ATLAS-BASED SEGMENTATION: EVALUATION OF A MULTI-ATLAS APPROACH FOR LUNG CANCER

Sara Pirozzi, B.S., Marri Horvat, M.S., Aaron S. Nelson, M.D., Jonathan W. Piper, B.S.

MIM Software Inc., Cleveland, OH

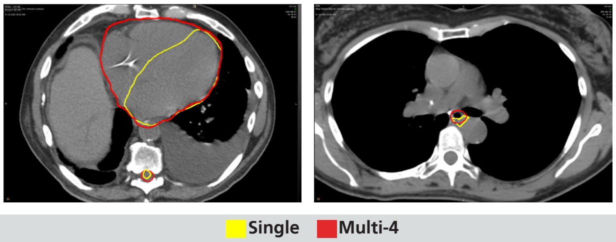
Purpose/Objectives

Manual contouring techniques are tedious and time consuming, increasing the importance of automatic segmentation approaches to reduce the contouring burden. Addressing this need, we previously demonstrated a single-best matched atlas-based segmentation method (SBM) that provided a contouring time savings of 67-86% for head and neck cancer and 46% for prostate cancer[1,2]. While offering significant time savings, single subject atlas segmentation may not adequately address the anatomical and positional variability that can occur even when using a subject that is found to be most similar to the patient. A new multi-atlas approach has been shown to provide greater accuracy than SBM for cancer of the head and neck, prostate, and liver[3,4,5]. The goal of this study was to evaluate the multi-atlas technique for lung cancer treatment planning.

Materials/Methods

An institution's SBRT lung atlas containing 82 subjects was utilized for atlas segmentation. Each atlas subject contained manually defined contours of the esophagus, cord, heart, left lung, right lung, and trachea. CT scans and contours for 16 subjects were evaluated. SBM used the one automatically determined best match for segmentation. Multi-atlas, Multi-3, Multi-4, and Multi-5, used multiple automatically determined best matches: 3, 4, and 5, respectively. The final segmentation for multi-atlas was generated using Majority Vote which comprises the area of overlap for at least half of the individual segmentations (2 of 3, 2 of 4, and 3 of 5, respectively). Average Dice Similarity Coefficients (DSC) were calculated for each structure to compare against manually defined "gold" standard contours for that subject. Overall percent improvement was calculated as the proportion of the error corrected by the method, or % difference on 1-DSC.

Figure 1
Comparison of Segmentation Results

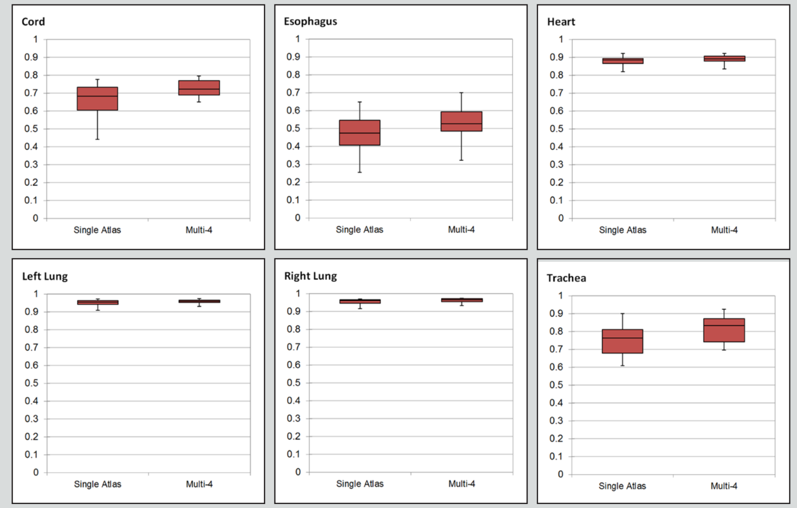


Comparison of segmentation results for the heart, cord, and esophagus for 1 and 4 atlas matches. Note the improved segmentation results using the greater number of atlas matches.

Table 1
Average Dice Similarity Coefficient

Structure	SBM	Multi-3	Multi-4	Multi-5
Cord	0.658	0.718	0.723	0.712
Esophagus	0.471	0.497	0.523	0.469
Heart	0.868	0.892	0.890	0.908
Lt Lung	0.946	0.955	0.953	0.956
Rt Lung	0.945	0.954	0.952	0.955
Trachea	0.753	0.795	0.813	0.809
Overall	**0.773**	**0.802**	**0.809**	**0.802**

Figure 2
Box and Whisker Plots Comparing the Dice Similarity Coefficients for 1 and 4 Atlas Matches



Results

All multi-atlas methods were significantly more accurate than SBM (p-value < 0.0005) with average DSC of 0.802 +/- 0.172, 0.809 +/ 0.163, 0.802 +/- 0.182 respectively for Multi-3, Multi-4, and Multi-5 compared to 0.773 +/- 0.187 for SBM. No significant differences existed between the different multi-atlas approaches. Accuracy for individual contours was improved by all multi-atlas methods (p-value <0.04) for the right and left lung, spinal cord, and heart. Multi-4 and Multi-5 were more accurate for the esophagus (p < 0.009) and trachea (p = 0.03) compared to SBM, while Multi-3 trended towards significance (p-value 0.10 and 0.06 respectively). Overall, Multi-4 showed the greatest improvement over SBM with 16% improvement followed by Multi-3 and Multi-5 at 12%.

Conclusions

Each multi-atlas approach resulted in significantly more accurate contours compared to the SBM. While still requiring some editing, this method for segmentation using multiple atlases shows promise for further decreasing the contouring time required for lung cancer.

References

1) Hu K, Lin A, Young A, Kubicek G, Piper JW, Nelson AS, Dolan J, Masino R, Machtay M. Timesavings for Contour Generation in Head and Neck IMRT: Multi-institutional Experience with an Atlas-based Segmentation Method. IJROBP. 2008; 72(1) Suppl: S391.

2) Lin A, Kubicek G, Piper JW, Nelson AS, Dicker AP, Valicenti RK. Atlas-Based Segmentation in Prostate IMRT: Timesavings in the Clinical Workflow. IJROBP. 2008; 72(1) Suppl: S328-329.

3) Pirozzi S, Piper J, Nelson AS. Atlas-based Segmentation: Comparison of Multiple Segmentation Approaches for Lymph Level Targets and Normal Structures in Head and Neck Cancer (HNC). International Journal of Radiation Oncology Biology* Physics. 2011; 81 (Supplement): Page S828.*

4) Pirozzi S, Horvat M, Nelson AS et al. Atlas-based Segmentation: Evaluation of a Multi-Atlas Approach for Prostate Cancer. Accepted for presentation at ASTRO 2012.

5) Horvat M, Pirozzi S, Nelson AS et al. Atlas-based Segmentation: A Comparison of Single and Multiple Atlas Matches for Automatic Liver Segmentation. Accepted for presentation at RSNA 2012.