Multi-Phase Coronary Magnetic Resonance Angiography Using a 3D Cones Trajectory

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Introduction

3D whole-heart free-breathing coronary MR angiography (MRA):

+ Simplifies prescription effort
+ Requires less patient cooperation
+ Supports retrospective reformats at arbitrary planes

but - Requires longer scan times
- Must account for respiratory and cardiac motion

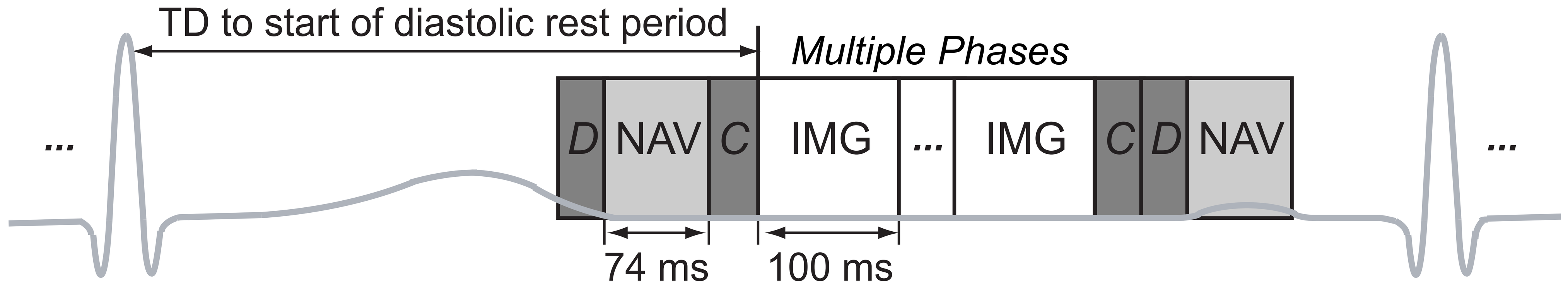
We present a new whole-heart coronary MRA technique based on:

1. The 3D cones readout trajectory [1, 2] to *reduce the scan time 3-fold* (compared to 3D Cartesian encoding) and *improve robustness to motion/flow*
2. 2D "navigator images" acquired directly through the heart to *track S/I & A/P respiratory motion*
3. Resolving multiple cardiac phases to *allow retrospective selection of the best phase(s)* for visualizing each coronary segment

Methods

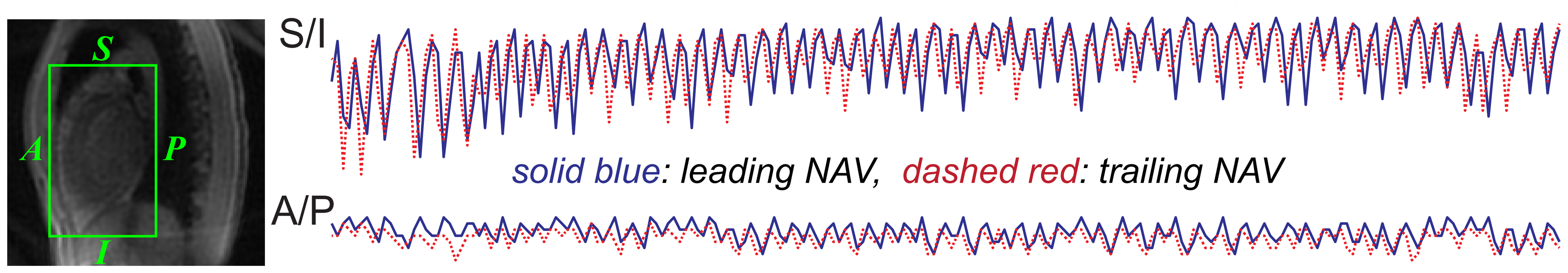
Acquisition:

- GE Signa 1.5 T Excite system; 8-channel cardiac coil; Axial slab.
- FOV = 28x28x14 cm^3; Resolution = 1.2x1.2x1.25 mm^3; 9142 cone readouts.
- Total scan time of 508 HBs (~7 min at 72 bpm).



NAV: 2D spiral, 12 TRs, GRE TE / TR = 1.4 / 6.2 ms, FA = 10^o; ***D***: 4 dummy TRs

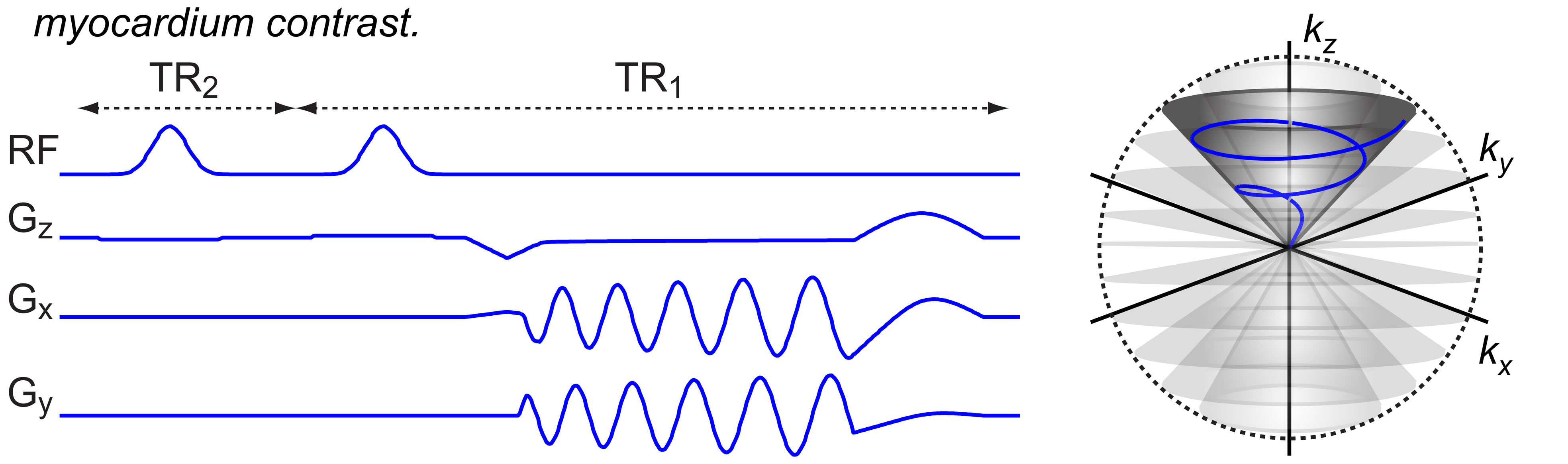
- *2D sagittal slices through the left ventricle track S/I & A/P respiratory translation.*



IMG: 3D cones, 18 TRs, ATR-SSFP TE / TR_1 / TR_2 = 0.57 / 4.37 / 1.15 ms, FA = 60^o

C: 10 cosine-ramp-weighted catalyzation TRs

- *Alternating-TR (ATR) SSFP* [3] *provides steady-state fat suppression and blood-myocardium contrast.*



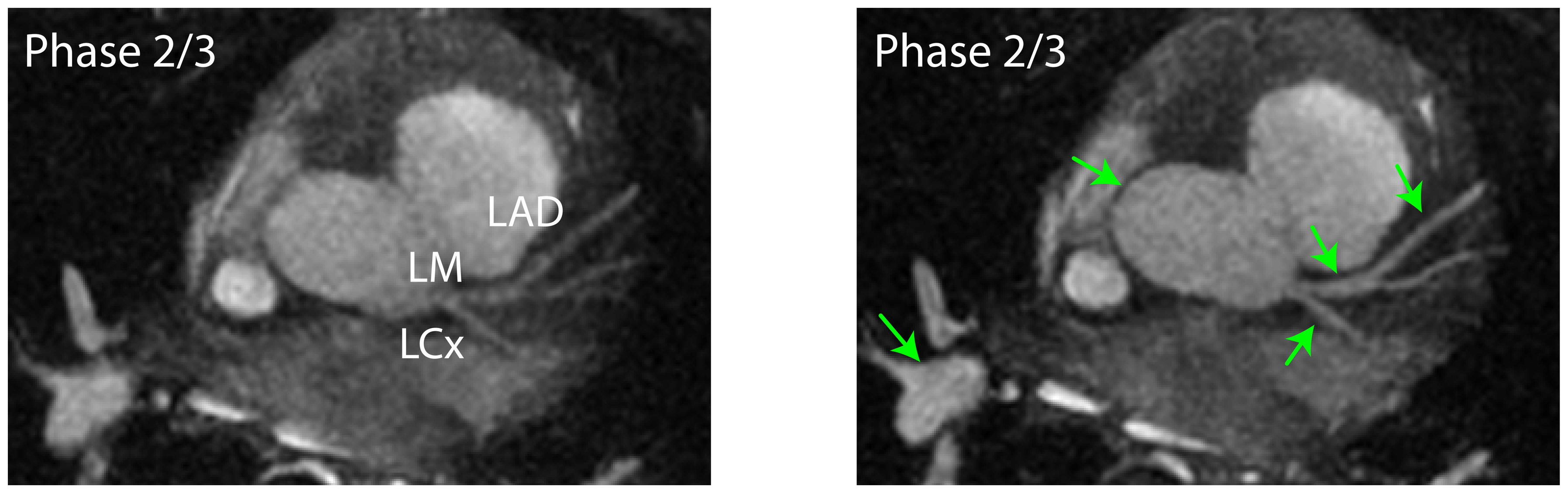
Reconstruction:

- S/I & A/P translation are estimated for each cone readout by linear interpolation between the leading/trailing NAVs within each heartbeat.
- All readouts are corrected for translation and used in gridding reconstruction.
- Multiple cardiac phases are reconstructed, with the option of sliding window reconstruction of intermediate cardiac phases.

Results

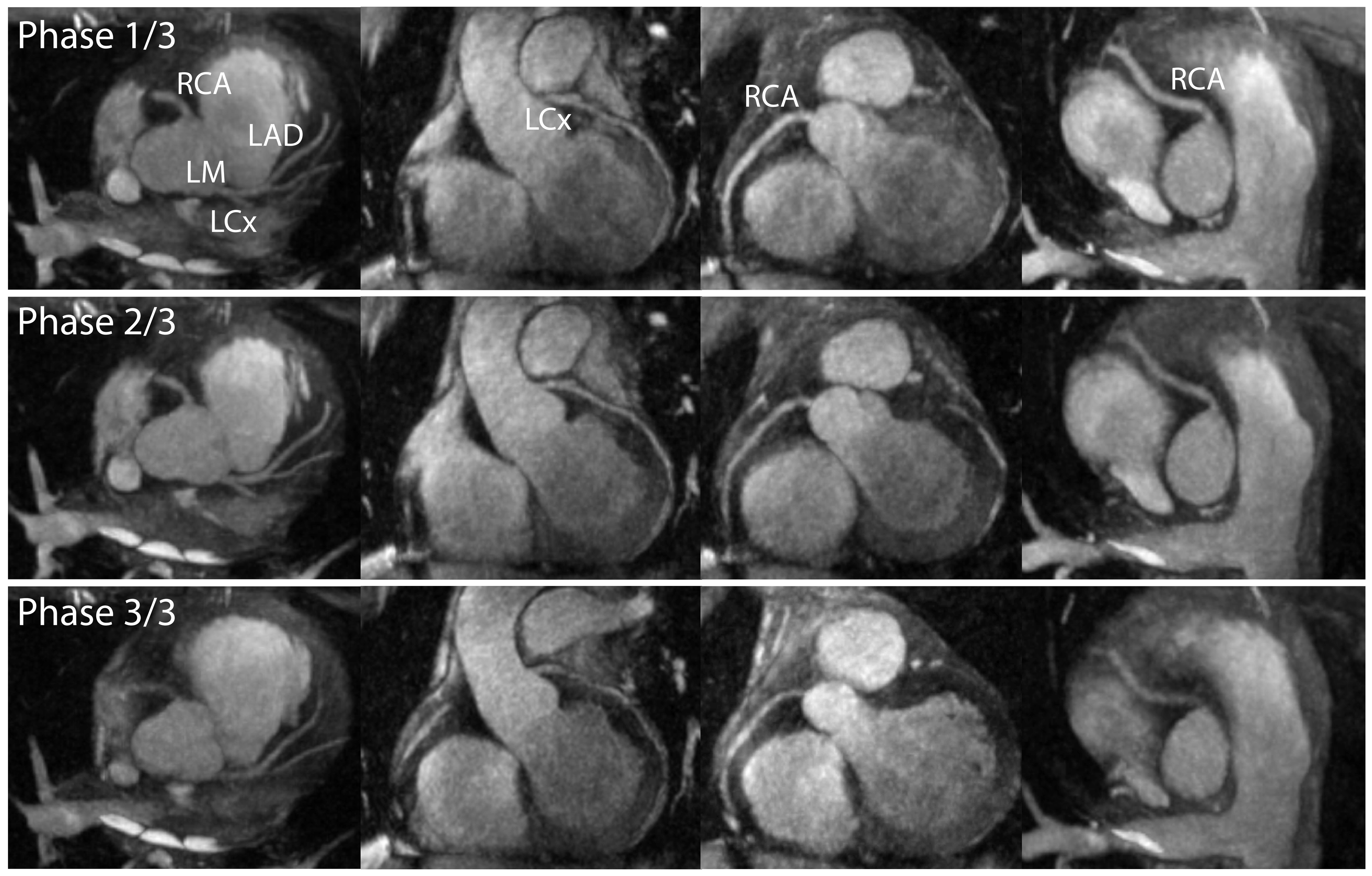
Reformatted thin-slab MIPs from a normal volunteer scan:

Before respiratory motion correction: *After 2D respiratory motion correction:*



- The LM, LAD, and LCx are already recognizable before respiratory motion correction due to the inherent robustness of cones.
- 2D respiratory motion correction substantially improves image quality.

Selected reformats at the 3 fully resolved 100-ms cardiac phases:



- For this subject, the RCA is best visualized in early diastole (phase 1) and becomes blurred in late diastole (phase 3).
- The LM, LAD, and LCx have longer rest periods and are best visualized in mid-diastole (phase 2), but also become blurred in late diastole (phase 3).

Discussion

- 3D cones reduce scan time 3-fold vs. 3D Cartesian encoding and provide greater robustness to motion/flow effects.
- "Navigator images" directly track 2D respiratory motion of the heart and enable robust compensation with 100% respiratory efficiency.
- Resolving multiple cardiac phases provides robustness to the initial choice of TD and subsequent heart-rate variations. Such a dataset can support retrospective selection of the best cardiac phase(s) for visualization, which may be different for each coronary segment [4].

References

[1] Gurney PT, et al., MRM 2006; 55: 575-582.
[2] Gurney PT, PhD Thesis, Stanford University, 2007.
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[4] Jahnke C, et al., Radiology 2006; 239: 71-78.

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