Limitations of Convolution Methods for Modeling Geometric Uncertainties in Radiation Treatment

Convolution methods have been incorporated into dose calculations to model the effect of geometric positioning uncertainties. These methods assume shift invariance of the dose distribution, and ignore the stochastic nature of the finite number of fractions. The magnitudes of the resulting errors are not well documented. We specifically address the issues of tissue inhomogeneities, surface contours, and the finite number of treatment fractions by using two approaches. First, the uncertainty in beam positioning was modeled with a Gaussian distribution. A static dose distribution (with surface and inhomogeneity corrections) was calculated and was convolved with the Gaussian to yield a 'blurred' dose distribution incorporating the uncertainties. Second, the dose was calculated using a finite number of laterally displaced individual beams (each with surface and inhomogeneity corrections) weighted by the same Gaussian. The difference between the results of the two methods indicates the error in the convolution method. This analysis was performed for phantoms as well as some clinical situations. Similarly, the effect of the finite number of treatment fractions was modeled by randomly sampling beam positions for each fraction. Significant differences (>5%) have been observed for some typical clinical situations. We conclude that for these algorithms to be of clinical use, they must be augmented to account for these sources of error.