

New clinical opportunities using lower field MRI

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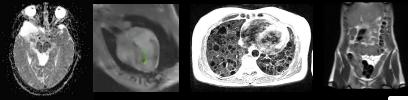
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New opportunities with mid/low field MRI

- High-performance lower field MRI technology
- New clinical applications
 1. Lower cost MRI
 2. MRI-guided cardiovascular procedures
 3. Comprehensive lung imaging
 4. Other: high susceptibility regions, implant accessibility



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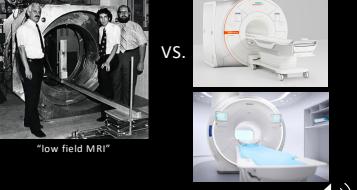
MRI system performance

High performance =

- Gradient performance
- Magnet design
- Receiver hardware
- RF transmission
- Pulse sequences
- Computational capabilities

"low field MRI"

VS.



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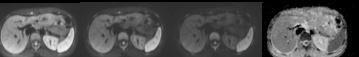
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MRI system performance

High performance =

- **Gradient performance**
 - Fast
 - Shielded
 - High fidelity
- Magnet design
- Receiver hardware
- RF transmission
- Pulse sequences
- Computational capabilities

$b = 50$ $b = 400$ $b = 800$ ADC map



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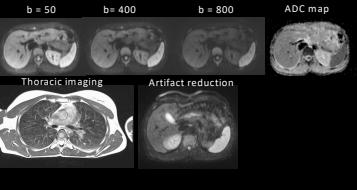
MRI system performance

High performance =

- Gradient performance
- **Magnet design**
 - BO homogeneity
 - Field stability
- Receiver hardware
- RF transmission
- Pulse sequences
- Computational capabilities

$b = 50$ $b = 400$ $b = 800$ ADC map

Thoracic imaging Artifact reduction



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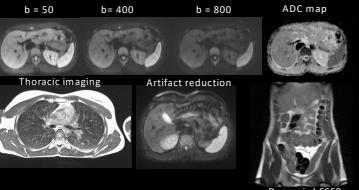
MRI system performance

High performance =

- Gradient performance
- Magnet design
- **Receiver hardware**
 - Local arrays
 - Receive chain architecture
- RF transmission
- Pulse sequences
- Computational capabilities

$b = 50$ $b = 400$ $b = 800$ ADC map

Thoracic imaging Artifact reduction Dynamic bSSFP



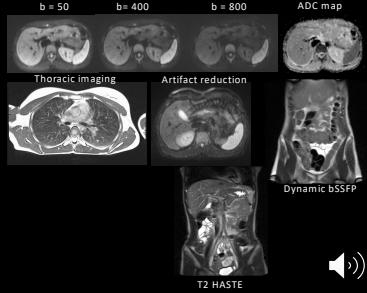
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MRI system performance

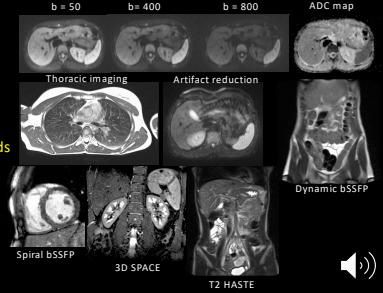
- High performance =
- Gradient performance
 - Magnet design
 - Receiver hardware
 - RF transmission
 - B1 homogeneity
 - SAR limitations
 - Pulse sequences
 - Computational capabilities



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MRI system performance

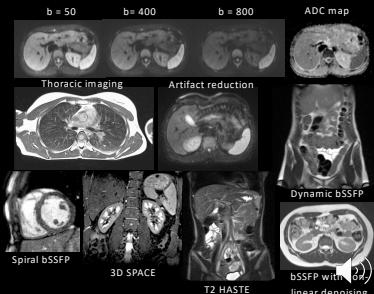
- High performance =
- Gradient performance
 - Magnet design
 - Receiver hardware
 - RF transmission
 - Pulse sequences
 - New acquisition methods
 - Optimized sequences
 - Free breathing
 - Computational capabilities



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MRI system performance

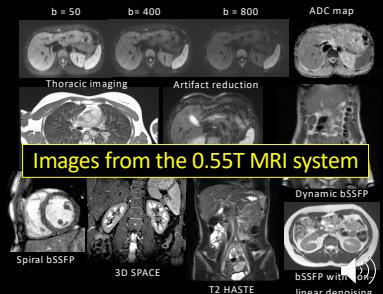
- High performance =
- Gradient performance
 - Magnet design
 - Receiver hardware
 - RF transmission
 - Pulse sequences
 - Computational capabilities
 - Compressed Sensing
 - AI reconstruction + processing



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MRI system performance

- High performance =
- Gradient performance
 - Magnet design
 - Receiver hardware
 - RF transmission
 - Pulse sequences
 - Computational capabilities



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Ramp down 1.5T → 0.55T

Pairs contemporary hardware and imaging methods with a lower field strength



Siemens MAGNETOM Aera

- Superconducting magnet design
 - <0.5ppm, <12Hz (25cm sphere)
- Fast, shielded, high fidelity gradients
 - 45mT/m @ 200mT/m/s
- Phased array coils
 - Spine-18, Body-6, Head/Neck-16 arrays

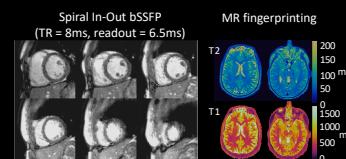
Campbell-Washburn AE, et al. Radiology, 293:384-393 (2019).

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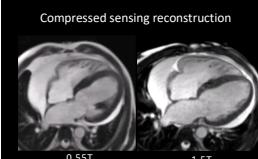
0.55T imaging methods

Efficient data sampling



Restivo MC, et al. Magn. Reson. Med.; 84(5):2364-2375 (2020).
Campbell-Washburn, et al. Under Review
Bandettini WP, et al. J Cardiovasc Magn Reson; 22(1):37 (2020).
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Advanced image reconstruction



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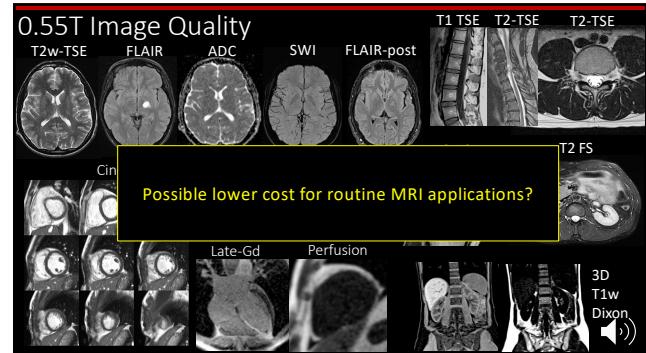
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1. Lower cost MRI

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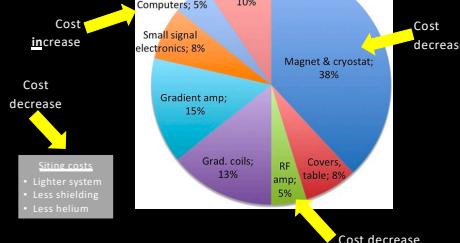


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System costs



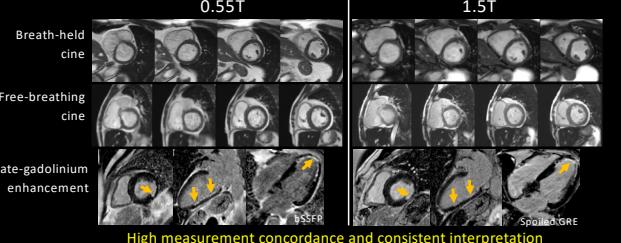
Wald LL, et al. JMRI, 52(3):686-696 (2020)

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0.55T vs. 1.5T cardiac imaging

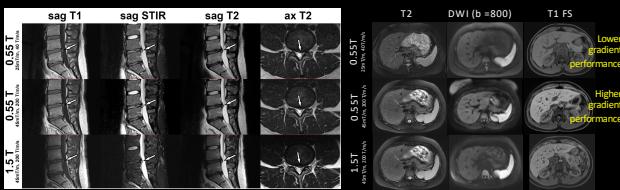


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0.55T vs. 1.5T spine and abdomen imaging

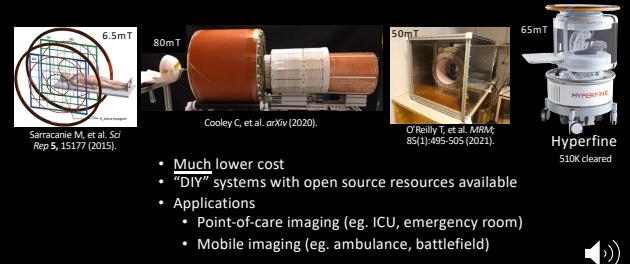


Images from NYU
Hersh Chandarana, Jan Fritz, Daniel Sodickson



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Ultra-low field MRI



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2. MRI-guided invasive procedures

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MRI guided catheterization



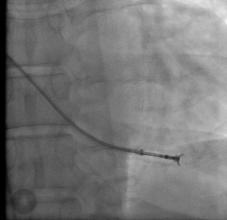
1.5T imaging

Real time bSSFP + flow sensitive saturation pulse
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MRI-guided cardiovascular interventions

X-Ray



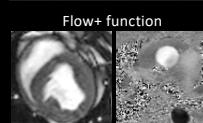
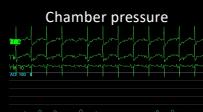
MRI



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MRI catheterization with plastic catheters



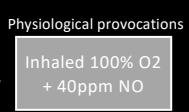
Accurate Pulmonary
Vascular Resistance

Physiological provocation

Inhaled 100% O₂
+ 40ppm NO

>115 patients at NIH
>50 pediatric patients at CNMC

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Metallic Device Safety



Medstar Washington Hospital Center

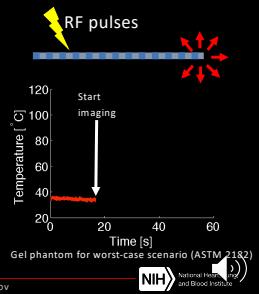


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Metallic Device Safety



Medstar Washington Hospital Center



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Reduce Device Heating

Use polymer devices?



MRI-safe materials are mechanically inadequate

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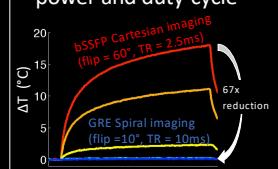
Reduce Device Heating

Use polymer devices?



MRI-safe materials are mechanically inadequate

Image with lower RF power and duty-cycle



bSSFP Cartesian imaging (flip = 60°, TR = 2.5ms)

GRE Spiral imaging (flip = 10°, TR = 10ms)

67x reduction

time

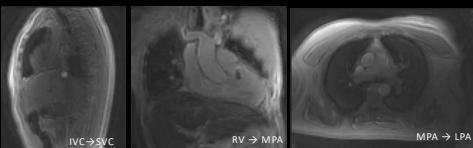
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First-in-human metallic device @ 1.5T

- Introduced a metallic guidewire for right heart catheterization
- Incremental stiffness and conspicuity to the catheter shaft
- Guidewire tip often not visible
- 100% procedural success vs. 94% without guidewire

IVC → SVC RV → MPA MPA → LPA

Campbell-Washburn AE. JCMR. 20(1):41 (2018).

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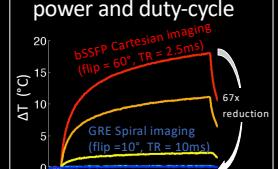
Reduce Device Heating

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bSSFP Cartesian imaging (flip = 60°, TR = 2.5ms)

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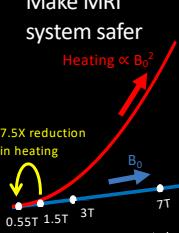
time

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Make MRI system safer

Heating $\propto B_0^2$



7.5X reduction in heating

0.55T 1.5T 3T 7T

B₀

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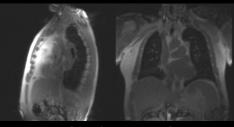
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Clinical right heart catheterization at 0.55T

Commercial Metal Guidewire
0.035"/180cm "Micro-J"-tip Terumo Glidewire

+
Standard real time MRI
Cartesian bSSFP, flip angle = 45°, TR = 4ms, partial saturation pulse = 60°



Real time bSSFP + partial saturation pulse (0.55T)

- No adverse events
- Multiple IRB approved metal devices
 - Guidewires
 - Stainless steel braided catheters

Campbell-Washburn AE, et al. Radiology, 293:384-393 (2019).

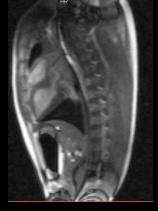
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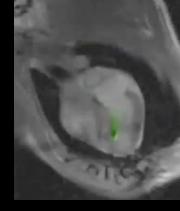
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Next procedures

Structural Heart Interventions



Therapeutic Chemoablation



The burden of safety is now on device visualization

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MRI-guided radiotherapy

0.35T – 1.5T MRI-linac systems are commercially available

Localization for irradiation Cardiac radioablation

Olsen J., et al. Mo Med; 112:358-360 (2015). Mayinger M., et al. Radiat Oncol; 152:203-207 (2020)

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3. Lung MRI

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MRI of the lung at 0.55T

CT 0.55T MRI

1.5T MRI

Patient with lymphangioleiomyomatosis (LAM)

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T2-weighted imaging

Healthy Volunteer LAM Cysts Cavitary Lesions 7mm Nodule

Edema Infiltrate Bronchiectasis

T2-weighted Turbo Spin Echo
TE = 47ms
Respiratory triggered
~10min for 32 slice coverage

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Imaging acute COVID-19 infection

MRI CT

Campbell-Washburn AE, et al. Radiology; 299:E246-E247 (2021).
Heiss R, et al. JMR; 76:49-51 (2021).
Azour L, et al. ISMRM 2021 #0219.

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Comparison with CT

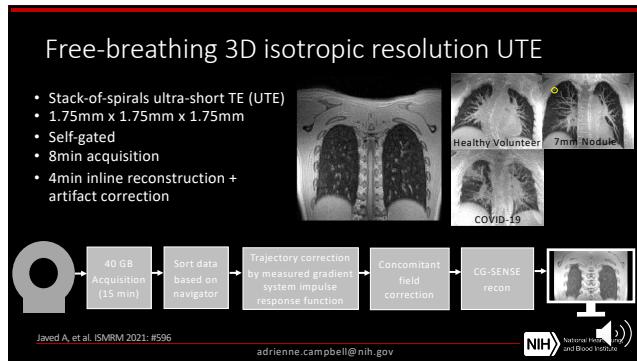
	Cohen's kappa statistic
Cavitation	1.00
Consolidation	1.00
Scattered solid nodularity	0.82
Mucus plug	0.68
Pleural effusion	0.64
Bronchiectasis or bronchial wall thickening	0.61
Ground glass opacity	0.57
Atelectasis or scarring	0.56
Tree-in-bud nodularity	0.48

n = 18

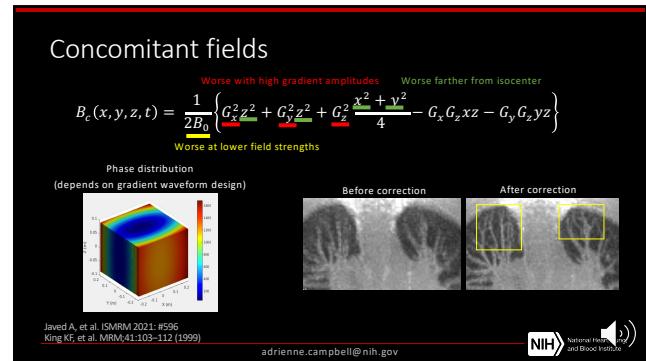
0.55T MRI CT
1.1mm x 1.1 mm x 6mm 0.8 mm x 0.8 mm x 2mm

Campbell-Washburn AE, et al. Radiology; Cardithoracic Imaging (in Press).
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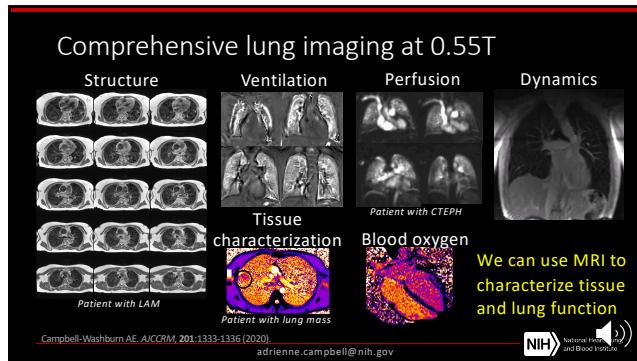
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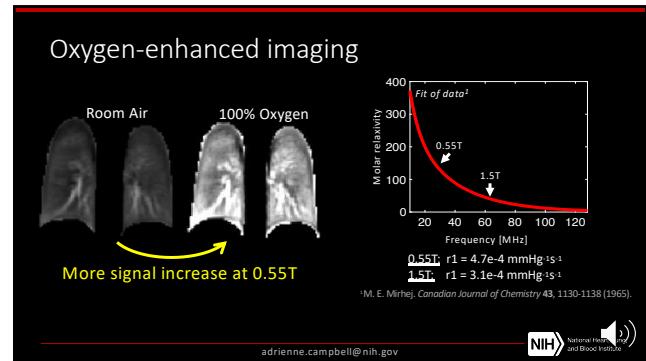
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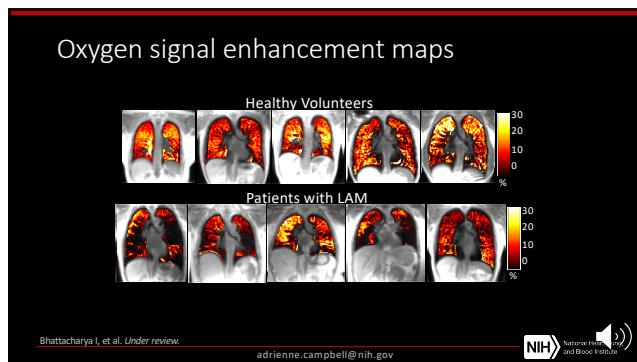
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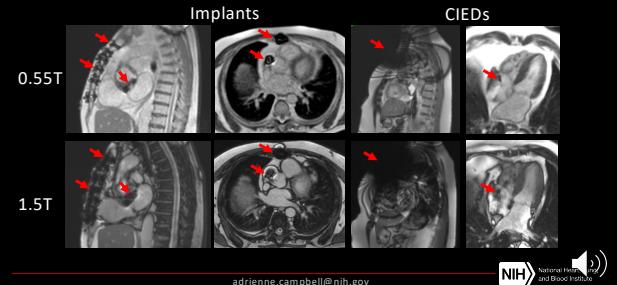
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Pacemakers + other implants are inherently safer



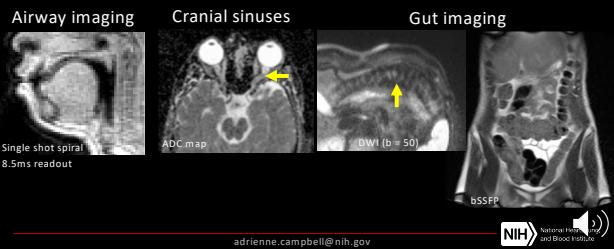
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Metallic device artifacts



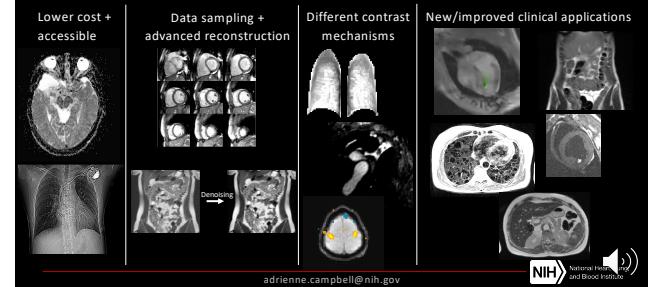
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Imaging high susceptibility regions



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Summary: High-performance low field MRI



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Acknowledgements

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