DOI:10.31557/APJCC.2026.11.6.795

EDITORIAL

# Artificial Intelligence–Driven Tumor Segmentation for Glioblastoma Surgical Planning; A Policy Brief

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*Asian Pac J Cancer Care*, **11 (6)**, 795-796 Submission Date: 07/02/2026 Acceptance Date: 09/01/2026

## Introduction

Maximal safe resection remains the cornerstone of glioblastoma management, as the extent of tumor removal is closely associated with patient survival and neurological preservation. However, the infiltrative nature of glioblastoma, indistinct tumor margins, and considerable interpatient heterogeneity continue to challenge accurate preoperative planning and surgical decision-making [1- 3]. Recent advances in artificial intelligence (AI), particularly deep learning–based image segmentation, are transforming glioblastoma surgical planning. Automated segmentation algorithms can accurately delineate tumor subregions while reducing the time and interobserver variability associated with manual contouring [4, 5]. Beyond image analysis, AI-driven tumor segmentation is emerging as a valuable decision-support tool for neuronavigation, resection planning, and personalized surgical strategies. Nevertheless, challenges including limited generalizability, variability in MRI protocols, and insufficient clinical validation remain significant barriers to routine implementation [6, 7]. In this editorial, we discuss the evolving role of AI-driven tumor segmentation in glioblastoma surgical planning and the key challenges that must be addressed for its successful clinical integration.

*Enhancing Preoperative Planning*

Manual segmentation of tumors has always been done through the process of manual delineation of the tumor by neuroradiologists and neurosurgeons, which is a very time-consuming and variable process [8]. The emergence of deep learning–based segmentation models has substantially improved the efficiency and consistency of this task [9]. Currently available algorithms can automatically segment enhancing tumor, non-enhancing tumor, necrotic core and peritumoral edema in multimodal MRI scans, with a performance close to that of expert-level annotations. However, apart from making the process of tumor segmentation more efficient, deep learning-based tumor segmentation models have added another advantage by providing clinically meaningful information for pre-operative planning through segmentation of tumors in three dimensions and calculation of tumor burden [10]. Through accurate depiction of the location of the tumor in relation to surrounding structures, neurosurgeons can predict the level of complexity of surgery and plan the optimal trajectory. Thus, AI-based segmentation is becoming an integral part of precision neurosurgery [11].

*Current Challenges*

Despite remarkable progress, several barriers continue to limit the routine clinical adoption of AI-driven tumor segmentation in glioblastoma surgery. One of the major concerns is the limited generalizability of existing models, as many algorithms are developed and validated using highly curated datasets that may not adequately represent the diversity of real-world clinical practice [12]. Variations in MRI acquisition protocols, scanner vendors, imaging quality, and patient populations can substantially affect model performance when deployed across different institutions. Another important challenge is the infiltrative nature of glioblastoma itself. Although deep learning models have achieved impressive accuracy in segmenting contrast-enhancing tumor regions, accurately delineating infiltrative tumor margins remains considerably more difficult. Furthermore, the lack of model explainability and prospective multicenter validation continues to hinder clinician confidence and regulatory approval [13, 14]. Future AI systems should therefore prioritize transparency, robustness, and seamless integration into existing neurosurgical workflows, ensuring that automated segmentation serves as a reliable decision-support tool rather than a replacement for clinical expertise.

*Future Directions*

The next generation of AI-driven tumor segmentation

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is expected to extend well beyond automated lesion delineation. Future developments will likely integrate multimodal MRI, functional imaging, radiomics, and molecular biomarkers to provide a more comprehensive characterization of glioblastoma. Such advances may enable individualized surgical planning by identifying tumor infiltration patterns, estimating the extent of safe resection, and predicting the risk of postoperative neurological deficits. Emerging technologies, including foundation models and real-time intraoperative AI applications, also hold considerable promise for enhancing surgical precision [15]. However, successful clinical translation will require close collaboration among neurosurgeons, neuroradiologists, AI researchers, and regulatory authorities to ensure that these technologies are accurate, transparent, and clinically reliable. Rather than replacing surgical expertise, AI should be viewed as a collaborative partner that augments clinical judgment and supports safer, more personalized neurosurgical care [16].

In conclusion, as AI continues to mature, tumor segmentation is poised to become an indispensable component of glioblastoma surgical planning rather than an optional imaging adjunct. Realizing this potential, however, will require rigorous clinical validation, standardized evaluation frameworks, and seamless integration into routine neurosurgical workflows. By translating technological advances into clinically actionable insights, AI-driven segmentation has the potential to redefine preoperative planning and establish a new standard for precision neurosurgical care.

*Keywords*

Glioblastoma, Artificial Intelligence, Tumor Segmentation, Surgical Planning, Deep Learning, Magnetic Resonance Imaging.

*Funding and Ethical Approval*

This study is part of research project No. 99288, approved by Sabzevar University of Medical Sciences under Ethics Code IR.MUMS.MEDICAL.REC.1399.711 and IRCT20210215050367N1.

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