Evaluating a Novel Supine Breast Coil for Improved SNR

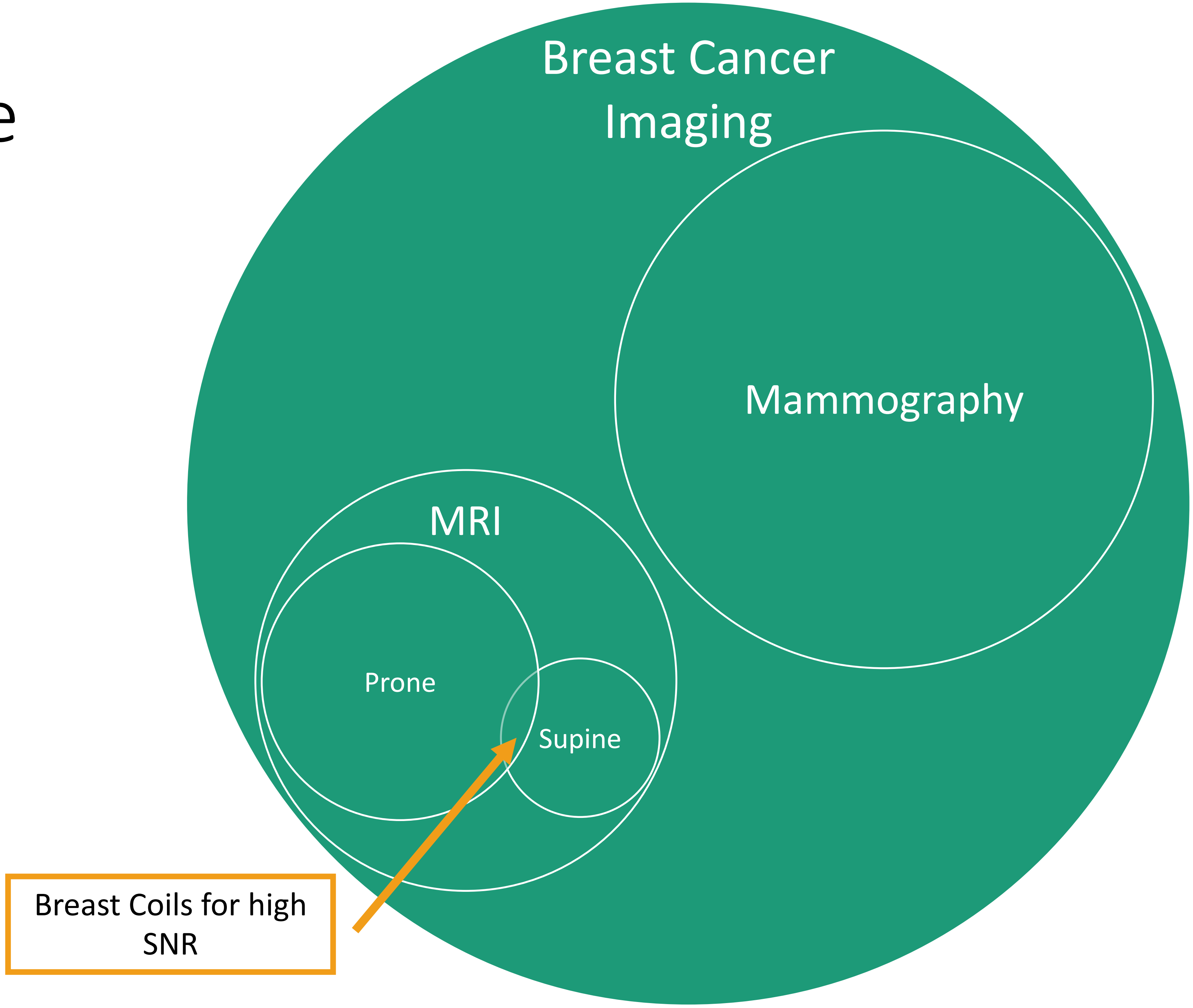
RSL/SCIT Seminar

July 6th, 2022

Jessica McKay-Nault

Advised by Dr. Brian Hargreaves and Dr. Bruce Daniel

Outline


Breast Cancer Imaging
Mammography
MRI
Prone
Supine
Breast Coils for high SNR

How have you been personally affected by Breast Cancer?

Breast cancer was expected to kill about 43,600 women in the US in 2021

[American Cancer Society]

How have you been personally affected by Breast Cancer?

None - I prefer not to answer

Fist - I don't know anyone affected by breast cancer

1 - Someone close to me has been diagnosed

2 - I personally know of at least one person who has been diagnosed

3 - I personally know of several people who have been diagnosed

4 - I personally know of many people who have been diagnosed

My history

My mom was diagnosed with breast cancer at age 42 → According to some guidelines, I am considered "high risk" and recommended to start **yearly mammogram and (contrast-enhanced) MRI** screening at age 30

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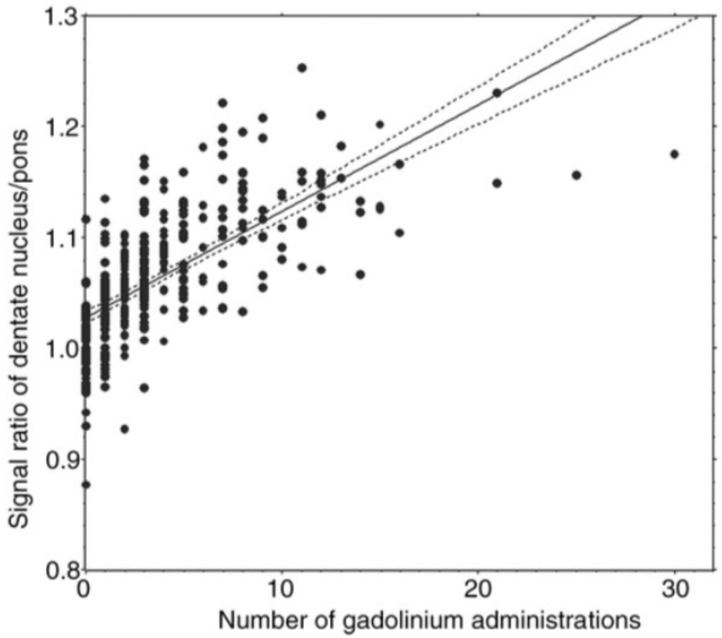
Original Research
Neuroradiology

High Signal Intensity in the Dentate Nucleus and Globus Pallidus on Unenhanced T1-weighted MR Images: Relationship with Increasing Cumulative Dose of a Gadolinium-based Contrast Material

Tomonori Kanda, Kazunari Ishii, Hiroki Kawaguchi, Kazuhiro Kitajima, Daisuke Takenaka

⌄ Author Affiliations

Published Online: Dec 7 2013 | https://doi.org/10.1148/radiol.13131669



https://pubs.rsna.org/doi/10.1148/radiol.13131669

MRI for Breast Cancer

- Currently requires contrast injection
- Used for staging disease, high-risk screening, and monitoring treatment response
- Typically acquired in the prone position, but recent work is developing supine breast imaging [Moran]
- Significantly more sensitive than mammography, especially for women with dense breasts
  - European Society of Breast Imaging recently changed recommendation to include MRI for women with dense breasts
- There is still controversy over breast cancer screening

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Published online 2020 Oct 29. doi: 10.1016/j.rcl.2020.09.004
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NIHMSID: NIHMS1707882
PMID: 33223002

Magnetic Resonance Imaging in Screening of Breast Cancer

Yiming Gao, MD,[a,*] Beatriu Reig, MD, MPH,[a] Laura Heacock, MS, MD,[a] Debbie L. Bennett, MD,[b] Samantha L. Heller, PhD, MD,[a] and Linda Moy, MD[a,c,d]

				Sensitivity	
Reference	Patients (n)	Rounds (n)[a]	Inclusion	MR Imaging (%)	MG (%)
2020[11]	8782	20,053	BRCA+/Fam	91	41
2019[12,b]	674	2812	Fam	98	87
2017[13]	296	1170	BRCA+/Fam	68	37
2015[22]	559	1506	BRCA+/Fam	90	38
2014[23]	221	1855	BRCA+	100	27
2012[26]	612	612	Mixed/Dense	88	52
2011[3]	501	1592	BRCA+/Fam	91	50
2010[4]	687	1679	BRCA+/Fam	93	33

"Prospective trials have shown that annual supplemental MR imaging in conjunction with mammography typically doubles the sensitivity of mammography alone and generally achieves sensitivities greater than 90%"

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Cancer Biol Med. 2017 Feb; 14(1): 1–8.
doi: 10.20892/j.issn.2095-3941.2016.0050
PMCID: PMC5365181
PMID: 28443199

Overdiagnosis of breast cancer in population screening: does it make breast screening worthless?

Nehmat Houssami*

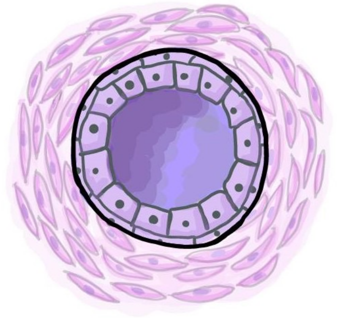
Study design	Range of estimates of BC overdiagnosis[21]
RCTs*	10% to 22%
Cohort studies	1.0% to 19.4%
Ecological studies	1.0% to 76.0%
Modelling studies	0.3% to 31.9%**

"The trade-off between the benefit and the collective harms of BC screening, including false-positives and overdiagnosis, is more finely balanced than initially recognized, however the snapshot of evidence presented on overdiagnosis does not mean that breast screening is worthless. Future efforts should be directed towards (a) ensuring that any changes in the implementation of BC screening optimize the balance between benefit and harms… (b) informing women of all the outcomes that may affect them when they participate in screening… and (c) investing in research that will help define and reduce the ensuing overtreatment of screen-detected BC."

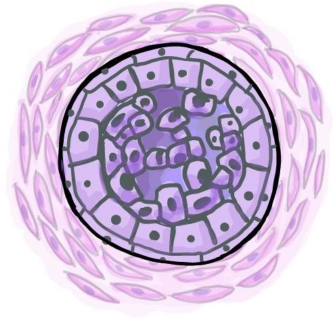
DCIS – Ductal Carcinoma in situ

- Is non-invasive, and the 20-year mortality rate is estimated to be only 3%
- Typically treated with surgery and often radiation
- Probably accounts for a large portion of overtreatment
- A candidate for active surveillance, but…
  - About 25% of patients with DCIS by core biopsy also have invasive disease that is missed in the biopsy
  - We need specificity for very small invasive lesions in a background of DCIS!

Normal Duct



DCIS



Invasive Carcinoma

Image: https://www.mypathologyreport.ca/

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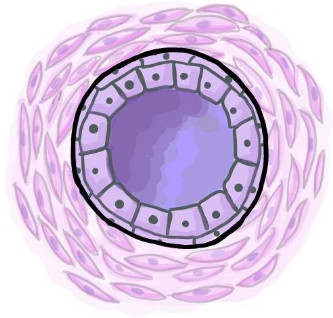
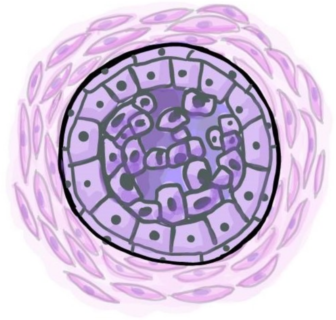


DCIS



Invasive Carcinoma

Image: https://www.mypathologyreport.ca/

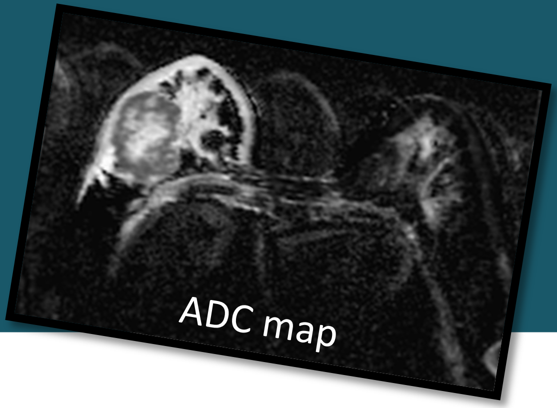
Our overarching goals

Goal 1: non-contrast MR screening

Goal 2: Characterization of DCIS

Contrast enhanced MRI
- High spatial resolution
- High temporal resolution

Advanced diffusion methods
- High SNR
- Reliable ADC
- High spatial resolution



Abbreviated Non-Contrast-Enhanced MRI for Breast Cancer Screening

Project Number	Former Number	Contact PI/Project Leader
5R01CA249893-02	1R01CA249893-01	HARGREAVES, BRIAN ANDREW

Goal 1: non-contrast MR screening

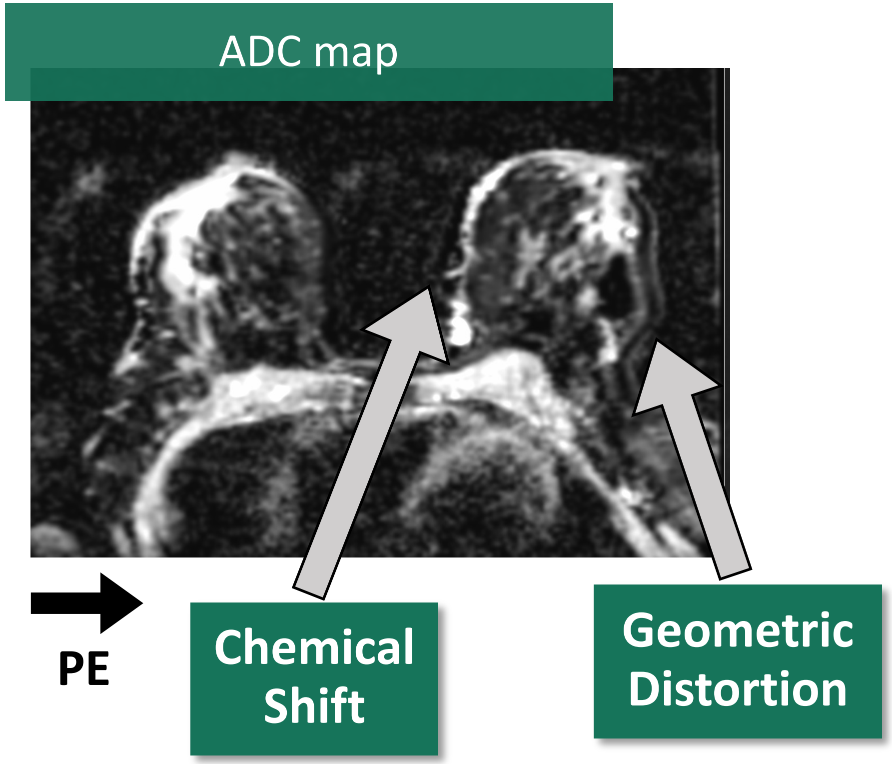
Goal 2: Characterization of DCIS

High-Resolution Breast MRI at 3.0T

Project Number	Contact PI/Project Leader
5R01EB009055-11	HARGREAVES, BRIAN ANDREW

...and others!

Challenges



Phase accrual ➔ geometric shift in PE direction:

$$\Delta y_{PE} = \frac{\Delta f}{BW_{PE}} FOV_{PE}$$

Δf: off resonance (Hz)

Major sources:

1. Fat (chemical shift)
2. B_0 inhomogeneity

$BW_{PE} = \frac{1}{t_{esp}}$: effective BW in PE direction

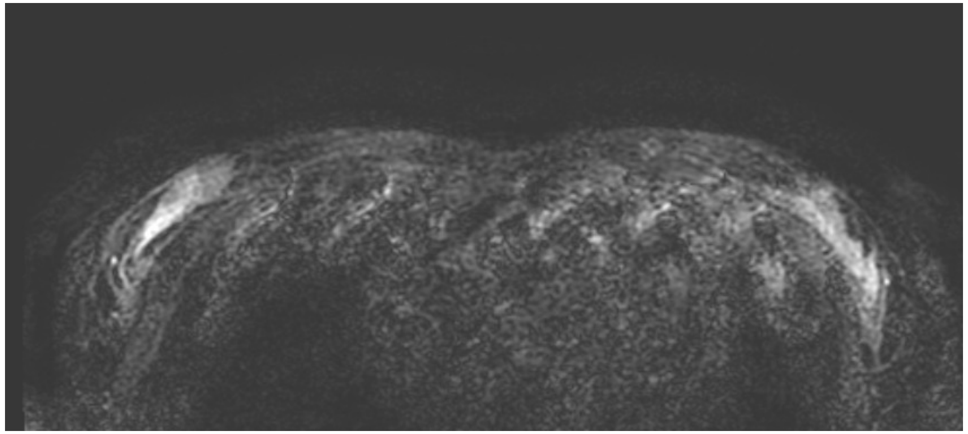
To reduce FOV_{PE}, we need parallel imaging and/or multishot EPI. Therefore, we need reliable sensitivity maps and g-factors

EPI is prone to ***Distortion***

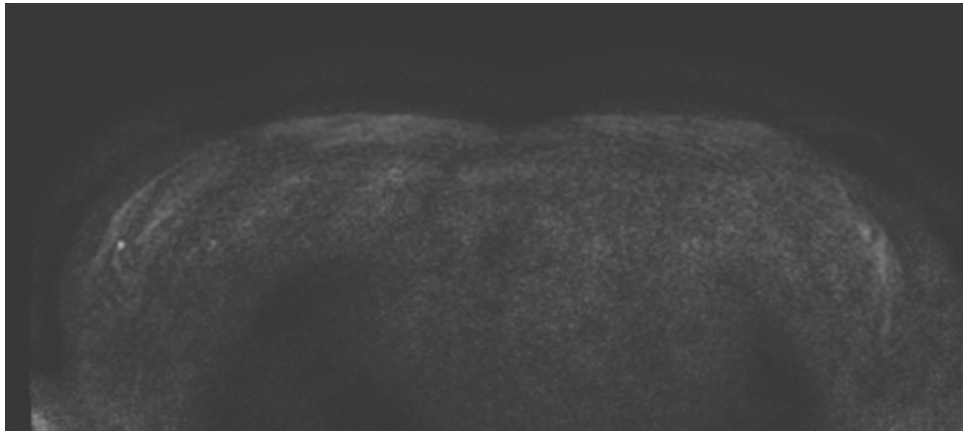
Especially in breast where ΔB_0 can be large.

Challenges

b = 0 s/mm^2, 1 NEX



b = 800 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

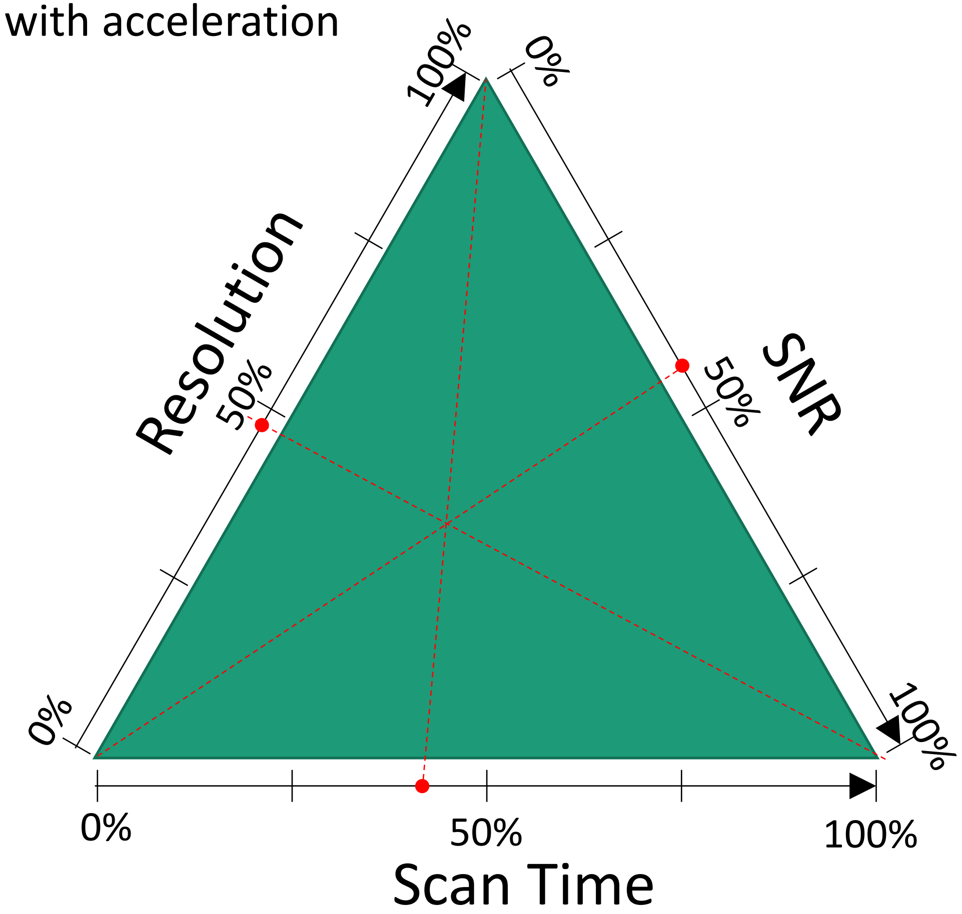
DWI is SNR starved!

Especially at high b-values

Scan time · Voxel size · Magnetization

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

$N_{PE} * R$
with acceleration



Scan time — Voxel size — Magnetization

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

$N_{PE} * R$
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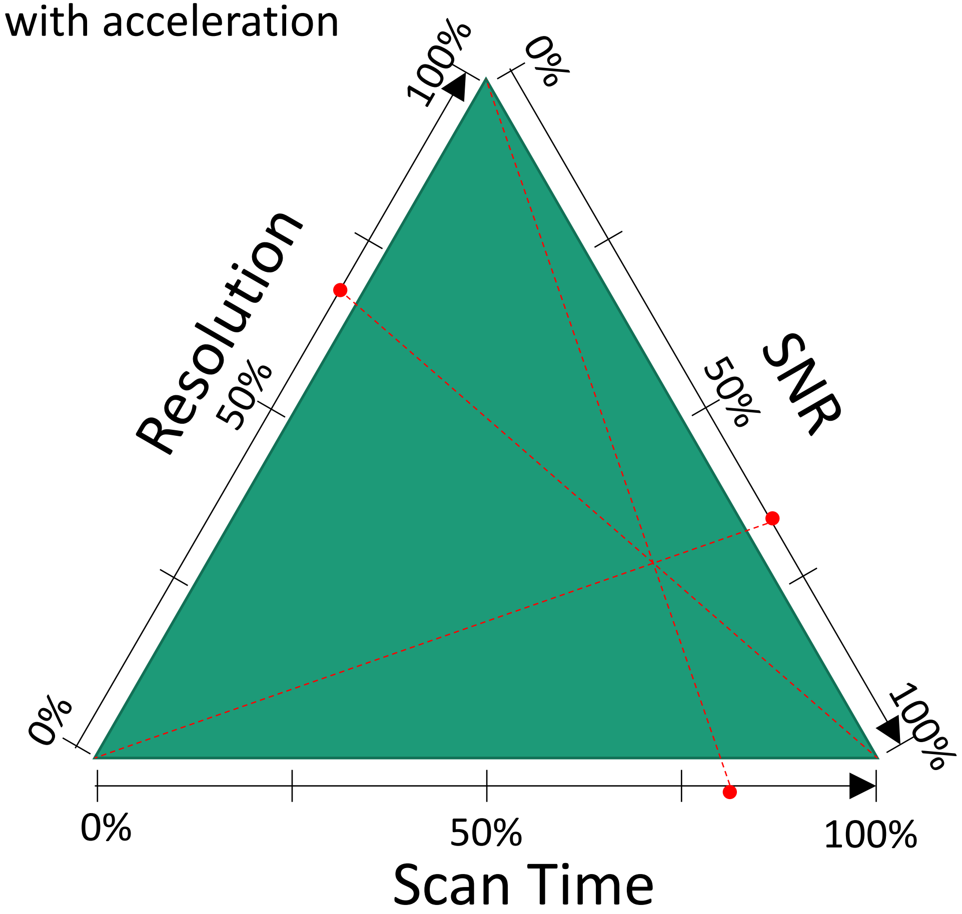


Diffusion:

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

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

Current b-value: $b_c = 600\ s/mm^2$
Desired b-value: $b_d = 800\ s/mm^2$
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

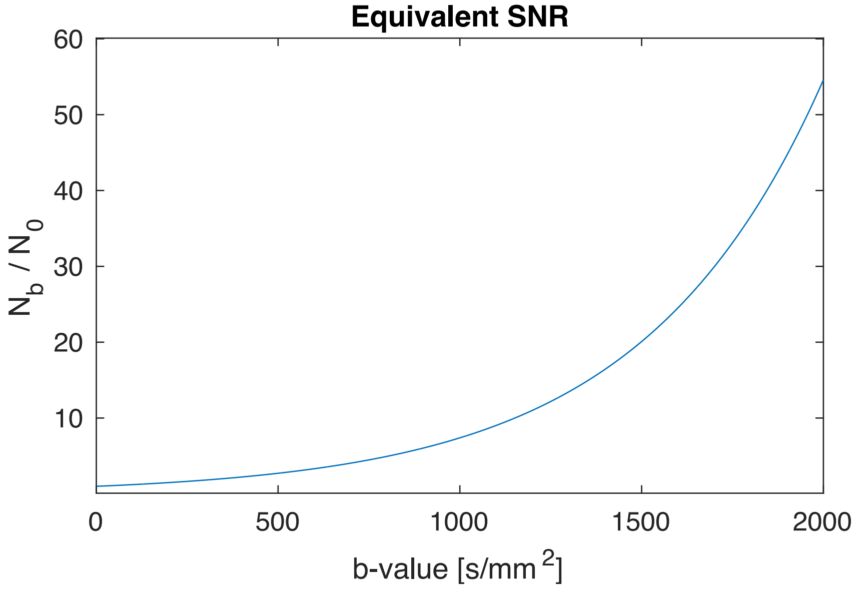
$$S_D\sqrt{N_D} = S_C\sqrt{N_C}$$
$$S_0 e^{-800*0.001}\sqrt{N_D} = S_0\, e^{-600*0.001}\sqrt{N_C}$$

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

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

Need 1.5x Averages

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

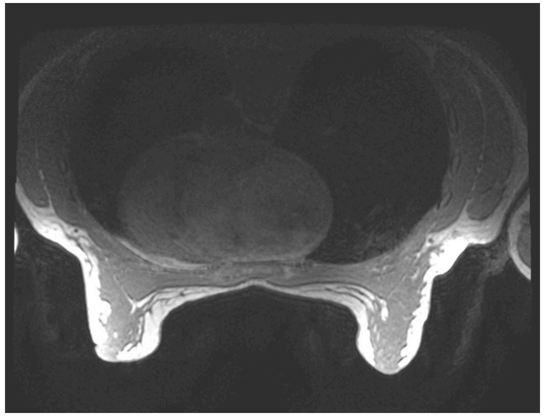


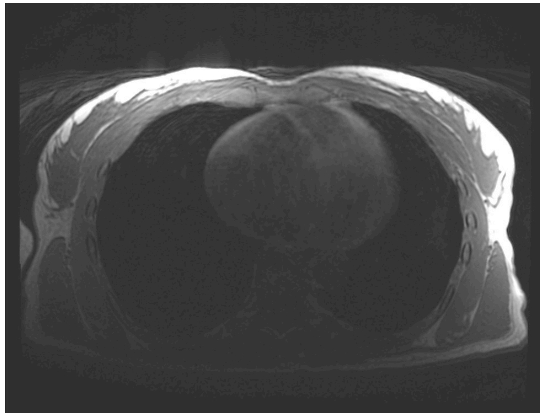
$$\frac{N_b}{N_0} = \left(e^{b*ADC}\right)^2$$

5 steps to help you squeeze the most SNR from DWI

- Reduce spatial resolution
- Acquire lots of averages – maybe a solution for lesion characterization but not great for fast non-contrast screening (at least in the long run)
- Use a coil with higher SNR
- Go to higher field strength – challenging in breast: not many coil options, sensitive to B_0 and B_1 inhomogeneity over large FOV
- Use super resolution?

Background: Supine Breast Imaging

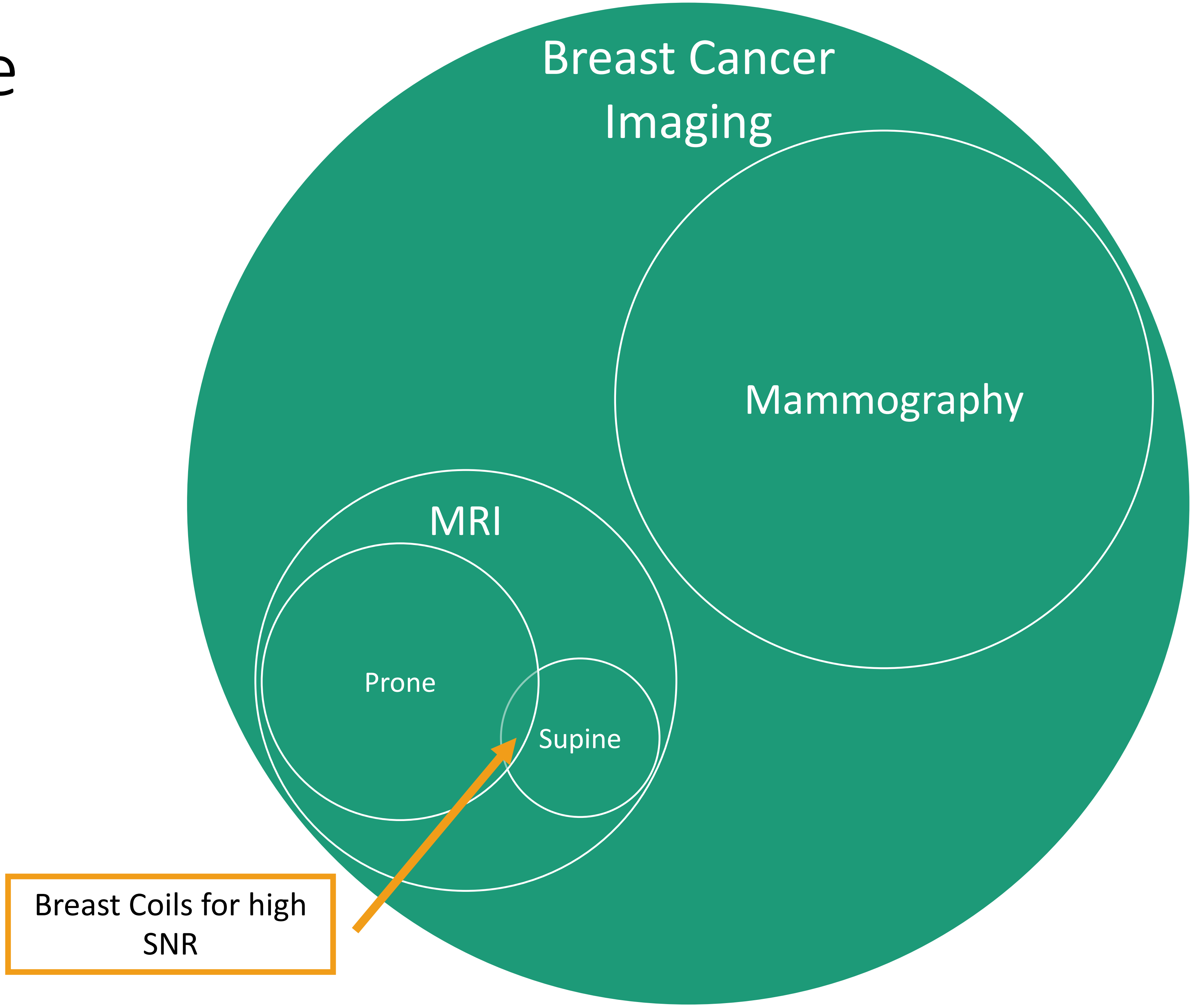




+ Established for clinical use
+ Reduced effect of respiratory motion
- Uncomfortable and awkward setup
- Coil reduces the available bore space
- Does not correlate to surgery or other imaging modalities

- Significant effect of respiratory motion
+ Comfortable and easy setup
+ Correlates to surgery or other imaging modalities

Outline


Breast Cancer Imaging
Mammography
MRI
Prone
Supine
Breast Coils for high SNR

Breast Coils

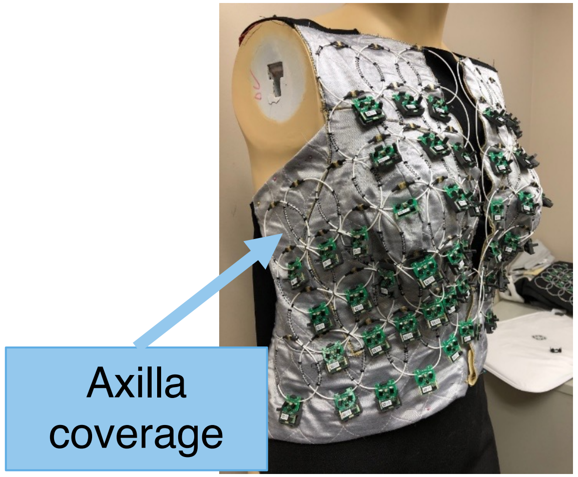

Standard breast coil

- Only prone imaging
- Very uncomfortable and large

An option for supine imaging

+ Flexible and comfortable
- Lower channel count in breast region
- Possible lack of axilla coverage

60-channel breast coil

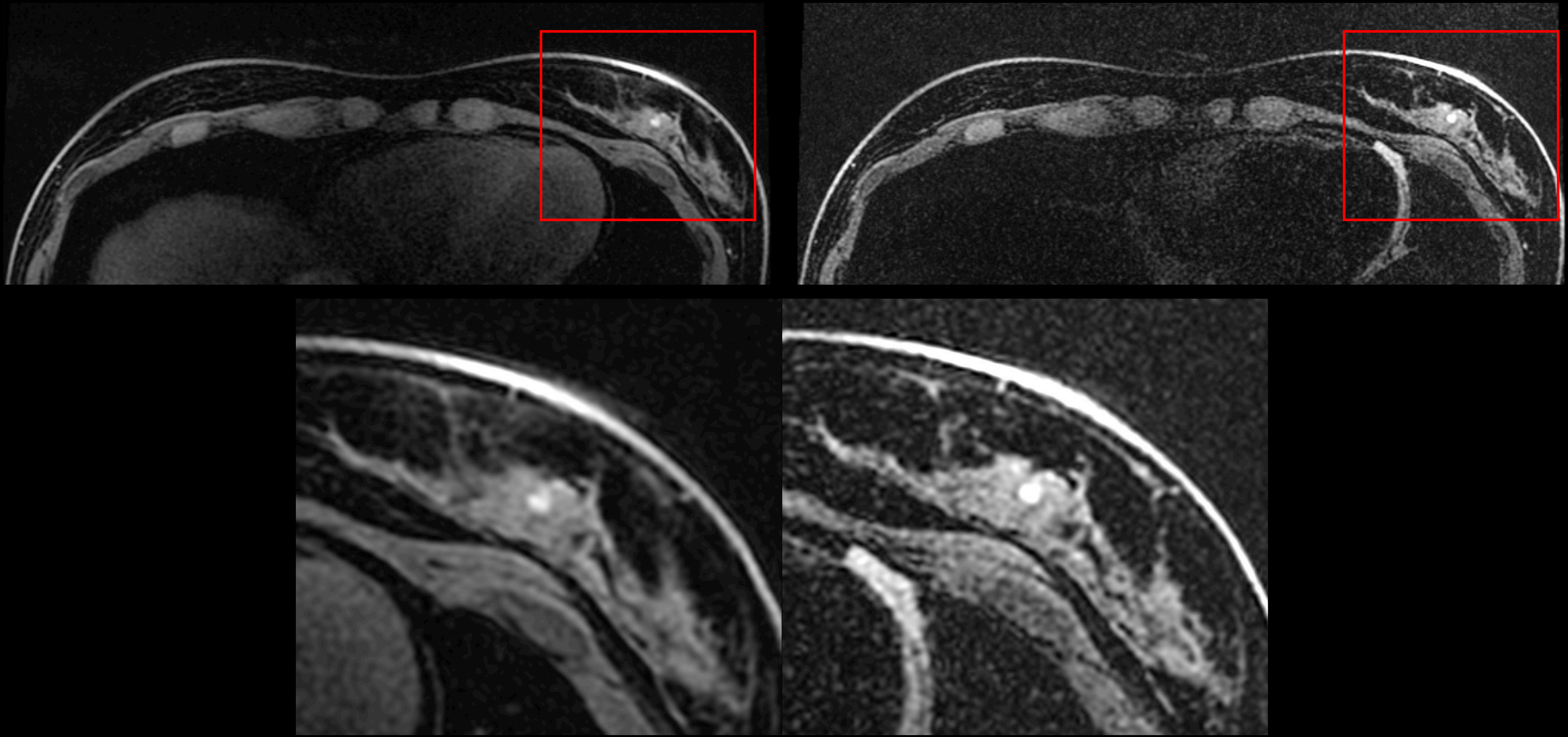


+ Form fitting to breast for close proximity
+ High channel count
+ Flexible and comfortable
+ Can be used both supine and prone (with support)

Supine LAVA-Flex Protocol in Volunteer

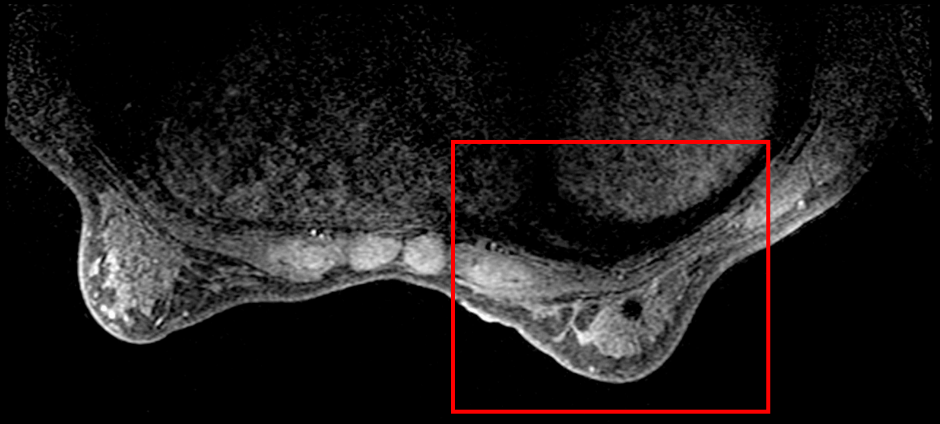
R=3x2, 1 x 1 x 1.6 mm^3, 20 sec BH

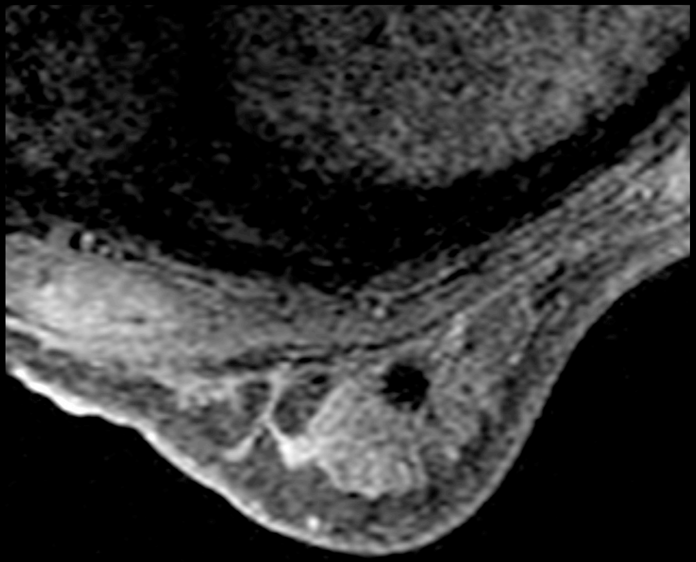
R=4x3, 0.9 x 0.9 x 1 mm^3, 20 sec BH



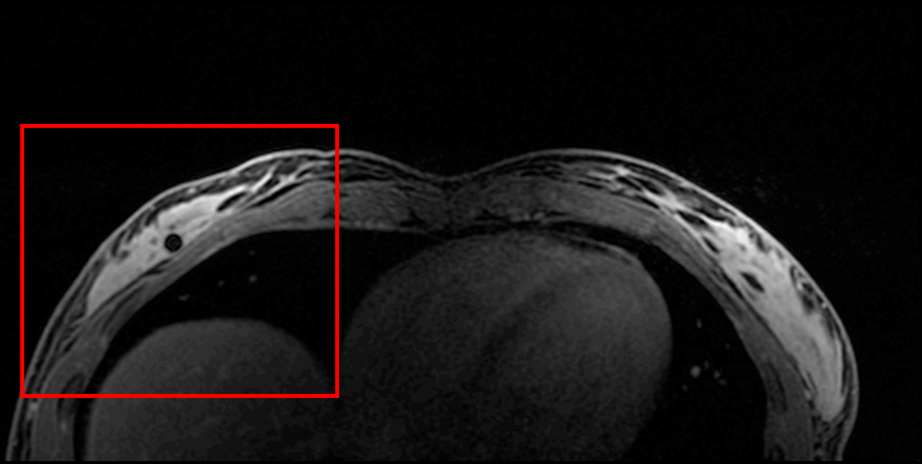
Patient #1: Late Phase Contrast Enhanced

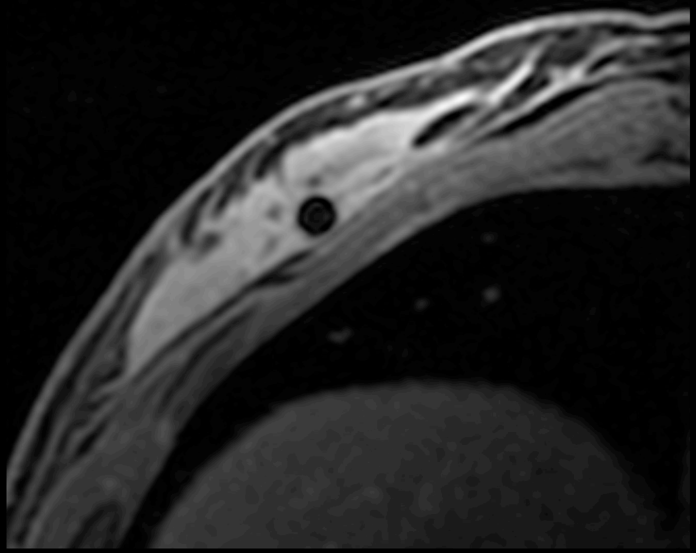
Standard Clinical DISCO, Prone w/ Sentinelle Breast Coil





LAVA Flex in 20 sec BH, Supine w/ 60-ch Breast Coil

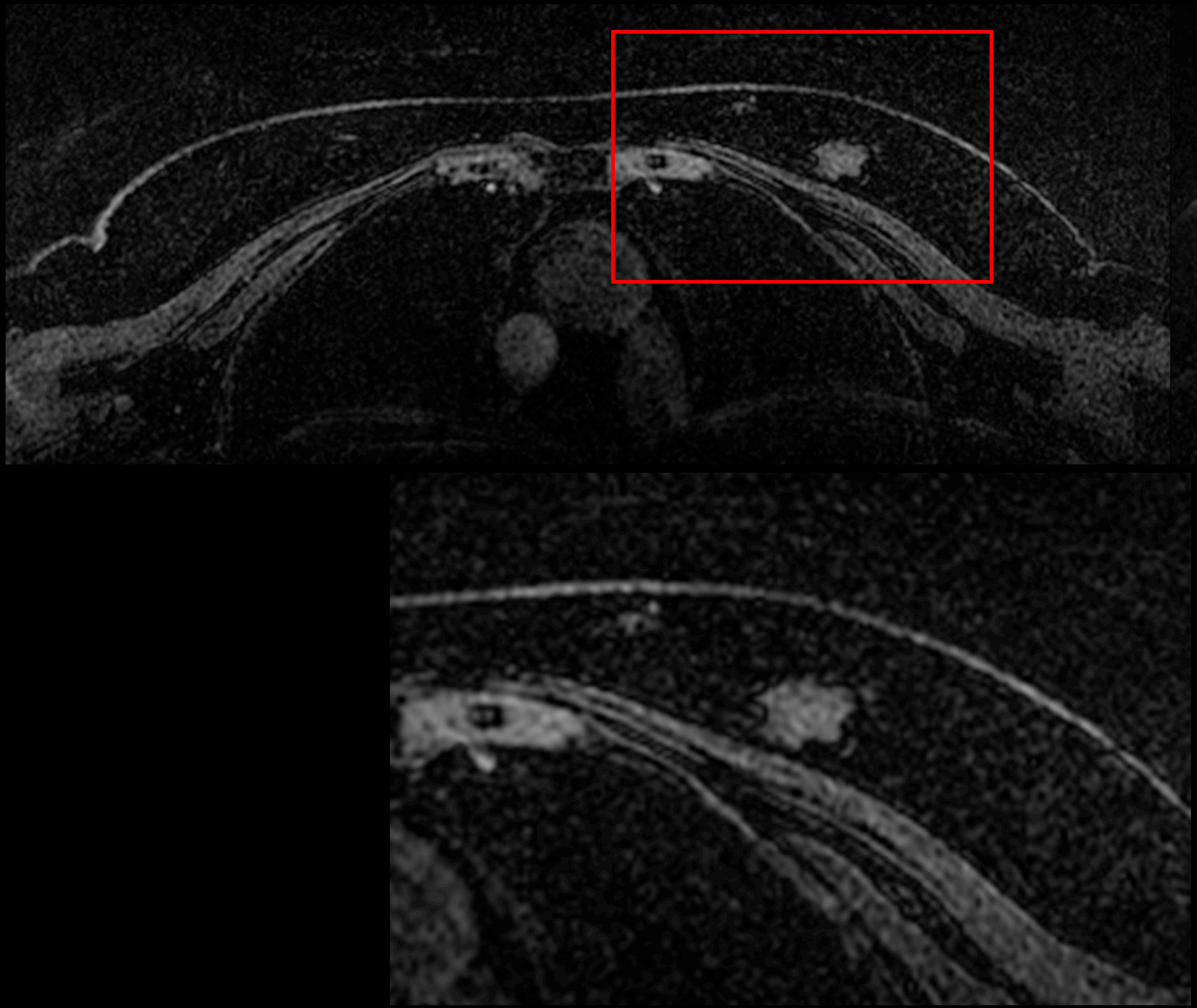




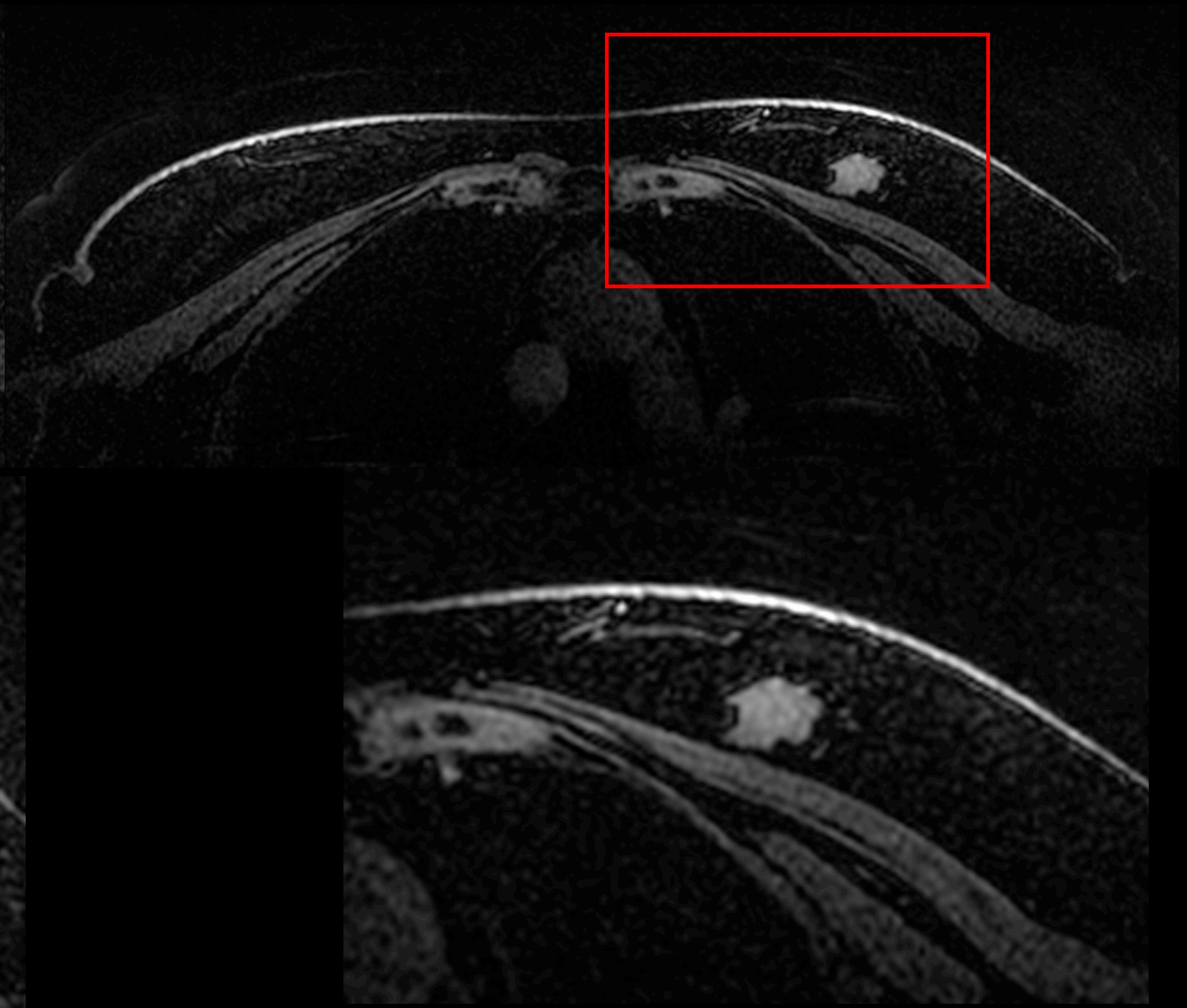
Patient #2: Pre-contrast

1 x 1 x 1 mm^3, R = 3x4, Phase Encode A/P w/ Breath Hold

Air Coil

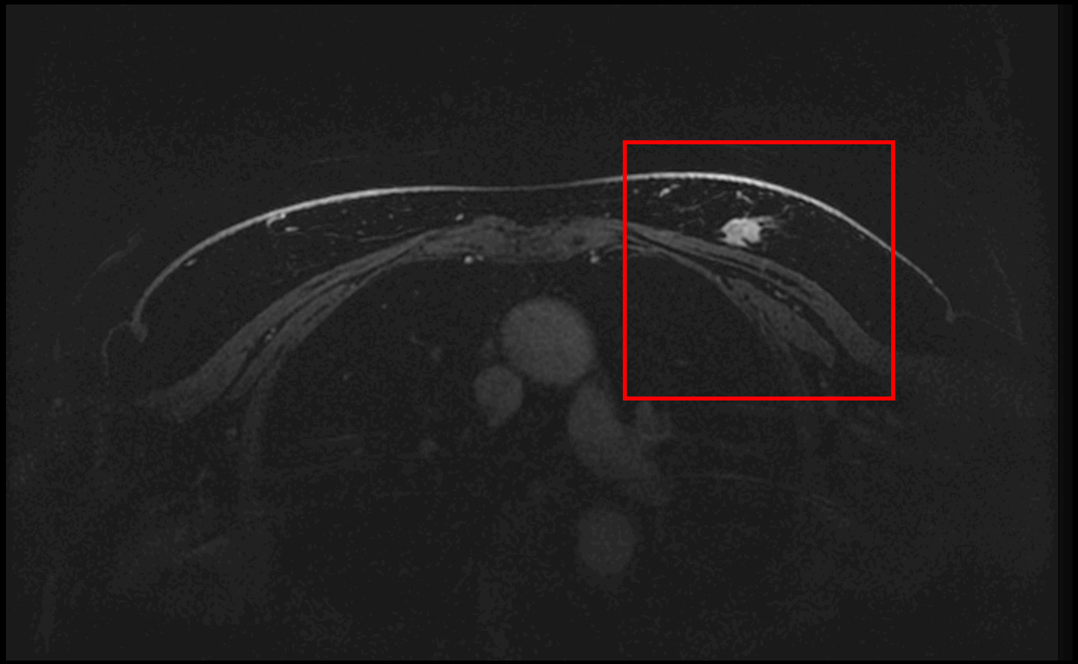


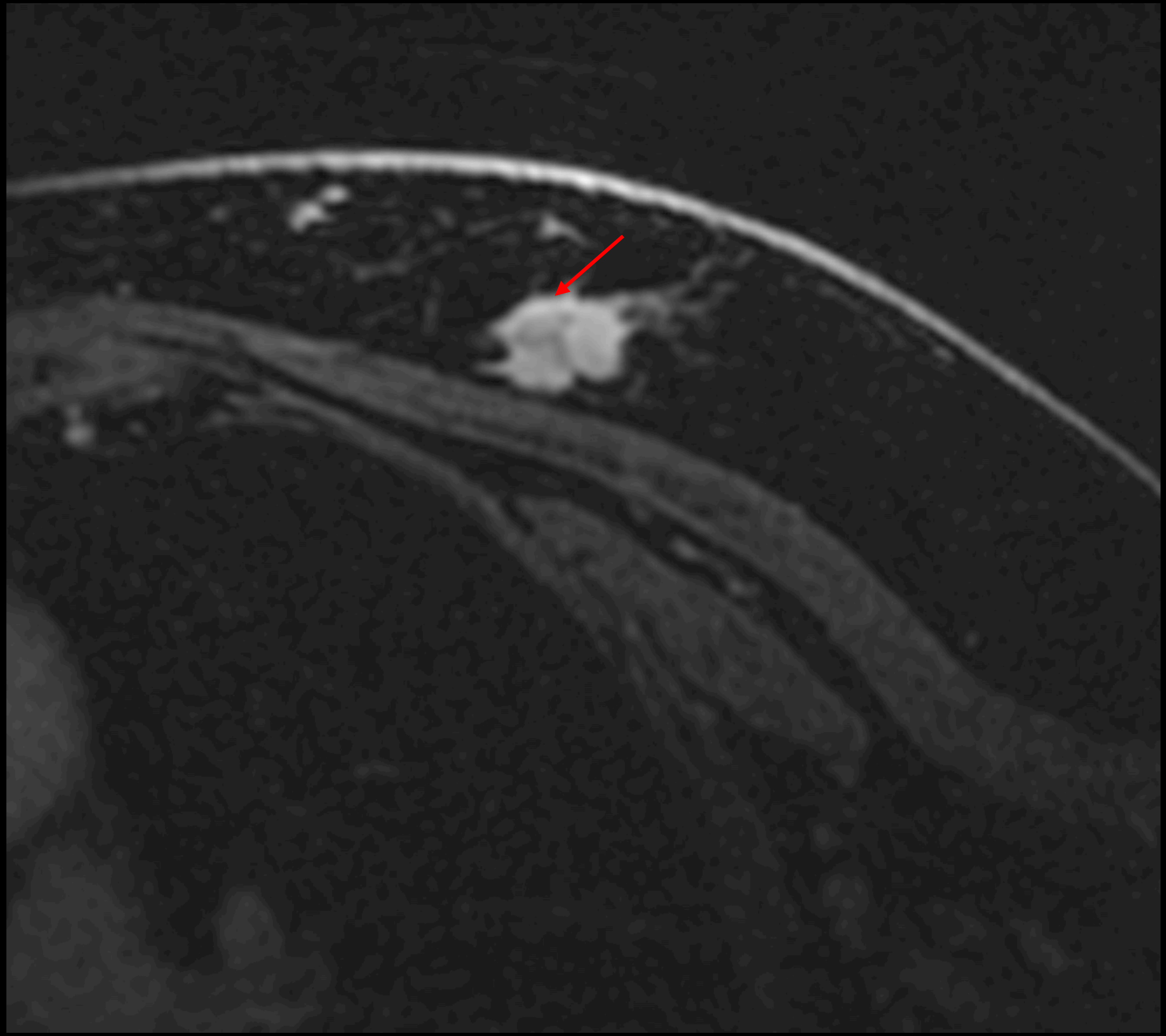
60-ch Breast Coil



Patient #2: Post-contrast

1 x 1 x 1 mm^3, R = 3x4, Phase Encode A/P w/ Breath Hold

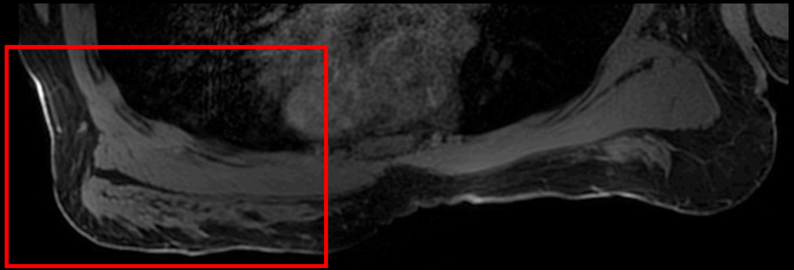




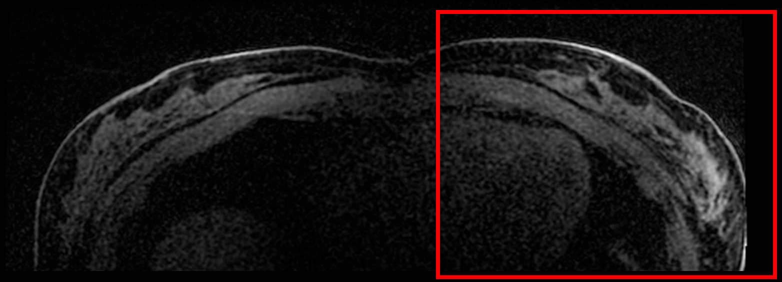
Volunteer

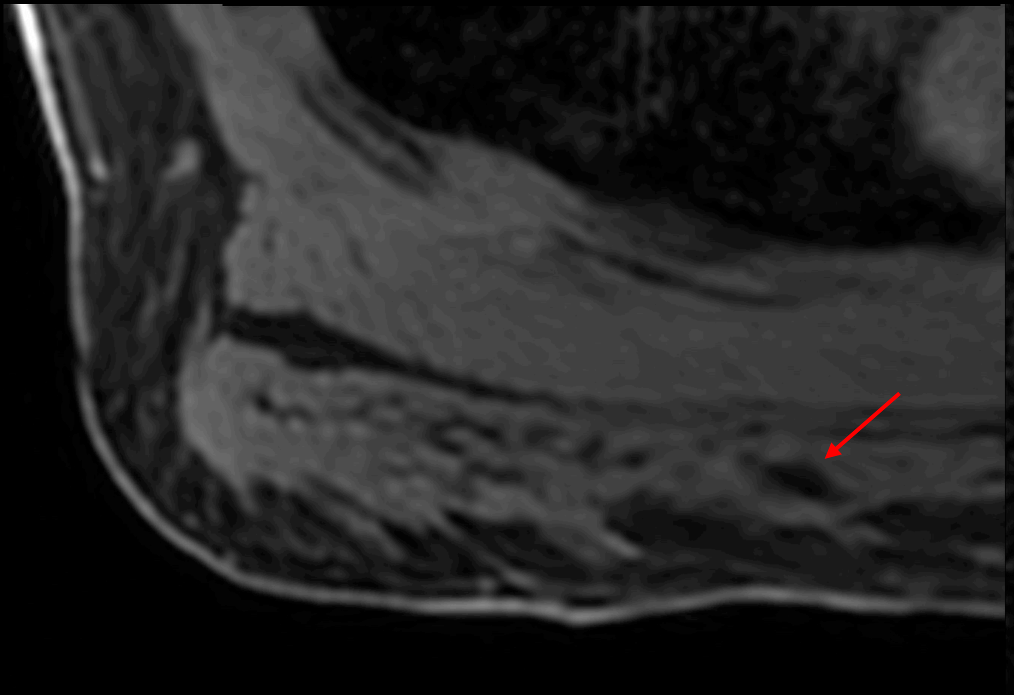
60-ch Breast Coil: Supine & Prone

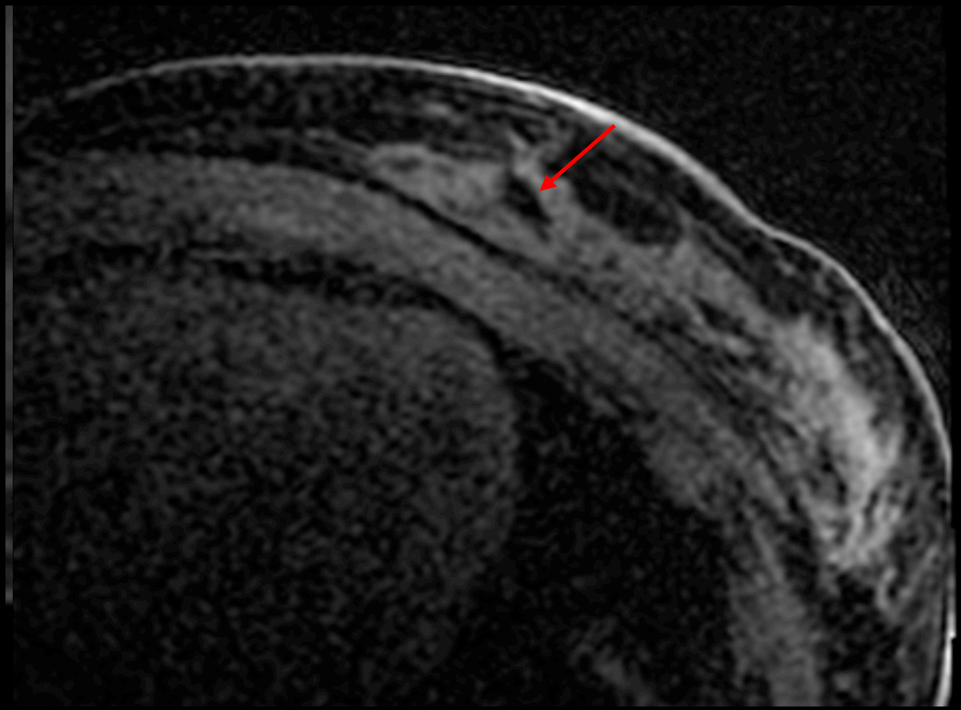
Prone VIBRANT, 1:08 Free Breathing
1 x 1 x 2 mm^3



Supine LAVA-Flex, 25 sec Breath Hold,
1.1 x 1.1 x 1 mm^3



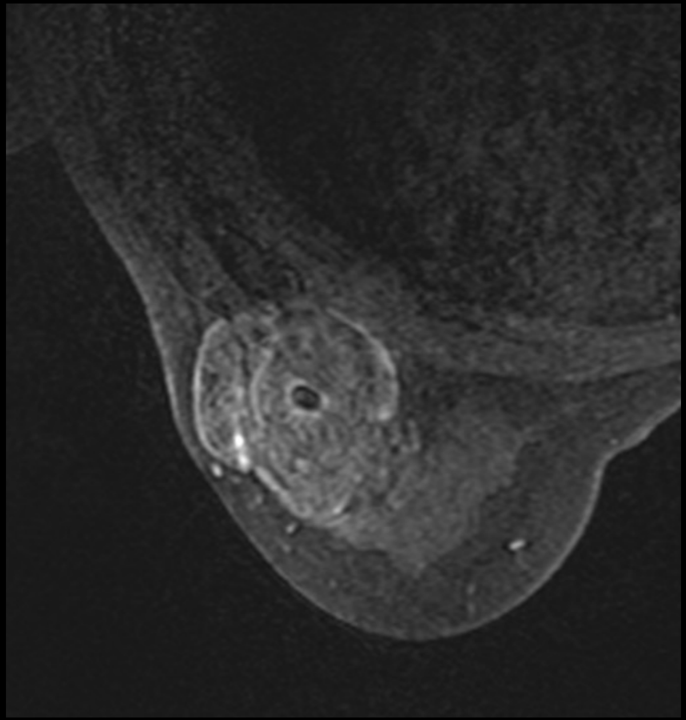




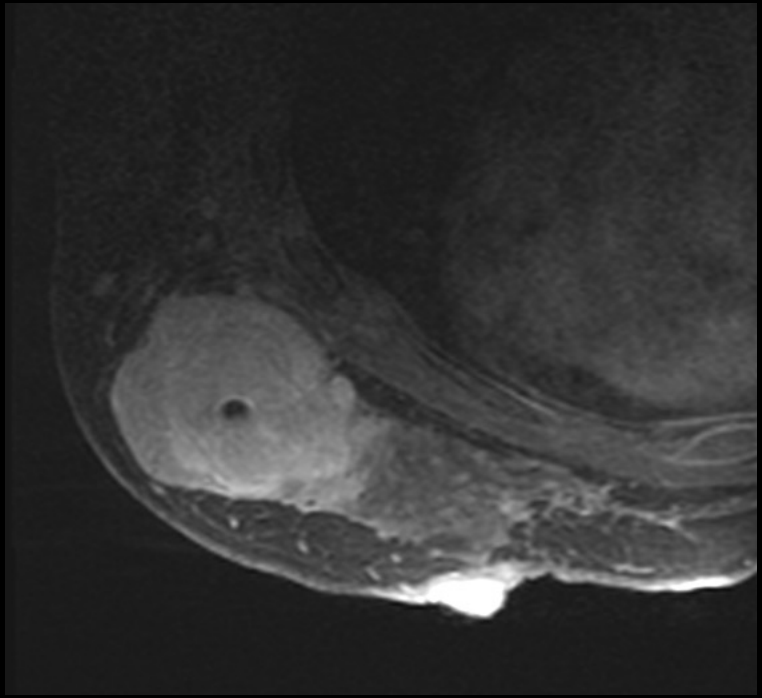
Patient, Late Phase

16-ch Sentinelle coil and 60-ch Breast Coil: Prone

16-ch Prone DISCO, Free Breathing

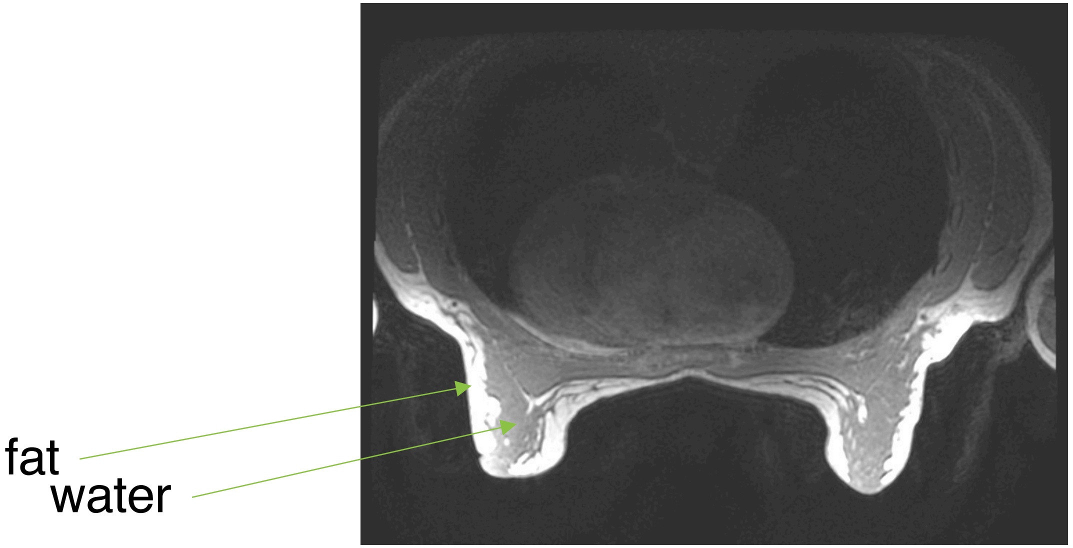


60-ch Prone DISCO, Free Breathing

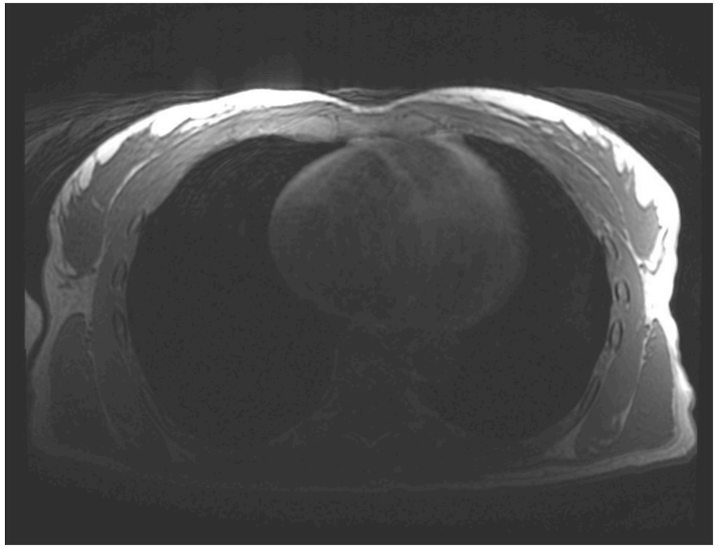


Goal

Prone



Supine

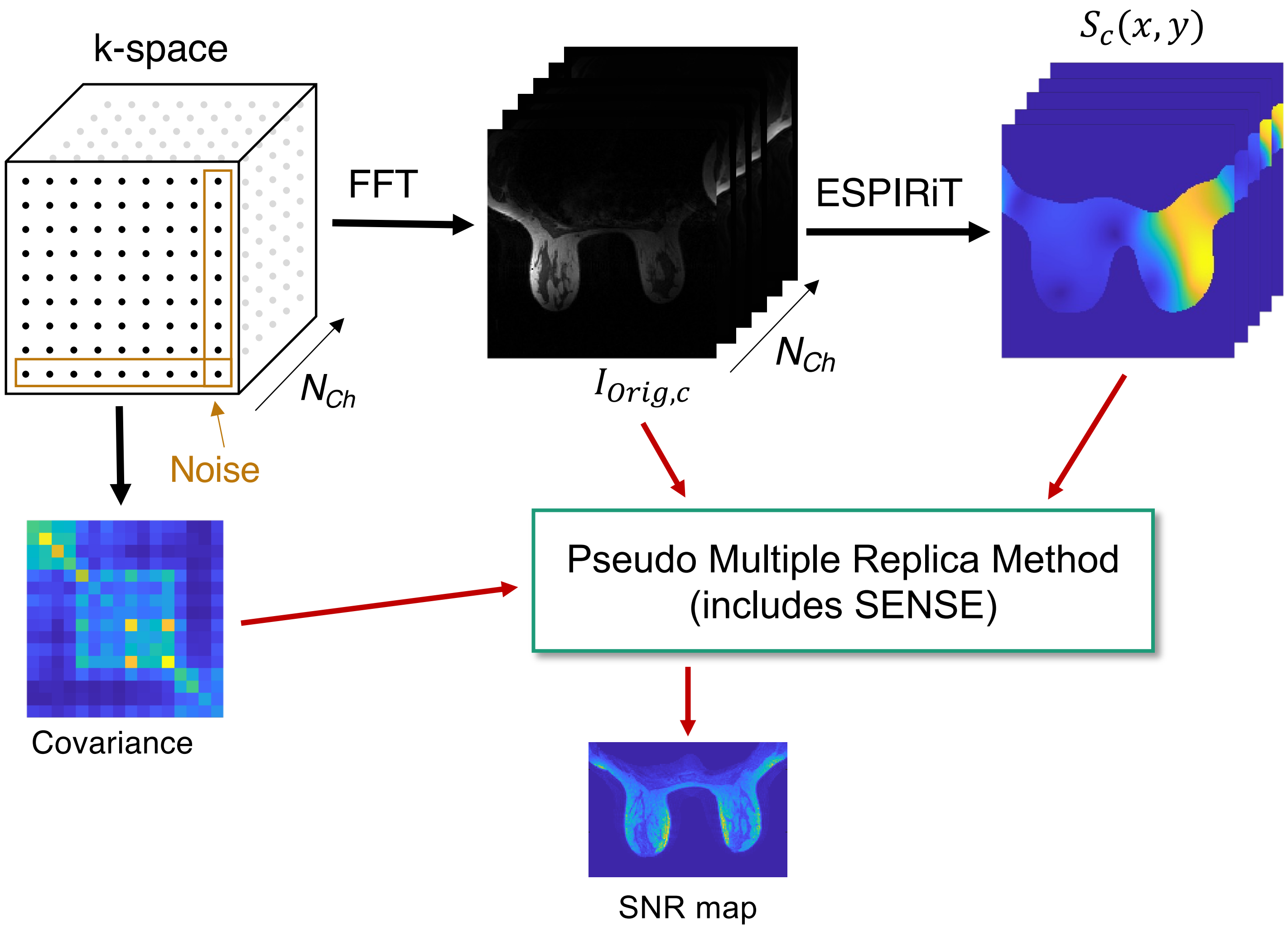


Purpose: *to apply a simple method to quantitatively compare prone and supine breast SNR distribution using a constant-tissue model and standard SNR measurement approach*

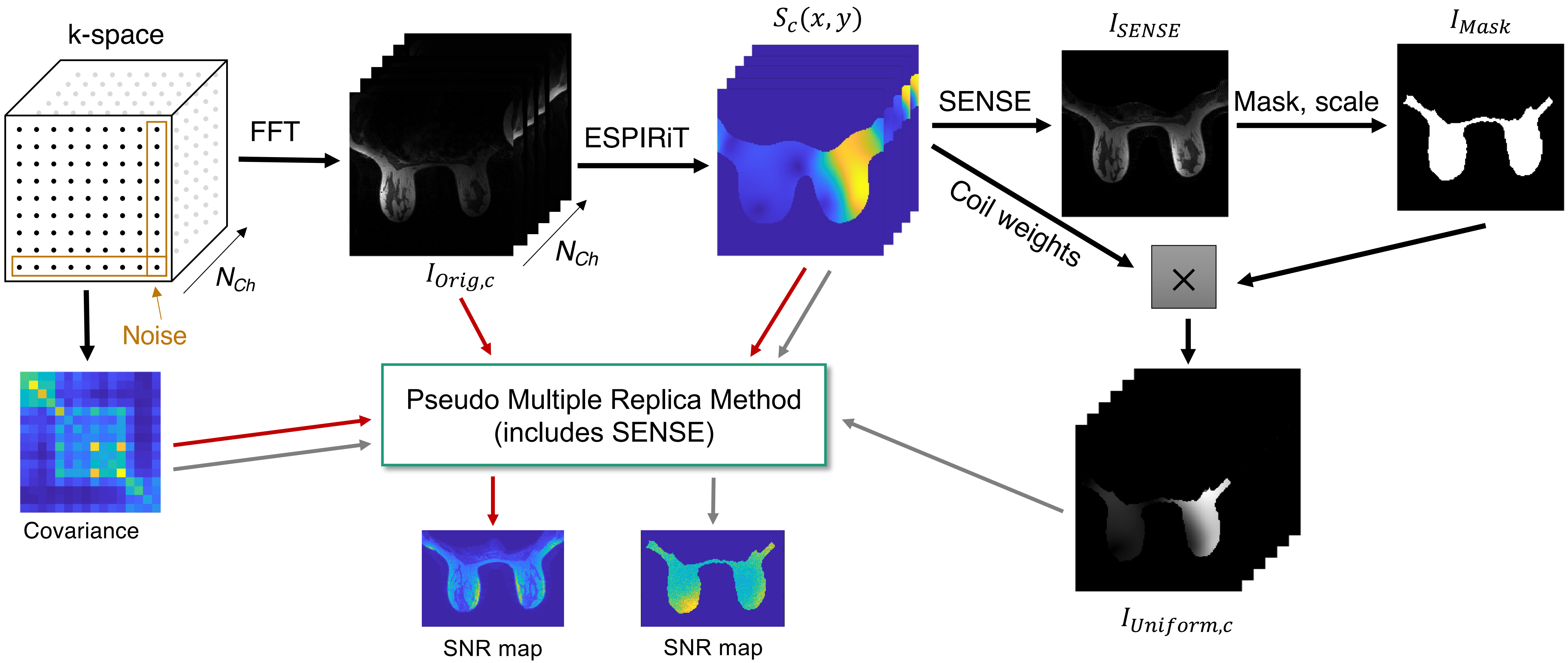
Methods: Data

- A 3D T1-weighted SPGR protocol was acquired in the prone and supine position with 2 mm isotropic resolution
- TR = 3.67 ms, TE = 2.1 ms, flip angle = 12°
- 3 T Premier (GE Healthcare)
- Deformable saline bag phantoms and 3 healthy volunteers
- The 16-ch Sentinelle coil was used in the prone position; the 60-ch breast prototype coil was used in the supine position

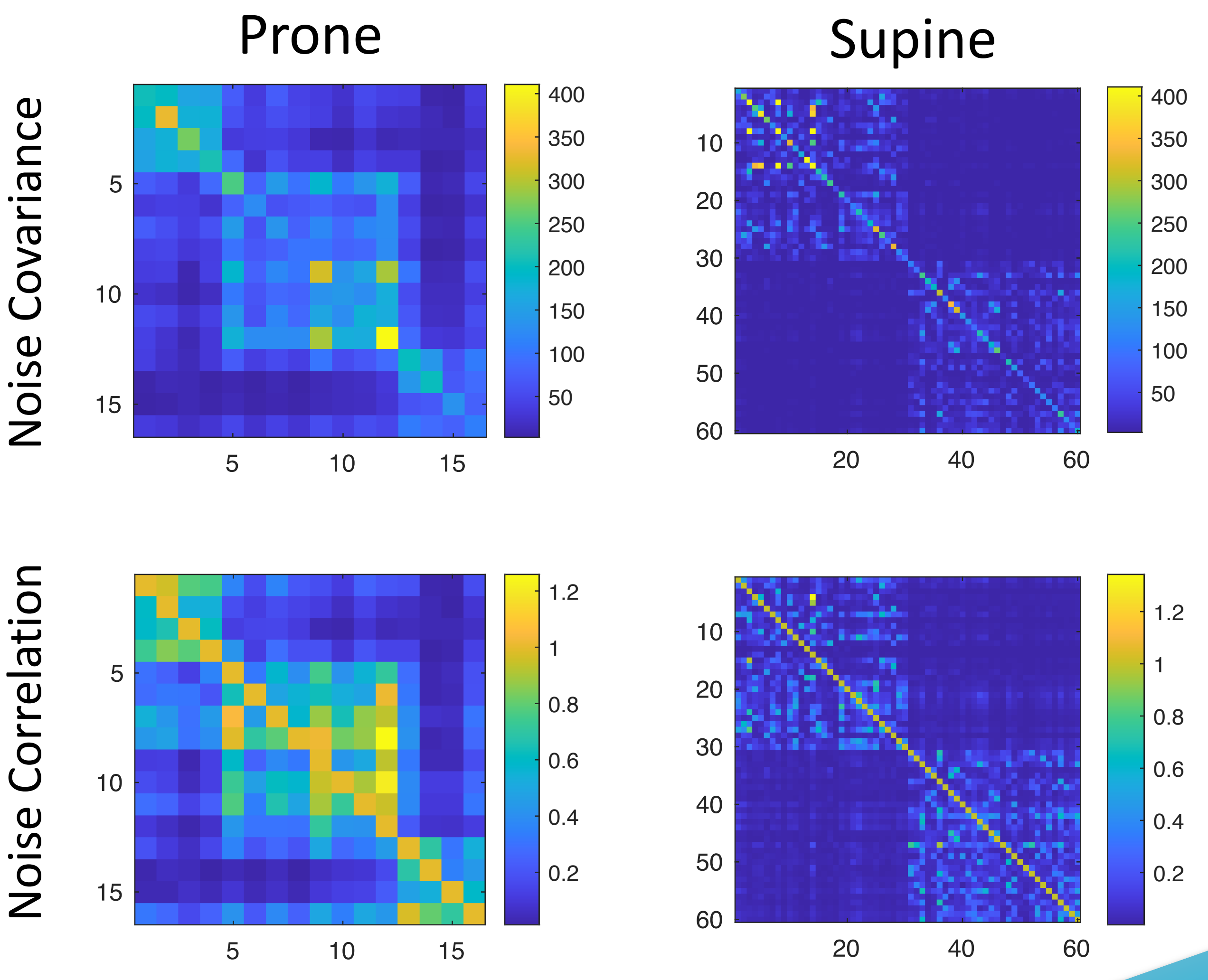
Methods: SNR Measurement



Methods: “Constant” Tissue

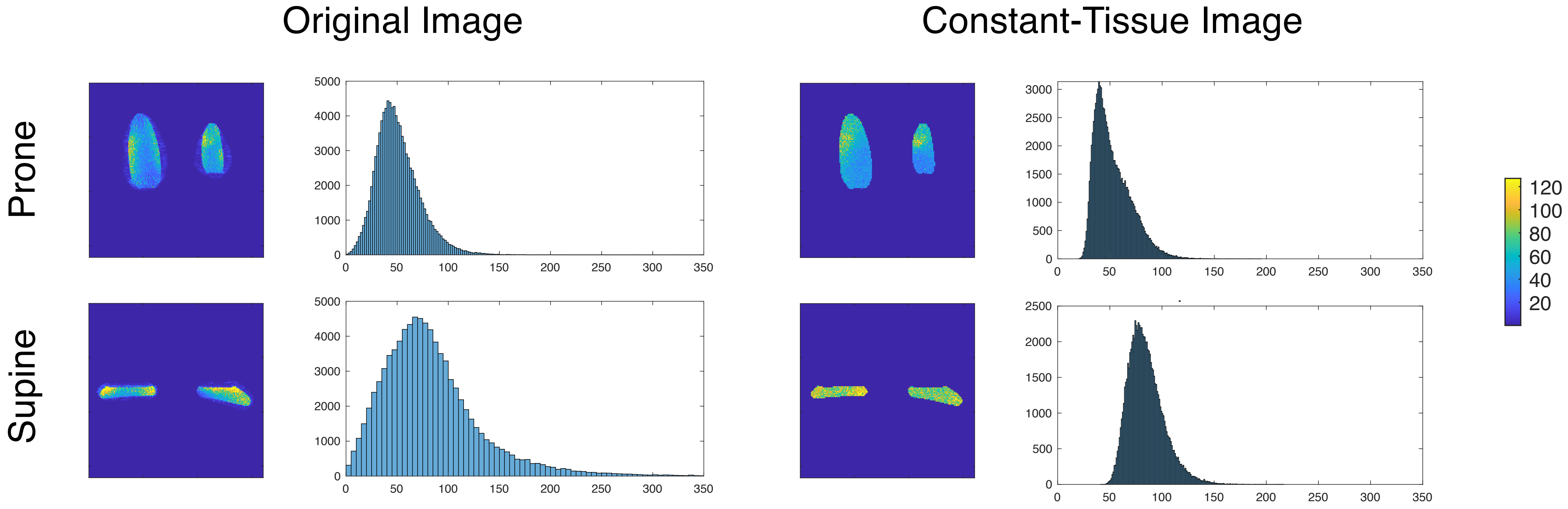


Results: Noise Covariance

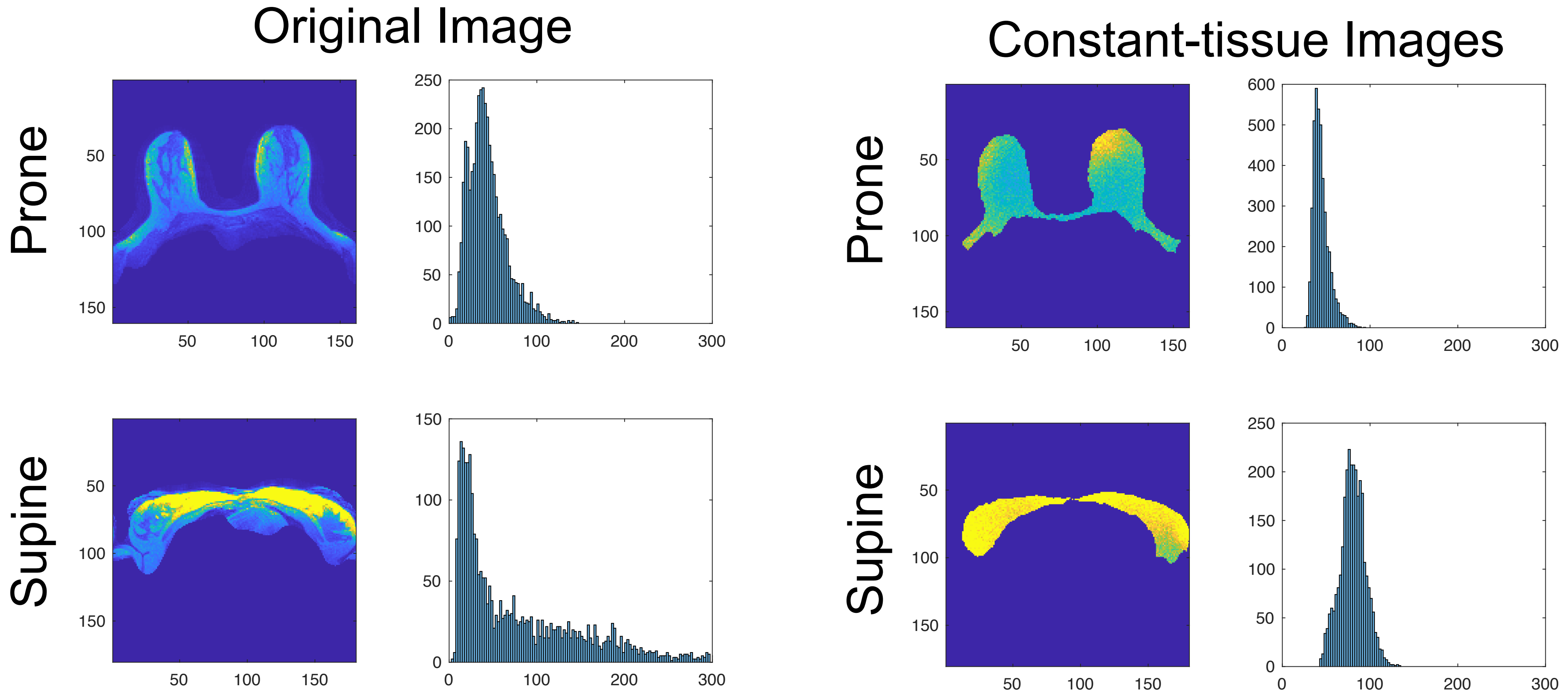


Similar noise levels

Results: SNR in Saline Phantom

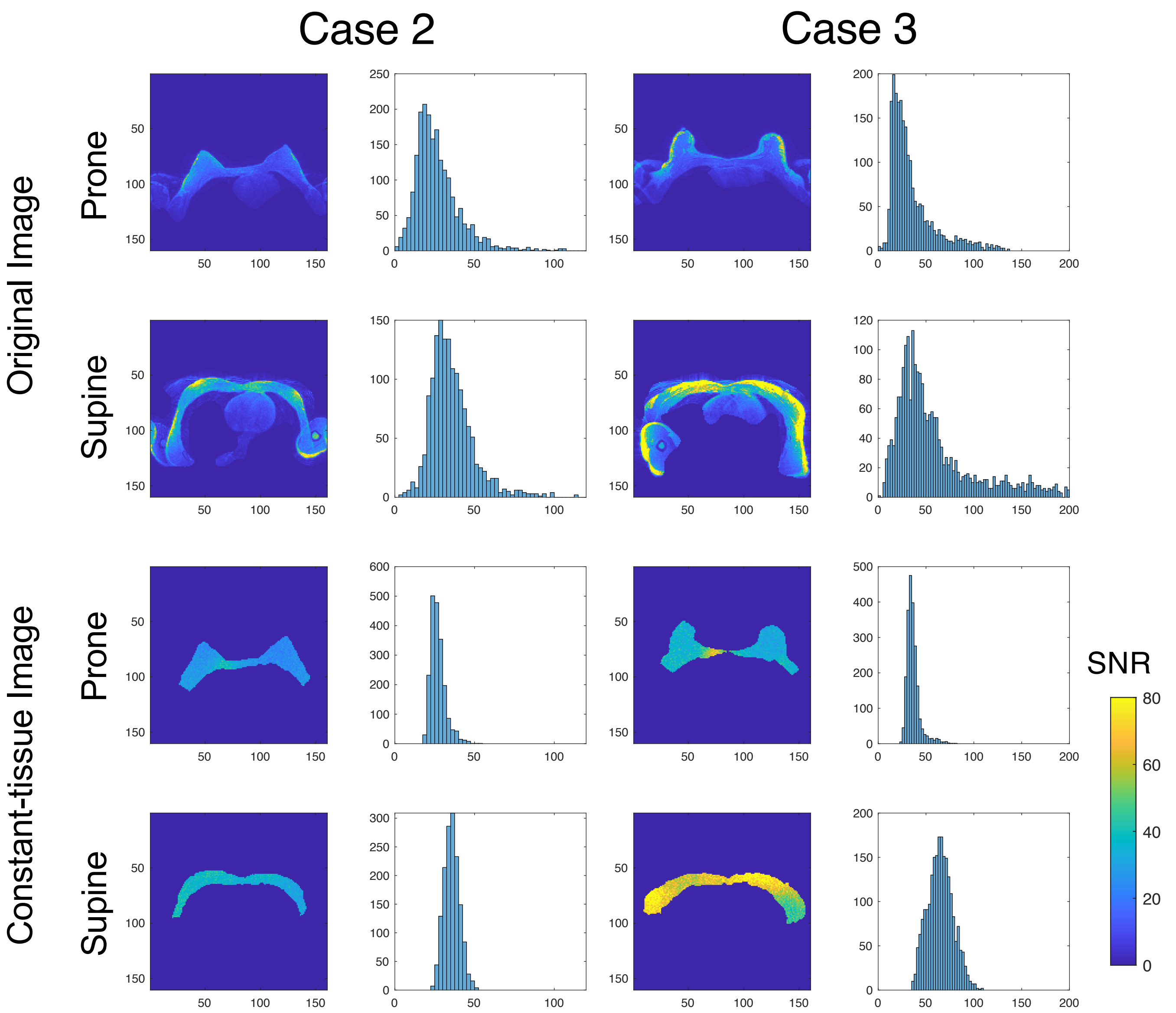


Results: Volunteer (Case 1)



Results: Volunteer

	Position	Image	Mean	Med	Std	Peak
Case 1	Prone	Original	44	40	22	39
		Uniform	45	43	9	64
	Supine	Original	83	52	78	14
		Uniform	80	80	14	54
Case 2	Prone	Original	27	24	15	19
		Uniform	27	26	5	36
	Supine	Original	36	33	14	29
		Uniform	36	36	5	49
Case 3	Prone	Original	35	27	24	16
		Uniform	36	35	7	39
	Supine	Original	64	46	53	36
		Uniform	65	65	13	71



Conclusion

- Robust tools to measure SNR are required for coil development and should be generalizable to various coils and physical positioning of the participant.
- The constant tissue model is an efficient tool to compare SNR across coils in a way that is independent of the tissue composition.
- The 60-channel supine breast coil consistently increased SNR across a phantom experiment and three volunteers. We expect to see a further advantage in the case of parallel imaging.

Other possible ideas

- Use fat as a reference
- Segment fat and water signals to measure average SNR in each individually
- Use ZTE (or other?) to minimize the contrast between water and fat

Next steps

- Compare DWI in the supine position between the Air coil and 60-ch coil
- Validate the “constant tissue” model
- Modify the prone support system

Feedback?

- Pitfalls?
- Other alternatives?
- Ideas for validation?
- Other applications?

Thank you!











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...and others!