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Automated MRI-Based Classification of Tumor Progression in Diffuse Midline Glioma Using Neural Networks

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Introduction/Background

Diffuse midline glioma (DMG) is a highly aggressive brain tumor with poor prognosis. Accurate longitudinal assessment of tumor progression is critical for clinical decision-making, but conventional radiologic evaluation is often limited by subjective interpretation. There is a growing need for automated methods that can detect and classify tumor change over time.

Methods/Intervention

Total of 751 MRI pairs (1502 scans) were retrospectively included from 155 DMG patients. For each pair, reference labels indicating whether tumor had increased, decreased, or remained stable were obtained from radiology reports. Two deep learning segmentation models were evaluated to classify longitudinal tumor change. A dedicated “longitudinal” model was specifically pre-trained to predict changing tumor areas using MRIs of both timepoints. The model outputs two distinct labels indicating areas of tumor increase and decrease. In contrast, an “independent” timepoint model outputs the segmentation mask of the entire tumor volume for each timepoint, and the predicted masks were subtracted to generate a map of change. From the resulting mask, "increased" and "decreased" voxels were counted to calculate the net change in tumor volume. These net volume numbers were thresholded to generate the class labels and the results were compared against the reference labels. Sensitivity (SEN), specificity (SPE), accuracy, and area under the ROC curve (AUC) were reported.

Results/Outcome

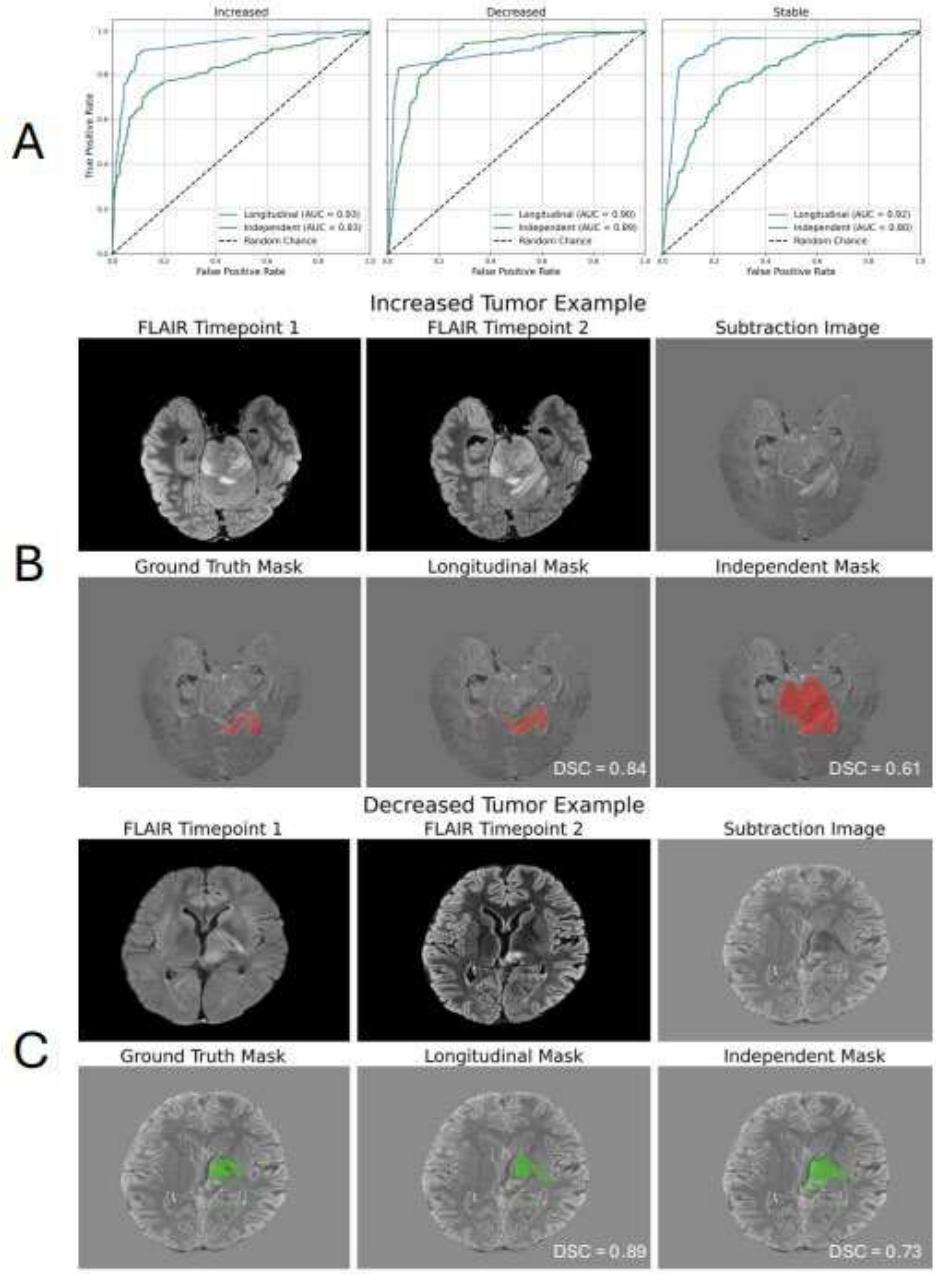
The longitudinal model achieved excellent classification performance for increased tumor change (threshold: +20.5 mm^3; SEN: 0.90, SPE: 0.89, accuracy: 0.90; AUC = 0.93), decreased tumor change (threshold: –20.8 mm^3; SEN: 0.83, SPE: 0.96, accuracy: 0.91; AUC = 0.90), and stable cases (SEN: 0.87, SPE: 0.91, accuracy: 0.89; AUC = 0.83). The independent model showed consistent but lower performance for classifying increased (threshold: +440.4 mm^3; SEN: 0.74, SPE: 0.84, accuracy: 0.80; AUC = 0.83), decreased (threshold: –2923.6 mm^3; SEN: 0.79, SPE: 0.87, accuracy: 0.83; AUC = 0.89), and stable (SEN: 0.74, SPE: 0.75, accuracy: 0.75; AUC = 0.80) cases.

Conclusion

A dedicated longitudinal model can better classify tumor changes in DMG compared to an independent timepoint model. Our findings support the integration of AI-based tools into longitudinal neuro-oncology workflows.

Statement of Impact

This approach may reduce inter-reader variability and improve early detection of treatment response or progression.



(A) Receiver operating characteristic (ROC) curves comparing the longitudinal and independent models for predicting tumor changes. Separate binary classification curves are shown for the prediction of increased (left), stable (middle), and decreased (right) tumor cases using reference labels. The longitudinal approach consistently outperformed the independent one in all categories. (B and C) Two correctly-classified representative cases demonstrating models' outputs. For each case, the top row shows FLAIR images from timepoint 1, timepoint 2, and their subtraction. The bottom row shows overlays of ground truth mask, prediction mask from the longitudinal model, and prediction mask from the independent model overlaid on the subtraction image. Red and green labels show an increase and decrease in the tumor mask, respectively. Dice scores are shown (DSC) for each model prediction for the whole case.

Keywords

Neural Networks; Diffuse Midline Glioma; Computer Vision; Magnetic Resonance Imaging; Longitudinal Analysis