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Deep learning-based whole breast segmentation for automated breast density measurements using fat-water decomposition MRI

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INTRODUCTION

- Breast cancer is among the most prevalent diseases for women in developed countries and is a public health concern.
- **Breast density (BD)** is a known and modifiable risk factor for breast cancer.
- BD is generally determined using mammography, imparting a significant radiation dose to the population.
- We previously published an accurate and reproducible method for measuring BD using fat-water decomposition MRI where a multi-step segmentation algorithm was employed (1). It consisted of determining upper and lower boundaries for the breast using the water and fat images respectively, and then creating the breast segmentation using a 3D region growing algorithm followed by automated removal of the nipple.
- Our previous algorithm requires cumbersome breast delineation with pre-defined parameters based on the images.

METHODS

- We used 182 fat-water MRI scans acquired from two scanners with radiologist's manual segmentation (ground truth) to train a U-Net (2). The network was provided a fat-water ratio map for each scan and trained to maximize the Dice index between the network output and the manual segmentation.
- A second set of 52 (26x2) test-retest scans was used for testing the U-Net segmentation and assessing the test-retest reliability.
- Test-retest reliability of MRI BD for the U-Net outputs was compared to those from the radiologist segmentations and the semi-automated algorithm by the mean difference between MRD for paired scans as well as the intraclass correlation coefficient (ICC).

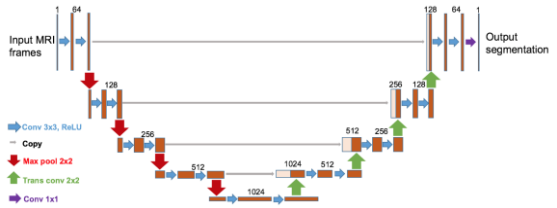

Figure 1. U-Net architecture

RESULTS

- The CNN achieved comparable segmentation accuracy to the previous algorithmic method in the testing set ($Dice_{CNN}$: 0.914±0.03; $Dice_{Algorithm}$: 0.911±0.03). Figure 2 shows a side-by-side comparison of manual, algorithmic and CNN segmentations.

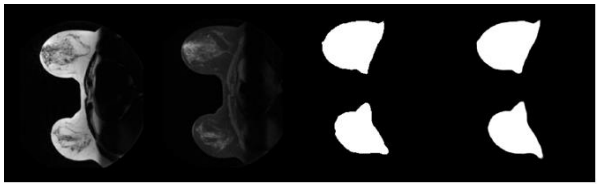

Figure 2. Example of U-Net output (right) relative to manual (center-right). Also shown are the fat (left) and water MRI data (center-left)

RESULTS (cont.)

- In terms of task-based comparison, the CNN exhibited nearly identical performance to the previous algorithmic method; both methods improve upon manual segmentation slightly in terms of reliability. Table 1 shows the precision measures for all three segmentation methods.

Segmentation Method		Manual	Previous Algorithm	CNN
Test-retest reliability	mean $\|\Delta_{1-2}\|$	1.35%	1.29%	1.29%
	std Δ_{1-2}	1.65%	1.57%	1.57%
	ICC [95% CI] (log)	0.979[0.954, 0.99]	0.986[0.969, 0.994]	0.983[0.962, 0.992]

Table 1. MRI BD test-retest performance for the three methods.

DISCUSSION

- The manual segmentation algorithm was cumbersome, requiring multiple processing steps and user supervision. Whereas our previous breast segmentation was fully automated, the algorithm required parameter tuning for the different scan sites and sequences utilized, and relies on assumption of FOV placement. In contrast, u-Net performed well for both scanners, independent of user-specified parameters, and spatially invariant. Moreover, the u-Net approach reduced processing time from several minutes with the previous automated technique to less than 10 seconds per subject once the network was trained.
- In totality, we observe that a u-Net provides segmentations with sufficient accuracy and precision to replace an automated pipeline previously used. The u-Net is not only entirely hands off and independent of parameters the user must provide, but it also provides segmentations for a whole breast in several seconds, even without GPU acceleration, as opposed to several minutes for the previous pipeline. These aspects make it more suitable for clinical adoption.

CONCLUSIONS

BD determined using U-Net showed test-retest reliability to that of a semi-automated algorithm and manual segmentation by a trained radiologist. This suggests that U-Net is a suitable tool for full automation of our MRI BD pipeline.

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References:

1. Ding J, Stopeck AT, Gao Y, Marron MT, Wertheim BC, Altbach MI, Galons JP, Roe DJ, Wang F, Maskarinec G. Reproducible automated breast density measure with no ionizing radiation using fat-water decomposition MRI. Journal of Magnetic Resonance Imaging 2018.
2. Ronneberger O, Fischer P, Brox T. U-net: Convolutional networks for biomedical image segmentation. 2015. Springer. p 234-241.