Dynamic Contrast-Enhanced 3D MR Imaging of the Breast with Fat/Water Separation and High Spatiotemporal Resolution using Dixon Radial Volumetric Encoding (Dixon-RAVE)

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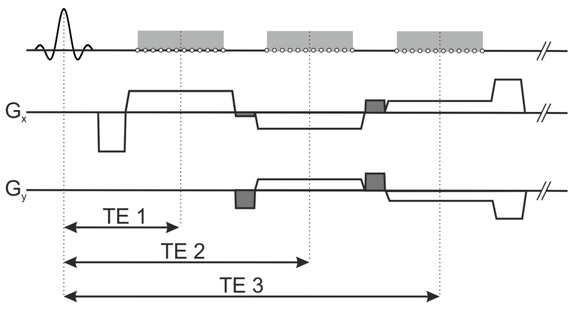
INTRODUCTION

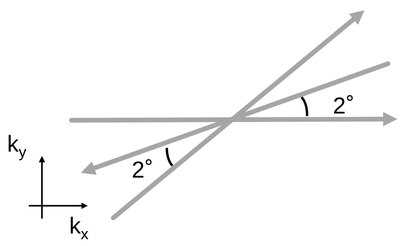
- Conventional breast protocols rely on contrast-enhanced fat-suppressed VIBE images. Problems: limited temporal resolution, inhomogeneous fat suppression
- Golden-angle Radial Sparse Parallel MRI (GRASP) enables dynamic contrast enhanced (DCE) MR imaging with high temporal resolution [1,2].
  Problem with inhomogeneous fat suppression remains
- Novel approach: Dixon-RAVE [3] integrates fat/water separation with GRASP imaging, allowing for more robust suppression of fat

METHODS

- **Dixon-RAVE data acquisition**

  3D stack-of-stars sequence | blipped bipolar multi-echo readout





Slightly rotated trajectory for each echo
→ improved incoherence

Continuous acquisition of 400 projections (scan time = 3:10 min, TR = 6.54 ms, spatial resolution = 1.0x1.0x1.2 mm^3), contrast injection after 2 minutes

- **Dixon-RAVE reconstruction**

  Model-based approach | Deblurring | Compressed Sensing | Parallel Imaging

  Grouping of 13 consecutive radial spokes
  Temporal resolution = 6.1 s/volume, 30 dynamic frames

Signal model

$$E(W,F,\Phi)_{c,t} = \mathrm{FT}\left(C_c \cdot \mathrm{e}^{2\pi i \cdot \Phi \cdot t_n} \cdot W\right) + D(t) \cdot \mathrm{FT}\left(C_c \cdot \mathrm{e}^{2\pi i \cdot \Phi \cdot t_n} \cdot F\right)$$

W = water, F = fat, Φ = B_0 field map, C_c = coil sensitivities,
D(t) = sampling operator, FT = NUFFT operator

Optimization problem

$$\underset{c,t}{\operatorname{argmin}} \sum \|E(W,F,\Phi)_{c,t} - y_{c,t}\|_2^2 + \lambda_W \|S(W)\|_1 + \lambda_F \|S(F)\|_1 + \lambda_\Phi \|S(\Phi)\|_1$$

$y_{c,t}$ = 4-dimensional k-space data (N_{read}xN_{proj}xN_ZxN_{frames}), S = temporal total variation

Solved with iterative Gauss-Newton algorithm, initialized with precomputed field map [4]

- **Patient study**

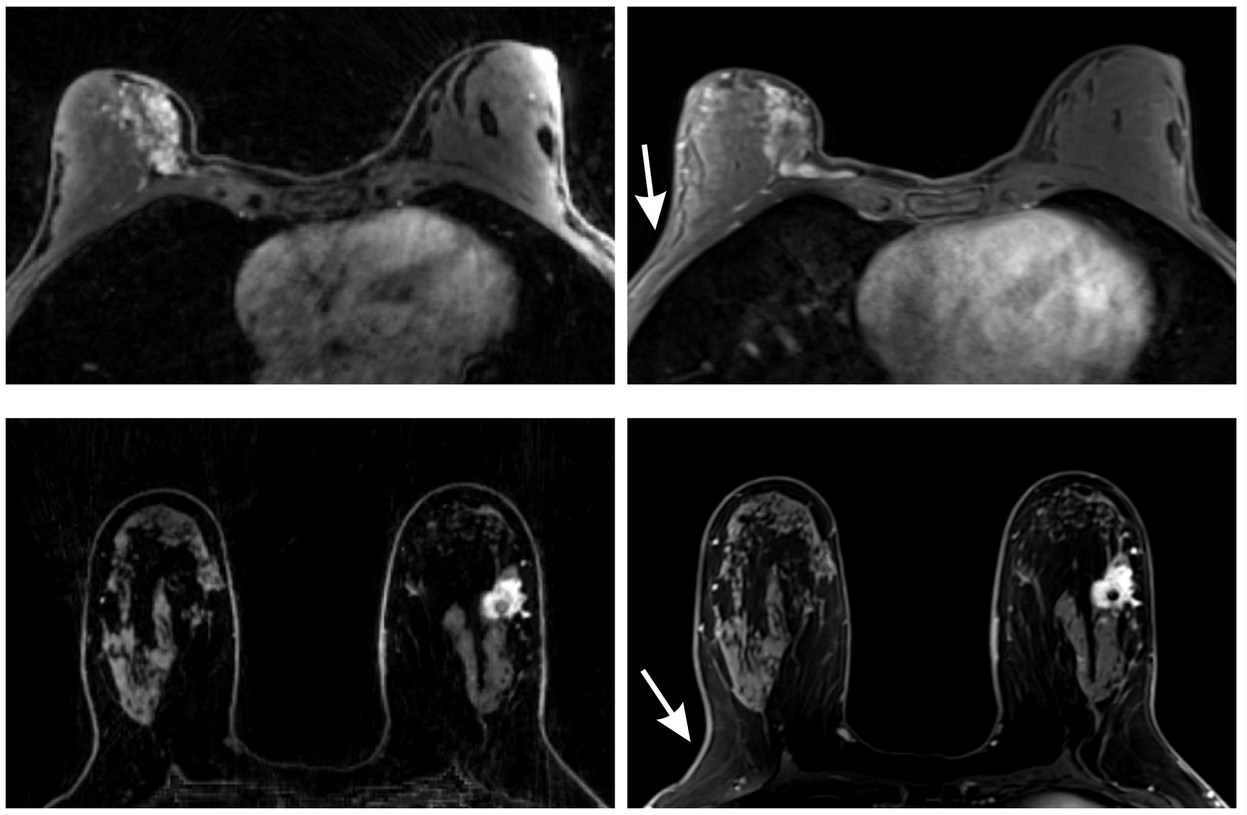
  9 patients (age 47.6 ± 15.8 years), 3T Trio (Siemens Healthineers, Erlangen)

  Diagnostic bilateral breast DCE-MRI

DCE-Dixon-RAVE | **Conventional fatsat VIBE**

Comparison: Last dynamic frame ⟷ First dynamic frame

RESULTS



Dixon-RAVE and fatsat VIBE results from two cancer patient scans. In some areas, fat suppression for conventional VIBE fails due to B_0 inhomogeneities (arrows), while Dixon-RAVE achieves uniform cancellation of fat.

- **Evaluation**

  Images scored by two radiologists
  5-point scale and Wilcoxon signed ranked test

	Dixon-RAVE	Fatsat VIBE	p-value
Degree of fat suppression	4.44±0.62	3.83±0.62	<0.005
Conspicuity of fibroglandular tissue from fat	4.33±0.69	3.61±0.61	<0.003
Overall image quality	3.67±0.49	3.67±0.59	1.00

CONCLUSION

- Dixon-RAVE enables 3D DCE fat/water separated breast imaging with high spatiotemporal resolution
- Improved fat suppression and higher conspicuity of fibroglandular tissue compared to conventional fat-suppressed VIBE
- Extraction of both water images (“fat-suppressed”) and fat images (“non-fat-suppressed”), combines entire T_1-weighted exam into single scan
- Possible extensions: Fat quantification, T_2*-mapping

REFERENCES

[1] Feng L et al, Magn Reson Med. 72:707-717 (2014)
[2] Kim SG et al, J Magn Reson Imag. 43:267-269 (2016)
[3] Benkert T et al, Magn Reson Med. Early view (2016)
[4] Berglund J et al, Magn Reson Med. 63:1659-1668 (2010)

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