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REVIEW

Segmentation of Glioblastoma Multiforme from MR Images – A comprehensive review

V.R. Simi [a], Justin Joseph [b,*]

[a] Dept. of Computer Science & Engg., Arunachala College of Engg. for Women, Tamil Nadu 629 203, India
[b] School of Electronics, St. Joseph's College of Engg. & Tech., Kerala 686 571, India

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Abstract Delineation of active tumor region and perifocal edema from Magnetic Resonance (MR) images of Glioblastoma Multiforme (GBM) is difficult as GBM is highly infiltrating and non-enhancing on imagery. The segmentation becomes challenging when the tissue classes in the perifocal region, such as White Matter (WM) and edema, similarly, necrosis and Gray Matter (GM) are homogenous in intensity and texture. Precise delineation of GBM-focus and perifocal edema is mandatory for surgical and Radio Therapy (RT) planning and for the evaluation of tumor progress and efficiency of treatment. This article is a comprehensive review on techniques used for the segmentation of GBM from MR images.

Contents

* Corresponding author at: Department of Instrumentation, St. Joseph's College of Engg. & Technology, Pala, Kottayam 686 579, Kerala, India. Mobile: +91 8547783968, +91 4822 239301, +91 4822 239302; fax: +91 4822 239307.
E-mail addresses: simijijeesh@gmail.com (V.R. Simi), josephjusti@gmail.com (J. Joseph).
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1. Introduction

Glioma is an intracranial neoplasm, deformed from glial cells. According to the American Cancer Society (ACS) directives, glioma can be primarily classified into ependymoma and astrocytoma. Glioblastoma Multiforme is the most common astrocytoma which is a high-grade glioma comprising grade III and

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grade IV of WHO grading. GBMs are usually present with extensive areas of necrosis, pseudo-palisading, vasogenic edema and infiltrative microscopic disease. Precise segmentation of active tumor region and perifocal edema extension from MRI is essential for planning stereotactic biopsy, GBM resection and Radio Therapy (RT). Volumetric estimation of GBM is vital in studying tumor progress and treatment efficiency. But this proliferative lesion is undifferentiated and non-enhancing on MR images.

None of the imaging modalities including Computed Tomography (CT) and MRI and even powerful MR sequences like spectroscopic perfusion studies offer sufficient image quality to differentiate GBM and its perifocal edema. T1-weighted images without contrast are less sensitive to GBM and edema. Even in heavily T2-weighted sequences, the GBM focus is not well separated from surrounding edema. Spectroscopic perfusion diffusion MRI studies fail to define the GBM extent from perifocal vasogenic edema, as tracking the exact point of spectral changes, corresponding to the tumor boundary, is difficult. Preoperative biopsy proven axial plane images of non-enhancing and highly infiltrating GBM of different MR series are depicted in Fig. 1.

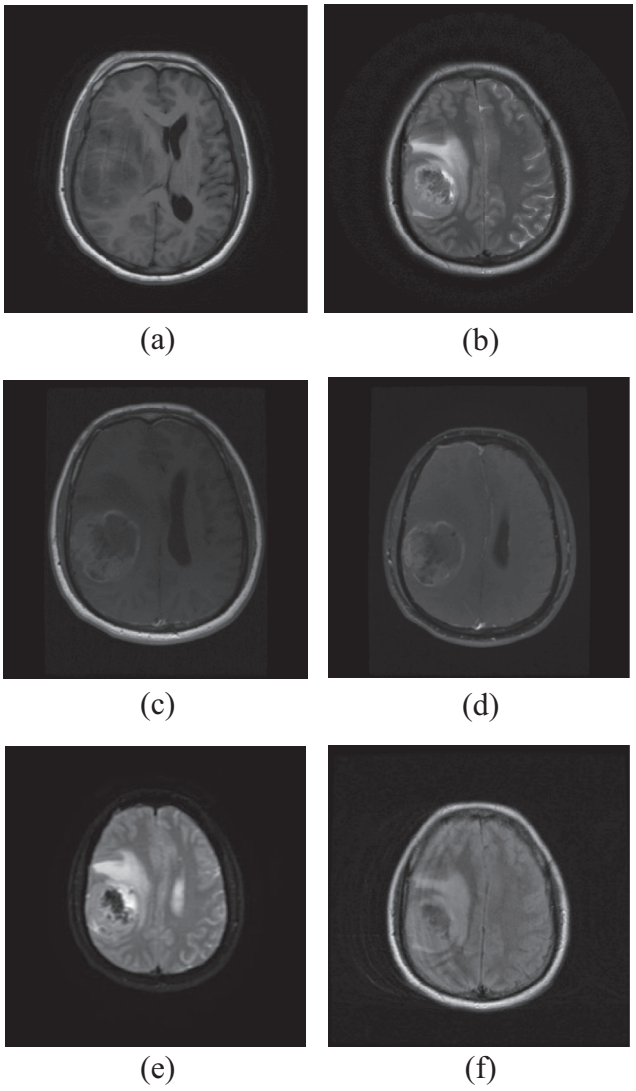

Fig. 1 Preoperative biopsy proven axial plane MR images of non-enhancing and highly infiltrating GBM of different sequences (a) T2 weighted (b) T1 weighted (c) spectroscopic (d) T1 contrast (e) Diffusion Weighted (f) FLAIR. (Image Courtesy: Hind Labs, Govt. Medical College, Kottayam, Kerala.)

Automated and computerized segmentation approaches for the delineation and quantification of GBM, or in general, any neoplasm, are meant to remove the subjectivity, inherent in time intense manual outlining. In addition to the poor tissue contrast on MRI, subregions in the active and perifocal areas of GBM exhibit homogenous gray levels. This intensity overlap happens between necrosis and Gray Matter (GM) and similarly, between White Matter (WM) and peritumoral edema. In sagittal and coronal planes the scenario become still complex. Hence, the segmentation of highly infiltrating and non-enhancing GBM from MR images is difficult than well enhanced lesions. This article presents a comprehensive review on the segmentation schemes experimented on GBM-edema complex.

2. Segmentation schemes for GBM

Elnakib et al. (1) identified the segmentation schemes popularly employed on medical images as rule-based, statistical, atlas-based and deformable model based techniques. Global as well as adaptive thresholding, region growing and region split-and-merge techniques were grouped under the rule based schemes. Atlas based method was broadly categorized as single and multi-atlas-based segmentation. Deformable models include parametric deformable models, geometric level-set based deformable models etc. Exclusive focus of this article is on segmentation of GBM rather than a broad perspective of segmentation of medical images.

Egger et al. (2) provided a variability analysis among the segmentation done by different physicians. Four physicians segmented GBMs in ten patients, once using the region-growing based Grow-Cut segmentation module of Slicer, and once by drawing boundaries completely manually, slice-by-slice. The time required for Grow-Cut segmentation was on an average 61% of the time required for the pure manual segmentation. A comparison of Slicer-based segmentation with manual slice-by-slice segmentation exhibited a Dice Similarity Coefficient (DSC) of $88.43 \pm 5.23\%$ and a Hausdorff Distance of 2.32 ± 5.23 mm.

Computerized volumetry and manual segmentation were compared in the retrospective study (3) on MR images of patients with native glioblastoma with the imaging performed at 24–48 h following resection and 2–4 months postoperatively. 1D and 2D measurements were performed by two neuro-radiologists. Computer-assisted volumetry was performed through a combination of region-based active contours and a level set approach. Tumor response was assessed by using established 1D, 2D, and volumetric standards. Twenty-nine patients were analyzed. Discrepancy in disease status between 1D and 2D compared with computer-assisted volumetry was 10.3% (3/29) and 17.2% (5/29), respectively. The mean time for segmentation between manual and computer-assisted volumetry techniques was 9.7 min and less than one minute, respectively. Inter-observer correlation was highest for volumetric measurements (0.995; 95% Concordance Index (CI), 0.990–0.997) compared with 1D (0.826; 95% CI, 0.695–0.904) and 2D (0.905; 95% CI, 0.828–0.948) measurements.