Multispectral Analysis of Magnetic Resonance Images for Glioma Grading

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Background: The wide spectrum of Magnetic Resonance Imaging techniques currently available in clinical scanners constitutes a promising tool for the non-invasive grading of glial brain tumors. The purpose of the current study was to investigate multiple MR-derived image features with respect to diagnostic accuracy and predictive power in glioma grading.

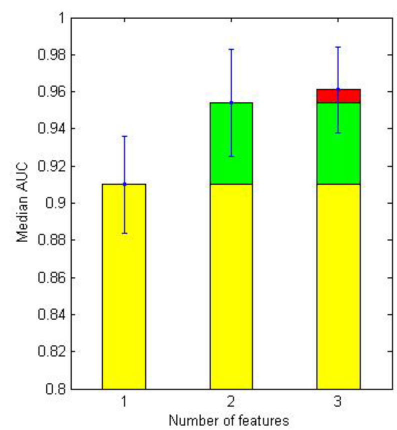
Methods: T1 pre- and post-contrast, T2, FLAIR and dynamic susceptibility contrast (DSC) scans of 74 glioma patients (29 grade II, 11 grade III, 34 grade IV) with histologically confirmed grade were studied. All volumes were coregistered to the T2 structural image. The images were postprocessed to generate relative CBV (rCBV), First Moment of the first-pass curve (FM) and relative Time-to-Peak (rTTP) maps by using established tracer kinetic models applied to the first-pass data and corrected for possible extravascular contrast agent leakage (1). Normalized CBV (nCBV) maps were created by voxel-wise division of the rCBV values by the mean rCBV value of a white matter ROI derived using the FMRIB Software Library (FSL). From each parametric map a set of statistics was obtained from an ROI encompassing the tumor volume as defined by an automatic seed growing algorithm on the FLAIR images and finished manually with aid of the T2 and T1 post-contrast MR images. The statistics obtained were the minimum (average of the lowest 5% of values), maximum (average of the highest 5% of values), entropy, kurtosis and skewness of the parameter distribution and height of the peak of the histogram of values. Further, maximum relative enhancement (mrEnhancement) was calculated as the mean of the highest quartile of the difference between post and pre contrast values, divided by the mean value of precontrast T1 values of the white matter ROI. A measure of roundness was calculated for each tumor by estimating the ratio between the radius of a sphere with the surface of the tumor ROI (calculated by summing the areas of all outer voxel surfaces) and dividing it by the radius of a sphere of same volume as the ROI. The volume of the ROI was also assessed. The full set of features calculated for each ROI is shown in the table..

For each possible combination of up to 5 features, a logistic regression model was fitted to a balanced, random sample of 15 HGG (high grade gliomas, grade III + grade IV) and 15 LGG (low grade gliomas, grade II). Model performance was assessed by applying the model to the remaining 44 subjects and calculating the area under the ROC curve (AUC). This bootstrap procedure was repeated 200 times to obtain median AUC (mAUC) and standard deviation.

Feature	**mAUC (STD)**
Median nCBV	0.635 (0.072)
Maximum nCBV	0.716 (0.057)
Minimum nCBV	0.617 (0.125)
Entropy nCBV	0.777 (0.053)
nCBV Kurtosis	0.693 (0.075)
nCBV Skewness	0.687 (0.062)
nCBV Histogram peak	0.740 (0.051)
Median FM	0.662 (0.090)
Maximum FM	0.763 (0.045)
Minimum FM	0.597 (0.099)
FM Entropy	0.758 (0.045)
MTT Kurtosis	0.501 (0.078)
MTT Skewness	0.487 (0.071)
TTP Entropy	0.516 (0.081)
TTP Kurtosis	0.510 (0.091)
TTP Skewness	0.593 (0.111)
mrEnhancement	0.910 (0.026)
Roundness	0.600 (0.070)
ROI Volume	0.595 (0.111)

Results: The feature with highest mAUC was mrEnh (mAUC = 0.910, STD = 0.026). The table shows mAUC(STD) for each of the features of the set when considered separately. The combination of 2 features with highest mAUC was mrEnh + Roundness (mAUC=0.954, STD = 0.029). For 3 features, the best combination was mrEnh + roundness + skewness of TTP (mAUC = 0.961, STD = 0.023). The figure shows the relative additional contribution for each contribution for each. No combination of 4 or 5 features improved mAUC with respect to the 3 features combination.

Conclusion: A set of statistics from MR images was tested to evaluate their combined predictive power in glioma grading from automatic tumor segmentation. For this sample, the combination of the mrEnhancement, roundness and skewness of TTP showed the best performance in the prediction of LGG vs HGG with a logistic regression model obtained from a separate training set. The main contribution comes from mrEnhancement, and the contribution of roundness and skewness of TTP is small. Limitations to the study include small size of the grade III glioma group, and inclusion of vessels in the segmentation of the tumor ROIs which may have reduced the mAUC for perfusion derived features with respect to other studies (2).



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