Margin calculation for temporally asymmetric respiratory motion

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Purpose: To adapt van Herk's recipe to account for temporal asymmetry of non-Gaussian distribution of respiratory motion in margin calculation.

Methods: The objective is to calculate two margins separately for the caudal/inhale edge and the cranial/exhale edge by finding the two equivalent Gaussian distributions to the actual non-Gaussian distribution (non-GD) that would produce the same blurred cumulated dose on each edge at a particular dose level. The standard deviation (SD) σ_m* of these equivalent distributions can then be quadratically combined with other random errors as in the conventional recipe. In order to avoid measuring the actual non-GD, we propose a numerical population-based model to determine σ_m* from two parameters, the SD σ_m and the asymmetry a_m of the non-GD, the latter being expressed as the difference between the geometrical average position and the time-weighted average position. The dynamic dose deposit to a moving target was simulated using diaphragmatic respiratory signals extracted from CBCT projections acquired at each treatment fraction of 33 patients. For each patient, σ_m* was deduced from the measurement of exhale and inhale margins required to obtain correct target coverage over the entire treatment course and used to build the model. Several isodose line prescriptions (80%, 85%, 90%, 95% and 99%) were investigated.

Results: The difference between inhale and exhale margins increases with the dose prescription level. This difference is frequently higher than 1 mm for the 95% and 99% isodose lines (28% and 56% of the patients respectively). It was found that σ_m* is strongly linearly correlated to σ_m and a_m. The coefficients of the model fitting this relationship were determined (R^2 > 0.96) and model errors appeared to be less than 0.2mm in average.

Conclusion: A simple model has been proposed to combine non-Gaussian asymmetric respiratory motion with other Gaussian random errors using the original van Herk's recipe.