ATLAS-BASED SEGMENTATION: COMPARISON OF MULTIPLE SEGMENTATION APPROACHES FOR LYMPH LEVEL TARGETS AND NORMAL STRUCTURES IN HEAD AND NECK CANCER

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Purpose

Manual contouring for Head and Neck Cancer IMRT can take hours, making automatic segmentation approaches essential. In a previous study we demonstrated a time savings of 68-87% using atlas-based segmentation for Head and Neck Cancer from a single best-matched atlas-subject[1]. In this study, we evaluated the automatic segmentation results from a single best-matched atlas compared to the combined segmentation results from multiple atlas matches (multi-atlas) using a 20 subject Head and Neck Cancer atlas containing targets and normal structures.

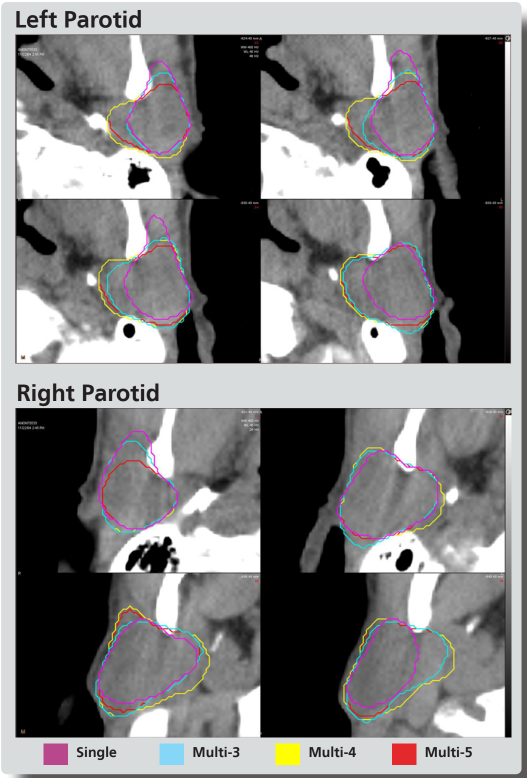
Materials/Methods

A 20 subject Head and Neck Cancer atlas was created in MIM Maestro (MIM Software Inc., Cleveland, OH). Each atlas-subject contained lymph level targets (Level I-VI), manually defined according to RTOG/EORTC guidelines, and normal structures. A leave-one-out analysis was used to compare automatic structures to the manually defined “gold” standard. Two methods of contour generation were used: 1) the automatically determined single best-matched atlas-subject and 2) multiple automatically determined best matches: Multi-3, Multi-4, and Multi-5. When using multi-atlases, the final segmentation was generated by determining the area of overlap for at least half of the individual segmentations (2 of 3, 2 of 4, and 3 of 5, respectively). An average Dice Similarity Coefficient (DSC) was calculated for 7 key structures including the neck levels, mandible, left and right parotid, larynx, spinal cord, and brainstem.

Results

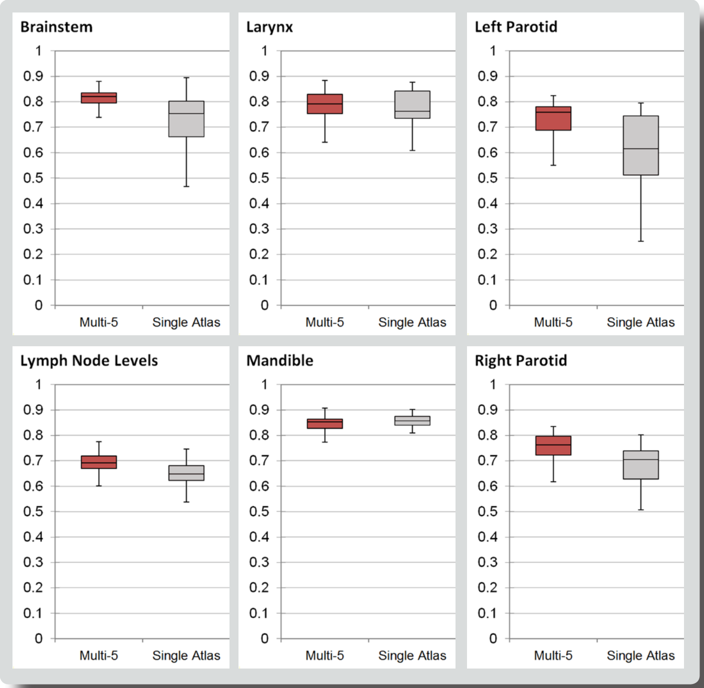
Across all the contours used for comparison, Multi-5 was the best, with an average DSC of 0.762 +/- 0.093, followed by Multi-4, Multi-3, and the best single atlas with average DSC of 0.761 +/- 0.099, 0.748 +/- 0.11, and 0.710 +/- 0.134, respectively. The difference between Multi-5 and Multi-4 was non-significant, while all other differences were significant (p-value < 0.01). For Multi-4, the average DSC for neck levels, mandible, left parotid, right parotid, larynx, spinal cord, and brainstem were 0.697, 0.845, 0.729, 0.758, 0.788, 0.719, and 0.790, respectively. The CTs evaluated ranged in number of segmented slices from 94-275 and required 47 +/- 7 seconds to segment using a single atlas.

Figure 1
Patient Image



Comparison of segmentation results for the left and right parotid for 1, 3, 4, and 5 atlas matches. Note the improved segmentation results with the greater number of atlas matches.

Figure 2
Average Dice Similarity Coefficient Comparison



Box and Whisker plots comparing the Dice Similarity Coefficients for 1 and 5 atlas matches.

Table 1
Average Dice Similarity Coefficient

Structure	Single Atlas	Multi-3	Multi-4	Multi-5
Brainstem	0.731	0.806	0.790	0.813
Larynx	0.768	0.779	0.788	0.780
Left Parotid	0.602	0.703	0.729	0.722
Levels	0.637	0.689	0.697	0.698
Mandible	0.858	0.842	0.845	0.843
Right Parotid	0.678	0.735	0.758	0.755
Spinal Cord	0.698	0.680	0.719	0.721
Overall	0.710	0.748	0.761	0.762
Average Time	47 +/- 7 sec	2.3 min	3.1 min	3.9 min

Average Dice Similarity Coefficient across 20 subjects using segmentation results from 1, 3, 4, and 5 best matches. Segmentation results for multi-atlases were combined using majority voting.

Conclusions

The multiple subject atlas segmentation approach was found to achieve the best similarity to manually defined contours. For the 20 patient atlas evaluated, Multi-4 which combined the four best single segmentations, was the best trade-off between accuracy and segmentation time by providing among the best contours in 3.5 minutes. While still requiring some editing, this method for segmentation using multiple atlases shows promise for further decreasing the contouring time required for Head and Neck Cancer.

Reference

[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.