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EASTERN TIME [GMT-4]

Learning Clinical Expertise Using Deep 3D Networks: An Automated Clinical Target Volume (CTV) Delineation for Non-Small Cell Lung Cancer Patients (NSCLC)

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INTRODUCTION

Patient-Specific clinical target volume (CTV) delineation can be the most difficult step in the process of defining the treatment volumes from the gross tumor volume (GTV). Delineating patient specific CTVs is a labor-intensive process, and accounts for the high workload for most radiation oncology department worldwide. This process also is prone to human errors with poor inter-observer consistency. In current treatment planning systems (TPS), the automated uniform expansions have been used to reduce those concerns. However, they ignore patient specific anatomic and clinical variables.

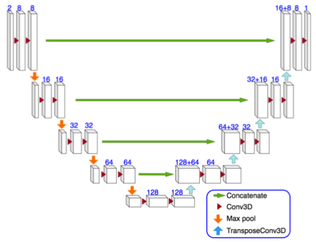
AIM

We developed an automated CTV delineation network for locally advanced NSCLC. Different with organ-at-risk segmentation based merely on images, our system learned to delineate using both patient specific anatomic and clinical variables, as well as physicians' clinical experience.

METHOD

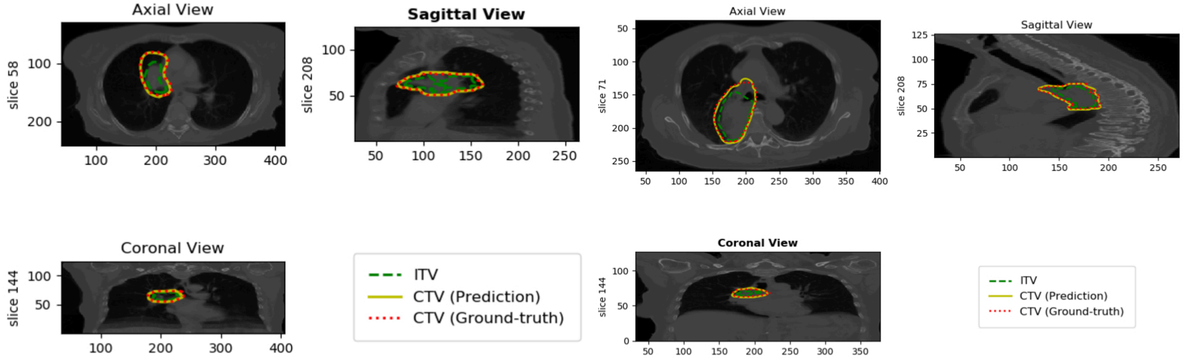
A deep full convolutional network (FCN) based solution:

- **Architecture**: A deep 3D U-net structure plus a customized loss function
- **Inputs**: two channel 3D image consisting of both patients' CT and their corresponding ITV
  - ITVs were contoured by physician from the 4D CT simulation scans
- **Output**: the predicted CTV delineation
- **Patient cohort**: fifty-four patients with locally advanced NSCLC in the right lung treated with standard chemotherapy and radiation
  - Training set: forty-six patients randomly selected
  - Testing set: the rest eight patients
- **Performance metrics**:
  - Quantitatively measured the missed and overlapped volume by precision, recall, and dice score
  - Visually inspected the critical organ avoidance of the predicted CTV by our network



RESULTS

- All CTV contoured by computer are visually inspected by the physicians.
  - Seven out of eight CTV predictions followed closely with the ground truth CTVs contoured by the physicians.
  - Only one had larger discrepancies near the apex of the upper lobe, but still acceptable by the physicians.
  - All predicted CTVs have acceptable sparing of the critical organs-at-risk.



(a) (b)

Figure 1. Two examples of the automated CTV delineation predicted by our trained network overlaid on the patient CT scan with tumor locations: a) in the right upper lobe; and b) in the right lower lobe. The yellow solid lines stand for the automated CTV predictions, the red dotted lines and green dashed lines are the ground-truth CTV and corresponding ITV drawn by the physicians. For both examples, we observed that the predicted CTVs agreed well with the ground-truth. Meanwhile, the critical organs, esophagus and heart, are spared by our CTV predictions.

	Test #1	Test #2	Test #3	Test #4	Test #5	Test #6	Test #7	Test #8	Mean
Precision	0.79	0.91	0.94	0.91	0.99	0.86	0.99	0.87	0.91
Recall	0.96	0.71	0.92	0.92	0.95	0.79	0.95	0.74	0.87
Dice score	0.87	0.79	0.93	0.92	0.97	0.82	0.97	0.80	0.88

Table 1. A quantitative evaluation of our automated CTV delineation system on eight testing patients. The precision is the fraction of the true volume in the predicted volume, and the recall is the fraction of the true volume in the ground-truth, respectively.

- The network performance was also evaluated using precision, recall and dice scores and summarized in Table 1.
  - The mean precision was 0.91
  - The mean recall was 0.87
  - The mean dice score was 0.88

CONCLUSIONS

The automated CTV delineation was utilized for right lung NSCLC patients using the deep learning method solely based on CTV images with manually contoured ITVs.

The model predicted CTVs agreed with physicians' contours reasonably well and were all acceptable by the physicians.

Even with a limited patient cohort, our deep-learning approach demonstrates the capability of learning physician's clinic expertise to intelligently contour clinical tumor volume with consideration of the patient specific anatomic and clinical variables, as well as the clinical expertise of the radiation oncologists.

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