Referenceless Nyquist Ghost Correction Outperforms Standard Navigator Based Method for DT-CMR

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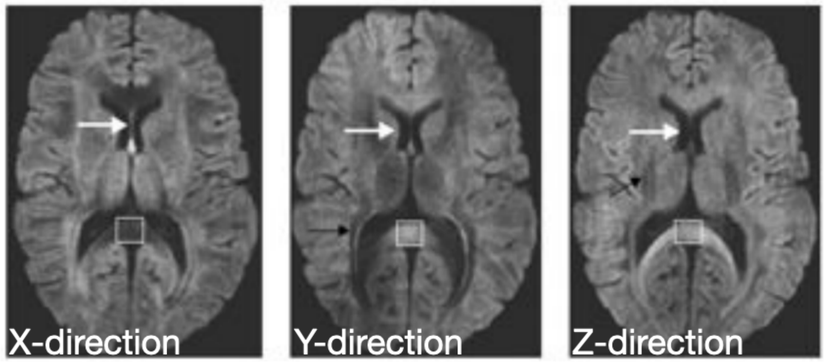
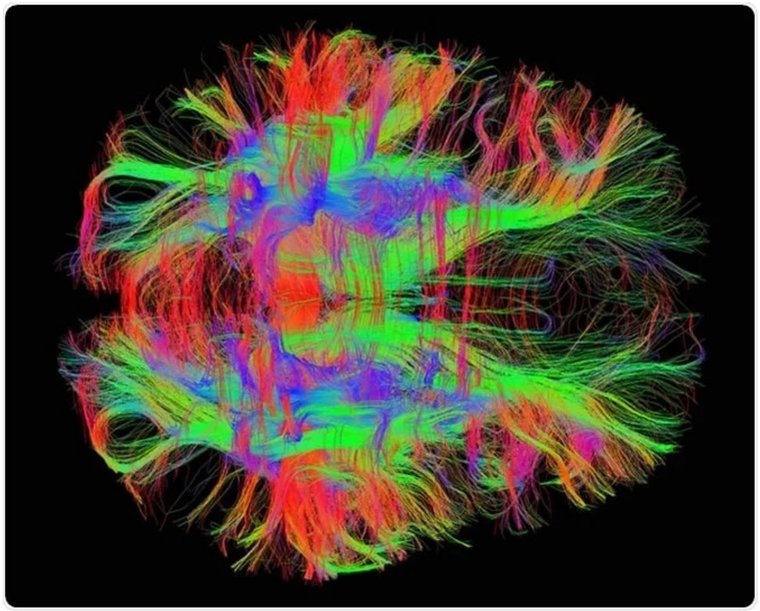
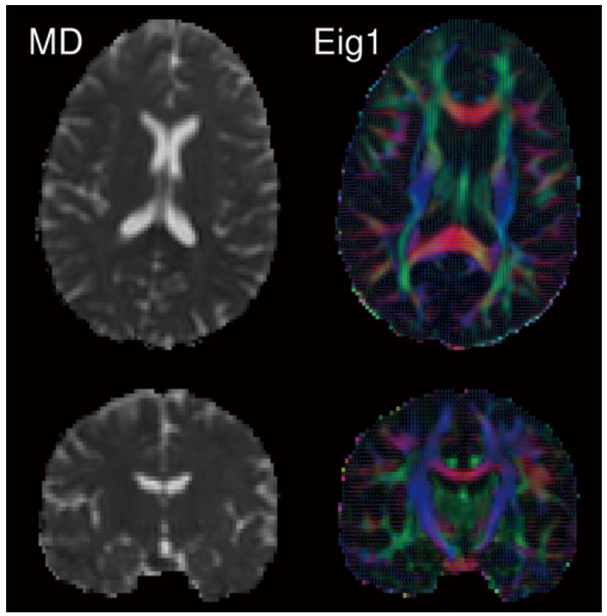
Introduction

Diffusion tensor

- Directly probe the movement of water molecules within the body
- Apply diffusion encoding in different directions and strength
- Provide insights into the functioning of various tissues and organs





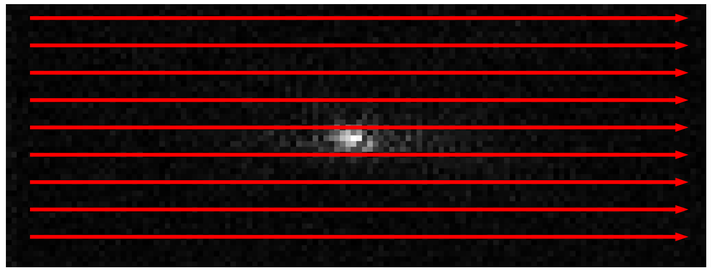


Introduction

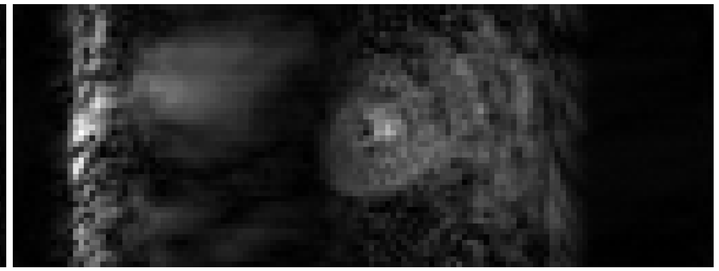
Cardiac and motion

- MRI is slow and heart is constantly in motion
- Ultra fast data acquisition method called Echo planar Imaging is used to freeze the motion of the heart
- Prone to imaging artifacts called Nyquist ghosting

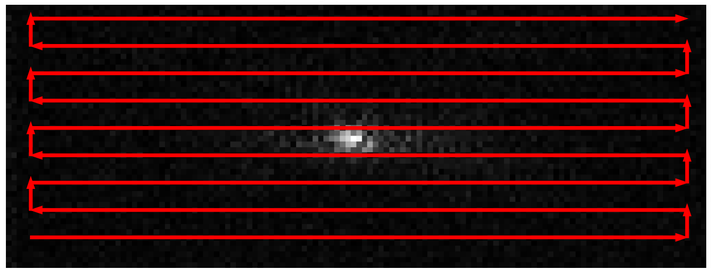
Cartesian sampling pattern in K-space



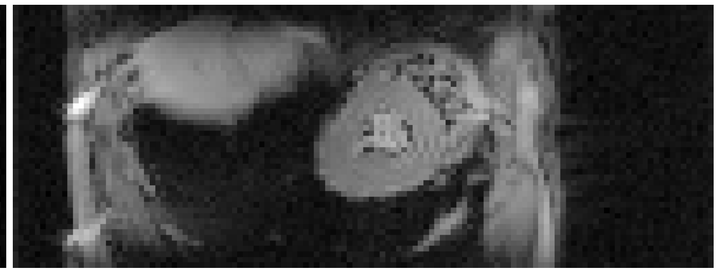
The corresponding magnitude Image



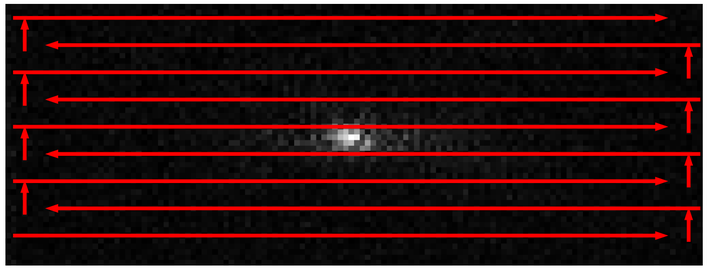
EPI sampling pattern in K-space



The corresponding magnitude Image



Example of the 'misaligned' EPI sampling pattern in K-space



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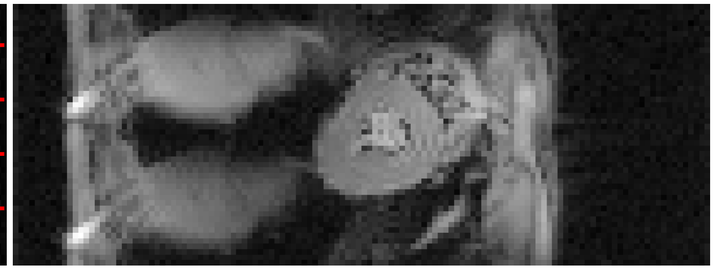

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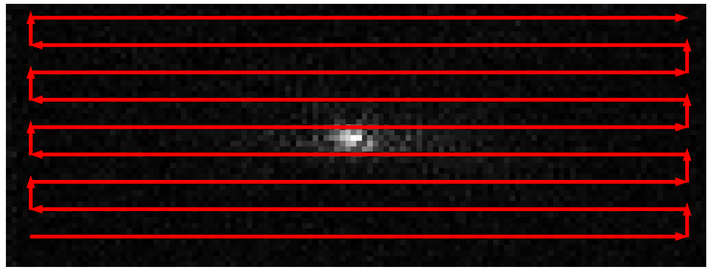

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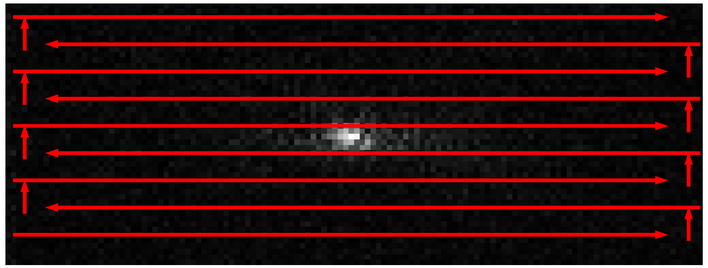


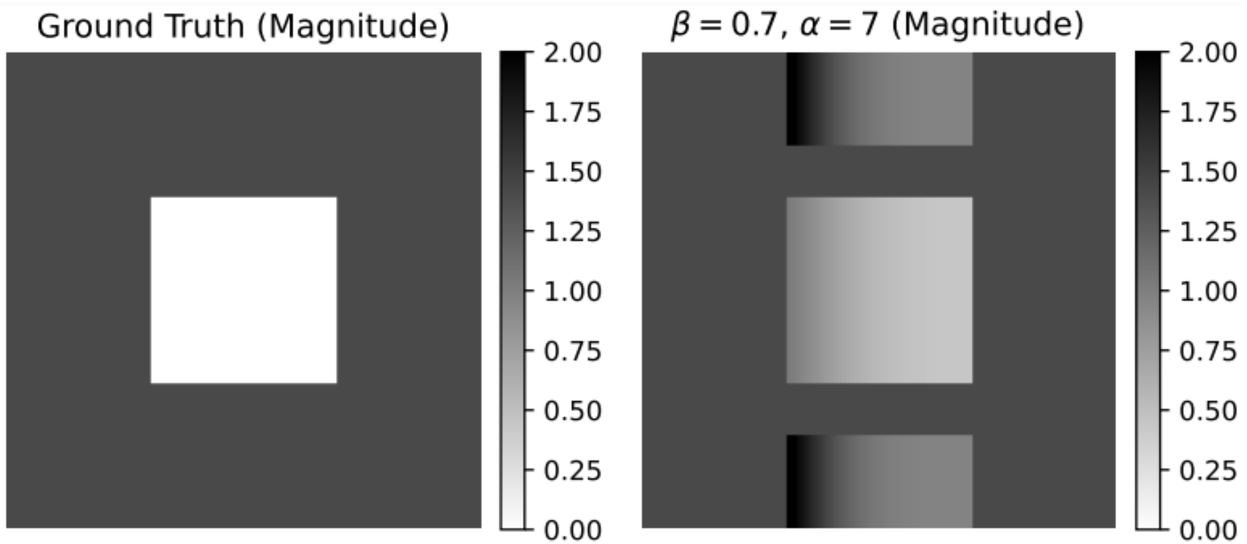
The corresponding magnitude Image

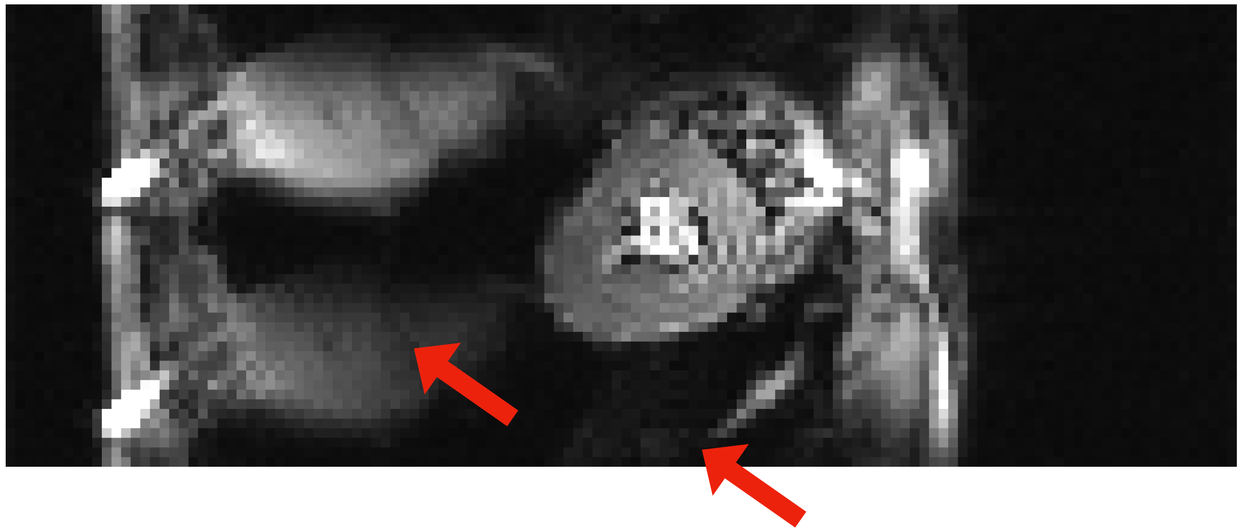
Shift in K-space = Phase ramp: $\Delta\phi = \frac{\pi\alpha}{N_x}x + \beta$

Introduction

Nyquist Ghost

- Caused by misalignment of the lines in K-space
- Ghosting artifact in the vertical direction
- Sinusoidal modulation of the object in the horizontal direction





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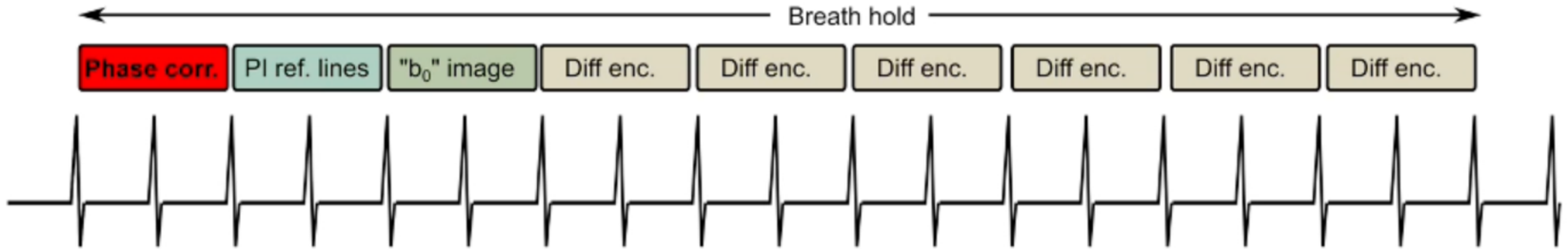
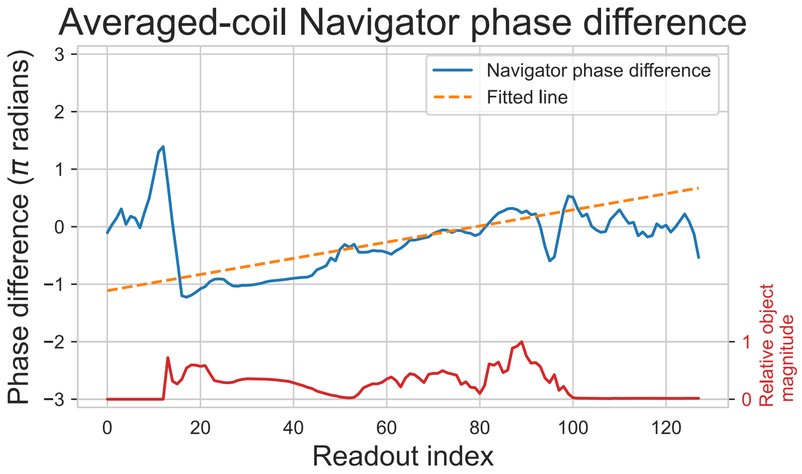
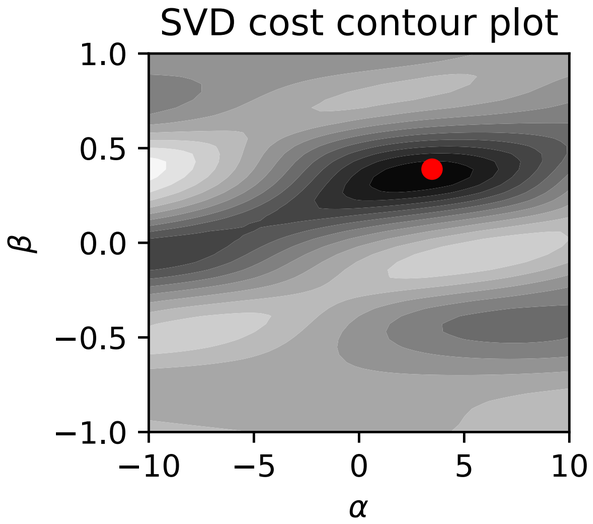


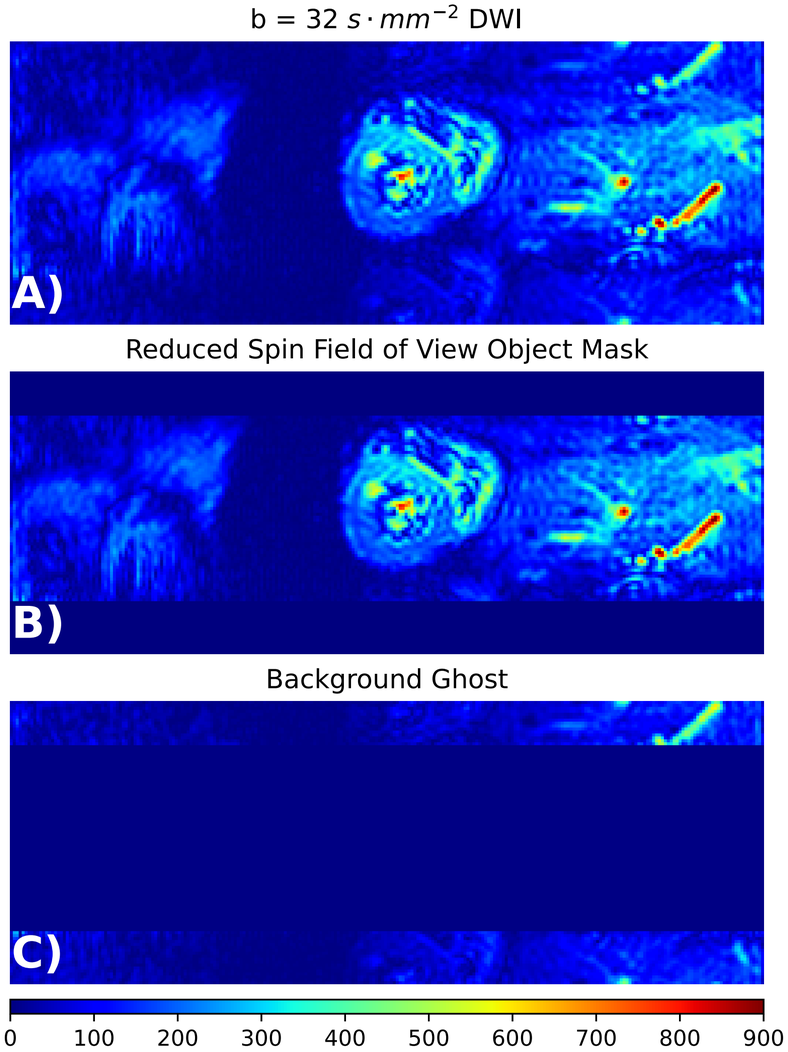




- Current method typically use separately acquired phase correction navigators, which are less effective
- Referenceless method performs an exhaustive search in the parameter space to minimize a cost function
- Here we evaluate different Nyquist correction methods in DT-CMR

Methods: Comparing different referenceless correction methods

- Three referenceless methods are tested
  - Entropy[1]
  - Low rank (SVD)[2]
  - Ghost/Object minimisation[3]
- Noise performance assessed in a DT-CMR phantom
- Compared to standard navigator phase correction for in-vivo data
  - 3T Siemens Magnetom Vida scanner
  - SE and STEAM sequence EPI acquisition from 20 healthy volunteers
- Calculate Ghost level



1. Heid (2000) MRM. 2. Clare (2005) MRM. 3. McKay (2018) MRM.

Results: simulation

- Three referenceless methods each effectively remove the ghosting artifacts
- Maps from the simulated maps appear similar to the ground truth except for the noise added in the simulation

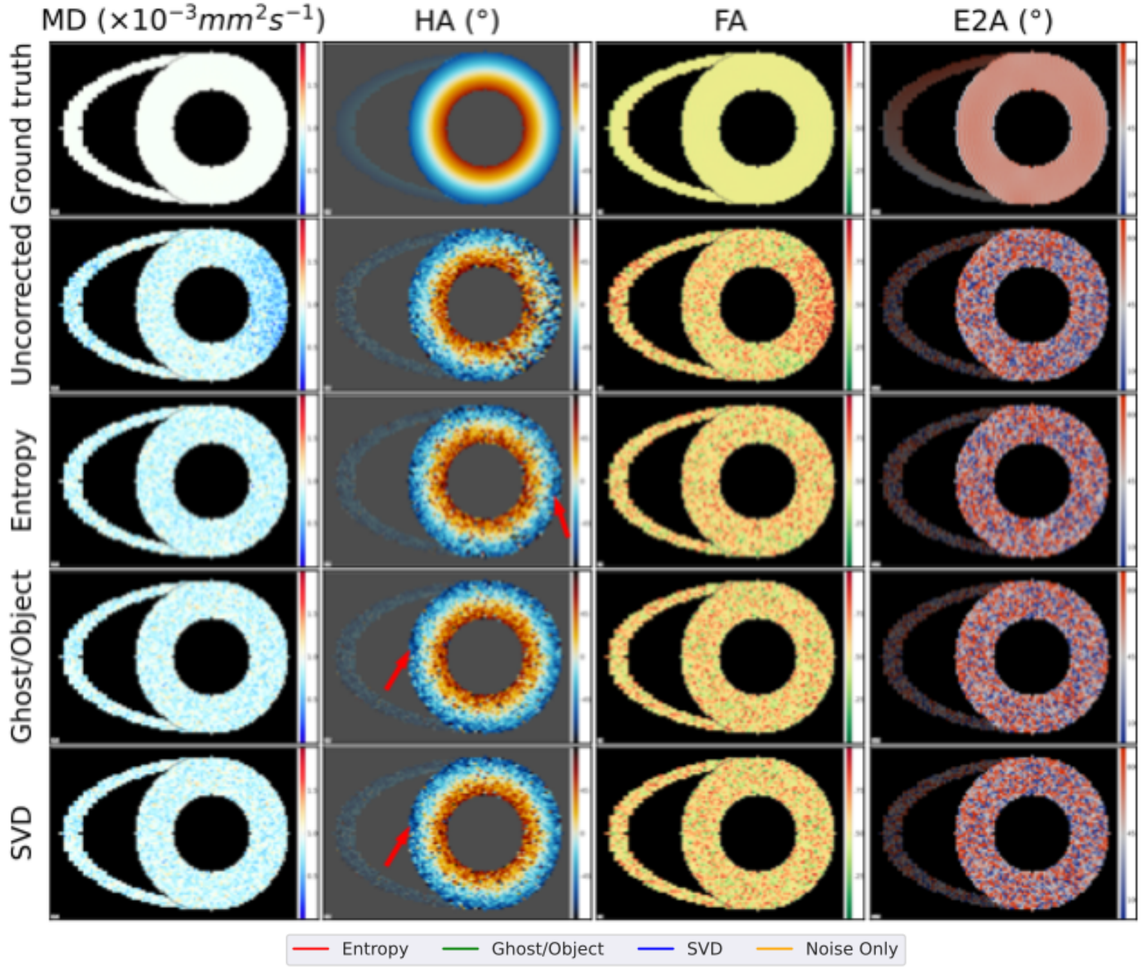
  - MD: Freedom of water diffusion

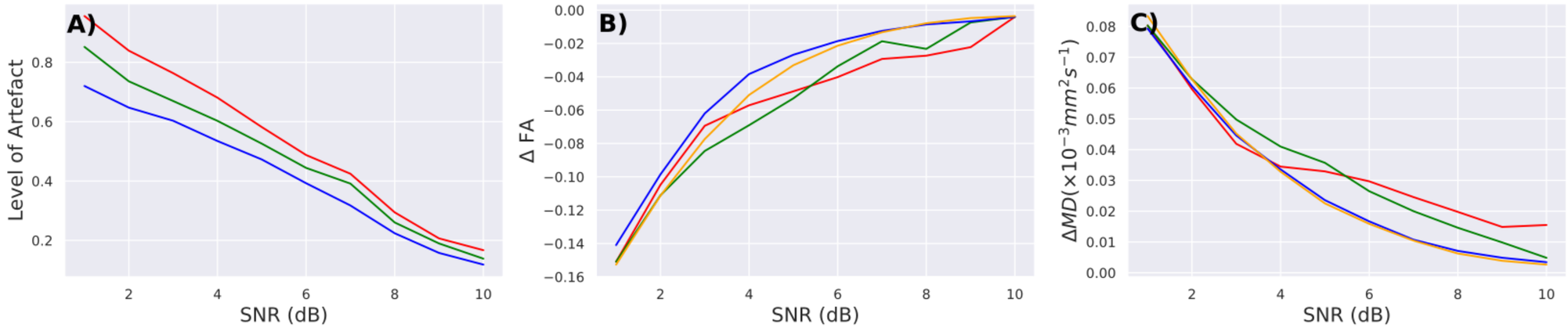
  - HA: Arrangement of the muscular fibres

  - FA: Directionality of water diffusion,

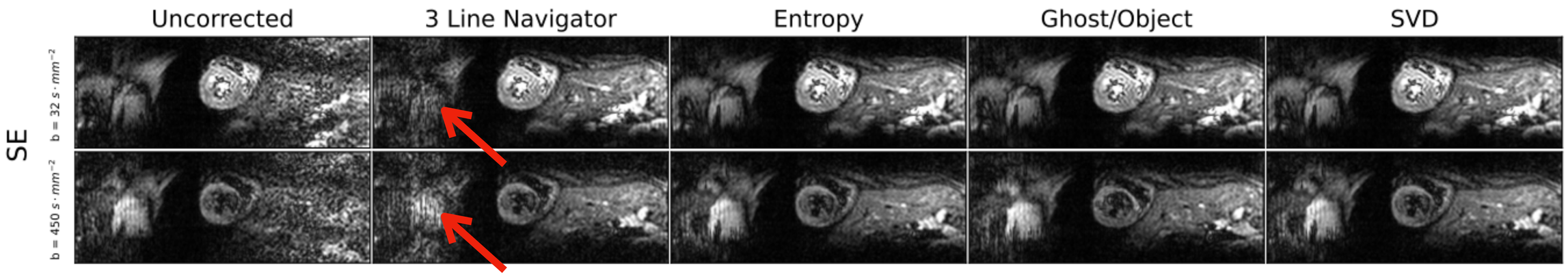
  - E2A: Orientation of the underlying micro-structural environment.

- The SVD has the lowest level of artifacts and closet FA and MD





Results: in-vivo



- Three referenceless methods remove the Nyquist ghost from the in vivo data and perform better than the standard method

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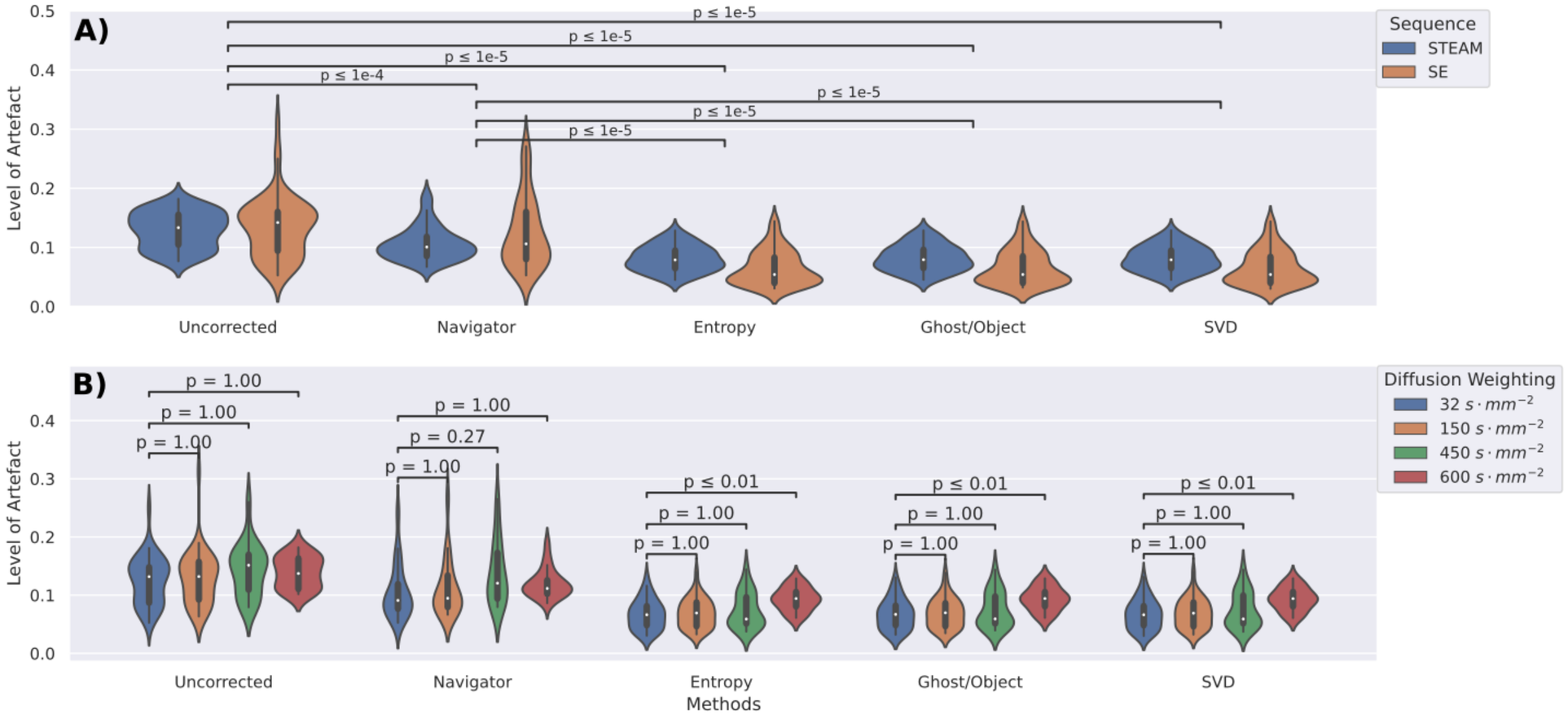

- Three referenceless methods remove the Nyquist ghost from the in vivo data and perform better than the standard method
- The performance remains consistent regardless of sequence and diffusion weighting

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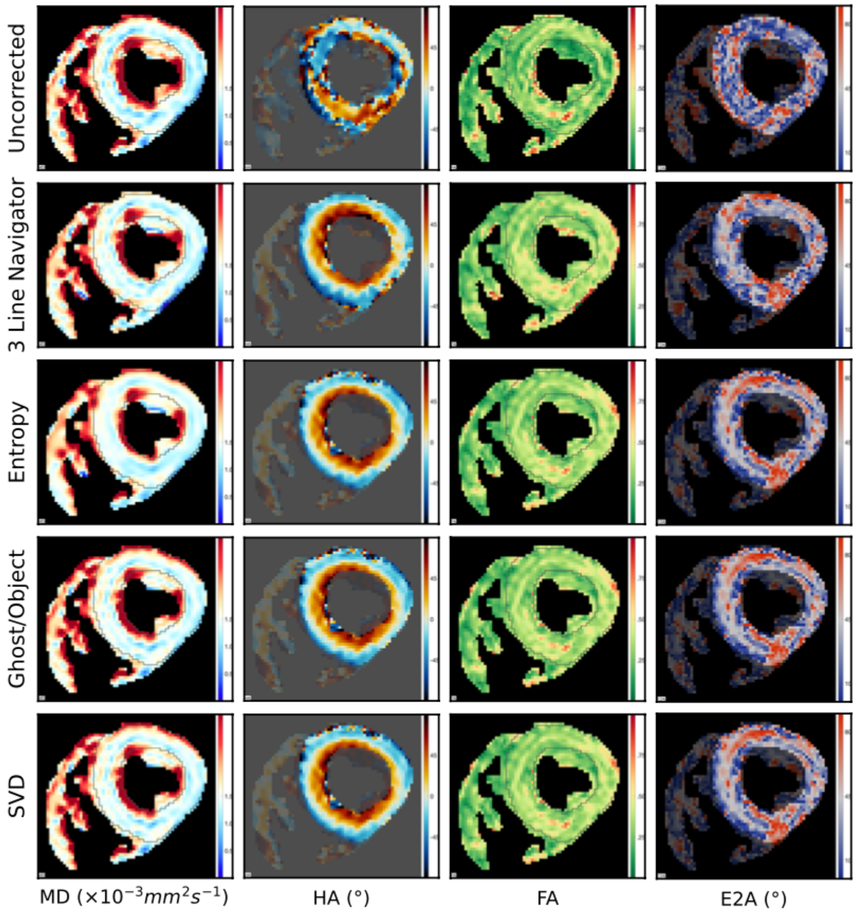

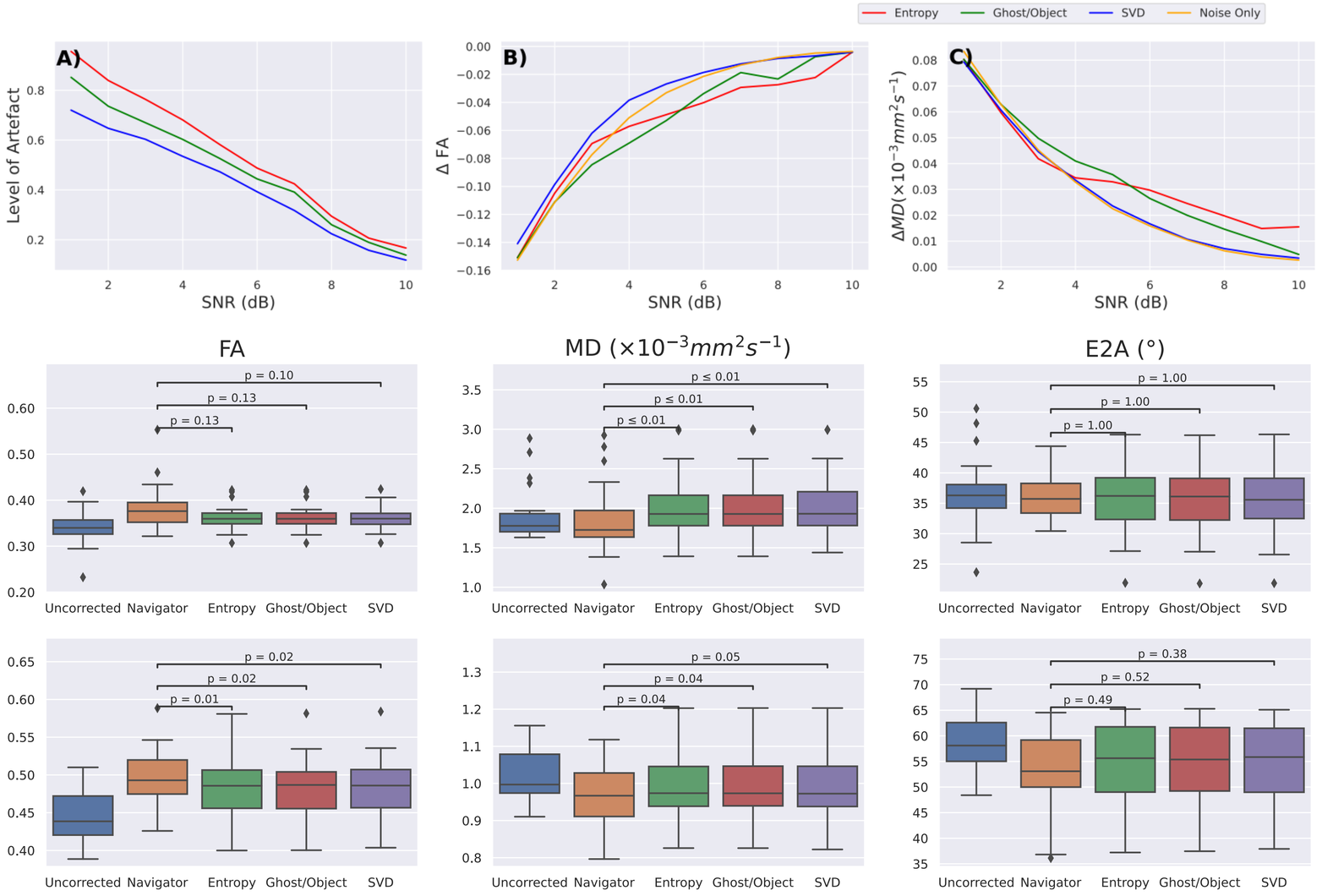

- DT-CMR maps obtained from the referenceless methods demonstrate only minor deviations from the values obtained when using navigator corrected data

Conclusion

- **Accuracy and reliability**: Referenceless methods exhibit superior performance compared to navigator-based approaches in effectively correcting Nyquist ghosts in DT-CMR data, thereby providing measurements of higher dependability.
- **Efficiency**: Referenceless methods obviate the requirement for an additional reference scan, consequently reducing the duration for which patients are required to hold their breath.
- **Clinical impact**: The implementation of these methods represents a significant advancement towards the translation of DT-CMR into a clinically indispensable tool.