ASSOCIATION BETWEEN TEXTURE FEATURE RATIOS AND PATIENT SURVIVAL IN GLIOBLASTOMA

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Background and purpose: Glioblastoma multiforme (GBM) is the most common and aggressive malignant brain tumor and its median survival duration of GBM patients is less than 15 months with multimodality treatments such as radiation therapy and chemotherapy with temozolomide (1). Several computer-based analyses including image texture analysis have been proposed to improve the diagnostic performance of imaging-derived measurements in cancer studies (2,3). In this study, we investigated tumor-derived texture feature ratios from rCBV values from DSC-MRI in two different tumor regions; the contrast-enhancing lesion (CEL) region and non-enhancing lesion (NEL) region. We extracted first-order statistics such as homogeneity, mean, standard deviation, skewness, and kurtosis from the intensity histogram, second-order statistics from Haralick texture features obtained from the intensity gray level co-occurrence matrix (GLCM), and kinetic textural features from the dynamic susceptibility contrast (DSC) MRI. The purpose of this study was to determine the association of these DSC-MRI textural feature ratios with overall survival rates of patients with GBM.

Material and Methods: A total of 24 GBM patients from The Cancer Genome Atlas on the basis of available perfusion DSC MRI data were obtained from The Cancer Imaging Archive. Relative cerebral blood volume (rCBV) values were calculated from ROIs within the CEL, the NEL, and the normal-appearing white matter (NAWM), respectively and normalized with the mean value of the rCBV intensities for the unaffected NAWM region. We applied an 11x11 sized Laplacian-of-Gaussian filter to a normalized rCBV ROIs to obtain filtered images and GLCMs were derived from both unfiltered and filtered images. Then, ratios of filtered texture descriptors to the unfiltered texture descriptors were calculated to yield texture feature ratios. Image gray-level heterogeneity was quantified by using first-order statistics such as homogeneity, mean, standard deviation, skewness, and kurtosis of the pixel intensity distribution. For the two-dimensional texture features, to quantify the spatial distribution of the pixel values within the ROI, we derive the GLCMs from the unfiltered and filtered images. We used eight gray levels with 1 pixel offset to compute the GLCMs from the filtered and unfiltered images. We then computed 13 different second-order Haralick statistical measures from the GLCMs (4). For the kinetic texture analysis, the gadolinium concentration time series of the DSC perfusion data in both CEL and NEL regions were extracted. Each ROI voxel from the dynamic perfusion dataset was normalized by the corresponding mean NAWM intensity, and all 18 features (one- and two-dimensional features) were calculated for each time point in the DSC series. Each time series texture feature was then fitted to a third order polynomial model (Eq.[1]) to yield four coefficients (b_0, b_1, b_2, b_3).

$$f(t) = b_0 + b_1 t + b_2 t^2 + b_3 t^3 \quad [1]$$

This four-dimensional coefficient vector was then projected to one-dimension using metric multidimensional scaling (5). In this study, the 18 texture feature ratios were compared between overall survival groups (≤ or > 12 months). Texture feature ratios were assessed with Kaplan-Meier and the receiver operating characteristic (ROC) analysis to measure their associations with overall survival. Survival difference between the groups was assessed via a log-rank test.

Results: For the CEL, there were strong positive correlations between homogeneity and inverse difference moment (IDM) (r=0.99, p<0.001), and there were strong negative correlations between angular second moment (ASM) and entropy (r=-0.94, p<0.001). For the NEL, there were strong positive correlations between the variance and sum average (r=0.94, p<0.001) and between the variance and sum variance (r=0.95, p<0.001). Kaplan-Meier survival curves for groups induced by the ROC optimized cutoffs for the CEL-derived homogeneity, ASM, IDM, and entropy are significantly different (p<0.05) indicating that these feature ratios were independent predictors of overall survival. Figure 1 shows the Kaplan-Meier survival curves for homogeneity. For NEL, skewness and variance ratios of rCBV texture were associated with overall survival in a statistically significant manner. For the kinetic texture analysis, the Haralick correlation feature showed a p-value close to 0.05.

Conclusions: Our study shows that several texture feature ratios from contrast-enhancing and non-enhancing lesion and kinetic texture analysis obtained from perfusion parameteric maps are associated with the survival status of the patients with GBM and provide useful information for predicting the survival in the patients with glioblastoma.

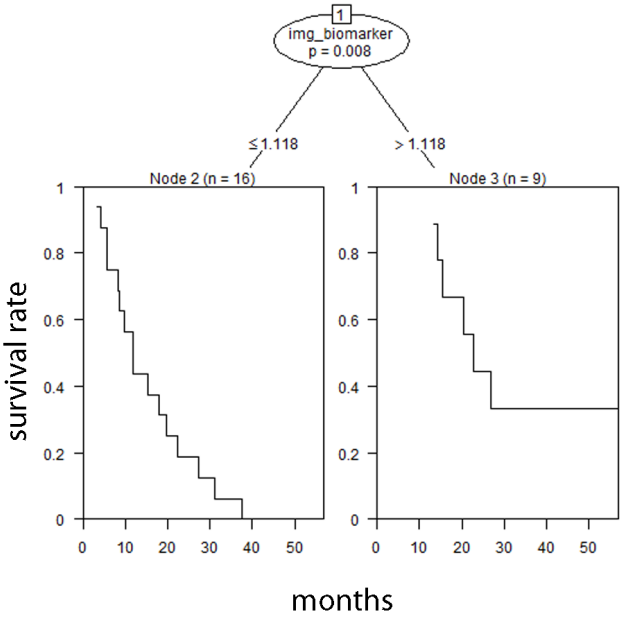

Fig. 1. Kaplan-Meier survival curves for homogeneity

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