Dose-mass vs. dose-volume optimization: a phantom study

**Background:** Dose calculations are performed through CT derived attenuation coefficients, which are mapped to electron density by a calibration procedure. The electron density governs the number of photon Compton interactions. Those Compton electrons lead to ionizations, which affect the underlying biological response in the living cells. Therefore, it seems natural to perform optimization based on masses rather than on volumes in inverse radiotherapy optimization.

**Materials and methods:** Consider applying to a volume of interest (VOI) the dose-volume

\[ F^3 = \sum_{i} \frac{(d_i - d^k)^2}{d^k} v_i \quad (1) \]

(DVH) objective function (Eq. 1), where \( d_i \) is the dose in voxel \( i \), \( d^k \) is the desired dose in each voxel, and \( v_i \) is voxel’s volume. If in each voxel the volume \( v_i \) is multiplied by voxel’s density \( \rho_i \)

\[ F^4 = \sum_{i} \frac{(d_i - d^k)^2}{d^k} m_i \quad (2) \]

then the equation transforms to a dose-mass (DMH) objective form (Eq. 2), where all the quantities are the same as in Eq. 1, with the exception of \( m_i \) which denotes the voxel’s mass.

**Results:** In the situation where the density in all voxels is constant, there should be no difference between DVH- and DMH-optimizations. However, if the media density is variable, the DMH solution of the inverse optimization problem will differ from the DVH solution and will remove a degree of degeneracy inherent in the DVH optimization. An example is illustrated on Figure 1. The red, green, and blue VOIs have densities of 0.8, 1.0, and 0.2 g/cm\(^3\). The orange VOI is a 1.0 g/cm\(^3\) target (PTV) which is irradiated by two beams: 1) through an AP beam traversing 0.8 g/cm\(^3\) density VOI, and 2) through a Lat beam traversing the 0.2 g/cm\(^3\) density VOI. Each beam is normalized to deliver average 100 cGy to the PTV. For the same average dose to the PTV the mean dose (blue dashed line) to the low density (0.2 g/cm\(^3\)) VOI is 20.5 cGy, while the mean dose (solid red line) to the high density (0.8 g/cm\(^3\)) red VOI is 25.2 cGy. Therefore, irradiating the PTV through the lower density VOI results in ~23% lower average dose to that VOI. If the low and high density VOIs from Fig. 1 are combined and DVH (cf. Eq. 1) and DMH (cf. Eq. 2) optimizations are performed such that dose-volume-histograms of the two optimizations schemes are matched. In case of DVH optimization, 60% of the dose is delivered through low density VOI and 40% is delivered through the low density VOI. In DMH case the split is 70% and 30%

**Conclusion:** Delivering dose to a target through low density VOIs: 1) facilitates the dose deposition to that target by the virtue of less material attenuating the beam, and 2) lower doses to the low density VOI because of the lack of scattering sources in this low density media.