Analysis of Electronic Densities and Integrated Doses in Multiform Glioblastomas Stereotactic Radiotherapy

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Abstract. In Radiotherapy, Integrated dose (ID) is the total delivered energy in a target. This physical parameter could be a predictor for complications such as brain edema and radionecrosis after stereotactic radiotherapy (SRT) treatments for brain tumors. ID depends on the tissue density and volume. Using CT patient images from the National Institute of Neurology and Neurosurgery and BrainScan\textsuperscript{©} software, this work presents the mean electronic density of 21 multiform glioblastomas (MGB), comparative results for normal tissue ID estimates for each case. The relationship between the estimated ID and the probability of complications is discussed.

INTRODUCTION

The integrated dose $ID$, is the total delivered energy in a radiotherapy target, it is defined by Eq.

$$ID = \int Ddm$$

This parameter has been proposed as a predictor to prevent complications following brain stereotactic radiosurgery of AVMs (arteriovenous malformations) [1]. ID depends on dose and irradiated volume and these parameters have shown to be highly related to radiation associated complications. We intend to explore this parameter utility in order predict those effects [2].

METHODS

A retrospective study was performed for 21 patients suffering from MGB treated in the Radiosurgery Unit at this Institute with a dedicated linac of 6 MV (Novalis, BrainLAB, Germany) with FSRT. Mean prescription dose for target lesions was 49.63 Gy (sd 22.33 Gy) in 18.1 mean fractions (sd 12.4).

For tumor densities calculations CT images from all the patients were analyzed using the BrainScan\textsuperscript{©} software for treatment planning. We have measured the
electronic densities of 120 different points of the designated target from each patient at four different slices. Planning volume was sketched in each CT image by an expert physician including lesion and brain edema. Points were selected near central target region and outlier values were excluded in the analysis.

Mean electronic densities (ED) for each tumor, as well as, for normal tissue where characterized using 60 points. For normal tissue points, target contralateral locations were chosen. Each tumor volume was registered using tridimensional software reconstruction of the target region. We standardized the dose grid size for 8 mm³ volume per voxel. Using differential DVH (Dose Volume Histogram), the mean dose was calculated for each voxel from the dose distribution over the whole irradiated volume.

To calculate the ID for each case we apply Eq. 1. As we are unable to measure the mass of the target directly, we used the relation between mass and density shown by Eq. 2. Where \( dv \) is a differential volume.

\[
dm = \rho dv = (ED)dv
\]

\[
ID = \int D dm = D(ED)dv
\]

Approximating density values to previously calculated mean electronic densities for each case and applying Eq. 3 we can find the total delivered energy to each target. As we are working with a finite number of voxels we approximated the integral with a sum as shown in Eq. 4.

\[
ID = \int D(ED)dv = (ED)\sum_{i} P(D_i)D_i
\]

By this method we calculated the integrated dose for each case. Patients clinical files were also explored looking for references of radiation associated complications.

**RESULTS**

The mean electronic density found for MGB’s was 1.031 ± 0.006 g/cm³ (Fig. 3), while mean value for the normal tissue was 1.038 ± 0.004 g/cm³. Both values are extremely close to water density showing its radio-equivalent properties. The total integrated doses were compared between patients; mean ID delivered to the target per fraction was 322.585 ± 113.831 mJ (Table 1). Mean value for ID delivered to normal tissue is 2.375 ± 1.675mJ (Fig. 1). Indications of radiation associated complications for normal tissue surrounding lesion were referred almost in all patient clinical files (Fig.2).

![Graph of Electronic Density Average of Each Tumor](image)

**FIGURE 1.** Graph of Electronic Density Average of Each Tumor.
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Previous publications for AVM and radiosurgery suggest a greater incidence of radiation associated complications for IDs higher than 150 mJ [1]. With only one exception all MGBs analyzed received IDs over this value. According to patients files 60% of the cases present complications which may indicate correlation between ID and brain edema. Further images analysis is needed in order to find clear correlations and predictive results.

REFERENCES