Non-Contrast Early Detection of Breast Cancer Using High-Resolution Restriction Spectrum Imaging

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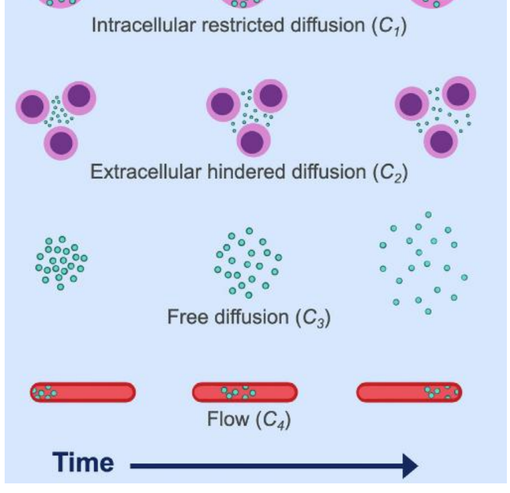
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Introduction

- Diffusion-weighted imaging (DWI)[1] holds great potential to perform as a non contrast technique for early detection of breast cancer.
- Restriction Spectrum Imaging (RSI)[2] is an advanced diffusion MRI framework that separates signal from cancer, edema, free water, and flow.
- RSI can discriminate between cancers and high-risk lesions from benign lesions and healthy breast tissue.[3]
- Multiband[4] MRI allows for high resolution diffusion MRI with 2 mm isotropic resolution, allowing for smaller cancer detection than current techniques at 4 mm through plane.

Principles of Diffusion MRI and RSI



- DWI relies on the diffusion of water molecules to provide insight into tissue cellularity.
- RSI is an organ-specific, multi-exponential model based on DWI that separates signal in pools of diffusion types, outputs are named compartment-maps (C-maps).[5]
- Healthy tissue tends to exhibit more free diffusion (high C_3 signal), while cancer tissue tends to exhibit more restricted diffusion (high C_1)

Methods

122 patients who underwent routine MRI due to high-risk status or with biopsy-proven cancer before surgery were selected.

Isotropic 2mm multishell DWI was collected using MB (Tacq = 4min 43s) along with clinical standard DWI and dynamic contrast-enhanced (DCE) imaging.

RSI models are multi-exponential: 3 and 4 compartment models were calculated using voxels from ROIs in 61 large cancers (largest dim > 2cm according to radiologists' reports).

Contrast-to-noise ratio (CNR) was measured from 28 lesions from a subset of 22 patients on C-maps, conventional ADC and DCE

C-values from 3C and 4C-RSI models, along with ADC values, were extracted from the subset of ROIs and used to train separate generalized models to discriminate between benign and malignant lesions. The models' predictions were then compared against the pathological reference standard.

Models

3C-RSI

$$S(b) = C_1 e^{-b*2.7\times10^{-4}} + C_2 e^{-b*1.7\times10^{-3}} + C_3 e^{-b*18\times10^{-3}}$$

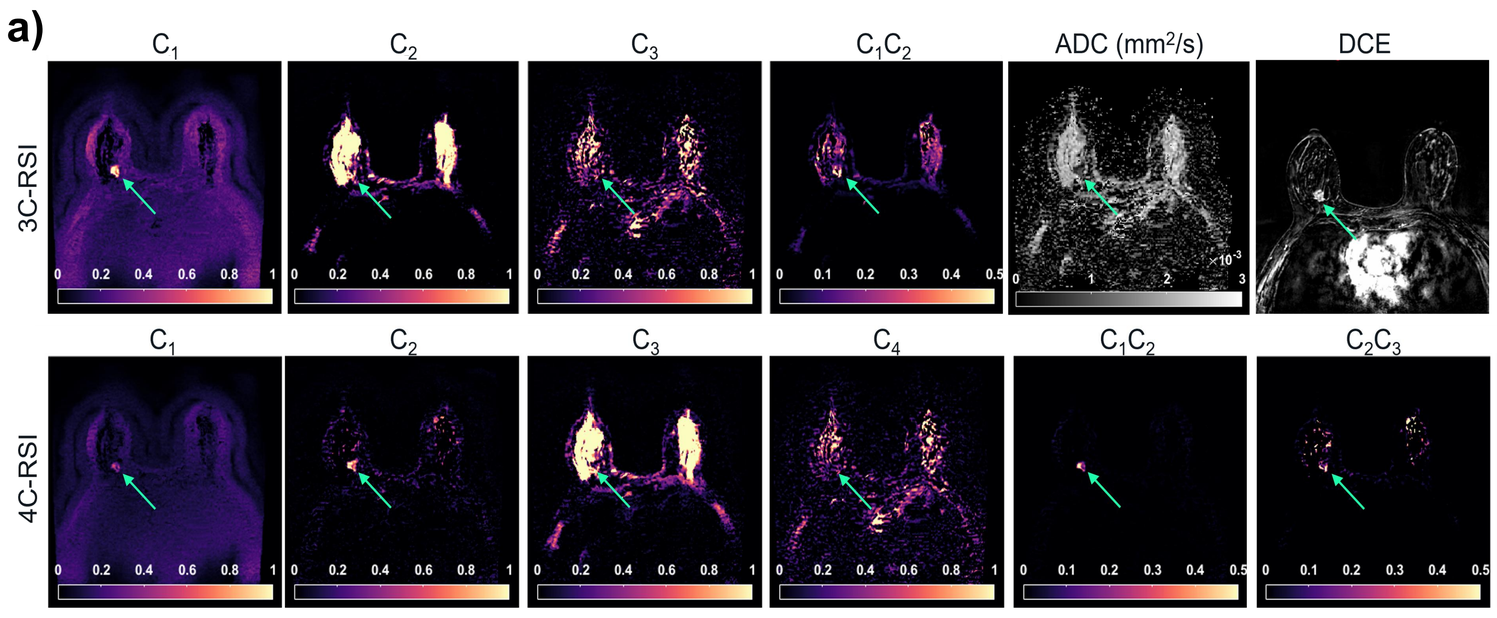
restricted — hindered — free/flow

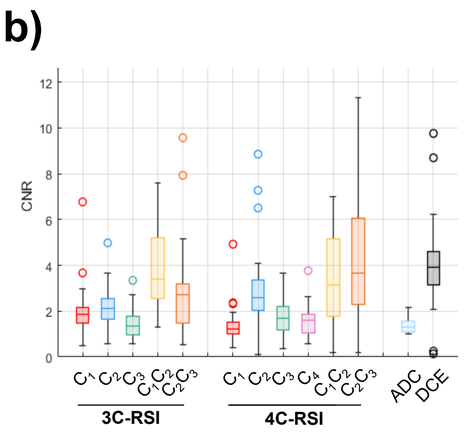
4C-RSI

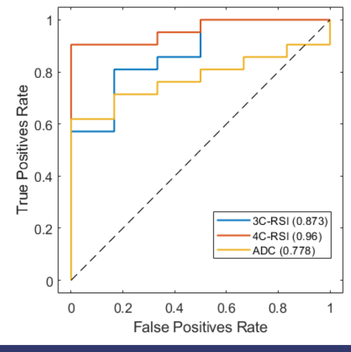
$$S(b) = C_1 + C_2 e^{-b*5.8\times10^{-4}} + C_3 e^{-b*1.9\times10^{-3}} + C_4 e^{-b*ADC_4}$$

highly restricted — restricted/hindered — hindered/free — flow

Results







a) 72-year-old patient with invasive ductal carcinoma of the right breast.

b) C_1C_2 and C_2C_3 had the highest CNR for both 3C and 4C-RSI among RSI outputs. DCE had the highest overall and ADC had the lowest with 4C-RSI C_1.

c) Of the 28 test lesions, 7 were biopsy-proven benign. ADC had an AUC of 0.778 while 3C and 4C-RSI had an AUC of 0.873 and 0.96, respectively.

Discussion

- In this study, we show that 3C and 4C-RSI models outperform conventional ADC in cancer detection and lesion assessment.
- Combination maps C_1C_2 and C_2C_3 showed CNR levels close to DCE's and 3C and 4C-RSI models had the higher AUC than ADC.
- Future steps of the project will include assessing what is the smallest lesion that can be detected by RSI models alone and close attention will be given to de-noising of images.

References

(1) Le Bihan, 1995; (2) White et al., 2013; (3) Loubrie et al., 2024; (4) Barth et al., 2016; (5) Zhong et al. 2022

Acknowledgements

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