Assessment of Improved Critical Structure Sparing using Biologically-Based Optimization for Volumetric Modulated Arc Therapy of Head and Neck Cancer

The gEUD was given by the formula (Niemierko, 1997):

$$gEUD = \left( \frac{1}{N} \sum_{i=1}^{N} \left( \frac{v_i}{D_i} \right)^{1/a} \right)^{1/a}$$

where $v_i$ is the the fraction of the reference volume homogenously irradiated to dose $D_i$, $N$ is the number of voxels and $a$ is a parameter that represents the dose–volume effect. The gEUD equals to mean dose when the the parameter “a” is set to “1”.

The gEUD-based optimization in Pinnacle 3 TPS (version 9.0, Philips Medical Systems) incorporates gEUDs in a quadratic cost function and the cost function is minimized using a gradient algorithm (Widesott et al., 2008, Mihaylov et al., 2012). While the relative weights for PTV1, PTV2 and PTV3 were between 70 -100, the relative weights for critical structures varied from 5 to 50 by trial and error for gEUD-based optimization using different values of “a” that changed from “1” to “10” (Qi et al., 2009). Both dose-volume-based and gEUD-based VMAT plans used the same beam arrangements which consist of 6MV, 280° dual arcs with 4° arc sampling.

On average, for PTV1, PTV2 and PTV3 D95, the differences between VMAT plans using gEUD-based optimization with “a” values of “1”, “5” and “10” and the Dose-Volume based optimization were less than 1%, 3% and 1% respectively. The significant sparing of cord, parotids, larynx and esophagus were achieved using gEUD-based optimization. The cord D2 (used as a surrogate for maximum dose) was decreased by 45% (from 38.7Gy with dose-volume based VMAT plan to 21.4Gy with gEUD-based VMAT plan utilizing a:5. On average, the parotid D50 decreased by up to 38% for individual patients. The dose to esophagus was also significantly reduced using gEUD-based optimization: D30 was decreased by up to 25% for gEUD-based plans using “a” parameter of “5”.

The gEUD-based optimization in volumetric modulated arc therapy of H&N cancer patients has a great potential to increase the critical structure sparing as compared to the dose-volume based (physical) VMAT. However, the parameter “a”, maximum EUDs and weights must be carefully chosen (optimized) to obtain the maximum sparing of the critical structures without compromising the target(s) coverage. The use of hybrid objectives utilizing both physical and biological may yield better target coverage and structure sparing for some cases. A study is underway to compare pure gEUD-based versus hybrid optimization of volumetric modulated arc therapy for the same set of patients.

References