Glioblastoma Multiforme (GBM) is highly infiltrative, making precise delineation of tumor margin difficult. Multi-parametric MRI has been shown to have advantages over contrast enhanced MRI as a method for determining the spatial extent of tumor involvement. Manual image segmentation and classification are time-consuming and prone to error. We propose a machine-learning based multi-parametric approach that uses radiologist generated labels to train a classifier that is able to classify tissue on a voxel-wise basis and automatically generate a tumor segmentation.

Methods

- Preoperative MRI examinations of subjects with GBM were chosen from the Comprehensive Neuro-oncology Data Repository (CONDOR) at Washington University in St. Louis and Swedish Neuroscience Institute (Seattle, WA).
- Eight MRI image types (primary and derived) were co-registered, transformed to a standard template space with 1mm isotropic voxels, and segmented (Fig 1a).
- A rule-based multi-parametric image analysis was conducted by a board certified neuroradiologist to define a standard for comparison (Fig 1b, also see Poster RA-24 for details).
- Voxels were generated by combining manual segmentations on the radiologist’s rule set and estimate of the probability of active tumor (Fig 1f).
- A Random Forests classifier was trained using a leave-one-out experimental paradigm. A linear regression analysis was also implemented for comparison.
- A leave-one-out experiment with N labeled data sets uses N-1 data sets to train the classifier and then predicts the labels of the Nth. This process is repeated until all data sets have been predicted by the classifier. Figure 2 illustrates the Radiologist’s multi-parametric tumor map and the map predicted by the Random Forests Classifier for one case.
- Receiver Operating Characteristic (ROC) analysis was used to compare the predictions of the Random Forests classifier and a linear regression-based classifier relative to the manual segmentation standard.

Introduction

- The Random Forests classifier generated a multi-parametric probability map that more accurately predicted radiologist-generated segmentations and tumor extent than did the linear classifier.

Conclusions

- The infiltrative nature of gliomas makes assessment of tumor burden a challenge, and multi-parametric imaging markers may offer a method to improve our measures of tumor invasion and, ultimately, extent of resection.
- By enhancing our multi-parametric approach with Machine Learning we eliminate manual segmentation and generate a probability map that incorporates contrast enhancement with additional MRI markers to produce a composite image that predicts the probability of viable tumor and tissue type.

Tumor Segmentation

- Figure 1. Rule-Based Radiologist Analysis Establishes “Truth”
  - A Machine-Learning Based Classifier for Predicting a Multi-Parametric Probability Map of Active Tumor Extent within Glioblastoma Multiforme

Tumor Multi-Parametric Probability Maps

- The Random Forests algorithm classifies other brain tissue as having a high probability of being cancer. Separating false positives from true positives in these areas is an area of active research.

References


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