Postoperative magnetic resonance imaging

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is important to determine Glioblastoma extent of resection.

Current imaging evaluation for glioblastoma management relies heavily on the subjective analysis of T1-weighted (T1W) magnetic resonance images.

Simple unidimensional and bidimensional measurements of T1W contrast-enhancing regions of the tumor are the crux of response criteria in clinical trials, although limitations of such methods have been reviewed previously in detail, particularly with regards to postsurgical tumor analysis.

Linear methods of measurement are not well suited for evaluating curvilinear tumor remnants such as those along the edges of a postoperative resection cavity. In addition, they may not accurately account for the presence of T1-hyperintense blood products (methemoglobin) in and around the resection site, which can be confused with enhancing tumor tissue. Although not currently the standard of care, these morphologic nuances can be accounted for by a neuroradiologist with 3-dimensional (3D) volume-rendering software that allows for the manual tracing of images, or “contouring”; however, this process is time consuming, cost prohibitive, and suffers from limited reproducibility.

To overcome these limitations, many sophisticated algorithms have been developed for the automated segmentation of multiple images; however, few have achieved the simplicity, speed, accuracy, and limited user interaction required for routine clinical use.

Moreover, many of the software environments in which these techniques have been designed are not standardized for clinical use, compounding the challenge of their implementation in clinical trials.

Due to the inadequacies surrounding the manual and automated segmentation methods that are currently available, it would be desirable to develop a hybrid method of tumor segmentation that is adaptable to various clinically available tools for the reproducible segmentation of contrast-enhancing tumors in multicenter neurosurgical trials.

Coupling a flexible image sampling method, such as region-of-interest blob (ROI blob) generation, to an unsupervised statistical classification algorithm appears to exhibit the clinically desired balance for semiautomated tumor segmentation. Two well-established classification schemes that can be adapted for unsupervised image segmentation are Otsu's multilevel thresholding (Otsu) and Fuzzy C-means clustering (Fuzzy).

The Otsu method uses discriminant statistical analysis for image histogram intensity thresholding, exhaustively determining intensity thresholds (between tissue classes) that minimize the intraclass variance among each class of voxels.

The division algorithm modifies each threshold by fitting the histogram with a number of probability curves and iteratively computing the variances and positions of each until curve overlap is minimized. The result is a 3D map with discrete classes containing voxels that exhibit similar signal intensities. When this method is used to divide a contrast-enhanced, T1W ROI blob into three or four classes, the resultant map differentiates strongly and weakly enhancing regions from surrounding tissues.

The Fuzzy algorithm similarly computes cluster centroids and clusters voxels on the basis of

intraclass/interclass signal intensity variance. Unlike Otsu, which classifies voxels into discrete clusters (hard clustering), Fuzzy treats each data element as a member of all clusters with an associated level of membership in each, which can be expressed as a continuous value (soft clustering).

Therefore, Fuzzy classification results in a set of maps, each representing a class with a similar signal intensity range, where each voxel's value indicates the degree of its residence (expressed as a probability) in that class. Fuzzy has been investigated for tumor segmentation using multidimensional feature vectors for the last couple of decades with varying degrees of success. However, to our knowledge, no investigation has been done to evaluate its performance coupled to ROI blob analysis [1)].

1)

Cordova JS, Schreibmann E, Hadjipanayis CG, Guo Y, Shu HK, Shim H, Holder CA. Quantitative tumor segmentation for evaluation of extent of glioblastoma resection to facilitate multisite clinical trials. Transl Oncol. 2014 Feb 1;7(1):40-7. eCollection 2014 Feb. PubMed PMID: 24772206; PubMed Central PMCID: PMC3998691.