

Motion Compensation (MoCo) for Simultaneous PET/MR Based on Strongly Undersampled Radial MR Data – A Simulation Study

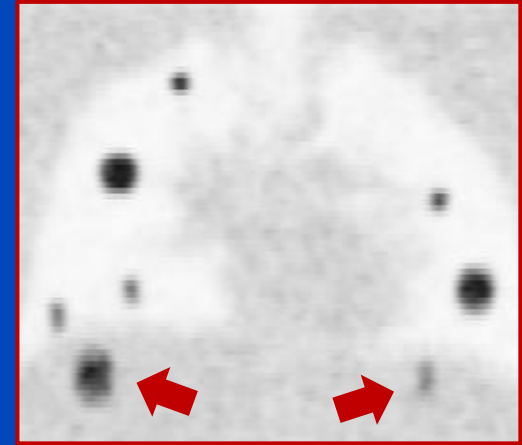
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Introduction

- One major obstacle in PET image reconstruction is patient motion (respiratory, cardiac, involuntary motion)
- Motion causes image blurring and an underestimation of the reconstructed activity
- Gating
 - divide (cyclic) motion into certain gates and reconstruct images from the data of each individual gate separately
 - trade-off between temporal resolution and an appropriate SNR and CNR of the reconstructed images
- **Recent approaches: Motion Compensation (MoCo)^{1,2}**
 - use MR information to estimate 4D motion vector fields (MVFs)
 - 4D MoCo PET reconstruction from complete rawdata

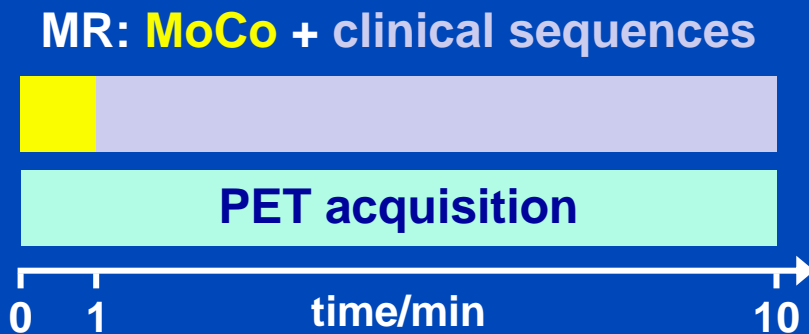


[1] Würslin et al. Respiratory motion correction in oncologic PET using T1-weighted MR imaging on a simultaneous whole-body PET/MR system. *J. Nucl. Med.* 2013.

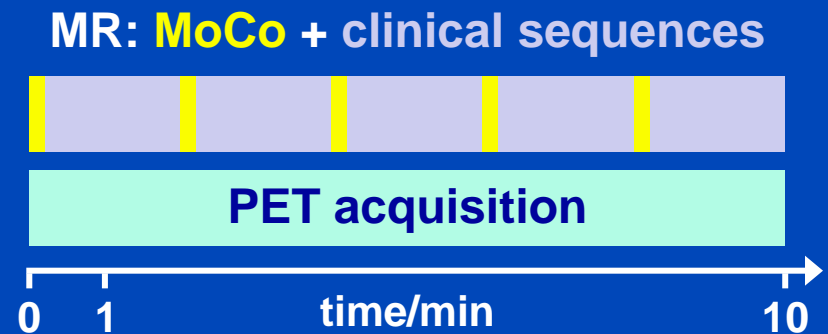
[2] Grimm et al. Self-gated MRI motion modeling for respiratory motion compensation in integrated PET/MRI. *Med. Image Anal.* 2015.

Aim of Work

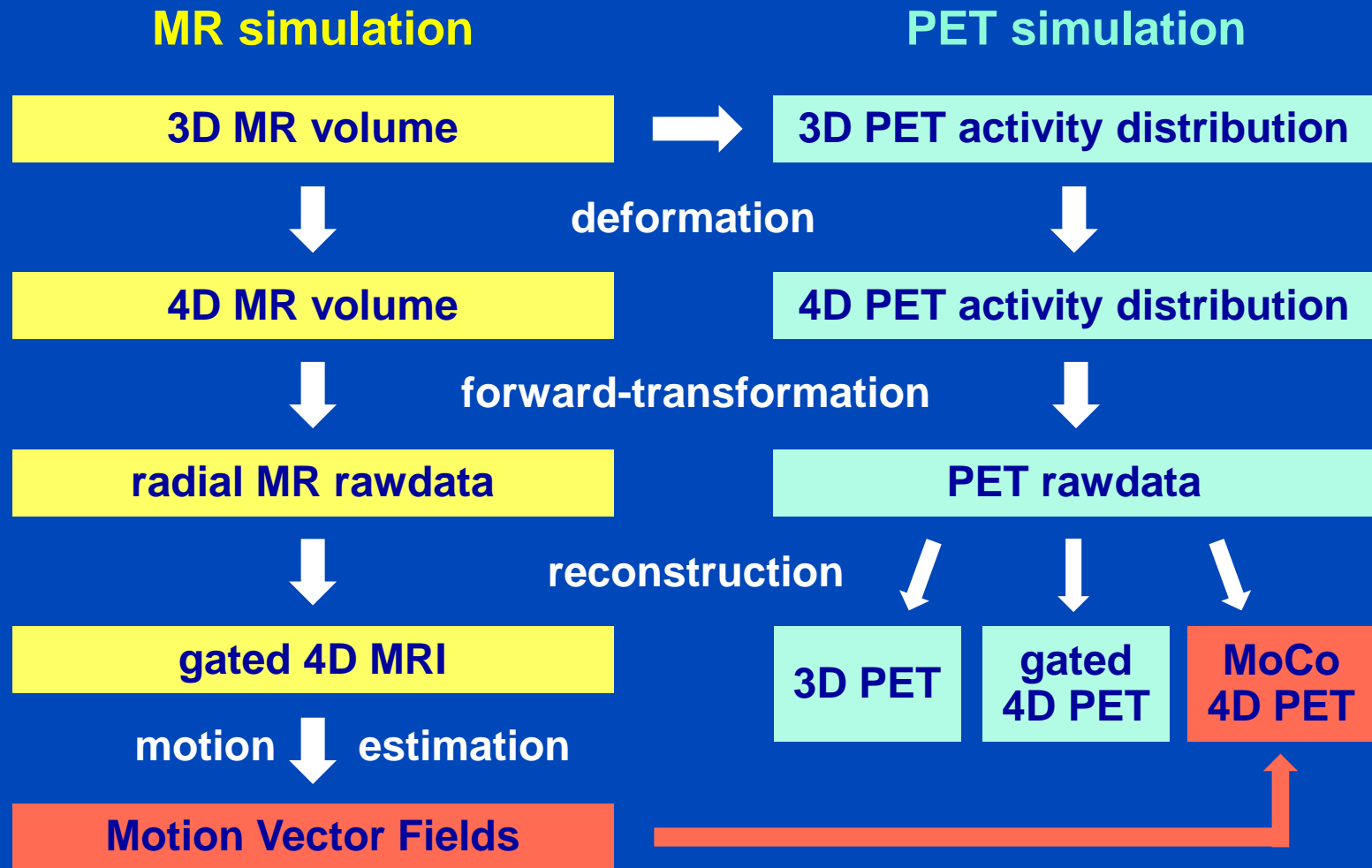
- Develop a framework for respiratory motion compensation of PET images
- Use information from a strongly undersampled radial MR sequence that
 - runs in parallel with the PET acquisition
 - requires less than 1 min of the acquisition time per bed position
 - can be interlaced with clinical MR sequences



OR



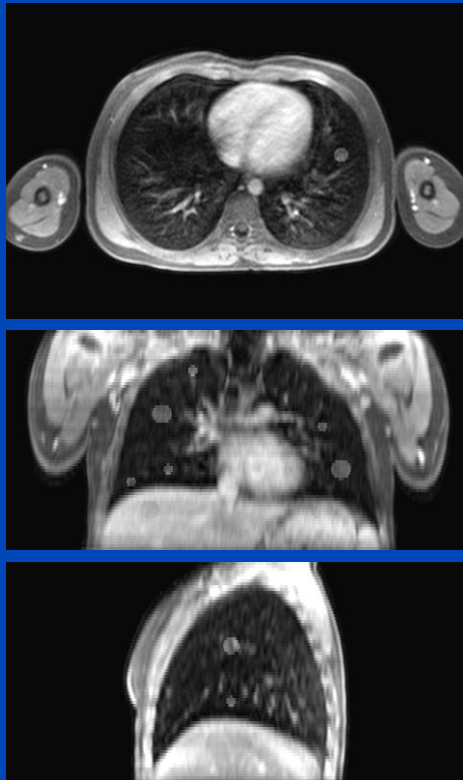
Overview of Simulation Study



MR

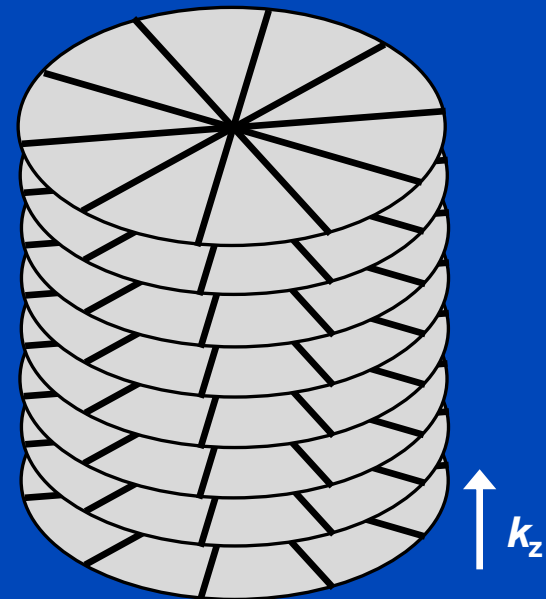
Simulation of Undersampled Data

4D MR volume



application of
artificially
generated DVFs

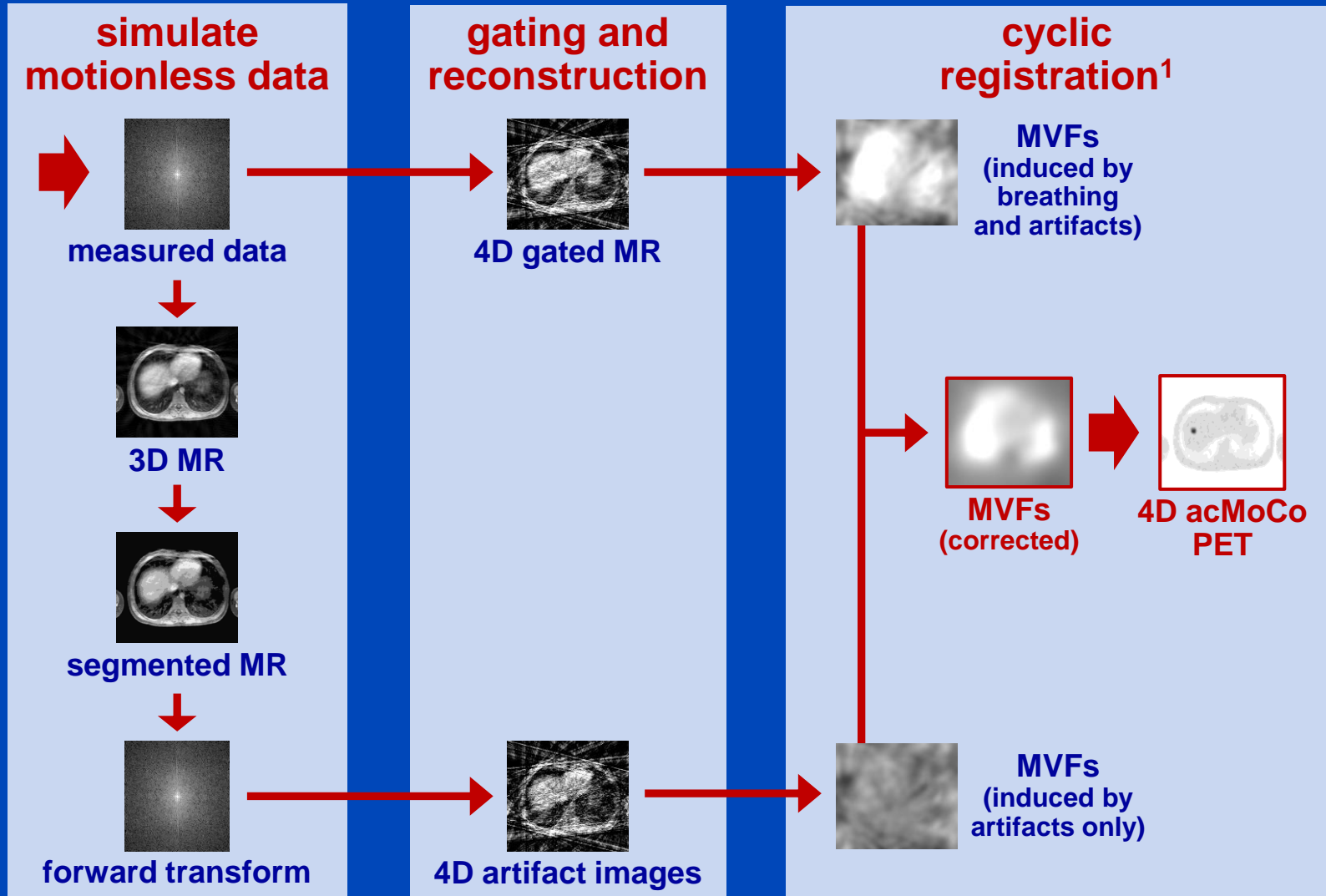
3D encoded radial
stack-of-stars sequence



- 160 radial spokes per slice
- 38 s for 80 slices ($TR = 3$ ms)
- data sorted retrospectively into 20 overlapping motion phases (10% width)
- 4D gated gridding reconstruction

MR

Artifact Model-Based Estimation of MVFs²



[1] Brehm et al. Self-adapting cyclic registration for motion-compensated cone-beam CT in image-guided radiation therapy. *Med. Phys.* 2012.

[2] Brehm et al. Artifact-resistant motion estimation with a patient-specific artifact model for motion-compensated cone-beam CT. *Med. Phys.* 2013.

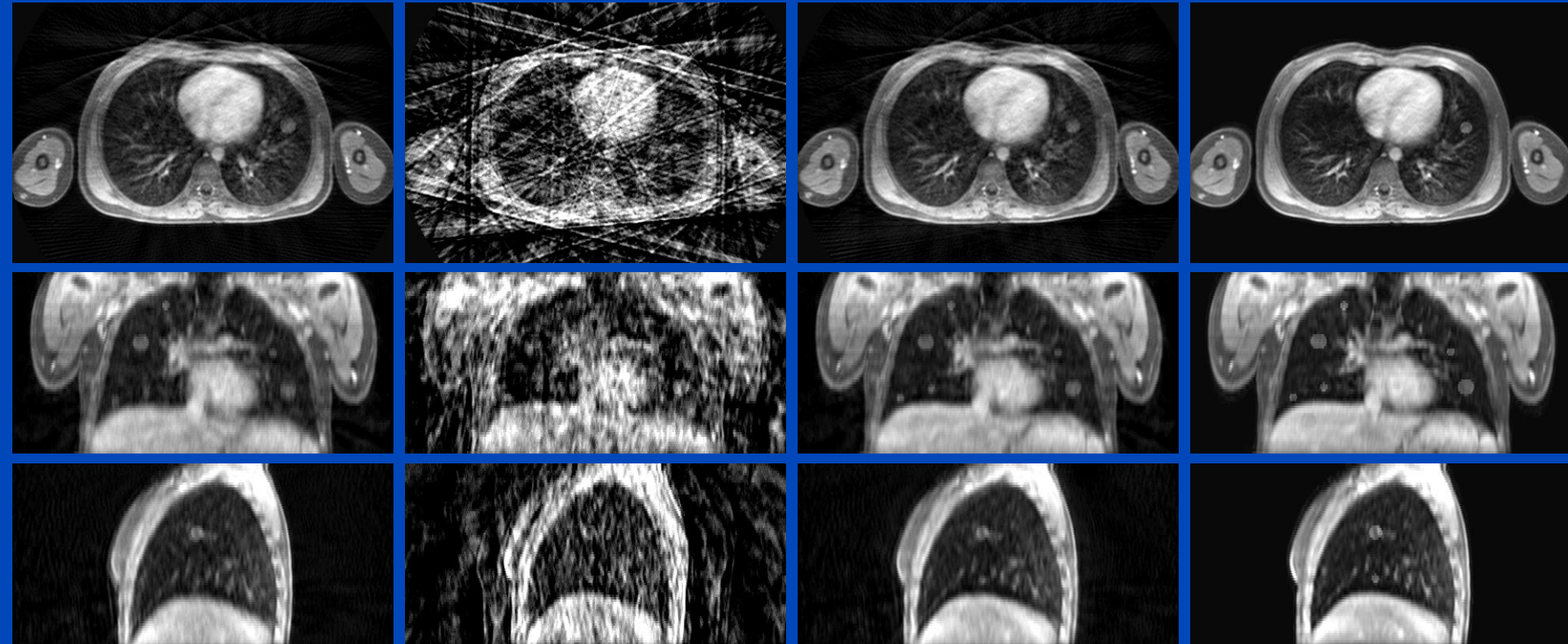
MR Results of Motion Compensation

3D

4D gated

4D acMoCo

4D ground truth



< 1 min/bed

< 1 min/bed
used for estimation
of MVFs

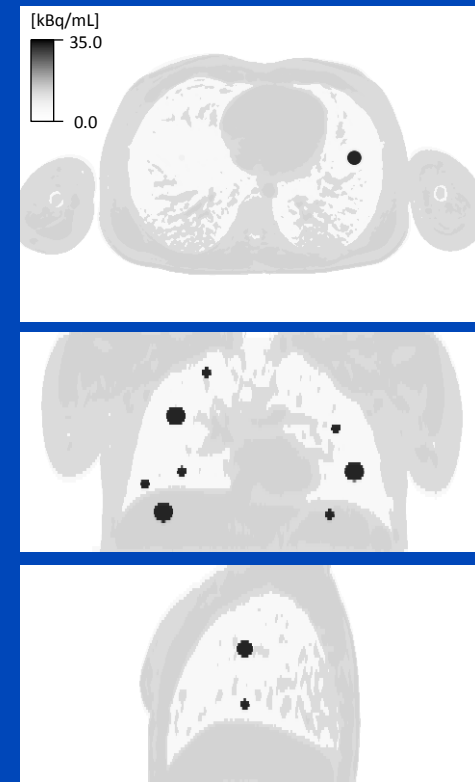
< 1 min/bed

PET

Simulation and Reconstruction

- **4D activity distribution**
 - soft tissue ($A = 5-6$ kBq/mL)
 - lungs ($A = 1$ kBq/mL)
 - 8 artificial hot lesions ($A = 30$ kBq/mL)
- **Rawdata simulation**
 - forward project activity distribution
 - add Poisson noise
 - geometry of Siemens Biograph mMR
- **Iterative reconstruction**
 - 3D OSEM using 2 iterations and 21 subsets
 - incorporation of MVFs into system matrix for 4D MoCo reconstruction

4D PET
activity distribution



PET

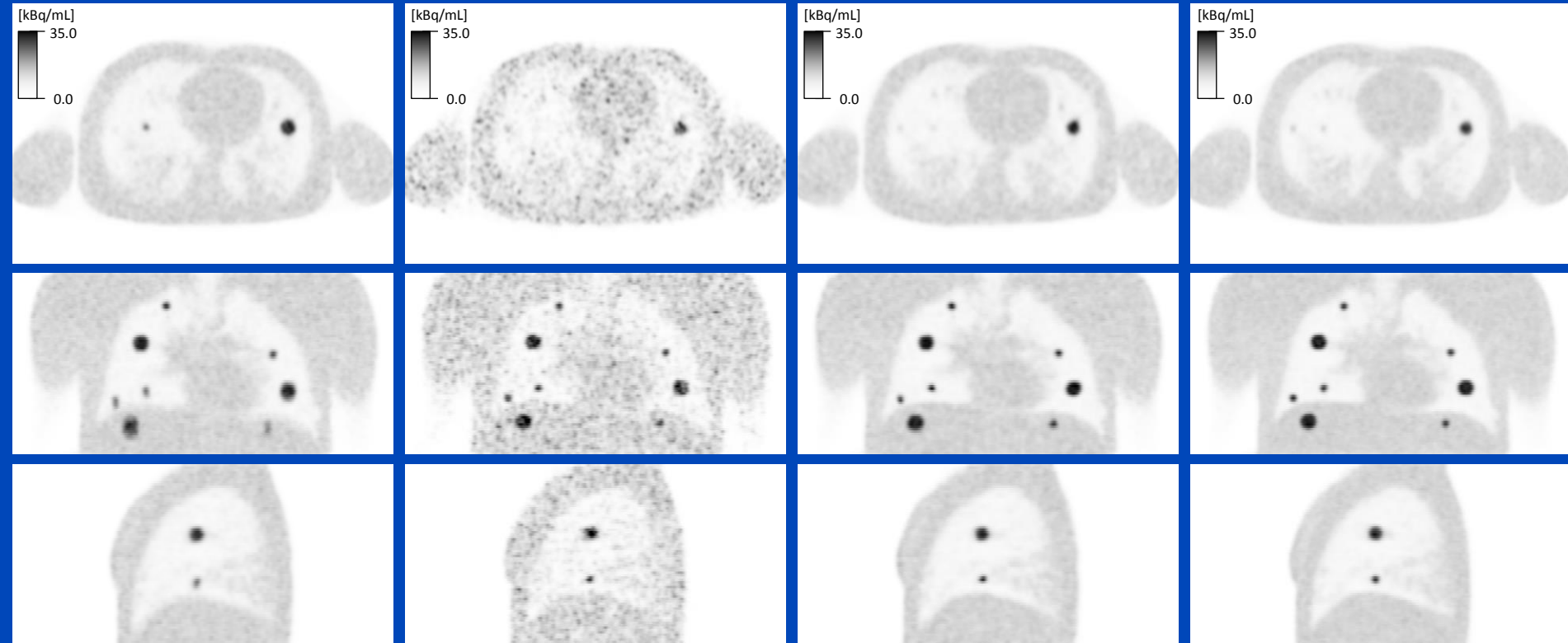
Results of Motion Compensation

3D

4D gated

4D acMoCo
MVFs from MR

4D ref gated
reference



10 min/bed

10 min/bed

10 min/bed

100 min/bed

same statistics as 3D due to
ten-fold measurement time

PET

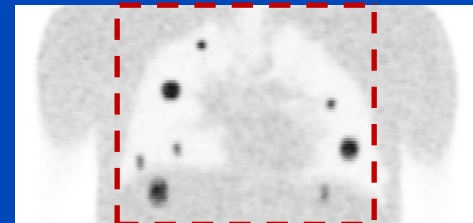
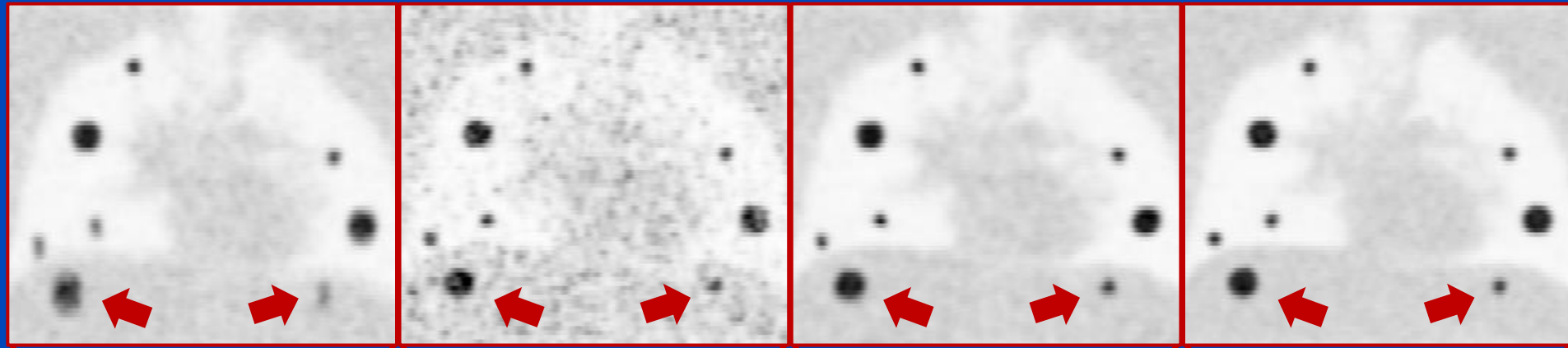
Results of Motion Compensation

3D

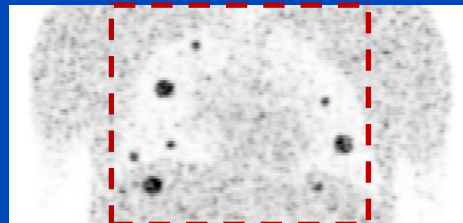
4D gated

4D acMoCo
MVFs from MR

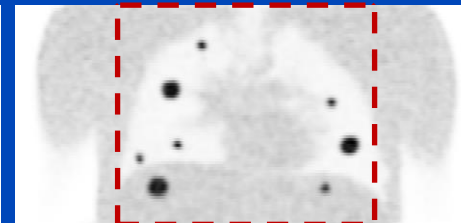
4D ref gated
reference



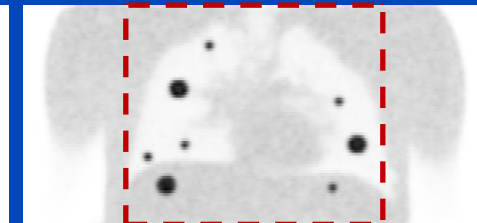
10 min/bed



10 min/bed



10 min/bed



100 min/bed

same statistics as 3D due to
ten-fold measurement time

Summary

- PET respiratory MoCo based on **strongly undersampled radial MR data acquired in less than 1 min**
- 3D encoded radial stack-of-stars MR sampling scheme
- **Artifact model-based registration** for estimation of MVFs
- 4D MoCo PET reconstruction
- Significant improvement of PET image quality in terms of temporal resolution or noise level

- **Outlook:** verification with measured patient data

Thank You!



The 4th International Conference on Image Formation in X-Ray Computed Tomography

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www.ct-meeting.org



Conference Chair

Marc Kachelrieß, German Cancer Research Center (DKFZ), Heidelberg, Germany

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

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