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Evaluation of image quality of deep-learning reconstructed EPI compared to RESOLVE in breast DW-MRI clinical practice

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Statements: Disclosures & Acknowledgements

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1. Background

Diffusion Weighted Imaging in breast MRI: current status & challenges in clinical practice

Screening:
sensitivity 81%, specificity 88% [1]
✓ Detection Rate 74.4% [2]

Diagnosis:
sensitivity 89%, specificity 82% [3]

Monitoring response to treatment:
sensitivity 89%, specificity 72% [1]

Despite DWI's high performance, it is used complementarily to DCE-MRI, due to:

- Low spatial resolution (4-5 mm)
- Poor image quality
- Low signal-to-noise ratio (SNR)
- Artifacts
- Need to standardize acquisition parameters

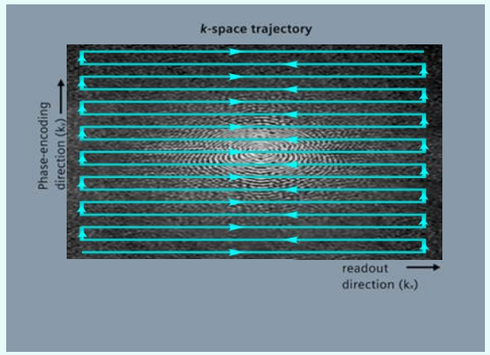
Research challenge: trade-off between spatial resolution and acquisition time

2. Aim & Objectives

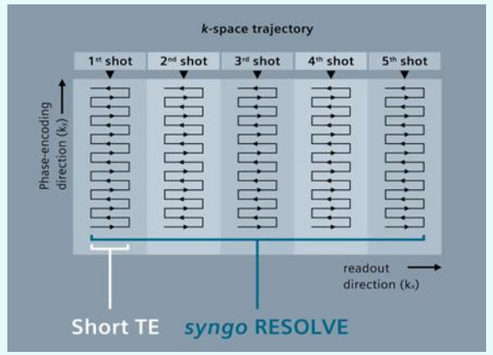
Aim: to evaluate the image quality of a prototype **Echo Planar Imaging-Deep Learning (EPI-DL)** sequence and compare it with the clinically used **Simultaneous Multi-slice (SMS) REadout Segmented Of Long Variable Echo trains (RESOLVE).**

K-space trajectories of fundamental (EPI & RESOLVE) DWI sequences

EPI



RESOLVE



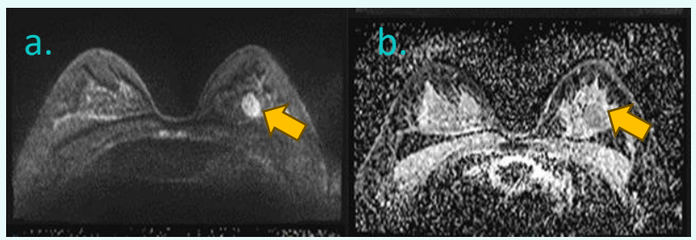


Figure 1: Benign breast lesion (yellow arrow) in a 34-year-old participant; a. EPI DWI high-b-value (b=800 sec/mm^2); b. EPI ADC map.

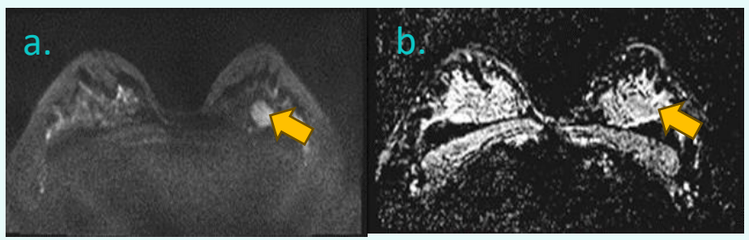


Figure 2: Benign breast lesion (yellow arrow) in a 34-year-old participant (same as in Figure 1); a. RESOLVE high-b-value (b=800 sec/mm^2); b. RESOLVE ADC map.

3. Materials & Methods

Patient cohort: 20 women with 20 histologically verified breast lesions

- 11 benign
- 9 malignant

MRI scanner 3.0 T

Table 1: DWI acquisition parameters for standard SMS-RESOLVE and EPI-DL sequences

Parameters	SMS-RESOLVE	EPI-DL
No of slices	28	38
Distance factor	20%	20%
Phase encoding direction	Posterior to Anterior	Posterior to Anterior
Voxel (mm^3)	1.5 x 1.5 x 4.0	1.5 x 1.5 x 3.0
TR (ms)	2670	8000
TE (ms)	55	86
FOV (mm^2)	340 x 340	340 x 340
Fat suppression	SPAIR	SPAIR
Acceleration mode	SMS	GRAPPA
Acceleration factor	2	2
Read-out segments	5	-
Read-out partial Fourier acquisition	5/8	-
Diffusion Mode	3D scan trace	3D scan trace
Diffusion directions	3 orthogonal (x, y, z)	3 orthogonal (x, y, z)
b value (s/mm^2); averages	0; 1	0; 1
	800; 3	800; 3
Acquisition time (min:s)	01:43	01:41

Abbreviations: DWI: Diffusion Weighted Imaging; EPI-DL: Echo-Planar-Imaging Deep-Learning; FOV: Field-Of-view; GRAPPA: Generalized Autocalibrating Partially Parallel Acquisitions; SMS: Simultaneous Multi-Slice; SPAIR: Spectral Attenuated Inversion Recovery; TE: Echo Time; TR: Repetition Time.

Evaluation of Image Quality

Qualitative: Reader study

- Question 1: Overall image quality
- Question 2: Lesion visibility
- Question 3: Lesion conspicuity
- Question 4: Image artifacts

Quantitative: image quality metrics

$$\mathrm{SNR} = \frac{\text{Mean SI of lesion}}{\text{SD SI of lesion}}$$

$$\mathrm{CNR} = \frac{|\text{Mean SI of lesion} - \text{Mean SI of normal tissue}|}{\sqrt{(\text{SD SI of lesion})^2 + (\text{SD SI of normal tissue})^2}}$$

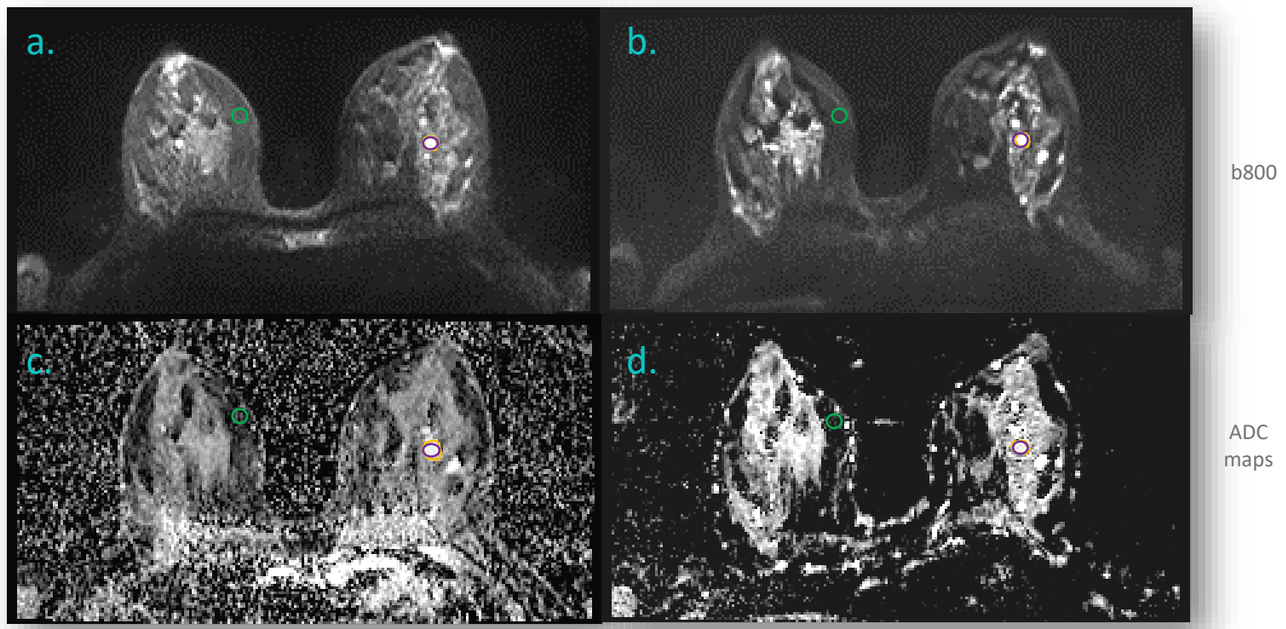


Figure 3: Benign breast lesion in a 56-year-old participant a. RESOLVE DWI high-b-value (b=800 sec/mm²); b. EPI-DL DWI high-b-value (b=800 sec/mm²); c. RESOLVE ADC map; d. EPI-DL ADC map. Region of Interest is manually segmented (yellow ROIs), circularly (purple ROIs), and normal fibroglandular tissue is circularly segmented (green ROIs).

Statistical analysis

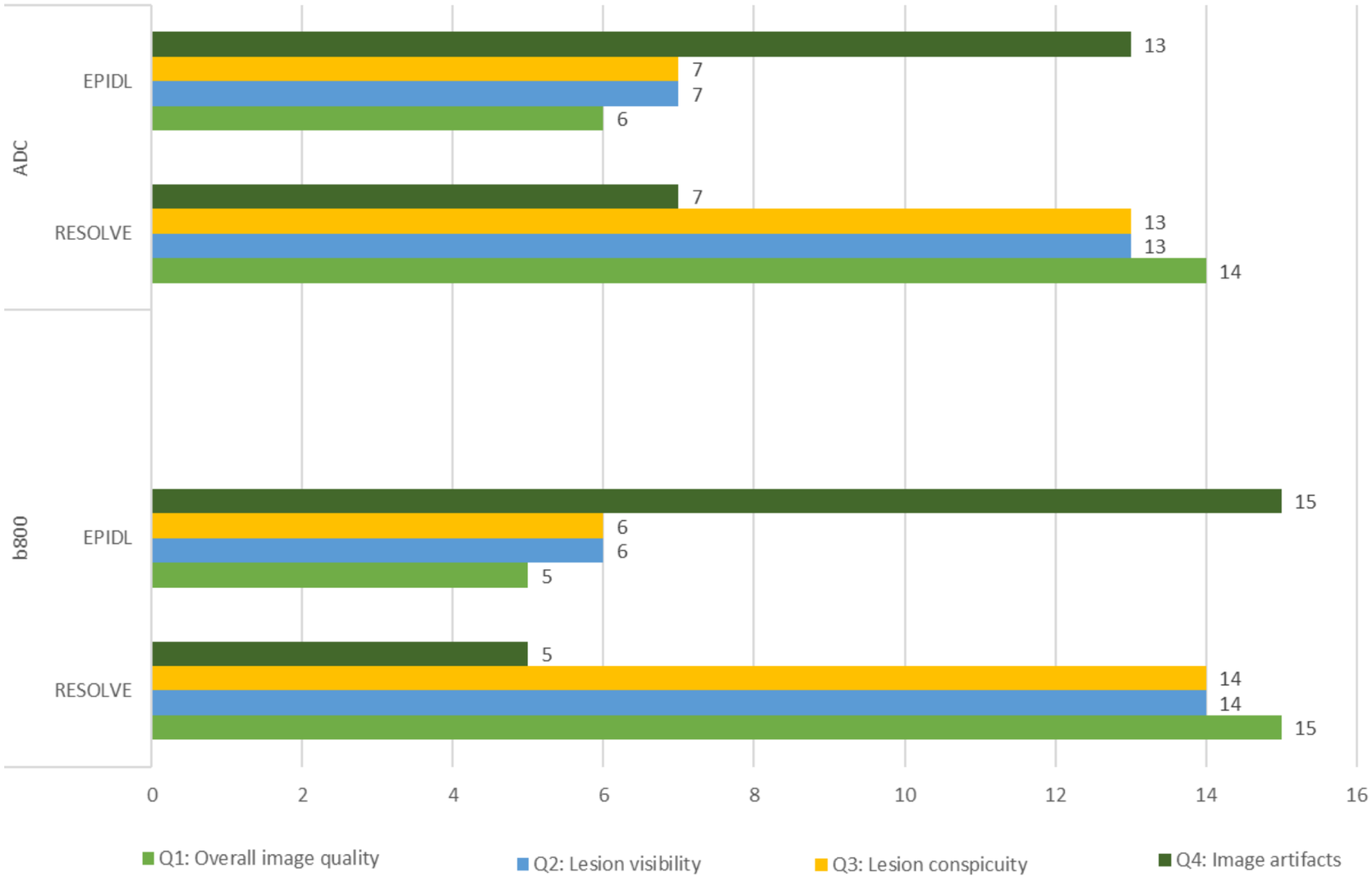
Normality distribution with Shapiro-Wilk test (a=0.05)

- T-test for normally distributed data (a=0.05)
- Wilcoxon signed rank test for non-normally distributed data (a=0.05)

Analysis was performed in R

4. Results: Qualitative evaluation

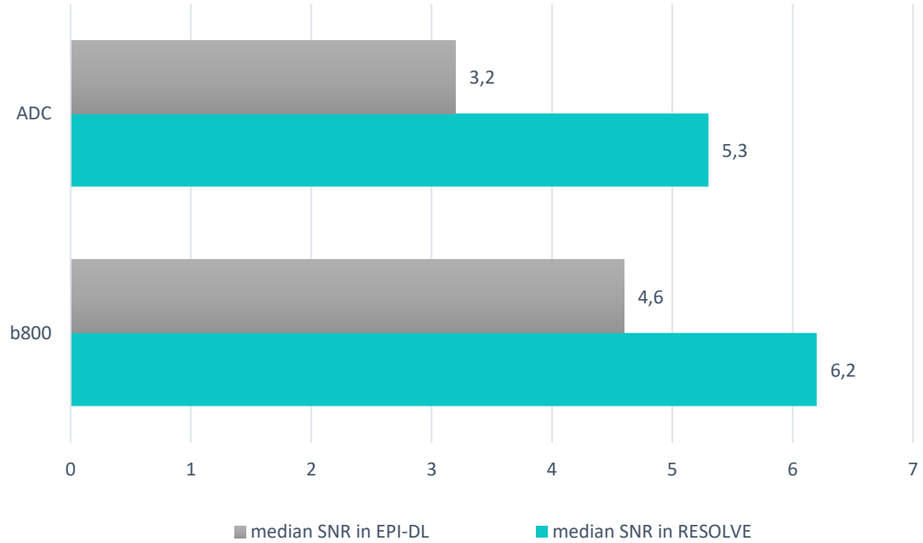
Reader's evaluation of Image Quality



4. Results: Quantitative evaluation of Image Quality

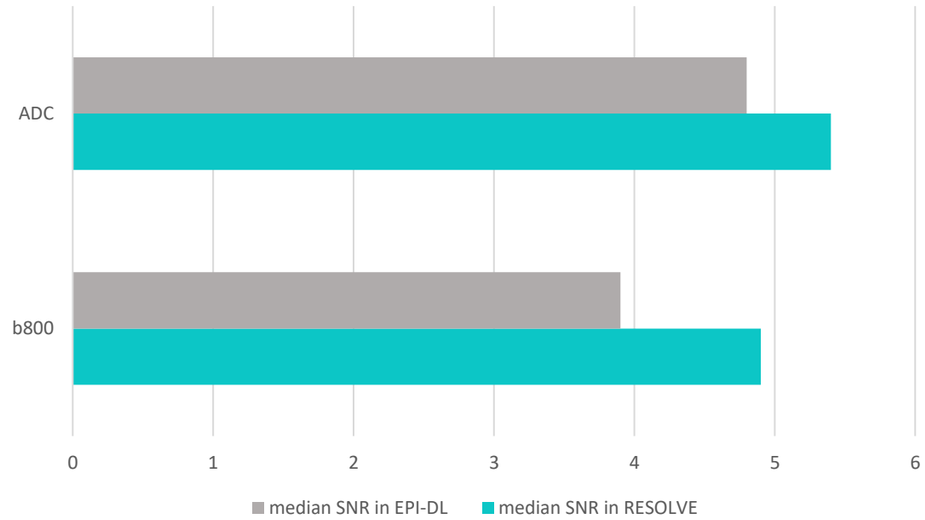
Manually defined ROIs

Type of image	RESOLVE	EPI-DL	p-value
	SNR Median, [IQR]	SNR Median, [IQR]	
b800	6.2, [2.2]	4.6, [2.8]	0.006*
ADC maps	5.3, [4.8]	3.2, [5.4]	0.001*
** Statistically significant difference*			



Circularly defined ROIs

Type of image	RESOLVE	EPI-DL	p-value
	SNR Median, [IQR]	SNR Median, [IQR]	
b800	4.9, [2.2]	3.9, [2.8]	0.35
ADC maps	5.4, [6.2]	3.1, [4.8]	0.001*
** Statistically significant difference*			



5. Conclusions

✓EPI-DL achieves good image quality compared to SMS-RESOLVE

✓EPI-DL suffers from EPI distortions and artifacts

✓Accelerated k-space reconstruction with Deep Learning algorithms may be clinically useful and pave the way to broader use of DWI in breast imaging

Thank you!

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6. References

[1] Gullo, R. L., Partridge, S. C., Shin, H. J., Thakur, S. B., & Pinker, K. (2024). Update on DWI for Breast Cancer Diagnosis and Treatment Monitoring. *AJR. American journal of roentgenology*, *222*(1), e2329933. https://doi.org/10.2214/AJR.23.29933

[2] Shin HJ, Diffusion-Weighted MRI for Breast Cancer Screening in High-Risk Women: Analysis of First Year Outcome for Invasive and In Situ Cancer Detection | S2-SSBR01-4, RSNA 2023

[3] Baxter GC, Graves MJ, Gilbert FJ, Patterson AJ. A Meta-analysis of the Diagnostic Performance of Diffusion MRI for Breast Lesion Characterization. Radiology. 2019 Jun;291(3):632-641. doi: 10.1148/radiol.2019182510. Epub 2019 Apr 23. PMID: 31012817.