Moving Metal Artifact Reduction (MMAR)

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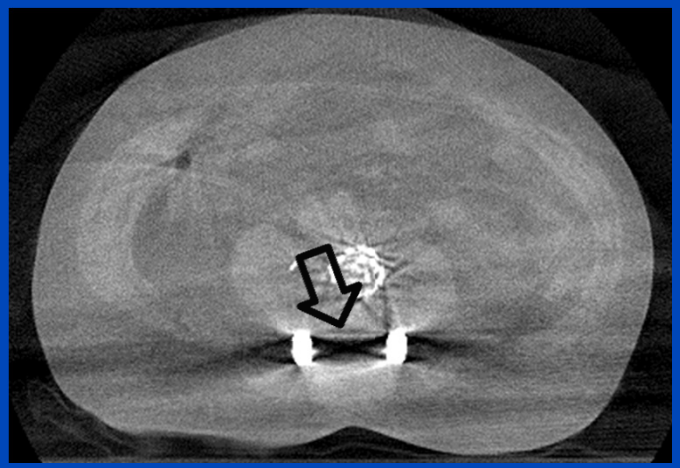
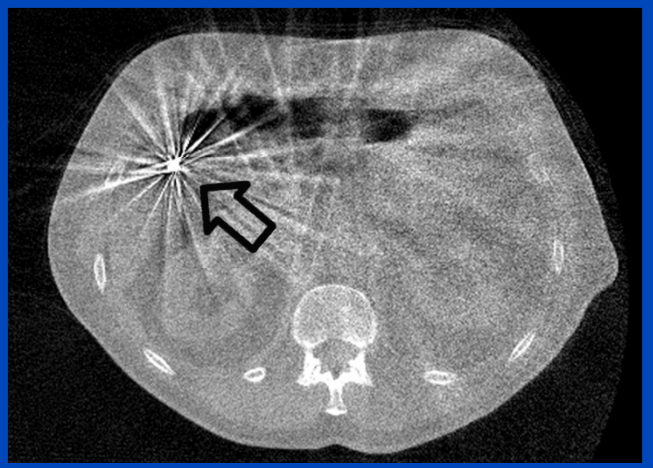
Metal Artifacts

- **Sharp contrast** (between metal object and surrounding tissue)
  - Nonlinear partial volume effect
  - Windmill artifacts
- **Beam hardening, scatter**
- **Motion (electrodes, stents, clips, …)**

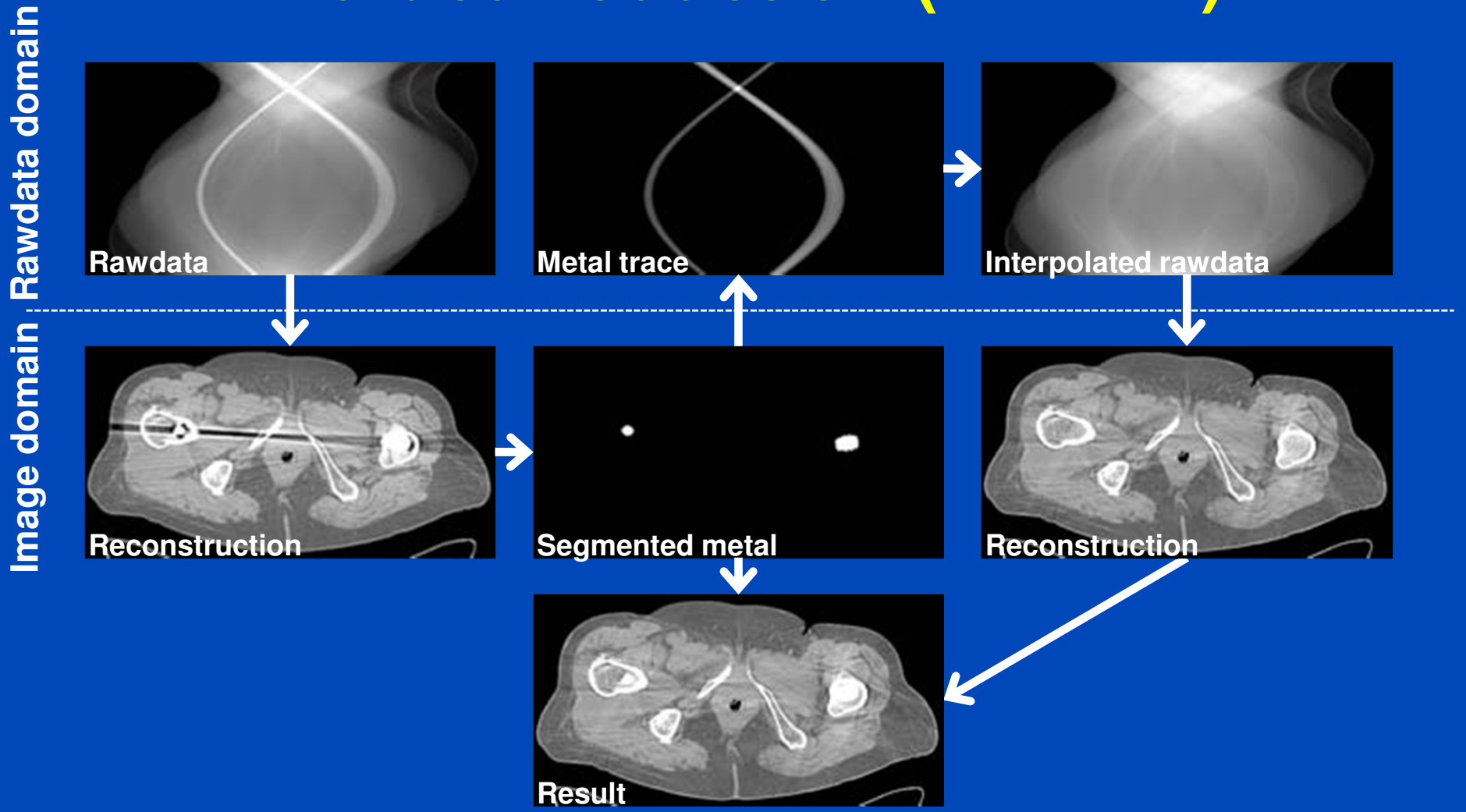


Metal artifact mainly due to beam hardening and scatter



Metal artifact mainly due to motion

Illustration of Conventional Metal Artifact Reduction (MAR-LI)



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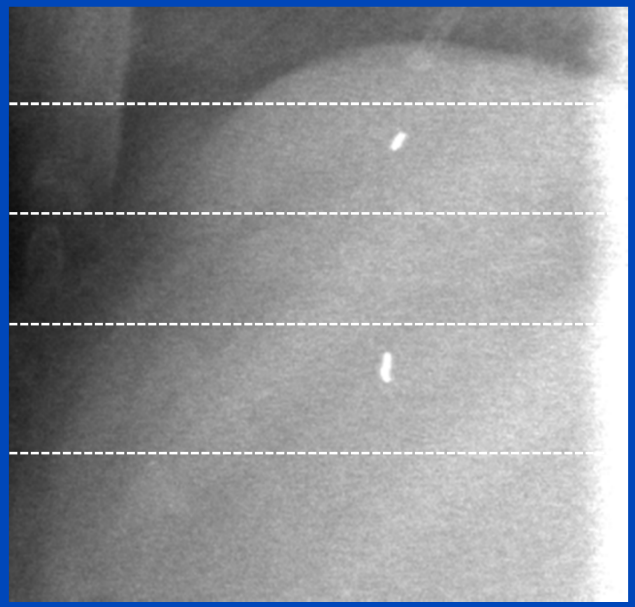
Metal Subject to Respiratory Motion

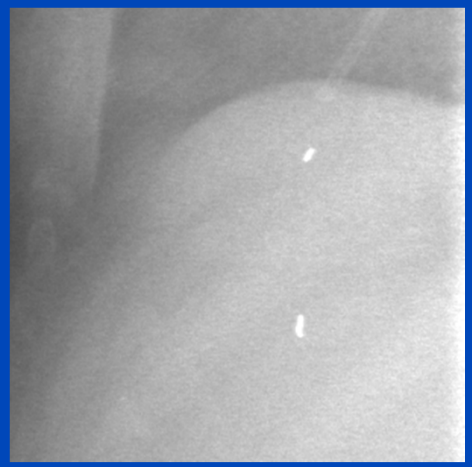
- Flat detector cone-beam CT scan
  - 6° per second maximum gantry rotation speed
    - » 60 seconds effective scan time
  - 20 complete breathing cycles within scan time



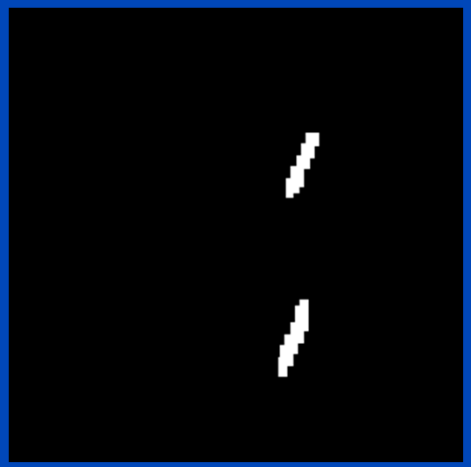
Rawdata

Metal Subject to Respiratory Motion and MAR-LI

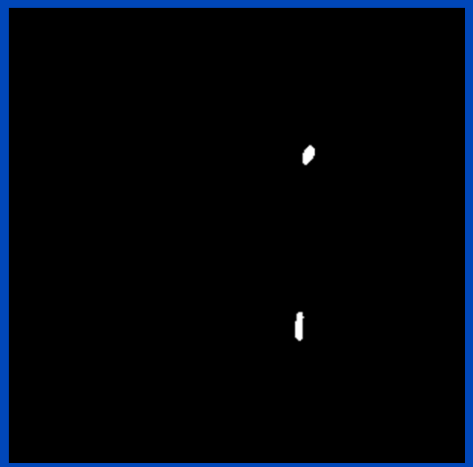
- In MAR-LI motion is not taken into account
  - Segmentation step yields motionless metal objects
  - Forward projection of motionless metal object (metal trace)
- Error in estimation of metal trace
  - Detected metal region is much larger than in reality



Rawdata



Metal shadow in MAR-LI

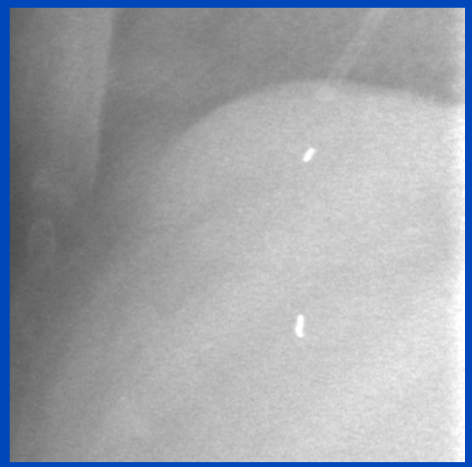


Desired solution

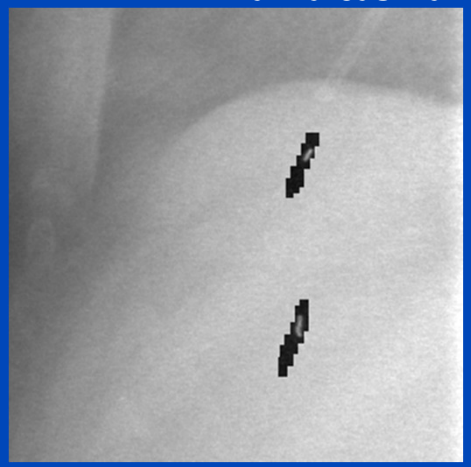
Metal Subject to Respiratory Motion and MAR-LI

- In MAR-LI motion is not taken into account
  - Segmentation step yields motionless metal objects
  - Forward projection of motionless metal object (metal trace)
- Error in estimation of metal trace
  - Detected metal region is much larger than in reality
  - Not all positions of metal objects during the scan are detected

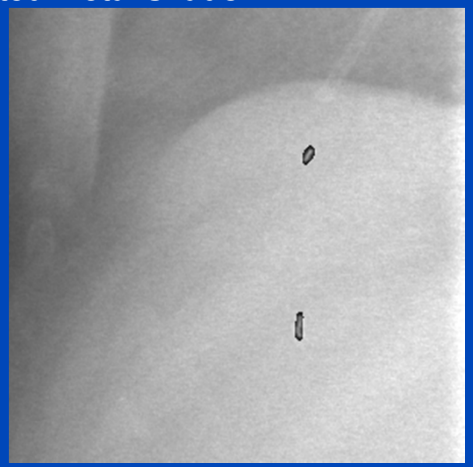
Dark areas mark estimated metal shadow



Rawdata



Metal shadow in MAR-LI



Desired solution

Rawdata-Based Segmentation

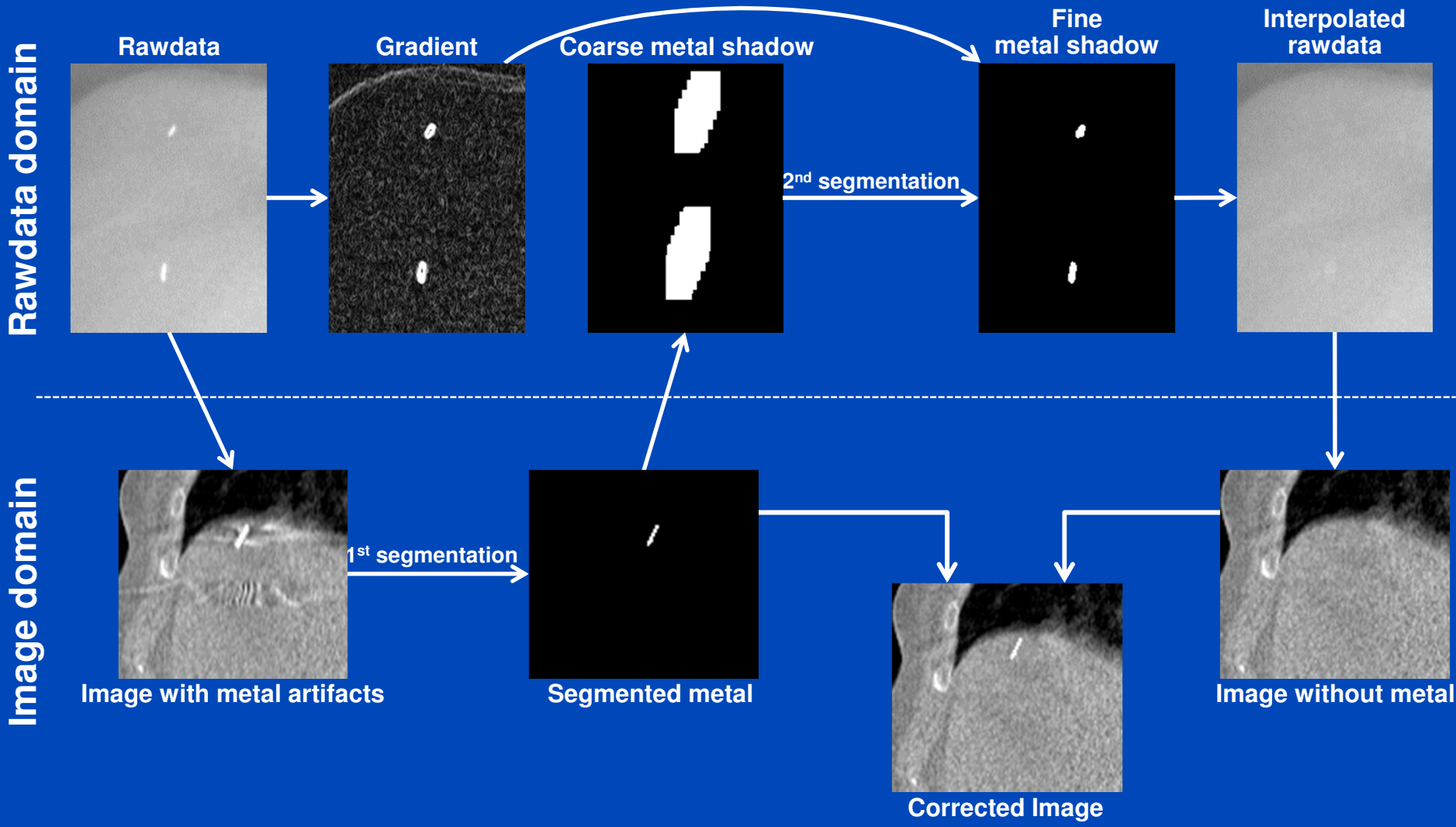
- MAR-LI uses image-based segmentation
- Several publications on rawdata-based segmentation for metal artifact reduction, e.g.
  - Zhang et al.: *Reducing metal artifacts in cone-beam CT images by preprocessing projection data*, Int J Radiat Oncol Biol Phys 67(3):924–932, March 2007
  - Veldkamp et al.: *Development and validation of segmentation and interpolation techniques in sinograms for metal artifact suppression in CT*, Med Phys 37(2):620–628, February 2010
- Lack of robustness in rawdata-based segmentation

Moving Metal Artifact Reduction (MMAR)

- **Requirements:**
  - Consider metal objects subject to (respiratory) motion
  - Segment the complete metal shadow, not more, not less

- **Solution: Combination of image-based and rawdata-based segmentation**
  - Refinement of the search area in rawdata domain by using prior information from image domain
    - » Tolerant segmentation in image domain
    - » Forward projection
    - » Segment in rawdata domain
  - Interpolate to fill the segmented metal shadow with reasonable values.

Illustration of MMAR



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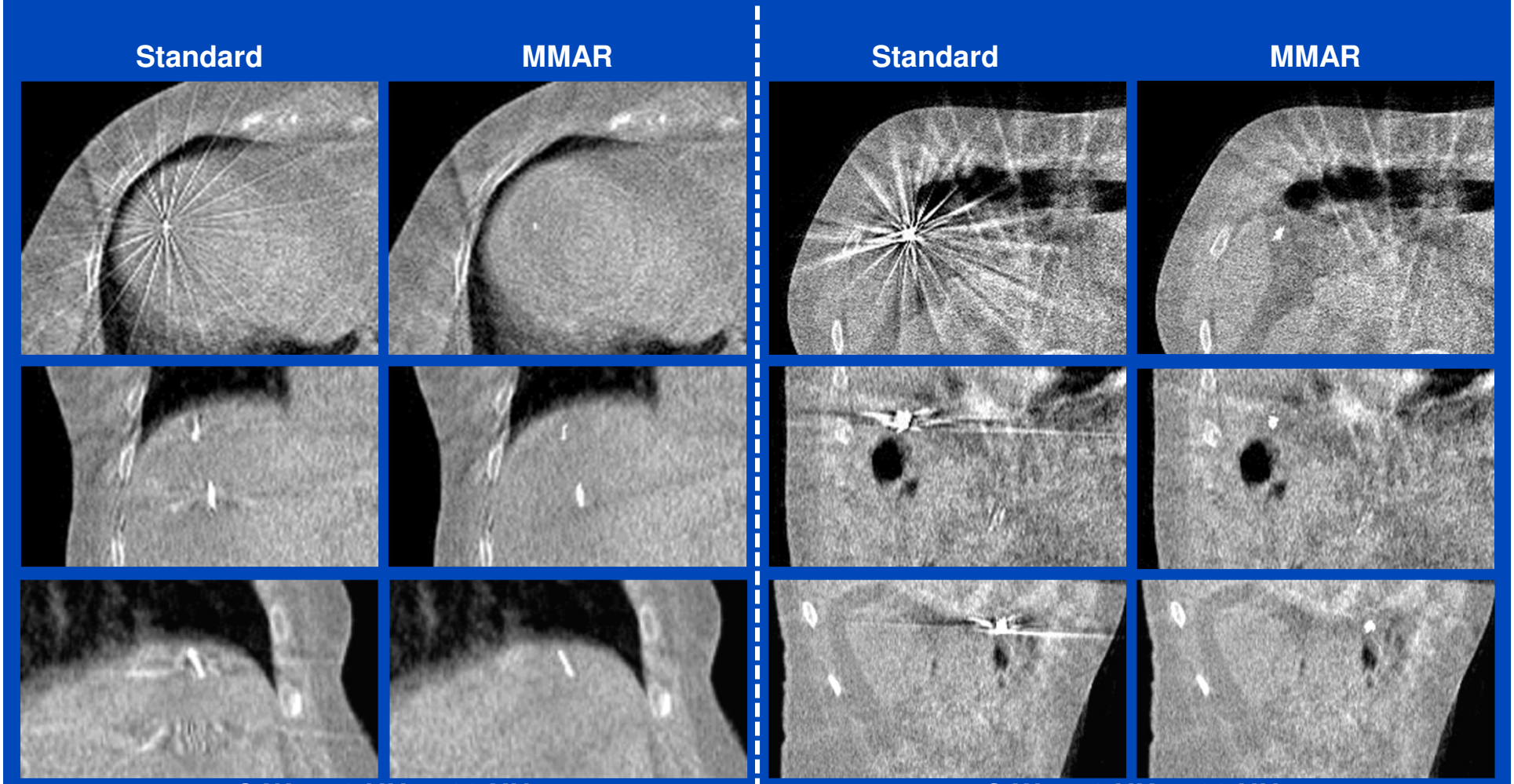
Results



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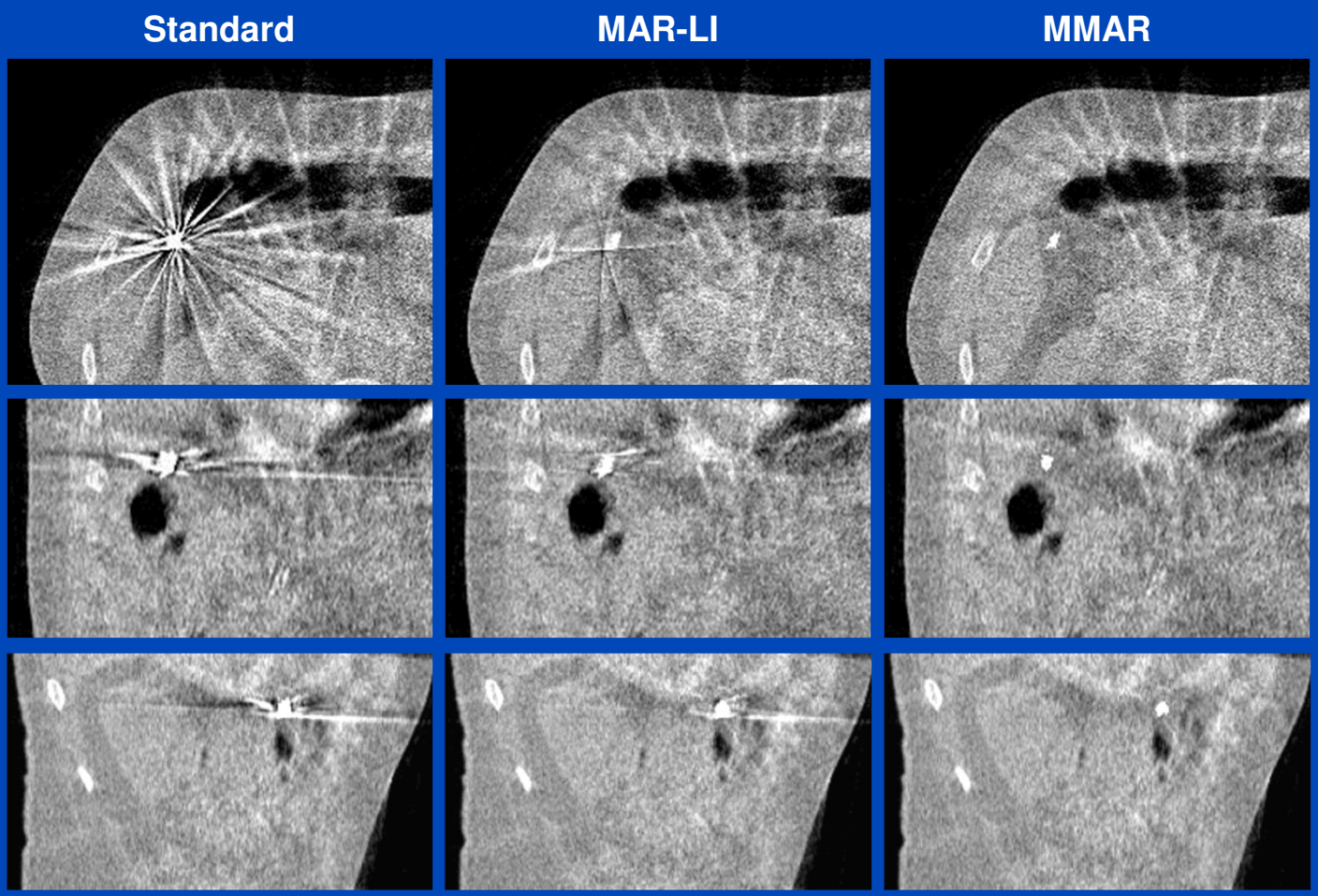
Results



C/W = 0 HU/1500 HU

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Summary of Preliminary Results

- Moving metal artifact reduction (MMAR) achieves a
  - significant reduction of metal artifacts in case of patient motion,
  - reliable segmentation of the metal independent on motion.
- In cases of no motion MMAR reduces to MAR-LI.
- MMAR can be combined with other MAR approaches than MAR-LI, e.g. with NMAR[1].

[1] E. Meyer, R. Raupach, M. Lell, B. Schmidt, and M. Kachelrieß. *Normalized metal artifact reduction (NMAR) in computed tomography,* Med. Phys. 37(10):5482-5493, October 2010

Thank You!

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