

High Cellularity Subvolume in Glioblastoma identified by High b-value Diffusion Weighted Images

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Target Audience: Clinicians and scientists interested in advanced analysis of high b-value diffusion-weighted imaging to differentiate high cellularity components of glioblastoma from edema

Purpose: The blood-brain(tumor)-barrier could have an impact on therapeutic efficacy of glioblastoma (GB), particularly in the non-enhanced subvolume, by limiting the amount of temozolomide (TMZ) that reaches tumor cells. It is a challenge to differentiate the non-enhanced solid tumor from edema using conventional FLAIR and ADC ($b \leq 1000 \text{ s/mm}^2$) images. This study aimed to develop and investigate a method to identify the high cellularity component of GB by using high b-value diffusion weighted (DW) images and mean intravoxel diffusion kurtosis, and to relate them to the pattern of treatment failure.

Methods: Sixteen patients (age: 24-77 years) with GB had MRI scans prior to concurrent TMZ and radiation therapy (RT). DW images were acquired in 3 orthogonal directions with b-values of 0, 1000, and 3000 s/mm^2 . Mean intravoxel diffusion kurtosis (DK) and diffusion coefficient (D) were calculated [1]. Gross tumor volumes defined on post-contrast T1-weighted (GTV-Gd) and T2 FLAIR images (GTV-FLAIR) were used for RT planning. Using the high b-value (3000 s/mm^2) DW images, in which fluid, edema, grey matter, and white matter, to an extent, are suppressed (Fig 1), the high cellularity abnormality volume (HCAV) of each patient was determined by a threshold (mean intensity + 2SD) obtained from a VOI in normal-appearing tissue and contralateral to the tumor. After co-registration of DW, FLAIR and post-contrast T1-weighted images pre RT, planned dose volumes and MRI at recurrence, spatial overlaps of the HCAV with the GTV-Gd, GTV-FLAIR, 95% radiation dose volume and pattern of failure were compared.

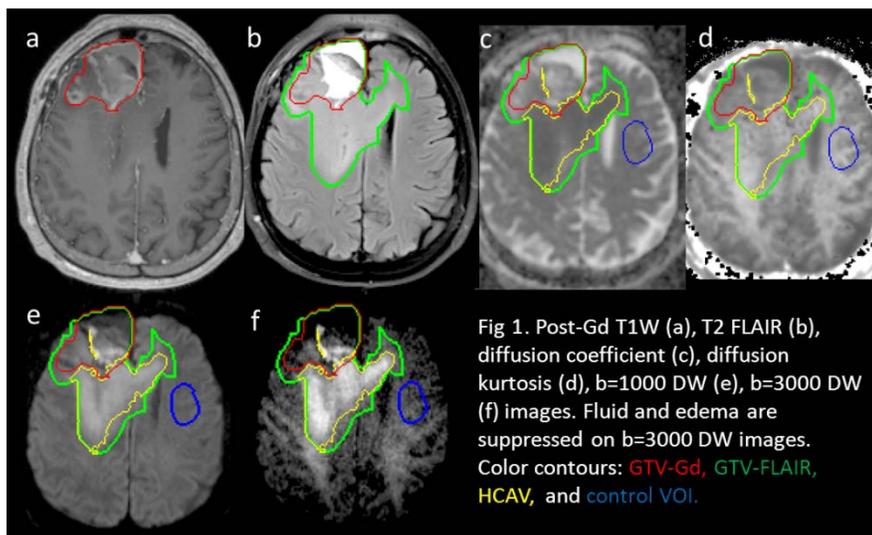


Fig 1. Post-Gd T1W (a), T2 FLAIR (b), diffusion coefficient (c), diffusion kurtosis (d), b=1000 DW (e), b=3000 DW (f) images. Fluid and edema are suppressed on b=3000 DW images. Color contours: GTV-Gd, GTV-FLAIR, HCAV, and control VOI.

The HCAVs extended beyond the GTVs-FLAIR in 6 patients. In 3 patients, the 95% prescribed radiation dose volumes covered less than 95% of the HCAVs (70%, 62% and 23%). Of the 8 patients who had recurrence, three had non-central recurrence (in-field, marginal and distant for each), of whom 2 had less than 95% spatial coverage of their HCAVs by the 95% dose volumes, indicating that the HCAV shows high risk for non-central recurrence. Interestingly, the intensity differences between the HCAVs and the control VOIs were not significant for D and DK ($p > 0.1$, paired t-test) indicating their limited roles for extracting the HCAV.

Conclusion: High b-value DW imaging could provide a means to extract the high cellularity components of GB and aid in RT target volume definition. Further follow-ups will allow us to investigate the probability of treatment failure in relation to the non-enhanced high cellularity in GB and radiation doses.

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References: [1] Jensen JH, Helpert JA, Ramani A, Lu H, Kaczynski K. Magn Reson Med 2005;53:1432-40.