Surgical Resection of Insular Gliomas and Roles of Functional Magnetic Resonance Imaging and Diffusion Tensor Imaging Tractography—Single Surgeon Experience

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■ OBJECTIVE: **In gliomas located in proximity to eloquent areas, near total resection and subsequent radiotherapy is often preferred to avoid postoperative neurologic complications. Preoperative functional magnetic resonance imaging (fMRI) and diffusion tensor imaging (DTI) tractography provide new insights into surgeries of insular gliomas. In this study we report our experience of surgical management of insular gliomas and the role of fMRI and DTI tractography in planning the resection.**

■ METHODS: **We retrospectively compared the clinical and outcome variables of 61 patients who underwent surgical resection of insular gliomas. The study population was divided into 2 groups according to the use of fMRI and DTI tractography in planning the resection.**

■ RESULTS: **The average age of the study population was 44.1 ± 12.6 years with 21 (34.4%) of the patients women. Nearly two thirds of them (40, or 65.6%) had World Health Organization grade II tumors, and 16 patients (26.2%) had grade IV tumors. The most common tumor was glioblastoma, observed in 16 patients (26.2%). In 10 (16.4%) patients, fMRI and DTI tractography were used. The overall mortality in the study population was 15 (24.6%). None of the patients where fMRI and DTI were used for planning the surgery died (29.4% vs. 0.0%; $P = 0.05$), and all of them had normal functioning (70.5% vs. 100.0%; $P = 0.05$) at 3 months' follow-up.**

■ CONCLUSION: **Surgical resection of insular gliomas remains a challenge to the neurosurgeon and demands good knowledge of anatomic landmarks. Use of fMRI and DTI tractography may help achieve a good outcome.**

INTRODUCTION

Nearly one fourth of all low-grade gliomas and up to 10% of all high-grade gliomas are observed in the insular region,[1] the anatomic interface between limbic system and neocortex. The propensity of gliomas in this region to spread along the complex neural and vascular anatomy of insula makes it challenging for the surgeon to reach and achieve a gross total resection (GTR).[2,3] Studies done by Yasargil et al[4] in the early 1990s reported safe transsylvian approach to resect insular gliomas with an accepted rate of complications and proposed a classification of insular gliomas based on their growth patterns. Recently, Sanai et al[5] proposed a new classification based on the resectability of insular gliomas and functional outcome of their resection measured by progression-free survival and overall survival.

Functional neuroimaging techniques like magnetic resonance imaging (fMRI) have revealed the involvement of insular cortex with language, gustatory, auditory, vestibular functioning, and sensorimotor integration.[6-8] Additionally, neuropsychiatric disturbances that involve cognitive and emotional processing have been associated with insular cortex.[9] Anatomically, the intricate neural network of insular cortex has been extensively studied by diffusion tensor imaging (DTI). DTI and fMRI have since been attributed for providing new insights into surgeries of insular gliomas. Furthermore, cortical and subcortical mapping

Key words
- DTI tractography
- Functional MRI
- Insular gliomas
- Outcome
- Surgical resection

Abbreviations and Acronyms
DTI: Diffusion tensor imaging
EOR: Extent of resection
fMRI: Functional magnetic resonance imaging
GTR: Gross total resection
NTR: Near total resection

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techniques in both awake and asleep patients have improved the safety of surgical management of insular gliomas.[5]

GTR can usually be achieved in gliomas located in noneloquent areas, but in gliomas located in proximity to eloquent areas, near total resection (NTR) and subsequent radiotherapy are often preferred to avoid postoperative neurologic complications.[10] Preoperative fMRI and DTI tractography have been proposed to help locate the functional sites at the cortical level and help the surgeon plan the surgery.[1,3] Despite evidence suggesting the role of fMRI and DTI tractography in surgical resection of insular gliomas, contradicting evidence suggests that under pathologic conditions, brain functions keep constantly changing at both microscopic and macroscopic levels with reorganization of functions to perilesional or contralesional brain areas.[11,12] This explains why tumors in few patients grow to considerable size with neurologic manifestations. Furthermore, studies comparing fMRI with electrocortical stimulation have reported incongruity between the modalities and concluded that the role of fMRI in insular gliomas needs further research. Similarly, studies on the role of DTI tractography on the extent of resection (EOR) in insular gliomas have reported that preoperative tumor volume influences the benefits of EOR and surgical outcome.[13]

The objective of the current study was to report our experience of the role of fMRI and DTI tractography in the surgical management of insular gliomas. In accordance with our objective, we compared the clinical, surgical, and outcome variables of patients with insular gliomas managed surgically with or without the use of fMRI and DTI tractography.

METHODS

Patient Selection

We retrospectively studied 61 consecutive patients with insular gliomas who underwent surgical resection at Krishna Institute of Medical Sciences, a tertiary referral center in South India. All resections were performed by the senior author (M.K.P) between May 2011 and May 2015. Pathology review was performed per World Health Organization (WHO) guidelines. Patients with grade I histology were excluded as their natural history and survival rates differ from other tumors of grades II to IV. For similar reasons, patients with multifocal lesions were also excluded. Clinical data were collected from patient records and interviews at review visits at the outpatient department. The study was approved by an institutional ethics committee.

The study population was divided into 2 groups on the basis of the use of fMRI and DTI tractography preoperatively while planning the surgery. In the first group of 51 patients, fMRI and DTI were not used for planning because necessary infrastructure and protocols were not available at the study center during the first 48 months; surgery was performed using anatomic landmarks. In contrast, in the second group of 10 patients, fMRI and DTI tractography were performed and surgery was planned (decision of biopsy or resection) after the detailed study of the fMRI and DTI tractography (Figure 1).

Surgical Technique

In the initial period of studying the first group of patients ($n = 51$), surgery and presurgical planning did not use image guidance (fMRI and DTI tractography). All the patients underwent general anesthesia in our series. We did not perform awake craniotomy in our series even for the dominant hemisphere lesion. Standard frontotemporal craniotomy was performed in all patients. Anatomic landmarks used to limit resection were perinsular sulcus (circular sulcus) limen insulae, and the thalamostriate arteries. The insular position of the tumor was termed on the basis of these anatomic landmarks.

In cases with involvement of the eloquent area by the tumor or corticospinal tract, a surgical procedure was tailored on the basis of anatomic landmarks and the use of subcortical stimulation of the corticospinal tracts (see Figure 1) and intraoperative neuronavigation.

Patient Outcome Measurements

Preoperatively and at each follow-up appointment, patients underwent neurologic examination by the senior neurosurgeon or a neurosurgical resident. Neurologic complication was defined as new-onset or worsening existing deficits related to motor, sensory, visual, and language function. Outpatient neurologic examinations were performed periodically at 1 week, 4–6 weeks, and 3 months after surgery. MRI results were performed as required to review tumor occurrence.

Presurgical Neuroradiologic Evaluation

All MRI examinations were performed on a 3 Tesla MR system (Philips Medical Systems, Best, Netherlands). All MRI examinations included a 3D T1-TFE sequence (TR = 10 ms, TE = 4.9 ms, flip angle = 8 degrees, TFE factor = 140, slice thickness = 1 mm) and a 3D Balanced–Fast Field Echo [B-FFE] (TR = 7.1 ms, TE 2.9 ms, flip angle = 45 degrees, number of slabs = 1, number of slices = 75). In addition, a DTI sequence (SE-EPI, TR = 7798 ms, TE = 77 ms, slice thickness 2 mm, no intersection gap, number of excitations = 2, acquisition matrix size 112 × 112, voxel size 1.7 × 1.7 × 2 mm, diffusion acquisitions in 15 directions, 1 baseline, b-value of 800 s/mm^2 and EPI factor 59) with an imaging time of 4 minutes and 53 seconds was acquired. Datasets of DTI were analyzed on an off-line workstation using commercially available processing software as provided by the manufacturer (FiberTrak, Philips Medical Systems). Fusion of DTI and 3D T1 TFE images was done by loading the anatomic data. Free-hand ROI was used for tracking corticospinal tract fibers with relation to tumors at 3 levels: 1) corona radiata, 2) insula, and 3) posterior limb of the internal capsule. In all analyses, default settings were used consisting of a minimum FA of 0.15, a maximum angle change of 27.0 degrees, and a minimum fiber length of 10.0 mm.

Statistical Analysis

After confirming the homogeneity of the data, all continuous variables were expressed as mean ± standard deviation, whereas all categorical variables were reported as frequencies/percentages. The study population was divided into 2 groups: group A (preoperative fMRI and DTI tractography were not used) and group B (preoperative fMRI and DTI tractography were used). While the differences between the groups for continuous variables were analyzed using independent Student's *t*-test, the Fisher exact test was used to evaluate categorical variables. A $P \leq 0.05$ was considered significant. All data analysis was done using Statistical Package for Social Sciences, version 17.0 for Windows (IBM Computers, Armonk, New York, USA).