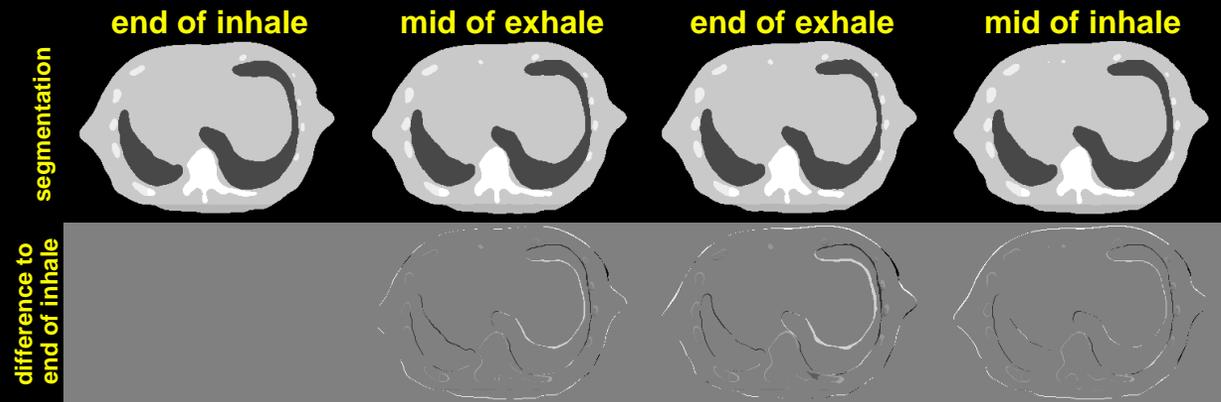


# Anatomical Constrained Motion Estimation

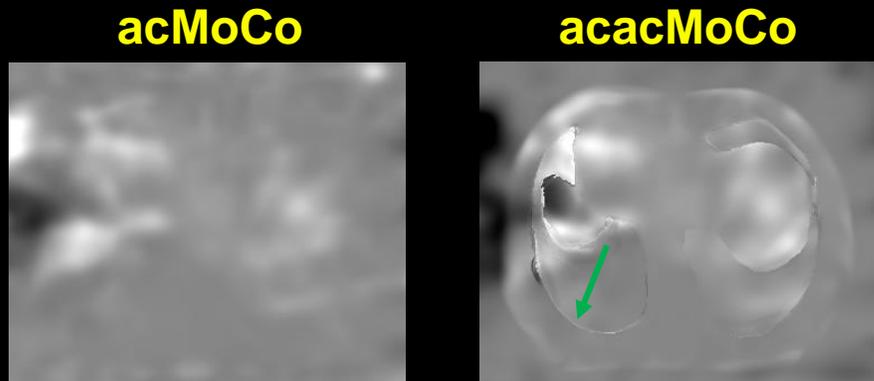
acMoCo | **anatomical-constrained acMoCo = acacMoCo**

Demons driven motion vector field  $u$  estimation:

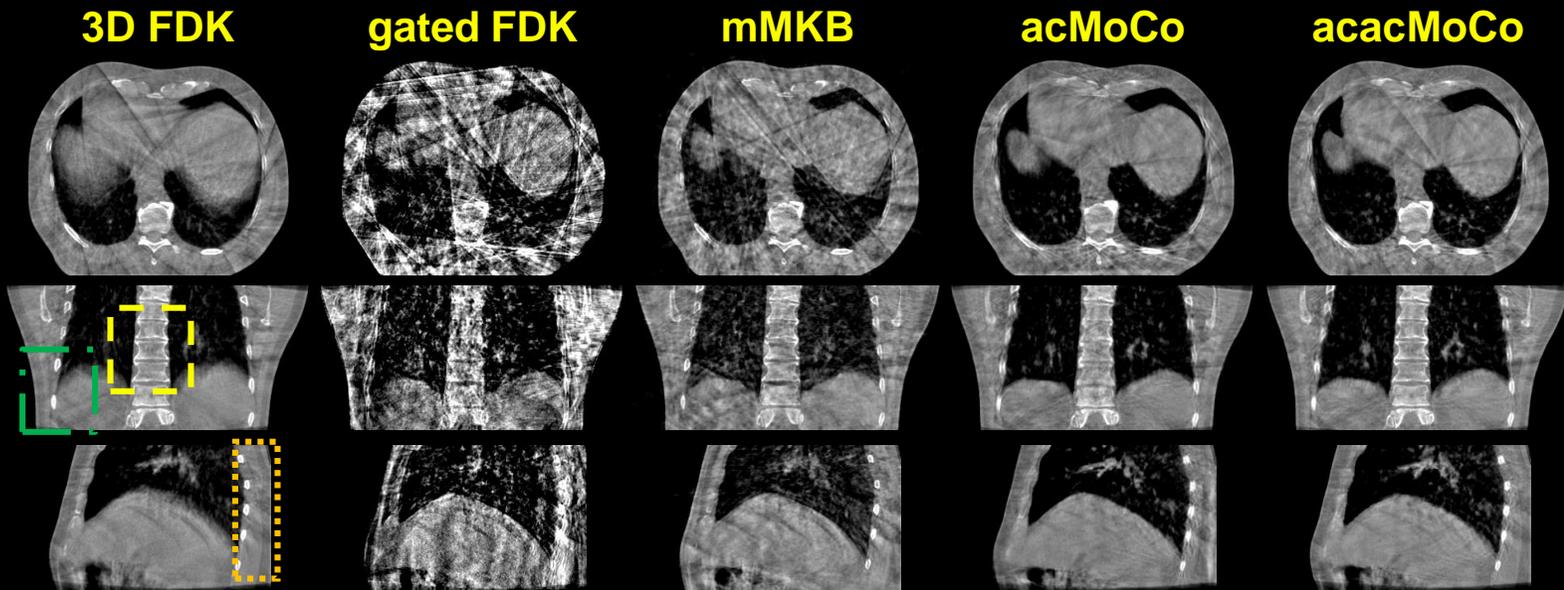
- Calculate update field  $\Delta u$ .
- Smooth  $\Delta u$  with Gaussian (FWHM = 17.7 mm).
- **Smooth  $\Delta u$  with guided bilateral filter on sliding interface borders (FWHM = 17.7 mm) to prevent perpendicular cross interface motion transfer.**
- **Apply 4D weights:  $\Delta u_{4D} = W_{4D} \cdot \Delta u$ .**
- Diffeomorphic composition  $u \rightarrow u \circ \Delta u$ .
- Smooth  $u$  with Gaussian (FWHM = 4.4 mm)



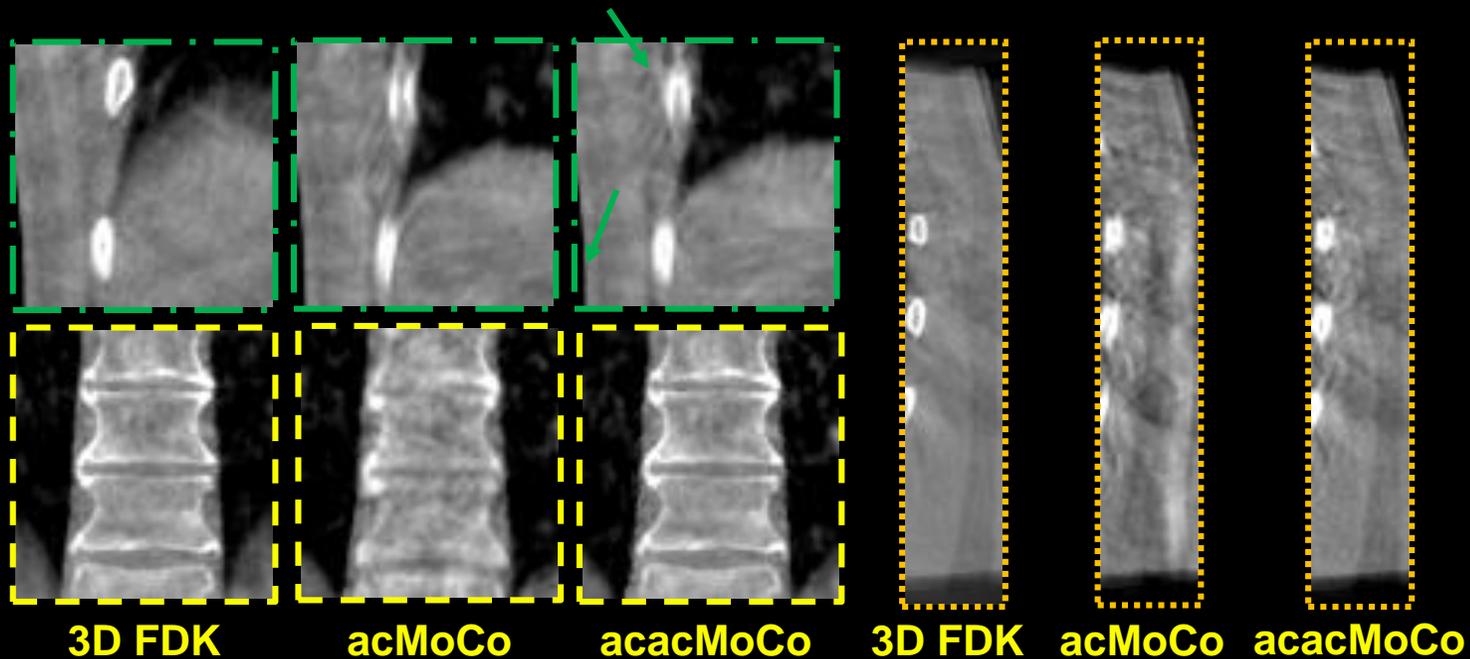
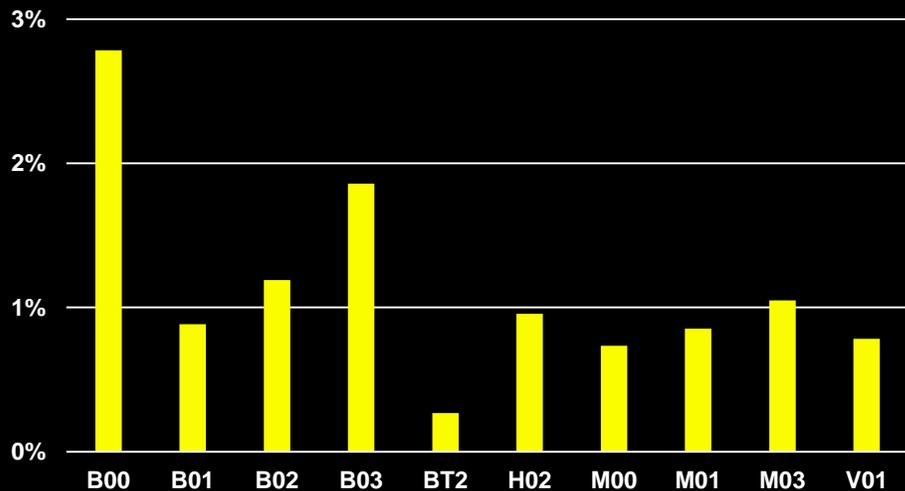
## Motion Vector Field Differences:



$C = 0 \text{ mm}, W = 3 \text{ mm}$



## Relative Sharpness<sup>1</sup> (End of Inhale) between acMoCo and acacMoCo:



# Conclusions

- **Anatomical boundary conditions are an useful addition for physiologically better registration results in MoCo 4D CBCT reconstruction.**
- **The sharpness and stationarity of the spine can be enforced.**
- **The motion at the lung boundary can be decoupled.**
- **Artifacts related to the couch are reduced.**