Optimal PTV Margin Expansions along Six Anatomic Directions in Oropharyngeal IGRT

**Innovation/Impact:** This work empirically determined the optimal anisotropic margin expansions for oropharyngeal cancer IGRT. These differed from conventional, clinically used margin expansions. This work is evidence-based and used a population of 20 patients with over 600 daily CT images.

**Introduction:** In fractionated head and neck radiation therapy, a geometric margin is added to the target in order to compensate for positional uncertainties from patient setup error and internal motion of anatomy. These margins are generally several millimeters in magnitude and are also isotropic. The magnitude of margin expansions may be calculated from analytical formulae using a limited number of empirical measurements. However, these frequently assume global, rigid changes in anatomy, and thus cannot fully describe tissue deformation. It is also implausible that ideal margins are isotropic. Neither the validity of conventional margin expansions, nor the magnitudes of optimal margin expansions are known. This work identified the optimal margin expansions in six anatomical directions that minimized the amount of normal tissue included within the margin while maintaining adequate target coverage for a population of patients.

**Methods:** For 20 patients, daily-acquired CT-on-rails images were registered to the patients' planning CT with a deformable image registration technique. Using the resulting vector fields, the positions of volume elements originally within the CTV (target voxels) or within a 1cm shell surrounding the CTV (normal tissue voxels) on the patients' planning CT were determined on the subsequent daily CTs. The proportion of target voxels that remain within some margin for a particular proportion of treatment fractions was considered the geometric target coverage provided by that margin. The included normal tissue was the relative volume of normal tissue voxels that were within the margin for a particular proportion of the treatment fractions.

The geometric target coverage was evaluated for 15,625 margins. These margins were created in MatLab (MathWorks, Natick, MA) by morphological dilation with an ellipsoidal structuring element. The structuring element was defined by the magnitude of six axes along the posterior, anterior, lateral, medial, inferior, and superior directions relative to the target's centroid. The 15,625 margins represent the 5^6 combinations of 1, 2, 3, 4, and 5mm expansions in each of the six anatomic directions.

The optimal margin was considered to be that which simultaneously minimized the median included normal tissue values at 10, 50, and 90% of treatment fractions while providing adequate geometric target coverage for at least 90% of patients. Four margins were optimized independently according to the following definitions of adequate geometric target coverage: 1) at least 90% of target voxels covered during at least 90% of treatment fractions ($V_{90\%\ge90\%}$), 2) at least 95% of target voxels covered during at least 90% of treatment fractions ($V_{90\%\ge95\%}$), 3) at least 90% of target voxels covered during at least 95% of treatment fractions ($V_{95\%\ge90\%}$), and 4) at least 95% of target voxels covered during at least 95% of treatment fractions ($V_{95\%\ge95\%}$).

The differences in the amount of normal tissue included in the optimized margins and isotropic margins were calculated.
Figure 1: Head and neck anatomy with color map depicting the proportion of treatment fractions that A) target voxels occur within the CTV, and that B) normal tissue voxels occur within a 5mm isotropic expansion of the CTV. Dark red and dark blue correspond to 100% and 0% of treatment fractions, respectively.

Figure 2: Geometric target coverage histogram. The anisotropic margin was optimized according to the $V_{90\%} \geq 90\%$ geometric target coverage criterion. Isotropic 1mm and isotropic 2mm margins are not depicted because they did not satisfy this criterion in at least 90% of patients.

Figure 3: Amount of normal tissue within margins normalized to that within a 5mm isotropic margin. The anisotropic margin was optimized according to the $V_{90\%} \geq 90\%$ criterion.

Table 1: The margin expansions optimized according to geometric target coverage criteria and the difference in amount of included normal tissue compared with isotropic margins. Shaded cells denote the optimization criterion was not met in at least 90% of patients.