

Supine Breast MRI with 60-channel Breast Coil

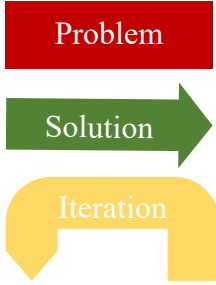
Jessica A McKay-Nault, Ph.D.



Stanford Cancer Imaging Training (SCIT) Seminar / RSL Weekly Seminar

Mentored by **Drs. Brian Hargreaves** and **Bruce Daniel**

October 6th, 2021



Breast cancer will kill about 43,600 women in the US in 2021 [American Cancer Society]

MRI screening to detect and treat cancer early

MRI screening is expensive and uses contrast agent (safety?)

Use DWI to detect cancer

DWI is SNR starved

DWI suffers from distortion

Increase averages

Use a coil with better SNR

Use parallel imaging and/or Multishot

Time consuming

Prone imaging:
- uncomfortable
- does not associate with geometry of surgery and other imaging

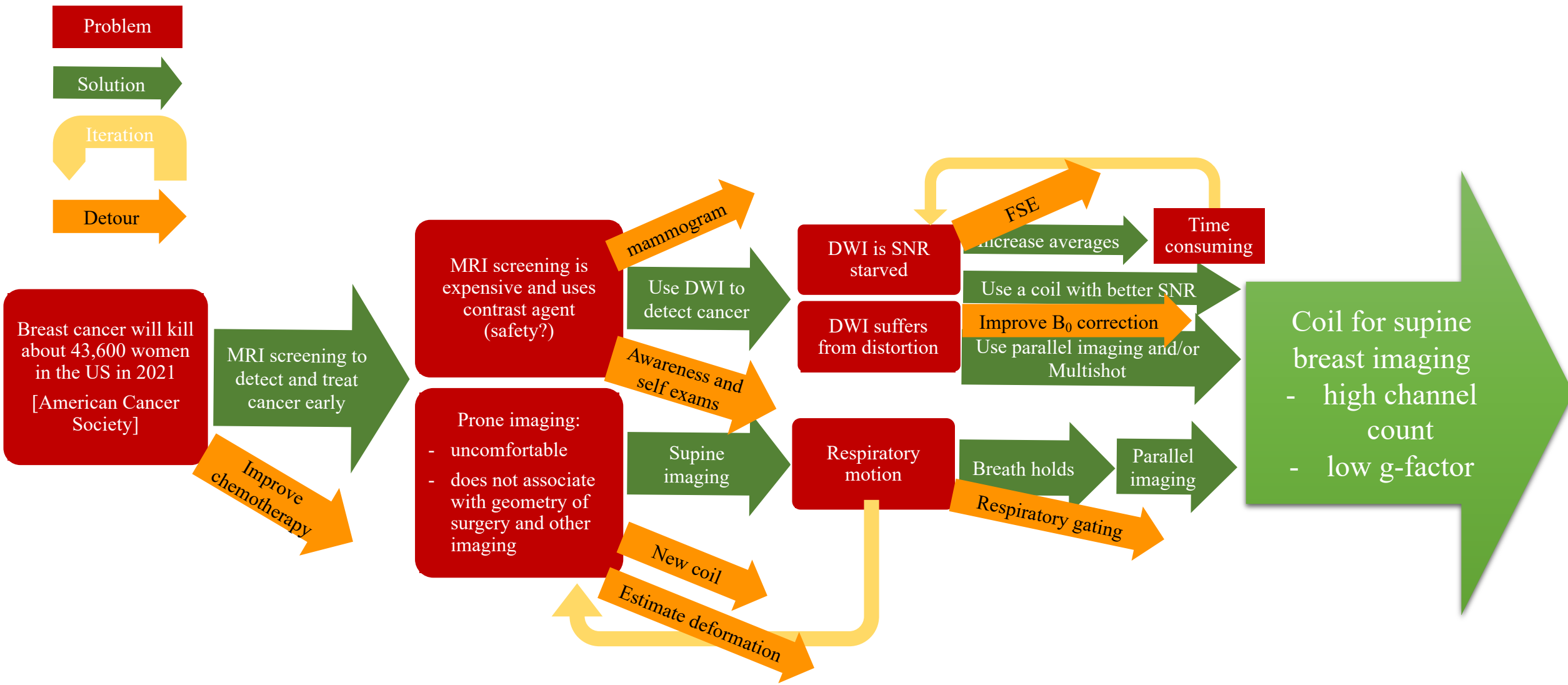
Supine imaging

Respiratory motion

Breath holds

Parallel imaging

Coil for supine breast imaging
- high channel count
- low g-factor



Problem

Solution

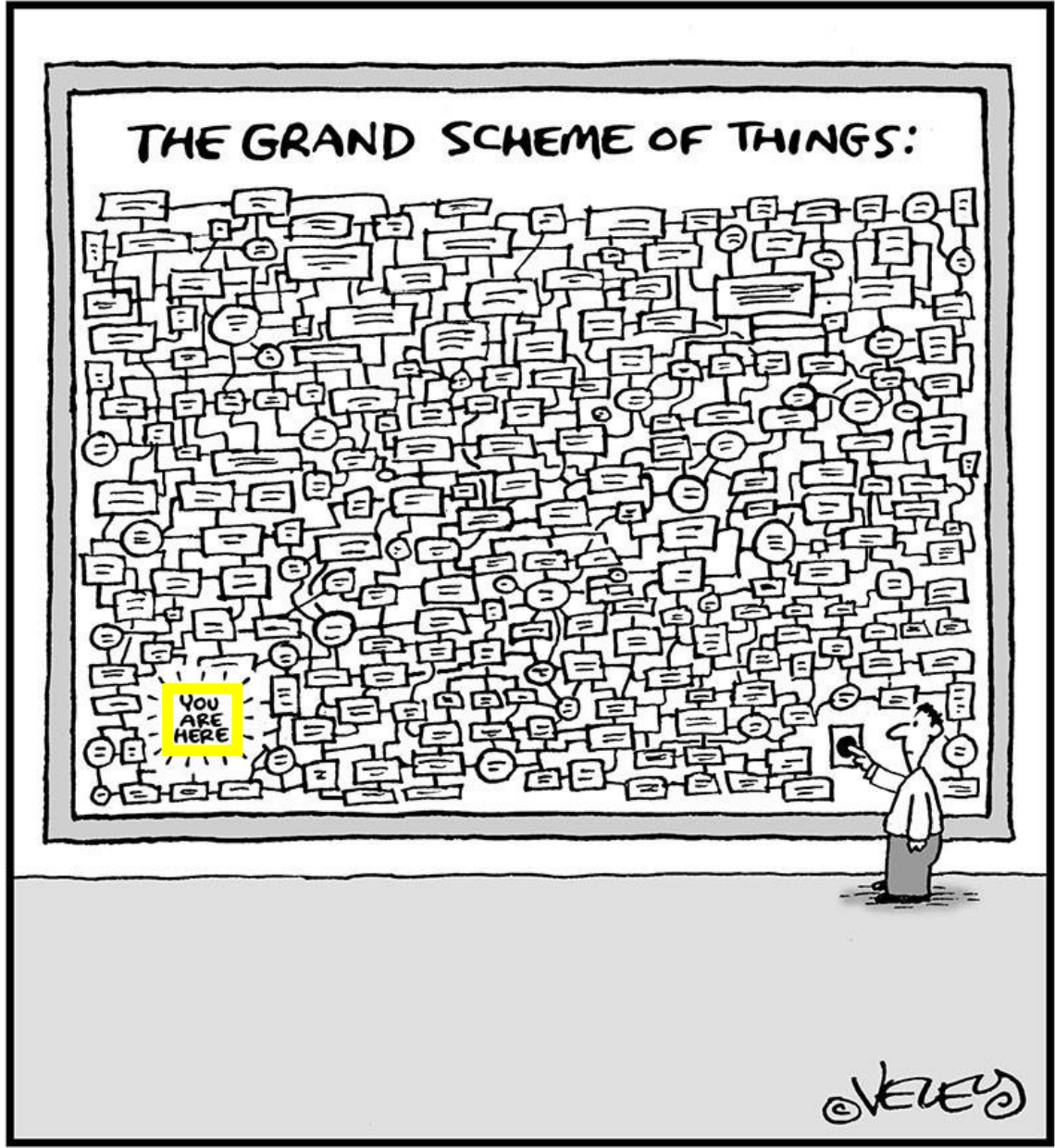
Iteration

Detour

Breast cancer will kill about 43,600 women in the US in 2021 [American Cancer Society]

MRI screening to detect and treat cancer early

Improve chemotherapy



CARTOONSTOCK.COM

CARTOONCOLLECTIONS.COM

Iteration

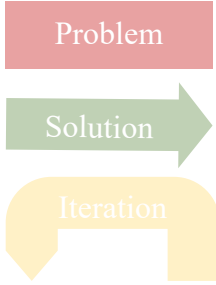
Time consuming

Higher SNR
Resolution
g and/or

Parallel imaging

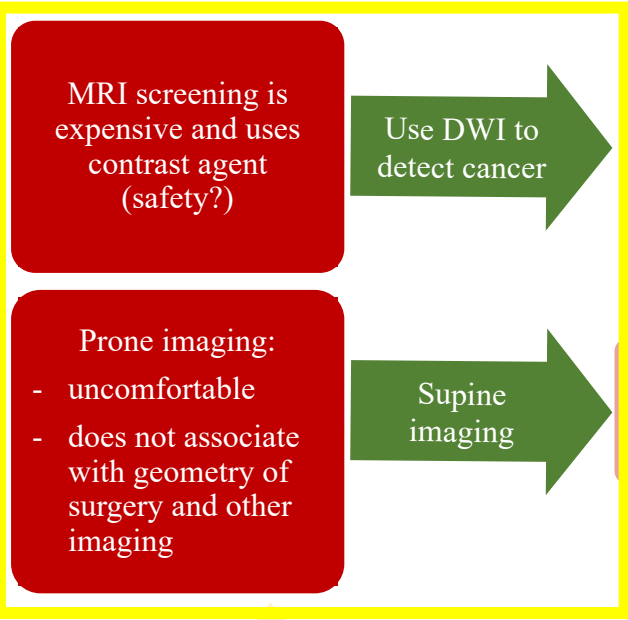
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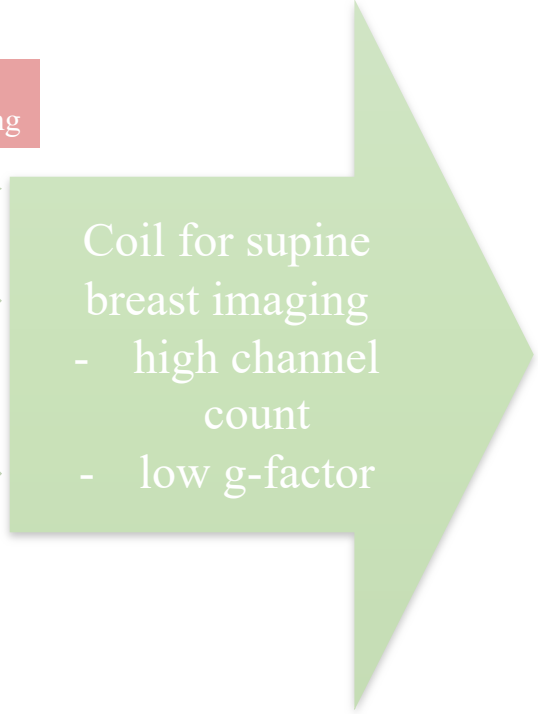
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Breath holds

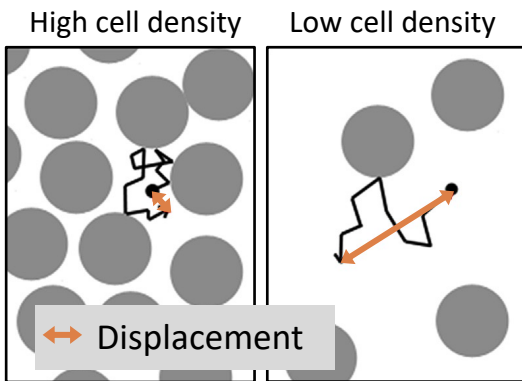
Parallel imaging

Time consuming

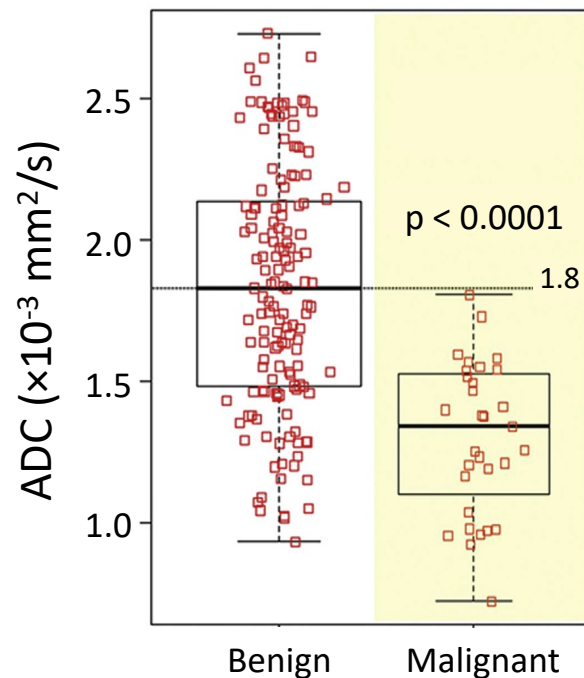


Breast DWI & ADC

ADC reflects cell density

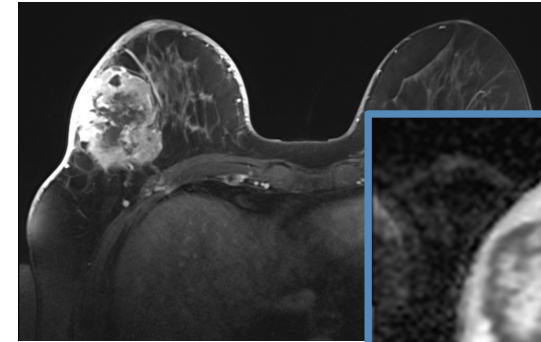


ADC reflects malignancy

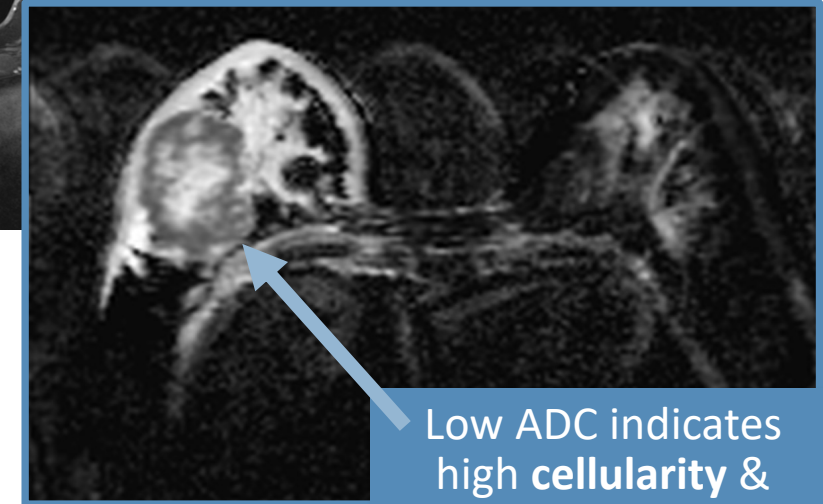


El Khouli, R.H. *et al.* (2010)

Post-contrast T₁-weighted



ADC map



Low ADC indicates high cellularity & malignancy

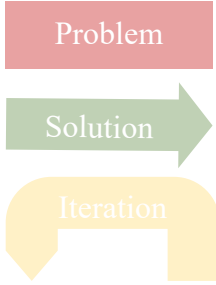
Clinical applications of DWI for breast cancer

- **Treatment monitoring:** Increasing ADC values indicate treatment response earlier than conventional measurements
- **Diagnosis and staging:** Increase specificity and reduce unnecessary biopsies??
- **Screening:** detection without contrast

Prone vs Supine Breast Imaging

- Breast MRI is typically acquired prone because of respiratory motion
- However...
 - Supine imaging has better correlation to surgery and other imaging modalities
 - Prone imaging is uncomfortable and awkward
 - Prone coils reduce the effective bore size
- Most supine MRI requires breath holds for high quality images
 - Therefore – **we need really really fast imaging!**





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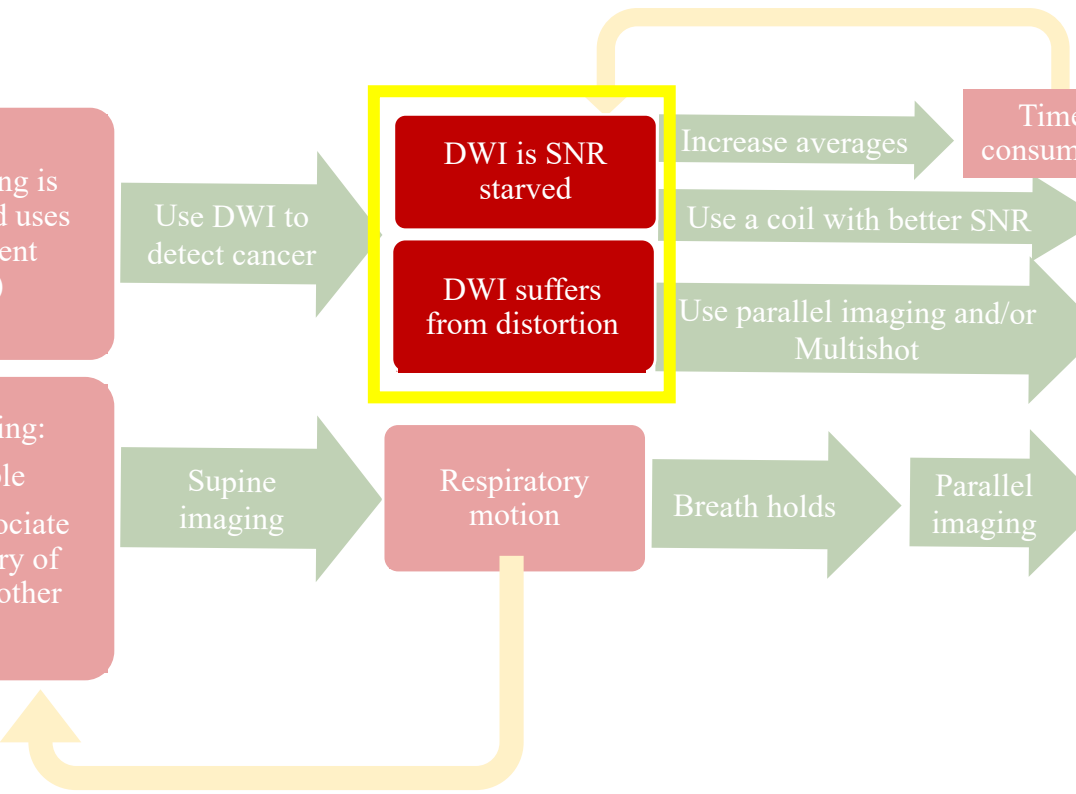
Use parallel imaging and/or Multishot

Breath holds

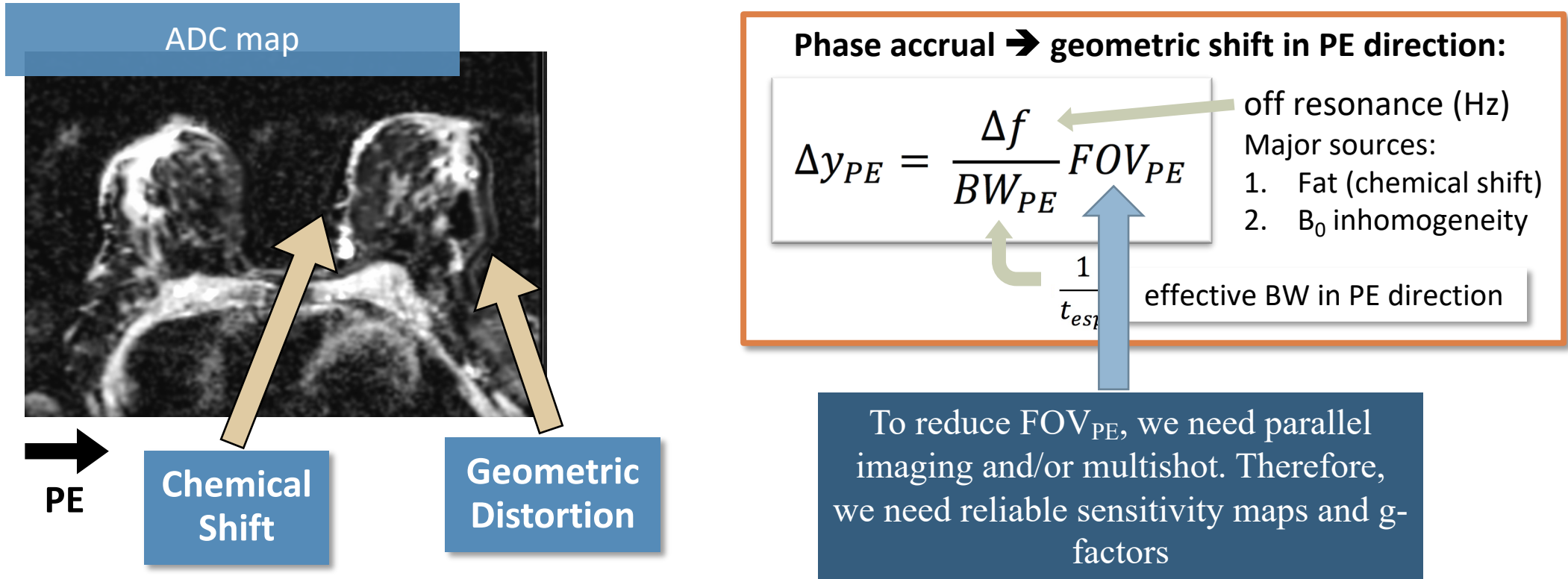
Parallel imaging

Time consuming

Coil for supine breast imaging
 - high channel count
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Challenges

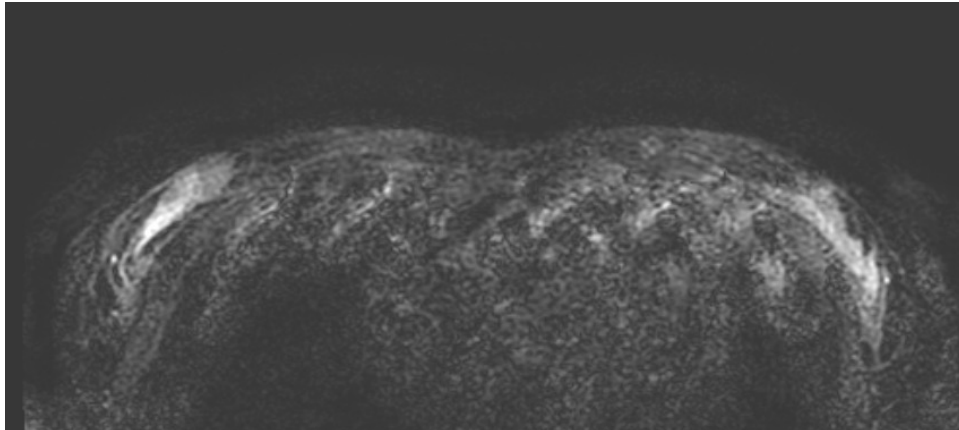


EPI is prone to *Distortion*

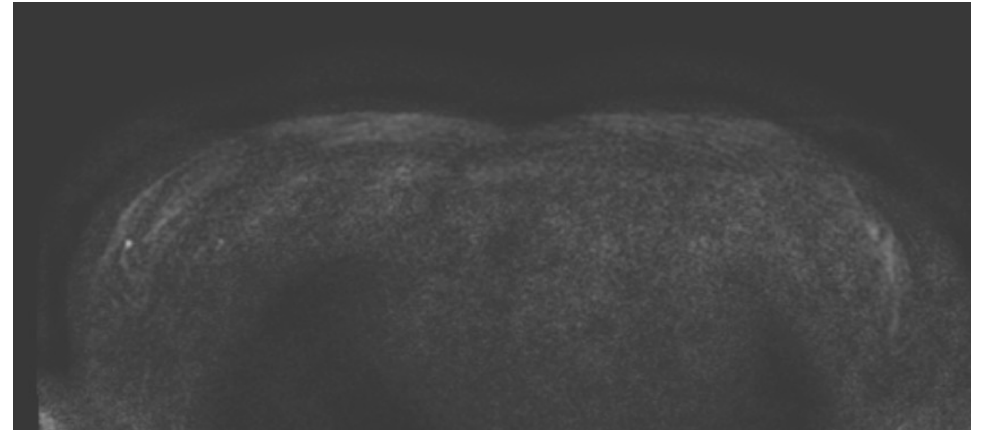
Especially in breast where ΔB_0 can be large.

Challenges

$b = 0 \text{ s/mm}^2$, 1 NEX



$b = 800 \text{ s/mm}^2$, 4 NEX



MUSE, 2-shot, Air coil with $R = 5$, Breath hold: 24 second
30 slices, 1.1 mm x 1.4 mm x 5 mm

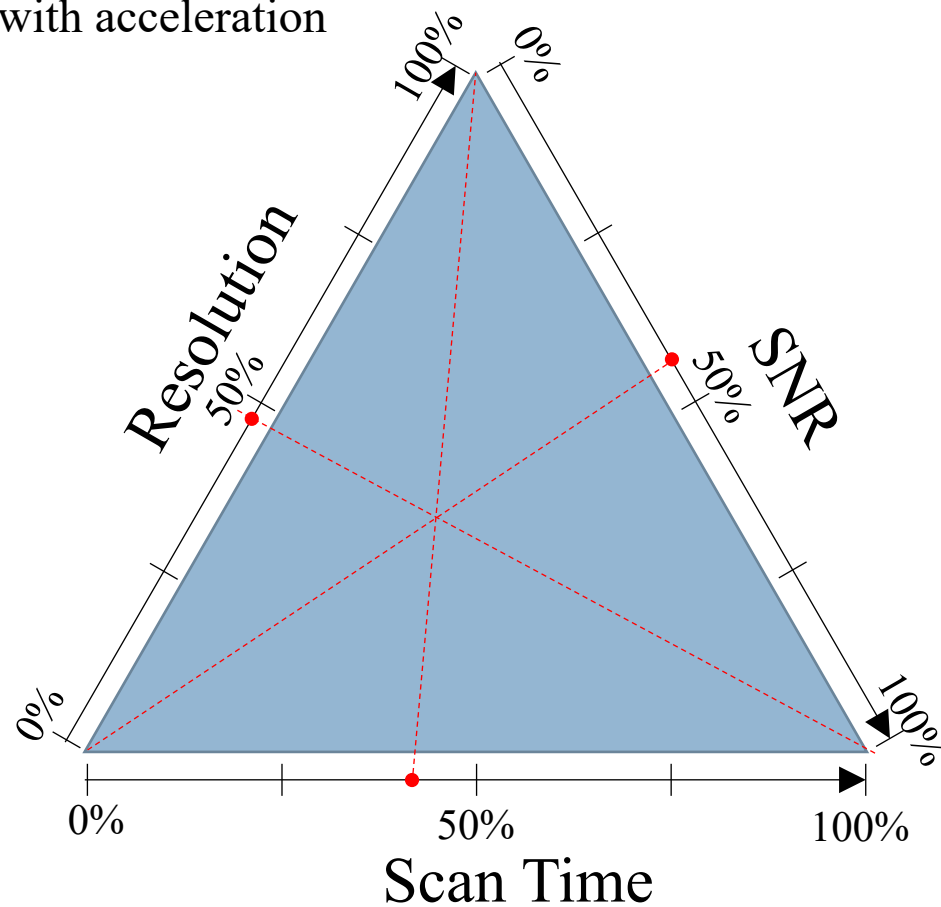
DWI is SNR starved!

Especially at high b-values

$$SNR \propto \sqrt{N_{ave} N_{PE} T_{read}} * \delta_x \delta_y \delta_z * M(\rho, T_1, T_2, B_0, \dots)$$

Scan time
Voxel size
Magnetization

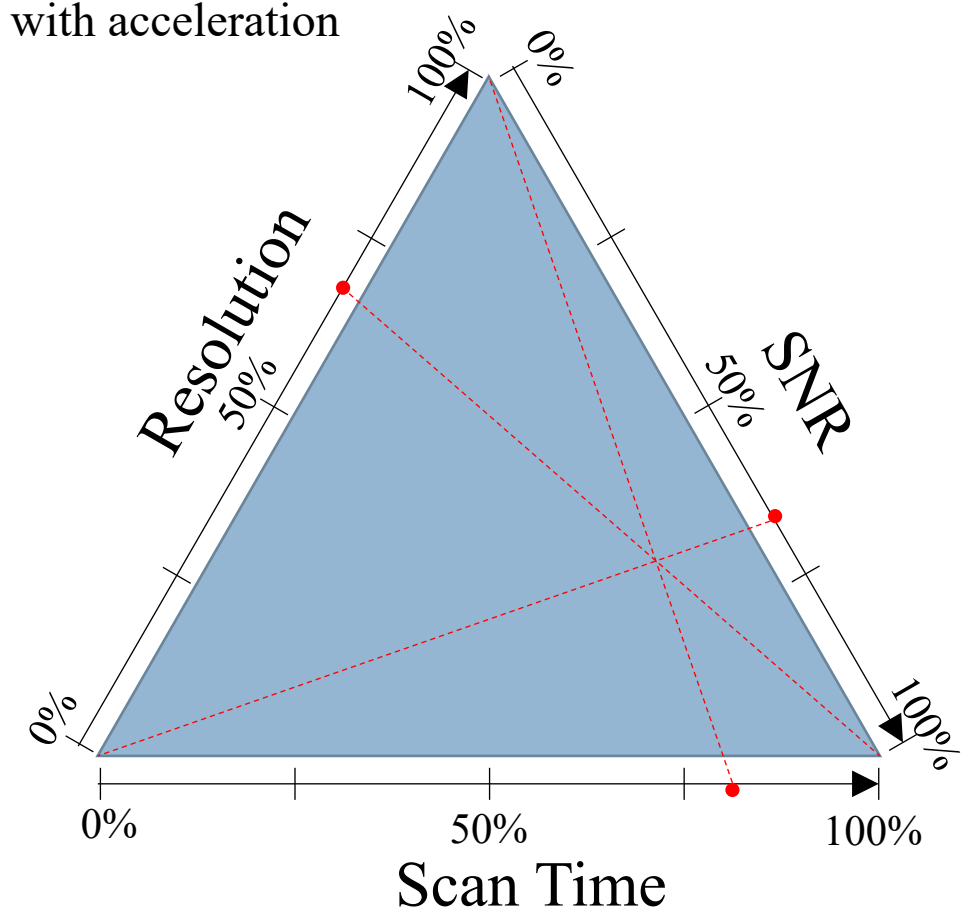
$N_{PE} * R$
with acceleration



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Scan time
Voxel size
Magnetization

$N_{PE} * R$
with acceleration



Diffusion:
 $S(b) = S_0 e^{-b * ADC}$

$$S(b) = S_0 e^{-b*ADC}$$

Current b-value: $b_c = 600 \text{ s/mm}^2$

Desired b-value: $b_d = 800 \text{ s/mm}^2$

Assume a lesion: $ADC \approx 1.0 \times 10^{-3}$

Same averaging

$$S_D = S_0 e^{-800*0.001}$$

$$S_C = S_0 e^{-600*0.001}$$

$$\frac{S_D}{S_C} = 0.82$$

Lose 20% SNR

Same SNR

$$S_D \sqrt{N_D} = S_C \sqrt{N_C}$$

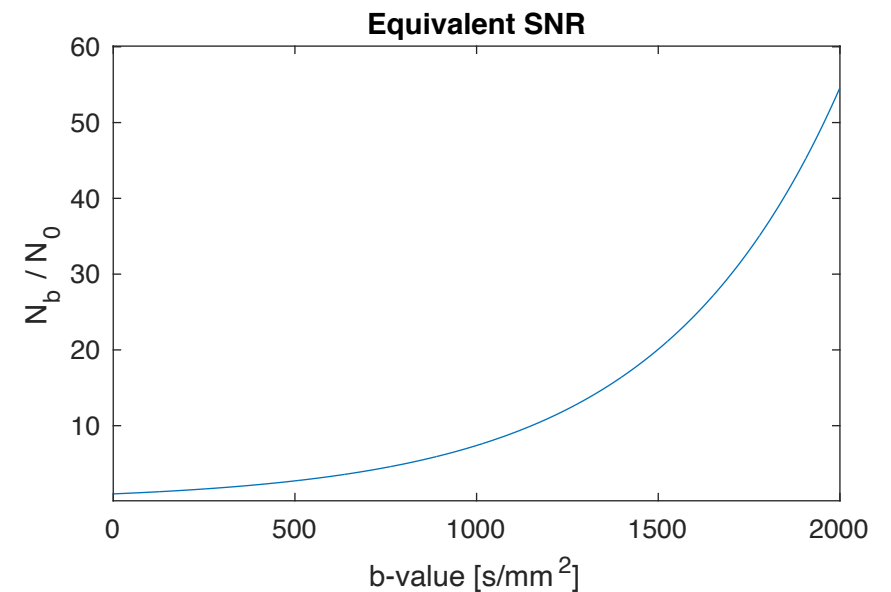
$$S_0 e^{-800*0.001} \sqrt{N_D} = S_0 e^{-600*0.001} \sqrt{N_C}$$

$$\frac{\sqrt{N_D}}{\sqrt{N_C}} = 1.22$$

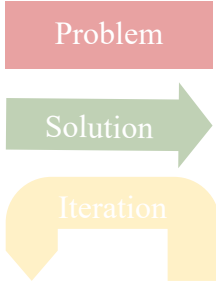
$$\frac{N_D}{N_C} = 1.5$$

Need 1.5x Averages

For $ADC = 1.0 \times 10^{-3} \text{ mm}^2/\text{s}$



$$\frac{N_b}{N_0} = (e^{b*ADC})^2$$



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Increase averages

Use a coil with better SNR

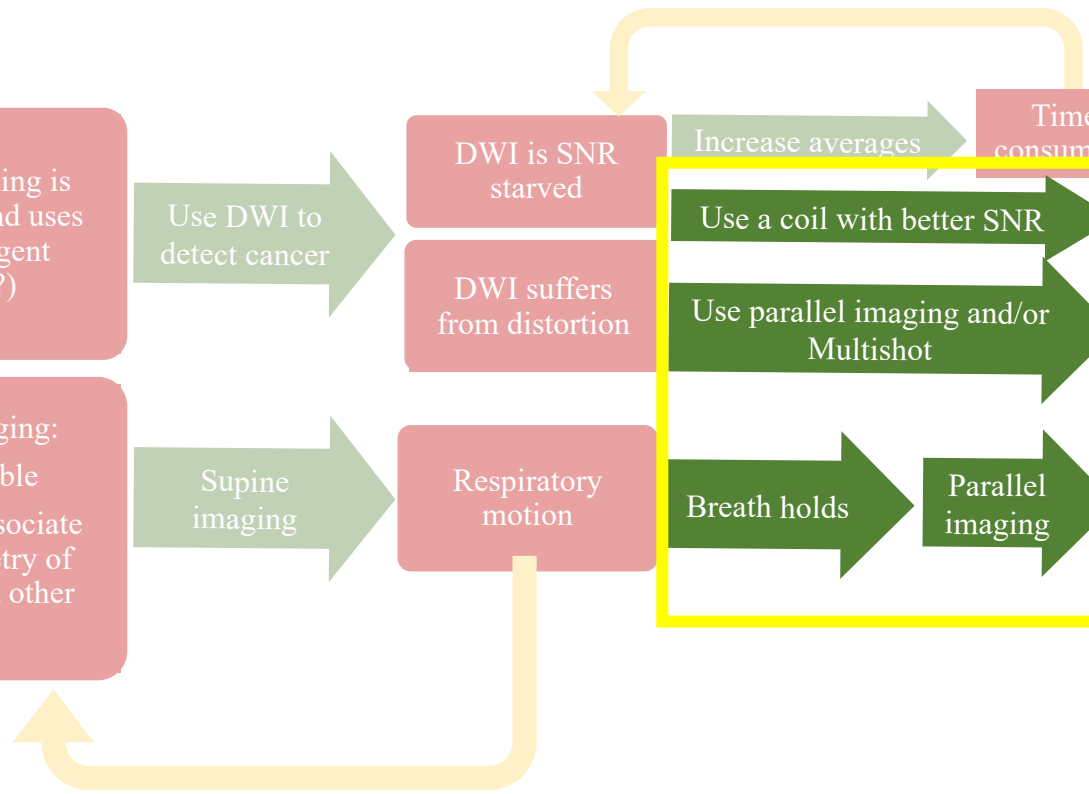
Use parallel imaging and/or Multishot

Breath holds

Parallel imaging

Time consuming

Coil for supine breast imaging
 - high channel count
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Motivation for a new coil

The standard breast coil



Problems:

- Only prone imaging

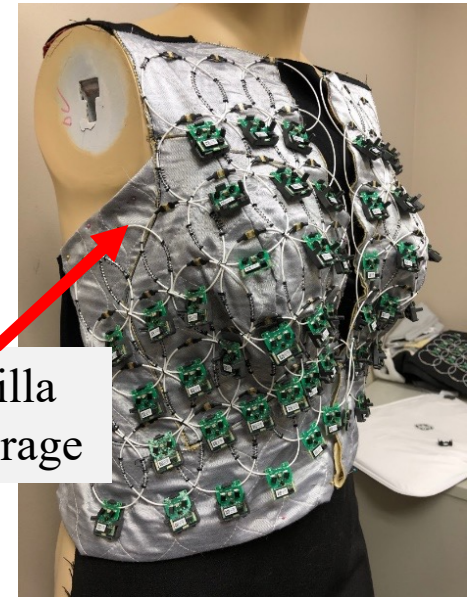
An option for supine imaging



Problems:

- Low channel count in breast region
- Axilla coverage?

60-channel breast coil



Axilla coverage

High SNR:

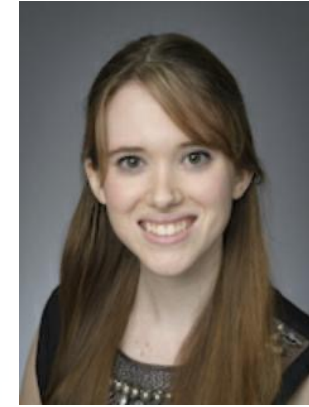
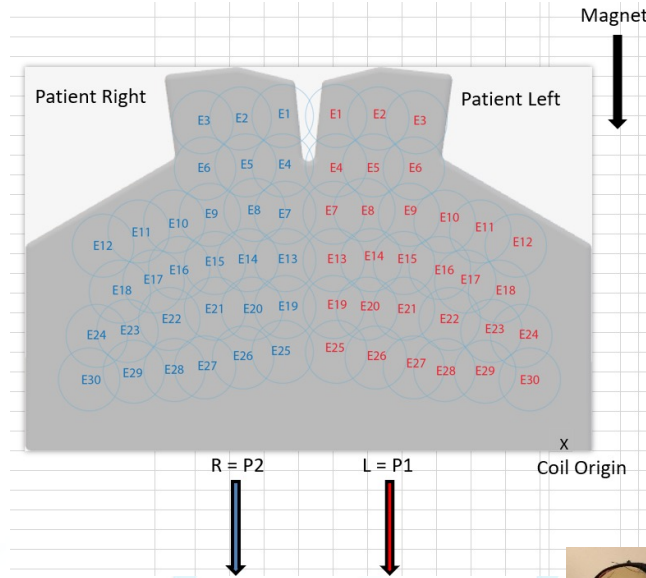
- Follows body contour, especially for larger breast size, for close proximity to breast
- High channel count



60-Channel Supine Breast Coil

Features:

- 60 elements (30 per half), 7-cm loops
- Heavily overlapped
- Coverage of chest wall and axilla
- Contoured design, up to 40DD
- Can accelerate up to 6x
- Positioning: Supine or Prone (with support)
- Separable halves



Jana Vincent



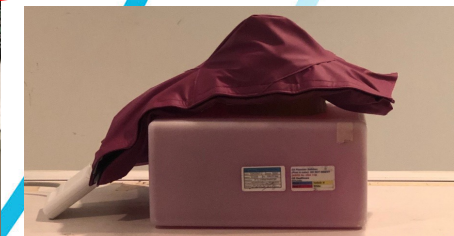
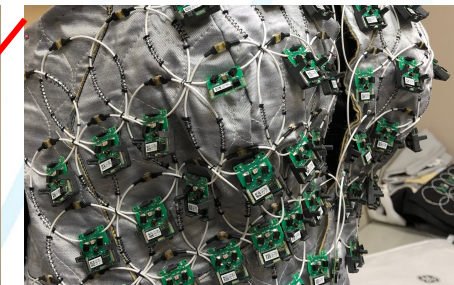
Fraser Robb

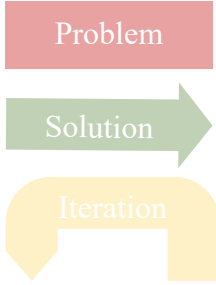


Front



Back





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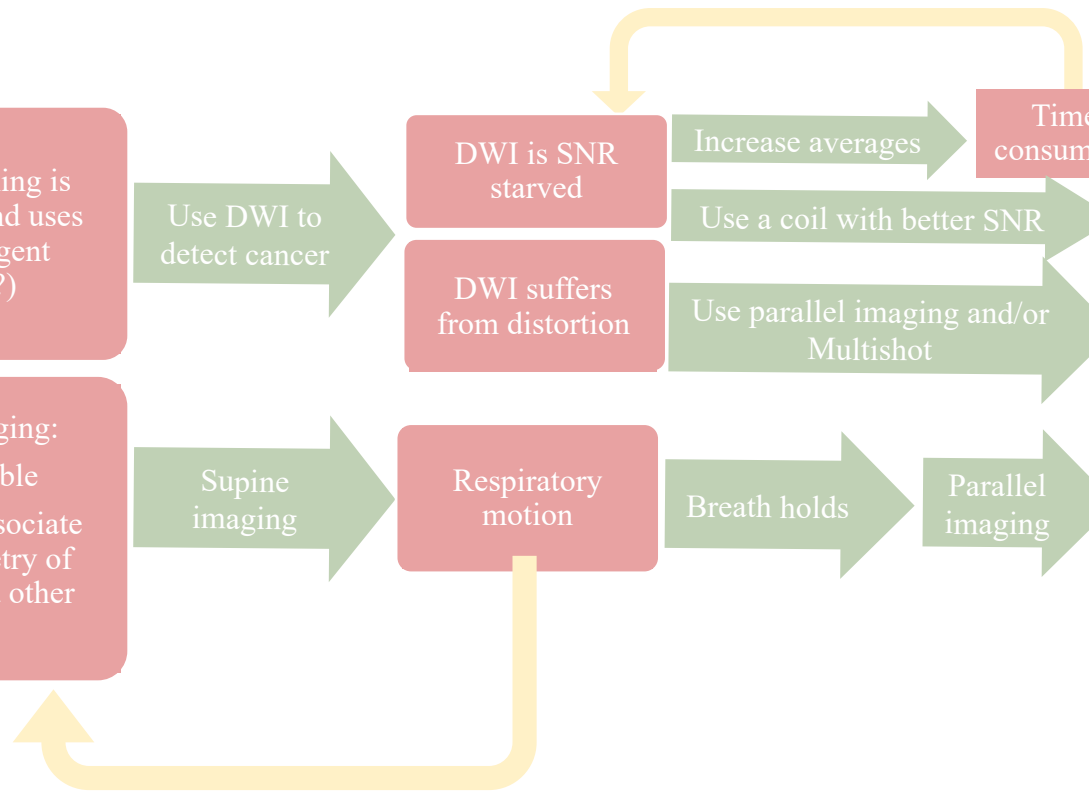
Breath holds

Parallel imaging

Time consuming

Coil for supine breast imaging
 - high channel count
 - low g-factor

Assess



Preliminary Results • Compare 60-channel breast prototype coil with 30-channel air coil

Methods

- Phantom
- Fully sampled
- retrospective
- Pseudo
- N = 100
- Used ES
- (BART)

$$SNR_{Red} = \frac{SNR_{full}}{g\sqrt{R}}$$

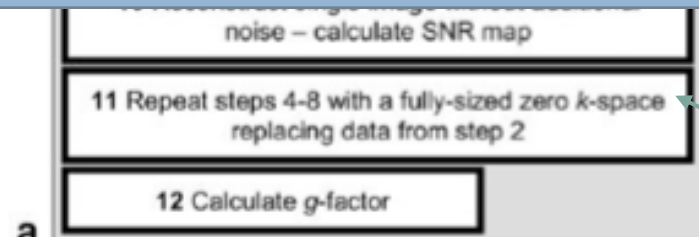
Under-sampled

The geometry factor describes the ability with the used coil configuration to separate pixels superimposed by aliasing. In practice it allows a priori SNR estimates and provides an important criterion for the design of dedicated coil arrays.

Pruessmann

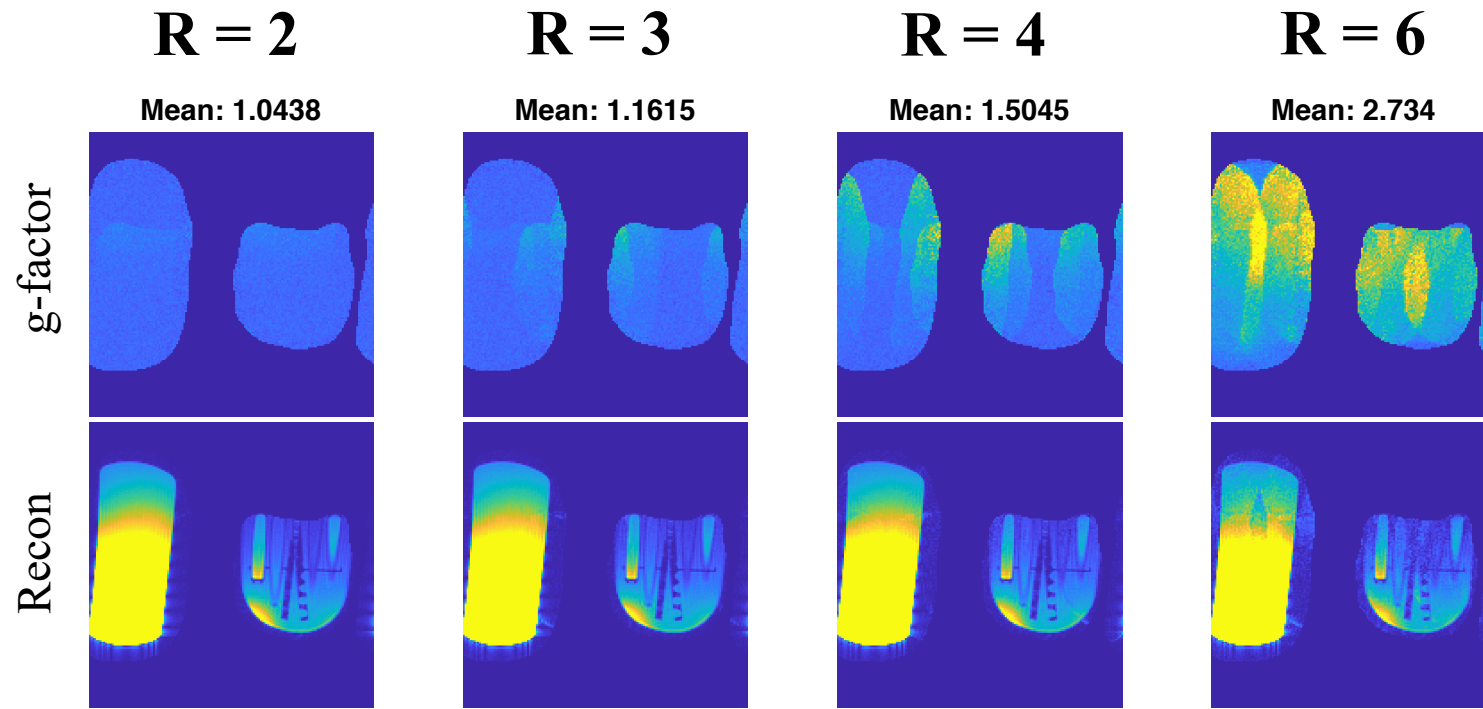


Acknowledgement:
Jeremiah Hess

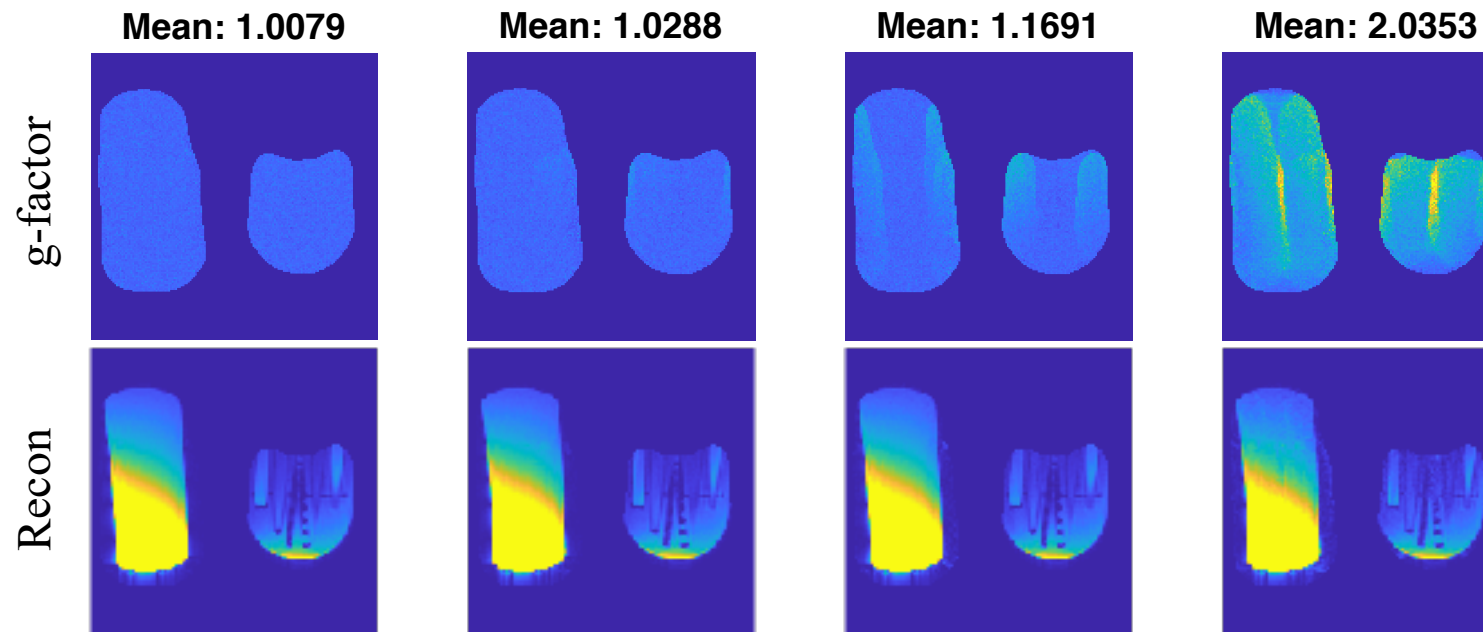


Fully-sampled

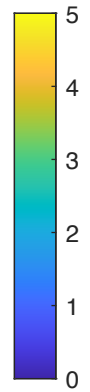
Air Coil



60-channel coil

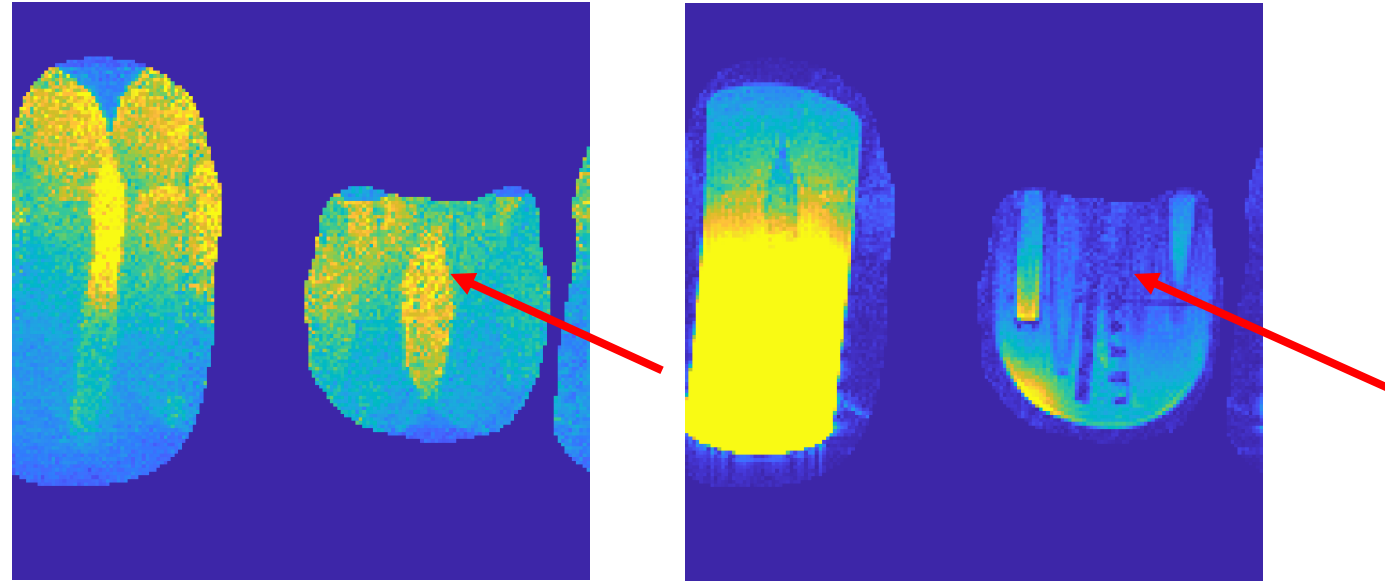


g-factor



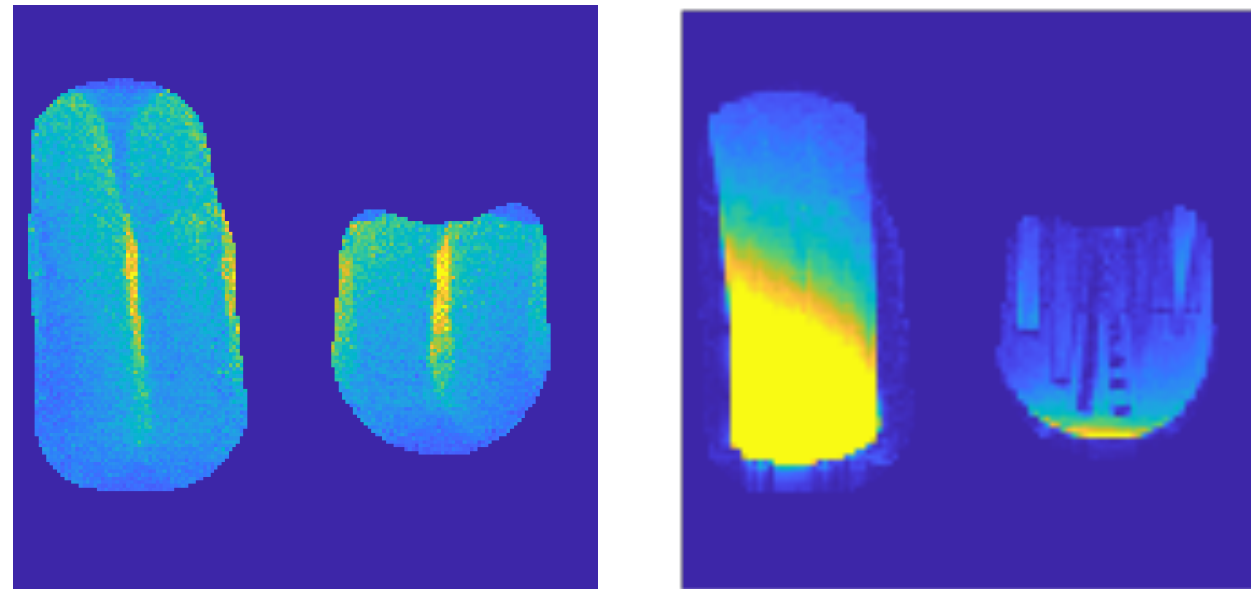
Mean: 2.734

Air Coil

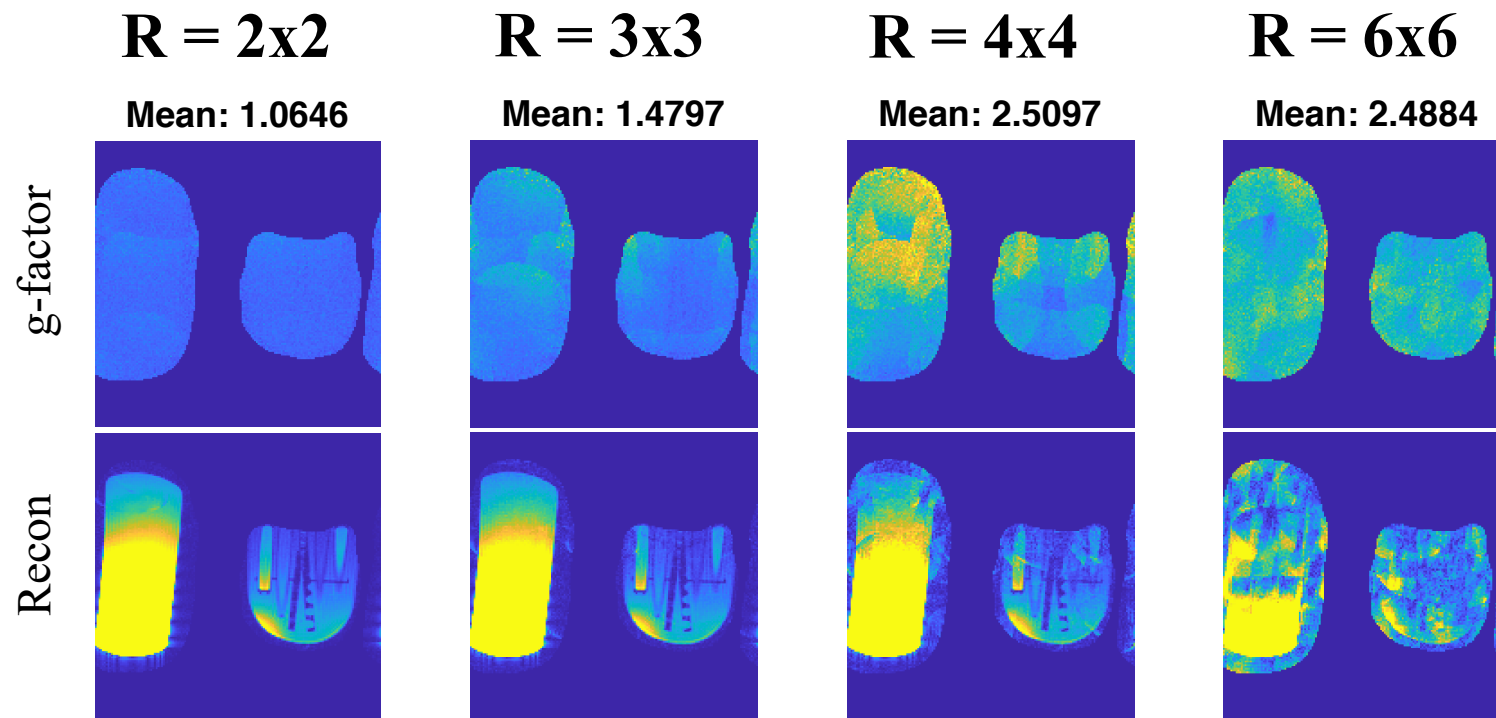


Mean: 2.0353

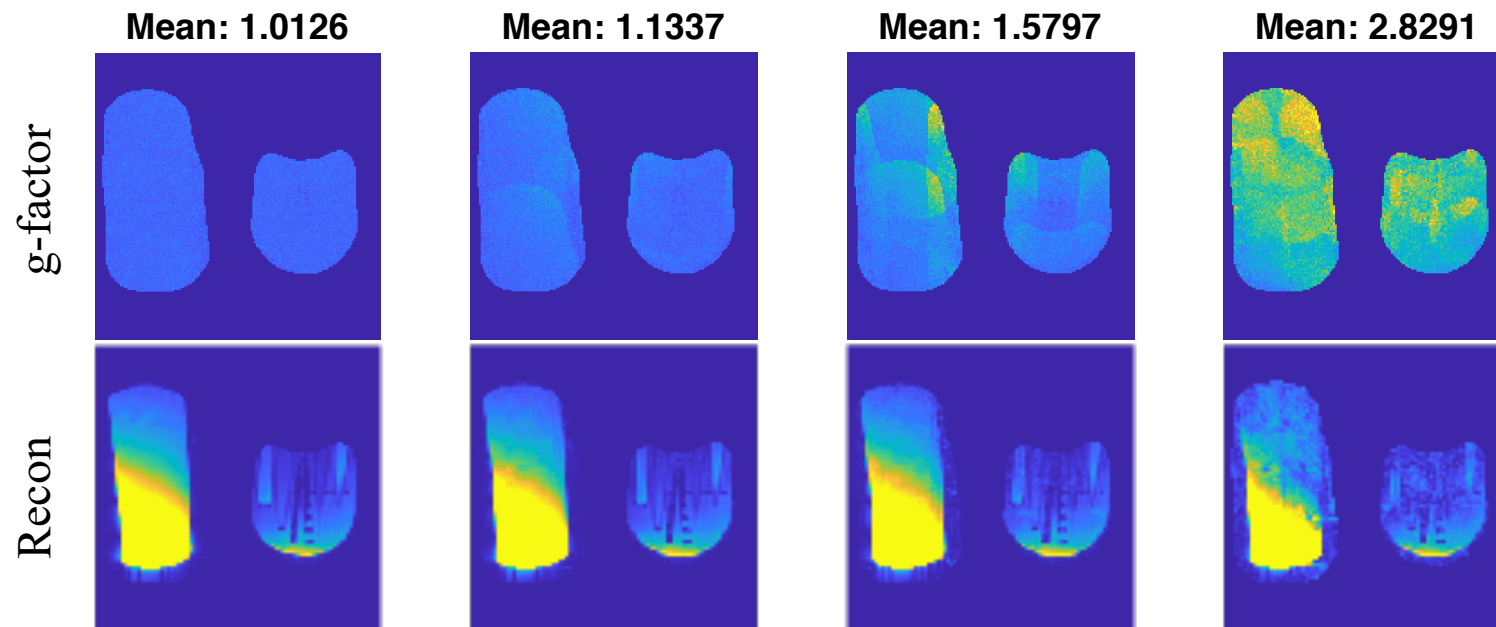
60-channel coil



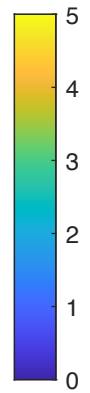
Air Coil



60-channel coil



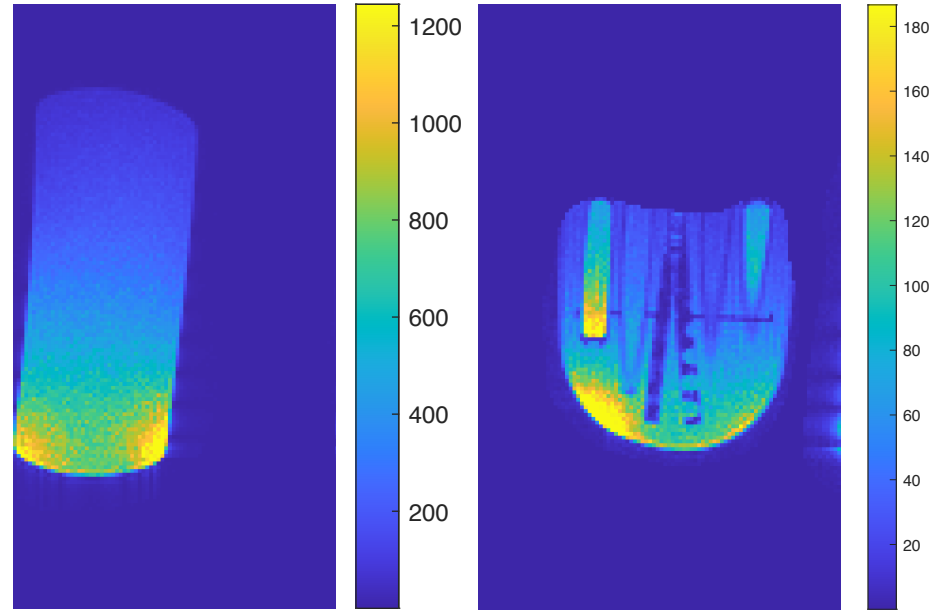
g-factor



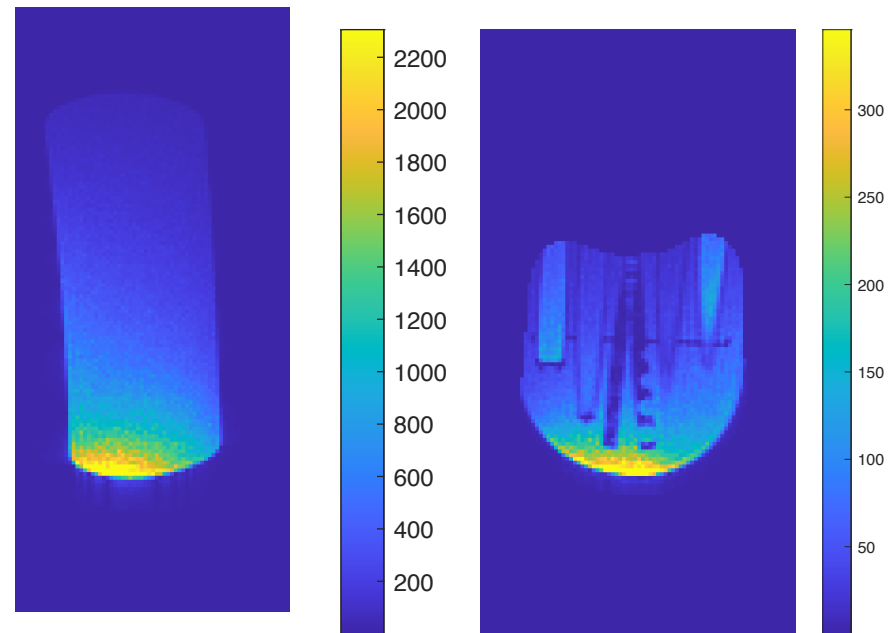
SNR

- Units??

Air Coil

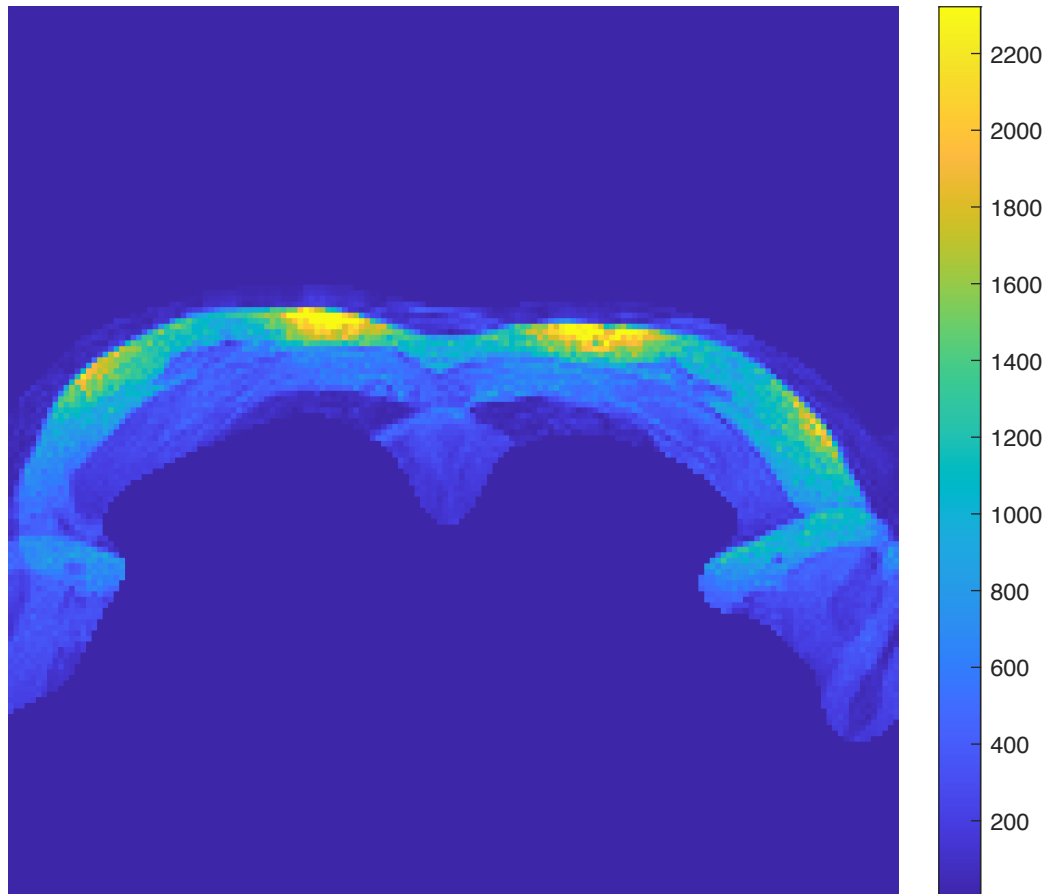


60-channel coil

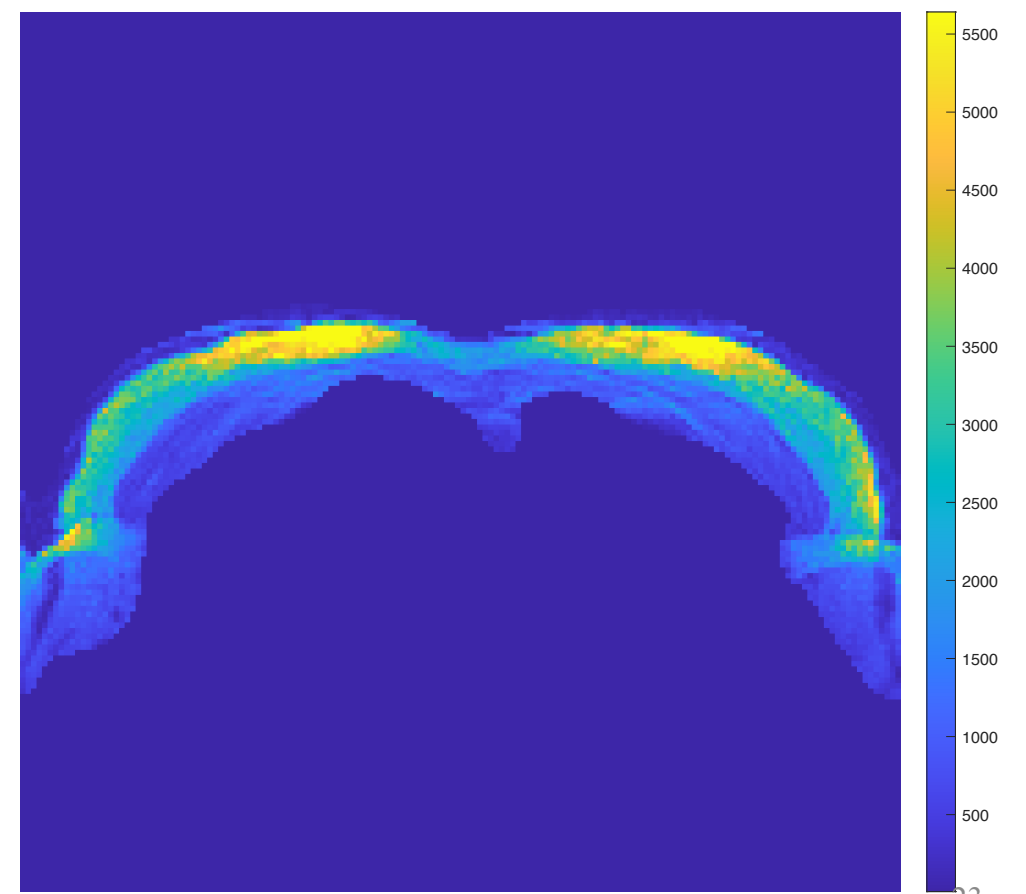


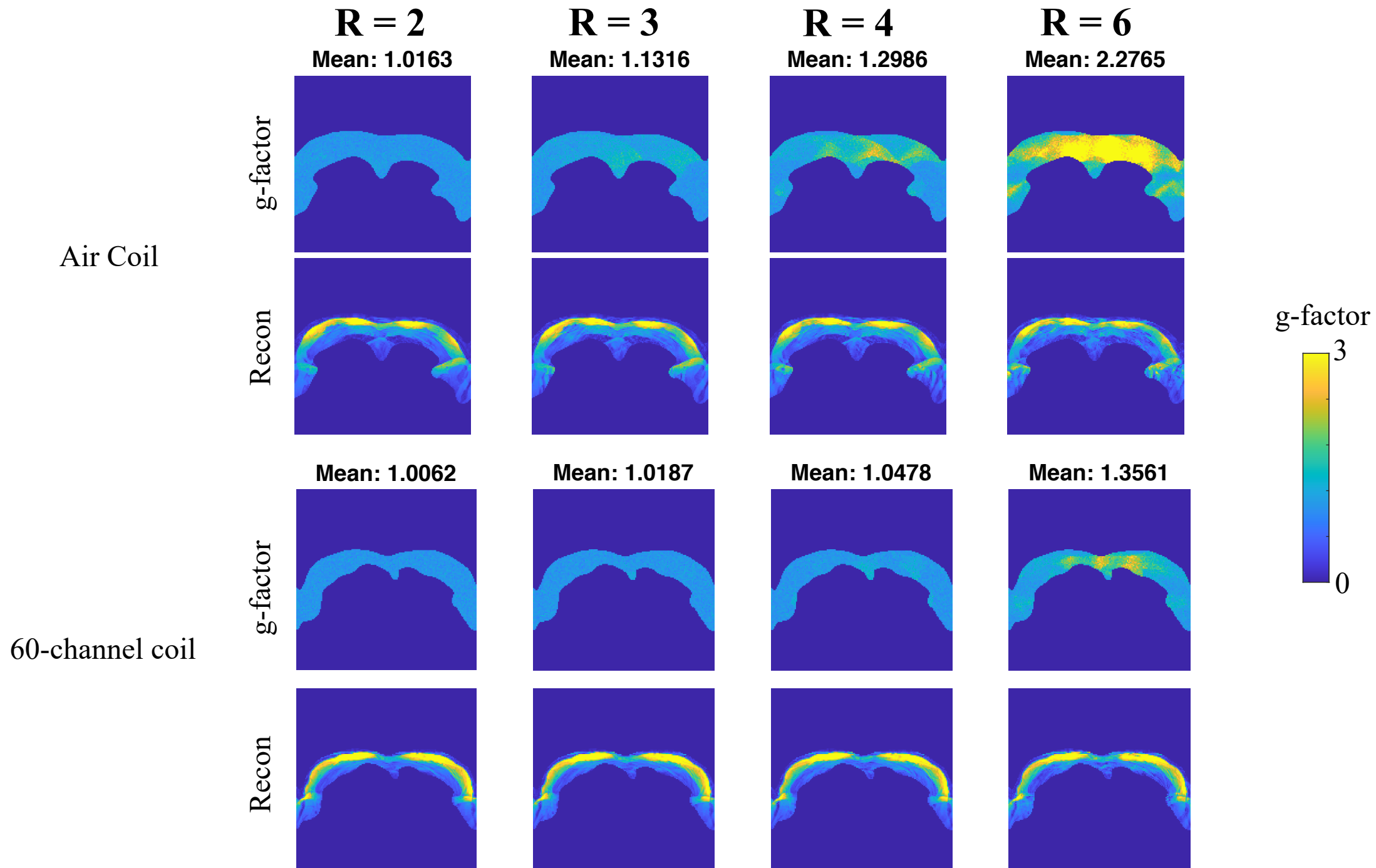
SNR maps

Air coil

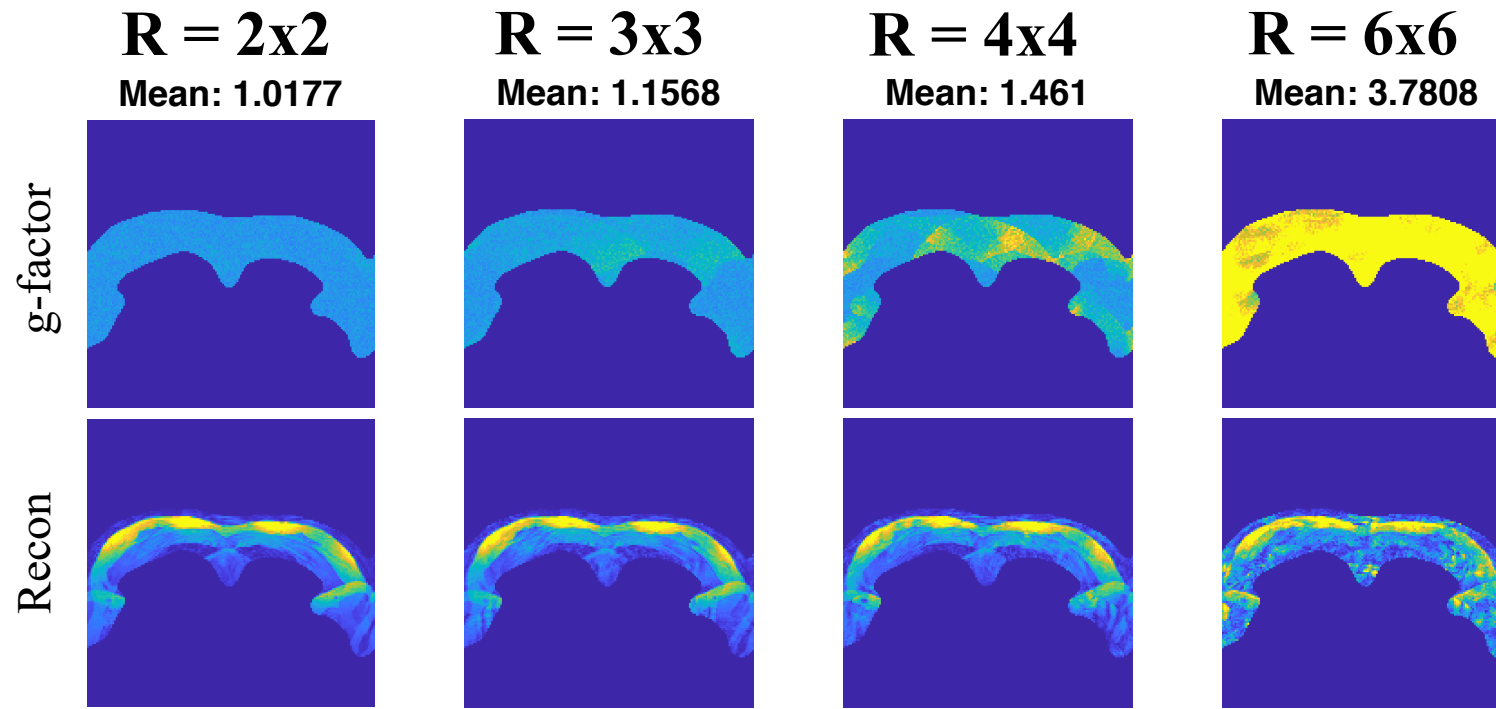


60-channel breast coil

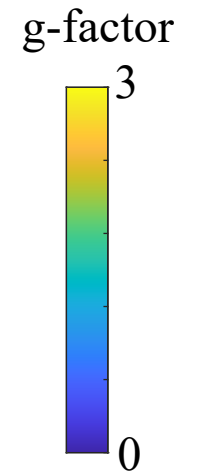
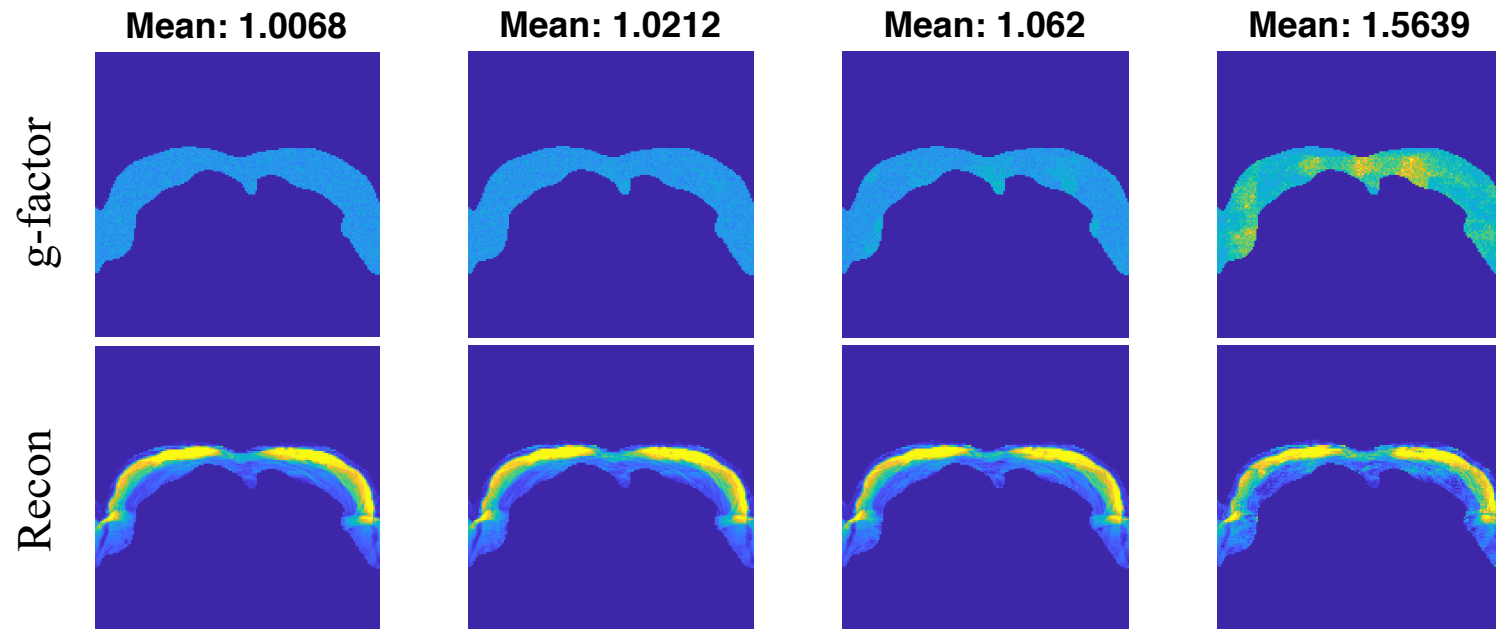




Air Coil



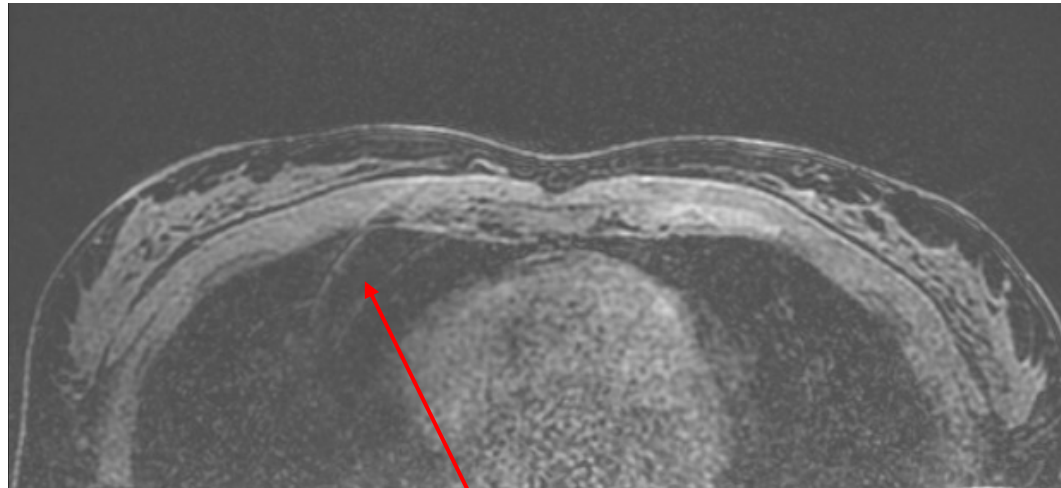
60-channel coil



DISCO Pre-Contrast

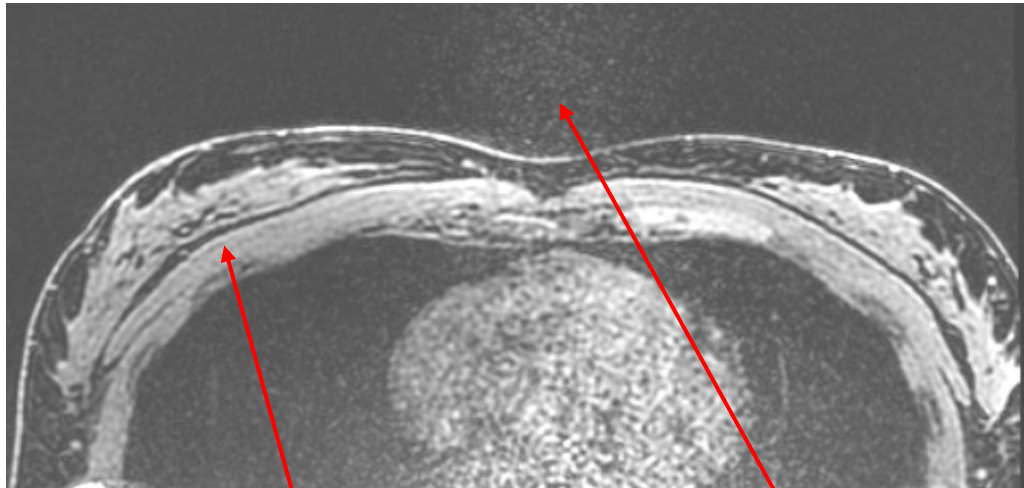
1.2 mm x 1.2 mm x 1 mm, Acceleration: 4 x 3, 17 sec breath hold

Air coil



Aliasing artifact

60-channel breast coil



High SNR

Spatially varying noise

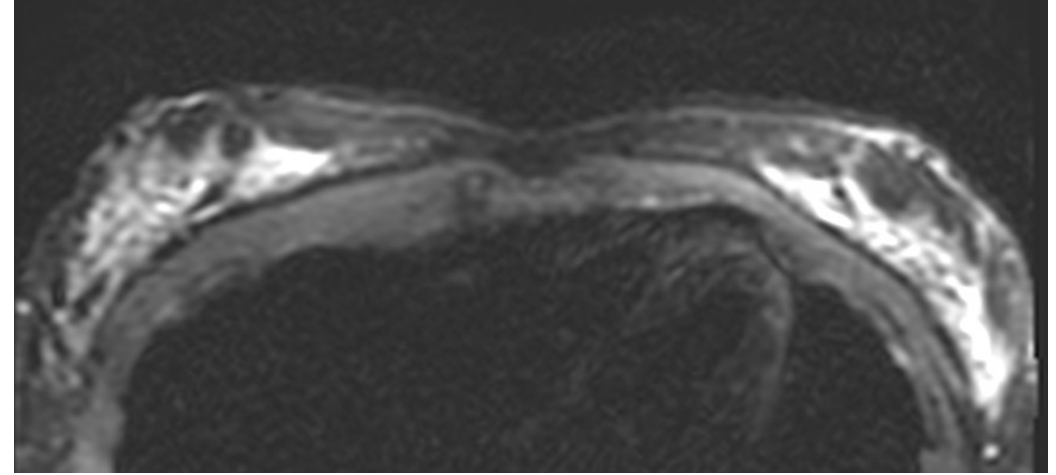
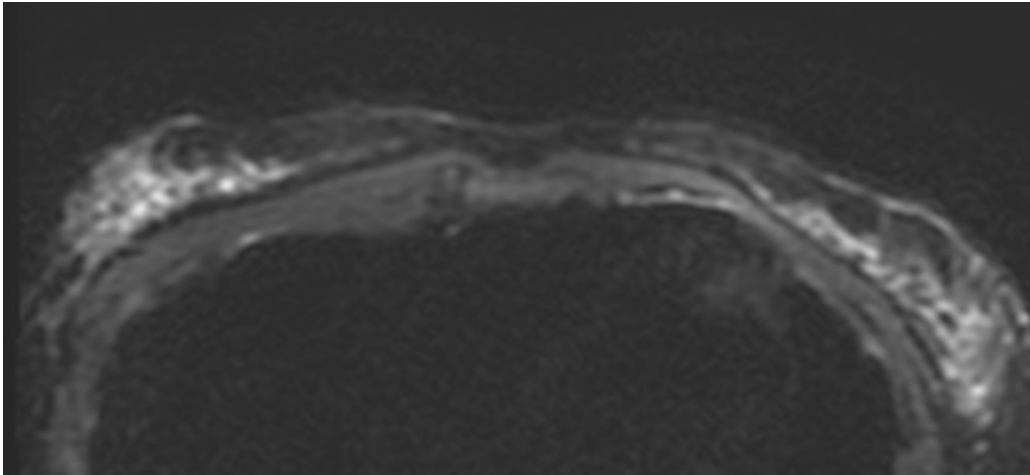
Goal: High spatial and temporal resolution to characterize the contrast uptake of the tumor.

Single Shot DWI

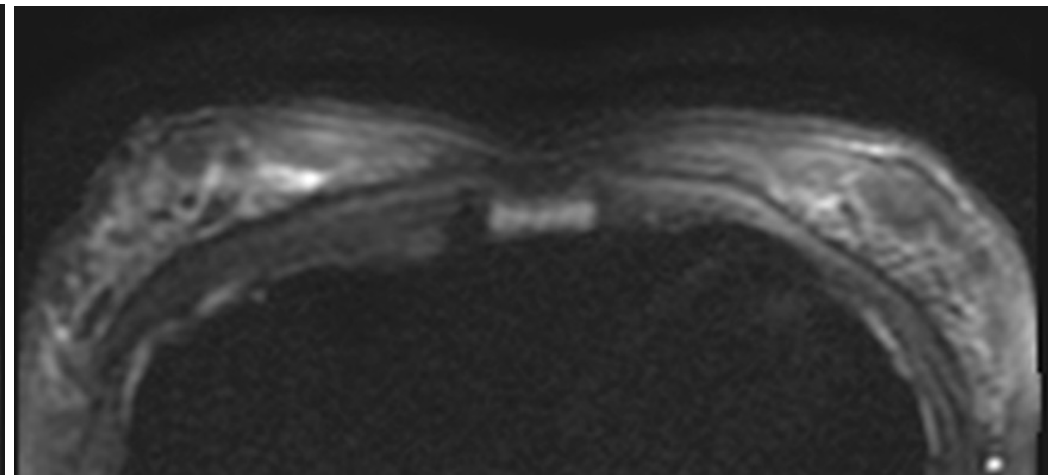
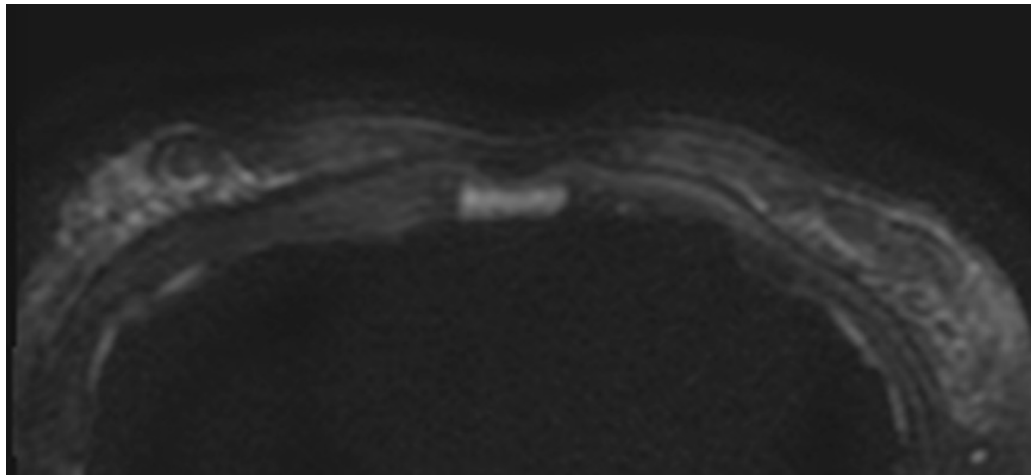
Air coil

60-channel breast coil

$b = 50$



$b = 800$



Discussion

- Challenges:
 - Difficult to compare SNR and g-factor maps with the standard breast coil (prone)
 - Would like to compare with InkSpace 24-channel pediatric coil
 - Not included here because it can only be used at 3T3
 - How to compare coils not scanners?
 - ESPIRiT – very sensitive to threshold in phantom case
 - Size of the data!!

Future Work

- Assess in the context of DWI
 - Breath hold or respiratory gated
 - High PI / N_{shots} to reduce distortion
- Push PI of DISCO protocol and explore spatial/temporal resolution tradeoff for characterizing breast cancer
- Possibly assess the coil in prone position
- Compare the coils in patients

Thank you!



...and others!