Clinical Evaluation of Atlas and Deep Learning-Based Automatic Contouring of Multiple Organs at Risk and Clinical Target Volumes for Breast Cancer

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Introduction

Since the majority of patients with breast cancer often survive for decades after receiving RT, they are at risk of late adverse events of radiation therapy such as cardiotoxicity [1], [2] and lymphedema [3], which can substantially decrease the quality of life. Therefore, the precise delineation of the clinical target volume (CTV), the heart structures as well as the organs-at-risk (OARs) have become important. The manual segmentation of such structures, which is currently the gold standard method, is laborious and subject to inter-observer variability. We present an automated segmentation solution based on a fully convolutional deep neural network (FCDN) trained for breast RT planning (Figure a). Furthermore, we have compared the performance of our model to atlas-based auto-segmentation (ABAS) using two commercial software to further validate the efficacy of our methods in comparison to conventional approaches.

Aim

1. To determine the clinical feasibility of auto-segmentation methods for target and normal organs

2. To compare the deep-learning-based auto-segmentation approach and commercially released atlas-based segmentation solutions.

Methods

Contrast-enhanced planning CT from 62 patients with breast cancer who underwent breast-conservation surgery was used in this study. Contours of OARs, CTVs and heart sub-structures were generated by ABAS from MIM and Mirada with 35 atlas library subjects and DLBAS using FCDN with 35 training sets The accuracy of segmentation was assessed on 14 test patients using the Dice coefficient with reference to the manually delineated contours.

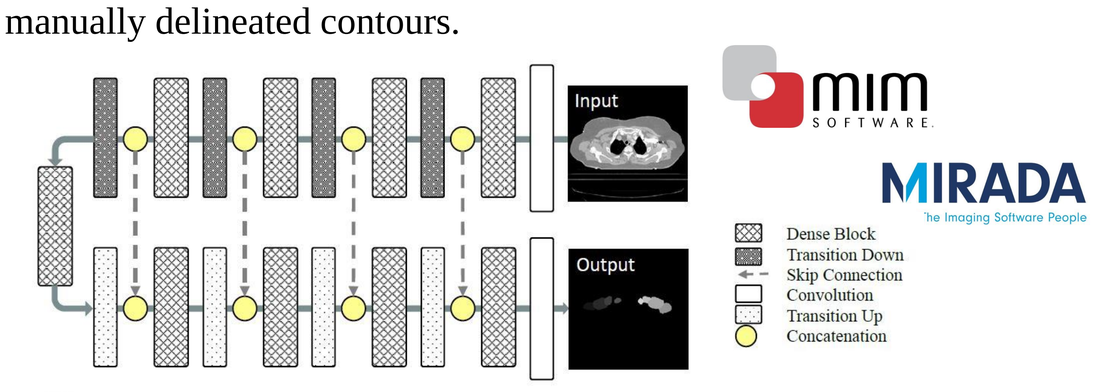


Figure (1) *: The schematic of the proposed fully convolutional DenseNet (FCDN) architecture*

Results

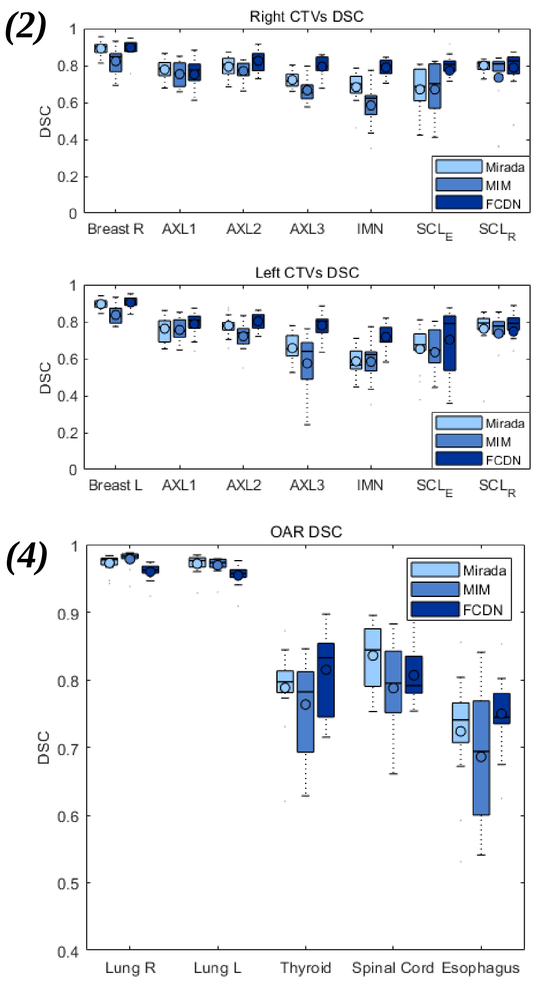
1. CTV Segmentation – Breast, Axillary, Intra-mammary, lymph node neck level 5 nodes

Our FCDN model produced acceptable average DSCs in seven out of eight right sided CTVs and in all left sided CTVs as in *Figure 2*. The FCDN model produced significantly higher DSCs than the ABAS in the right and left IMN. The ABAS methods produced lower scores in the left CTVs than in the right, especially in AXL3, IMN, and SCL (E). A typical example case is shown in Figure a.

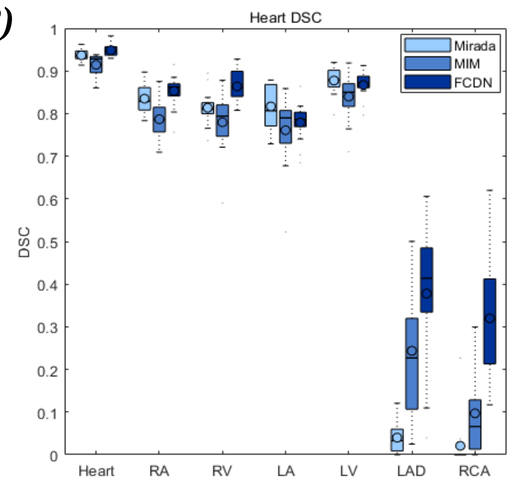
2. Heart Segmentation – whole heart, right & left ventricles, right & left atria, RCA and LAD

The difference between the atlas and deep learning methods was not as significant as shown in Figures 3 and 5b. The performance of Mirada was comparable to FCDN, producing a higher average DSC than the FCDN for the left atrium.

(2)

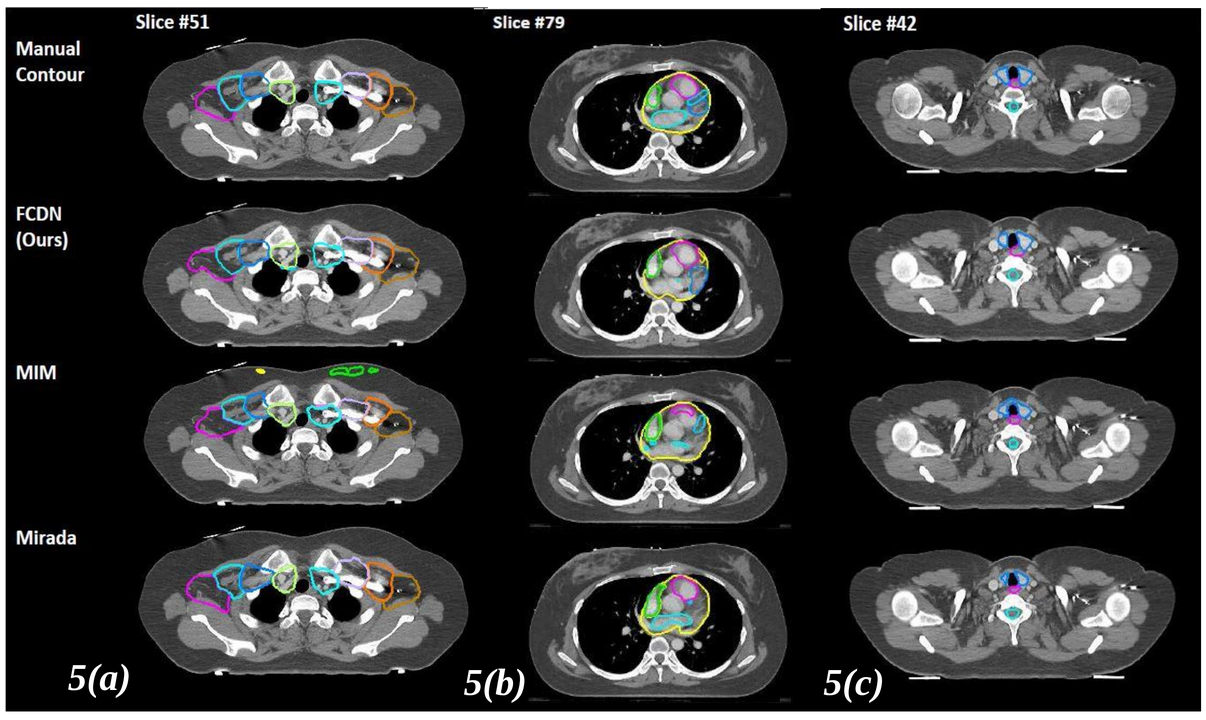


(3)



(4)

Figures (2) – (4) *: Boxplots comparing the performance of FCDN, Mirada and MIM for the CTVs , Heart and OARs, respectively*



Figures 5(a) – (c) *: Two example slices showing heart contours from manual, FCDN, MIM atlas, and Mirada atlas segmentations for the CTVs, Heart and OARs, respectively*

3. OAR Segmentation – right & left lungs, esophagus, spinal cord, thyroid

FCDN had the best average DSC for most structures, but not for the right and left lung (see *Figures 4 and 5c*). The quality of FCDN for spinal cord and esophagus was better, with consistent volume variation over the test sets. Lung ABAS was slightly better than FCDN, and the best average DSC was produced by MIM's atlas segmentation.

Conclusion / Future Works

In summary, we assessed the clinical feasibility of ABAS, from MIM and Mirada, and DLBAS, using FCDN algorithms, to segment target volumes and OARs, including heart substructures. Compared to ABAS, DLBAS was more consistent and robust in its performance across the majority of structures. In this preclinical study, we have confirmed the plausibility of these segmentation solutions for clinical implementations.

Further multi-institutional collaborations are still required in order to optimize the clinical utilization of auto-segmentation using either ABAS or DLBAS to determine the optimal therapeutic ratio in an individualized RT plan for treating breast cancer. We are also planning to further provide clinical significance of auto-segmentation through clinical tests such as Turing test and dosimetric evaluations.

REFERENCES

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