AI-based Multi-modal MRI Model to Predict Post-operative Ventriculoperitoneal Shunt Placement Following Posterior Fossa Tumor Resection in Pediatric Patients

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Background

Posterior fossa tumors (PFTs) are commonly located along the brain's midline and invade the fourth ventricle, leading to obstruction of CSF flow and potentially causing hydrocephalus, particularly in pediatric patients. Notwithstanding PFT resection, postoperative hydrocephalus persists in a subset of patients, necessitating CSF diversion via shunts. The characteristics of these patients remain unclear, making it imperative to identify preoperative indicators that predict the need for postoperative ventriculoperitoneal shunt (**VPS**).

Methods

To enhance surgical planning and patient recovery outcomes, it is beneficial to predict the likelihood of postoperative ventriculoperitoneal shunting (VPS) necessity based on preoperative MRI scans. Our research incorporates four types of features gained from MRI image as multi-inputs to build an XGBoost (eXtreme Gradient Boosting) model to predict the necessity of postoperative VPS (Fig. 1)

Features

P **Pathological types** of PFTs, gained from preoperative assesment, including: Medulloblastoma, Ependymoma, Glioma, Pilomyxoid Astrocytoma.

E **Embedding features:** Delineate and crop PFTs and uncovered areas of fourth ventricle as Region of Interest (ROI), used as input to train a deep learning attention based CNN using contrstive learning, and extract the embedding features denoted as E.

M **Midline features:** Resampled image to 1mm, based on tumor segmentation, calculated the tumor's central position and annotated the brain's midline (Fig.3), then quantified their distance and left-right portion.

R **Radiomics features:** Extracted from the PFTs regions for intratumoral heterogeneity analysis, employed spearman correlation and random forest for feature selection.

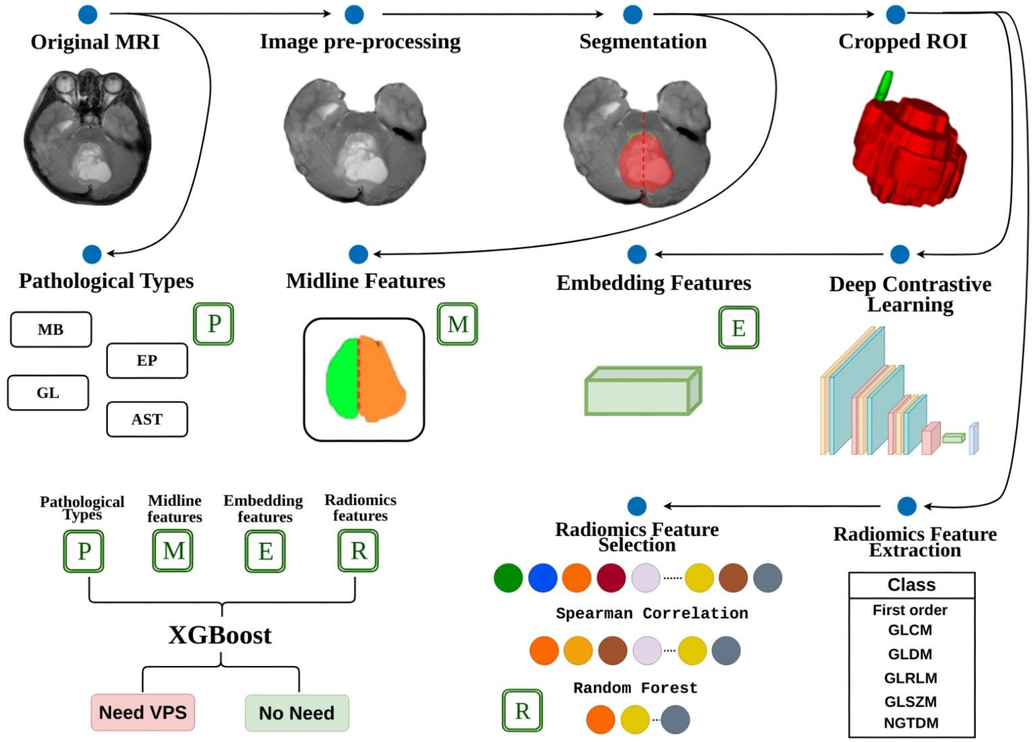

Fig. 1 VPS prediction procedure

Feature types	Sensitivity	Specificity	F1 - score	AUC
Radiomics	0.38	0.56	0.45	0.72
R + Midline	0.54	0.88	0.67	0.79
R + M + Pathological Type	0.54	0.70	0.61	0.76
R + M + P Embedding Features	**0.77**	**0.91**	**0.83**	**0.86**

Fig. 2 Models evaluation

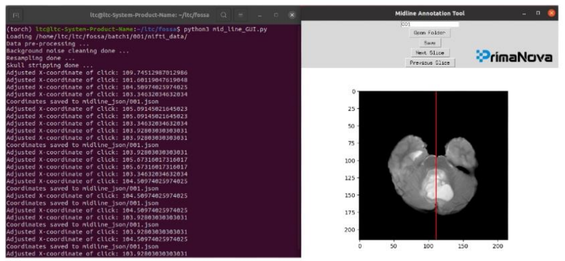

Fig. 3 Brain's Midline semi-automatic annotation tool

Experiments and Result

In this study, we retrospectively collected 119 patients' MRI images, including 36 instances requiring ventriculoperitoneal shunt (VPS). The data was divided into a training set of 79 cases (66%) and a testing set of 40 cases. Initially, training an XGBoost model using only Radiomics features yielded an AUC (Area Under the Curve) of 0.72 and an F1-score of 0.45 (Fig. 2). By incorporating Midline features, these metrics improved to an AUC of 0.79 and an F1-score of 0.67. However, adding pathological types features did not further enhance the model's performance. Lastly, further integration of attention-based CNN embedding features significantly boosted the model's effectiveness, achieving an AUC of **0.863**, a specificity of **0.91**, and a sensitivity of **0.77**.

Conclusion and Future works

In this study, we incorporated clinical insights on PFT cases with features extracted from MRI images by computer vision techniques, including spatial relationships between tumors and the fourth ventricle, midline features, etc. We developed a predictive model combining these aspects with Radiomics-based tumor heterogeneity analysis and tumor's pathological types, and achieved substantial predictive ability for postoperative VPS. In future studies, we plan to quantify cerebrospinal fluid extravasation on FLAIR images as additional input parameters to refine predictive accuracy. Additionally, employ external validation datasets from multiple clinical centres involving over 200 cases to verify the generalizability and robustness of the model.