Abstract of Ph.D. Thesis

**Development of Methods Based Upon Machine Learning, Deep Learning, and Quantitative MRI for Objective Assessment of Brain Tumors**

Virendra Kumar Yadav (2018BMZ8310), Research Scholar

# ABSTRACT

This thesis addresses some of the critical challenges in brain tumor diagnosis, classification, and post-surgical evaluations. By leveraging advanced quantitative imaging techniques, machine learning, and deep learning approaches, the studies aim to bridge some of the existing gaps in tumor segmentation, grading, and treatment planning, thereby improving diagnostic accuracy and optimizing therapeutic interventions.

Accurate segmentation of tumor tissues on magnetic resonance imaging (MRI) images is vital for clinicians to make informed decisions regarding treatment strategies and monitor disease progression effectively. In this thesis, three sub-studies were conducted to develop frameworks using machine learning (ML) and deep learning (DL) models to segment gliomas and their subcomponents, such as enhancing tumors, non-enhancing tumors, and necrotic regions. The studies utilized multi-parametric MRI data from glioma patients. Optimization of the segmentation frameworks, including U-Net, MultiRes U-Net, and nnU-Net architectures, ensured robust and generalizable performance across multicenter datasets.

Grading and classification of gliomas, a critical aspect of brain tumor management that influences prognosis and therapeutic strategies. Conventional MR imaging often falls short of capturing the physiological changes associated with tumor progression, necessitating advanced imaging methods. In this thesis we have carried two sub-studies for pre-operative glioma grading and subtype classification using quantitative DCE-MRI parameters and ML models.

The first study focuses on distinguishing low-grade gliomas from high-grade gliomas based on quantitative perfusion parameters. The second study further classifies glioblastomas into IDH wild type and IDH mutant subtypes, which have distinct prognostic and therapeutic implications. A novel imaging biomarker, the "Fragmented Tumor Vasculature (FTV) sign," observed on susceptibility-weighted imaging, was proposed for differentiating $IDH_{wt}$ glioblastomas from $IDH_{mt}$ grade 4 astrocytomas.

Post-surgical evaluation of glioblastoma: distinguishing true progression from pseudoprogression and accurately segmenting post-surgical cavities is quite important for treatment assessment. We have carried two studies on post-surgical evaluation, first study integrates quantitative diffusion and perfusion MRI parameters with MGMT promoter methylation status to develop ML models for TP and PsP discrimination. On conventional neuroimaging, TP and PsP often present similar features, leading to diagnostic uncertainty for radiologists and oncologists. Misclassification can result in unnecessary repeat surgeries or the administration of expensive and potentially harmful therapies. By providing a precise distinction between TP and PsP, the proposed framework enables oncologists to adapt treatment plans promptly and reduce the psychological burden of "scanxiety" experienced by patients and their families. The second study introduces a U-Net-based DL framework for segmenting post-surgical cavities in glioma patients. Accurate segmentation of resection cavities is essential for assessing the extent of tumor removal, planning subsequent treatments like radiation therapy, and monitoring disease recurrence.

Collectively, the studies presented in this thesis leverage quantitative multi-parametric MRI data and advanced ML/DL methodologies to address significant challenges in brain tumor management. By automating tumor segmentation, improving grading and classification accuracy, and enhancing post-surgical evaluation, these methods aim to optimize diagnostic workflows and support clinicians in making data-driven decisions.