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# Proton dose calculation incorporating respiratory motion


## Purpose

Protons are sensitive to the tissue density variations in the beam path. The dose actually delivered could be incorrectly predicted by the static patient model in the presence of significant organ motion. The purpose of this work was to investigate methods to predict dose delivered to the patients by incorporating respiratory motion effects into proton dose calculation.

## Method

The convolution method and direct simulation method were implemented. For convolution method, the dose distribution calculated for the exhale phase was convolved with a one-dimensional asymmetric probability distribution function (PDF) along superior-inferior (SI) direction. For direct simulation method, the organ position change was simulated by moving the co-planar beams in the direction opposite to the organ motion. The dose distribution was recalculated for each simulated position, and combined with the weights determined by the same PDF used by the convolution method. The methods were evaluated on a 2-beam and a 3-beam esophagus proton treatment plan in which the ITV method was used to compensate for the respiratory motion.

## Result

There were significant dose deviations due to respiratory motion at the air-tissue junction perpendicular to the organ motion direction, and at the superior and inferior edges of the static dose distribution. Differences up to 15% were observed in the target region and 30% in the air-tissue region between the motion-encoded dose distribution and the static dose distribution. Examination of the dose volume histogram indicated that two methods yielded very close estimation of respiratory motion effect on dose distribution.

## Conclusion

The convolution method is nearly equivalent to the direct simulation for proton for the studied esophagus case. Incorporation of the organ motion could lead to a more realistic estimation of dose distribution for proton treatment plans.