



Original Article

Predictors of stimulation-induced seizures during perirolandic glioma resection using intraoperative mapping techniques

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ABSTRACT

Background: Intraoperative mapping techniques maximize safety and efficacy during perirolandic glioma resection but may induce seizures and limit the procedure. We aim to report the incidence and predictors of stimulation-induced seizures during mapping either patient is awake or under general anesthesia (GA).

Methods: Retrospective analysis of 64 patients (40 awake and 24 GA) with perirolandic glioma underwent resection using intraoperative mapping techniques between 2014 and 2019. Preoperative data, operative details, postoperative neurological status, and extent of resection (EOR) were analyzed. Predictors of intraoperative seizures were assessed.

Results: The mean cortical and subcortical stimulation intensities needed to evoke motor responses were significantly lower in awake cases than in GA patients (4.9 ± 0.42 vs. 8.9 ± 1.2 mA) and (8.3 ± 0.62 vs. 12.1 ± 1.1 mA), respectively ($P = 0.01$). Incidence of intraoperative seizures was lower but statistically non-significant in awake cases (10% vs. 12.5%) ($P = 0.76$). Preoperative multiple antiepileptic drugs (AEDs) ($P = 0.03$) and low-grade glioma ($P = 0.04$) were statistically significant predictors for intraoperative seizures. Mean EOR in awake cases was 92.03% and 90.05% in GA cases ($P = 0.23$). Postoperative deficits were permanent after 3 months only in 5% of awake patients versus 8.3% of GA group ($P = 0.59$).

Conclusion: Awake craniotomy with intraoperative mapping can be done safely for perirolandic gliomas with lower but statistically nonsignificant incidence of intraoperative seizures and this could be attributed to statistically significant lower stimulation intensities required for mapping. Preoperative multiple AEDs and low-grade glioma are significant predictors for intraoperative seizures.

Keywords: Awake craniotomy, Brain mapping, Eloquent areas, Intraoperative seizures, Perirolandic glioma

INTRODUCTION

Surgical resection of perirolandic gliomas within or adjacent to sensorimotor eloquent areas represents a great challenge for neurosurgeons.^[13,18,27] As maximal surgical resection of hemispheric gliomas has shown a positive impact on the patient's outcome, the goal of surgery in the treatment of perirolandic gliomas is to resect the maximum tumor volume and to spare sensorimotor functions.^[4,5,7,21,26,34,39] However, it is difficult to identify these eloquent areas intra-operatively,

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particularly in the presence of a lesion likely to induce a mass effect and/or a functional reorganization. Consequently, the surgery of such tumors frequently results in poor extent of resection (EOR) or permanent postoperative deficits, or both.^[6,8,16] Despite advances in functional imaging such as functional magnetic resonance imaging (fMRI), diffuse tensor imaging (DTI), as well as intraoperative neuronavigation techniques, the ability to rely on these modalities to identify eloquent areas is still limited and unreliable. Thus, intraoperative brain mapping remains the gold standard for identification of these essential regions.^[13,18,32]

Intraoperative mapping techniques including cortical and subcortical stimulation can be done to identify motor pathways during perirolandic glioma resection, while patient is awake to utilize patient's cooperation in continuous assessment of voluntary motor movements during resection, or patient is under general anesthesia (GA).^[13,41] However, using direct electrical stimulation for mapping either awake or under GA in such tumors were reported to risk causing stimulation-induced intraoperative seizures which can lead to difficulty in further mapping and monitoring the motor function and may lead to abort the operation in case of awake craniotomies.^[12,29,41]

Recent studies recommended intraoperative mapping, while patient is awake for better neurological outcomes and higher EOR compared to similar surgery done under GA.^[13,33,41] Furthermore, anesthetic agents can affect motor excitability and the accuracy of mapping and neurophysiological monitoring.^[40] On the other hand, some surgeons prefer to use awake craniotomy only for lesions related to language eloquent areas, as some studies have suggested that awake craniotomy for perirolandic lesions may have a higher incidence of intraoperative seizures.^[15,29]

In this study, we aim to report the incidence and evaluate predictors of intraoperative stimulation-induced seizures during perirolandic glioma resection using mapping techniques either awake or under GA, as one of the most important intraoperative risks which can affect the surgical outcomes. EOR and postoperative neurological outcome were also analyzed to evaluate role of intraoperative mapping in such cases.

MATERIALS AND METHODS

Patients population

This retrospective study was based on collected data of 64 patients with hemispheric perirolandic glioma (3 cm anterior or posterior to the motor cortex) who underwent surgical resection using intraoperative cortical and subcortical mapping techniques either under awake craniotomy (40 patients) or craniotomy under GA (24 patients), between 2014 and 2019 by the same neurosurgery

and anesthesia teams. The institutional review board approved this study.

Patients with the following inclusion criteria were operated under awake craniotomy (awake group): (1) Age >18 and <70 years old without major cardiopulmonary co-morbidities. (2) Fluent in speaking and understanding without preoperative cognitive impairment (mini mental state examination more than 24). (3) Do not have severe language deficits (greater than 30% of naming errors) or motor deficits less than antigravity motor function. (4) Do not show severe anxiety or emotional instability (The State-Trait Anxiety Inventory score less than 55).^[25] (5) Patient is accepting and understanding the technique and the type of procedure.

Patients, who did not meet these criteria, were operated under (GA Group) using total intravenous protocol (TIVA), with intraoperative neurophysiological mapping and monitoring techniques. Written informed consent was also obtained from all patients.

Patients' demographics, co-morbidities, presenting symptoms, preoperative seizure history and medications, preoperative neurological examination, operative details including intraoperative electrophysiological mapping and monitoring values, immediate and late postoperative neurological status, histopathology, and EOR based on volumetric analysis of pre- and postoperative MRI studies were collected. The Karnofsky Performance Scale (KPS) was used to assess preoperative and postoperative functional status.

Preoperative evaluation

Preoperative full physical and neuropsychological assessments were done for all patients and type of procedure either awake or under GA was chosen by the senior surgeon according to the inclusion criteria mentioned before. For all patients, MRI brain with contrast was done to determine tumor location, characters, and size, then fMRI and DTI were done to detect relation of the tumor to the cortical and subcortical motor tracts. In our cases, the use of anticonvulsant drugs was necessary whether they had a preoperative seizure or not and serum levels were achieved days before surgery.

Anesthetic and surgical technique

*Awake group

Awake craniotomy under local anesthesia and monitored conscious sedation protocol was used. The patient was comfortably positioned with a warm-air blanket to avoid shivering. Continuous intraoperative monitoring was done using electrocardiogram, pulse oximeter, and noninvasive arterial blood pressure monitors. Bi-spectral index (BIS)

was also used to monitor the level of consciousness. Oxygen (2 L/min) was administered through a nasal cannula. Intravenous propofol (1.5 - 2.5 mg/kg) and fentanyl (1 µg/kg) were administered to tolerate the circumferential scalp block to the supratrochlear, supraorbital, zygomaticotemporal, auriculotemporal, greater occipital, and lesser occipital nerves. The local anesthetic was bupivacaine-lidocaine mixture with adjuvants as Mg sulfate and dexamethasone as previously reported by our team.^[28] Usually 3-5 ml is enough for each nerve. A field block was then applied in the region of the incision. Typical agents used for sedation during surgery are infusions of propofol or dexmedetomidine, with fentanyl (25 µg) bolus every 30 min on regular pattern. Propofol infusion was maintained at a rate of 25–75 µg/kg/min. Dexmedetomidine (1 µg/kg) was administered intravenously over 20 min as an initial loading dose, followed by continuous infusion of 0.1–0.7 µg/kg/h as a maintenance dose using a syringe pump. BIS was kept between 60 and 90. Fifteen minutes before starting cortical mapping, propofol was stopped and the dose of dexmedetomidine was reduced to 0.1 µg/kg/h until BIS became >90. Craniotomy was performed with exposure of the lesion plus a 2- to 4-cm margin, depending on the need to map adjacent functional tissue and to ensure positive motor mapping before starting resection, larger craniotomies were performed to provide more control of brain swelling and more chance for complete safe resection in cases with significant edema and mass effect on preoperative radiological images. A bipolar stimulator with the tips 5 mm apart attached to intraoperative neuromonitoring device was used (ISIS, IOM system, INOMED, Inc) or (NIM Eclipse, Medtronic, Minneapolis, Minnesota), 50-60 Hz constant current biphasic square wave and duration of 1–2 s per stimulation were used. Electrocorticography (ECoG) was done by a strip electrode placed at the cortical areas of interest to monitor for after discharges by neurophysiologist. Stimulation was started with 2 mA increased to a maximum (6–10) mA until motor function was established then sterile numbered marks were placed on positive cortical areas. Positive mapping was reported if contralateral involuntary movement of the face, arm, or leg or impaired motor function during active movement by the patient occurred while stimulation of motor cortex. Contralateral paresthesia was reported on primary sensory area stimulation. Serial subcortical stimulations were started when the resection was carried to the depth of white matter tracts and repeated every 4–5 mm during resection advancement.

***GA group**

For patients who underwent surgery under GA, same monitors were used as in awake patients. The primary anesthetic concern for those patients is the avoidance of halogenated inhaled agents, which can increase the latency

and decrease the amplitude of evoked potentials. In addition, chemical muscle relaxants must be avoided. Propofol-based TIVA was used. Initial bolus dose of propofol (1.52.5 mg/kg) was given plus fentanyl (1 µg/kg) then endotracheal tube or laryngeal mask airway of an appropriate size was applied. Maintenance doses of propofol (6–12 mg/kg/h) with fentanyl (25 µg) bolus every 30 min regularly. BIS index was maintained between 40 and 60, and during mapping was around 60. Motor evoked potentials (motor evoked potential), phase reversals were attached to the patients before surgery, stimulation was started with 4 mA increased to 20 mA maximum with strip electrode for ECoG as in awake cases.

***Both groups**

Standard microsurgical resection techniques were performed either for awake or GA cases. Intraoperative ultrasonography (EUB-405 plus ultrasound scanner, HITACHI) was used in all cases for locating the lesions, choosing the shortest route, defining their margins, and evaluating the EOR. Once cortical mapping had been done, the area of cortical resection was then outlined. The main aim in all cases was maximal resection with minimal neurological deficit. The tumor boundary close to the eloquent areas was kept to be resected last. If functional impairment occurred, either clinical for awake cases or decreased MEPs for GA cases, the resection would be stopped. If the impairment was confirmed and did not improve within 5 min after exclusion of other factors of impairment, the resection would not be resumed. If the impairment subsided, continuation or termination of the resection was dependent on senior surgeon decision according to nature of tumor and prior discussion with the patient.

Management of intraoperative stimulation-induced seizure: (For all cases)

Ice-cold saline or Ringer's lactate was always available for cortical irrigation in case of any seizure. Mapping was stopped for 5 min and sedatives were avoided for further successful mapping. If prolonged or recurrent seizure was encountered, small doses of propofol or/and midazolam were given with reload of antiepileptic medication. Emergent airway strategies as laryngeal mask airway or endotracheal tube were in place (for awake cases) in case of sudden complications.

Postoperative course and follow-up

All patients were sent to ICU for monitoring and transferred to the general ward once stable. Postcraniotomy standard treatments were prescribed including steroids and dehydrating measures for cerebral edema, antiepileptic medications, and analgesia. Same antiepileptic medications

were kept postoperative as pre-operatively for at least 1 month, and then their antiepileptics and dosages were managed in conjunction with neurologist according to preoperative seizures history and intra/postoperative seizures. Postoperative evaluation of neurological outcome was done at 3 different times: (1) after the surgery, when the patients could be fully evaluated and (2) at the 1- and 3-month follow-up visits. Early postoperative MRI with contrast was performed in all cases within 72 h and at 3 months follow-up to document the EOR using (3D Slicer version 4 software, BWH and 3D Slicer contributors) by independent neuroradiologist blinded to clinical and operative data. EOR was graded as following: gross total resection (GTR) indicated more than 98% resection; near total resection when there was more than 90% resection, subtotal resection when there was 50–90% resection, and partial resection (PR) when it was less than 50%.

Statistical analysis

All data were collected, tabulated, and statistically analyzed using SPSS v.23.0.0 (IBM Corp., Armonk, New York, United States). Quantitative data were expressed as mean or median (range), and qualitative data were expressed as absolute frequencies (number) and relative frequencies (percentage). Percent of categorical variables was compared using a Pearson Chi-square test when appropriate. Risk assessment was done by relative risk and confidence interval 95% (CI 95%). A logistic regression univariate model was used to assess for significant predictors of intraoperative stimulation-induced seizures then significant variables were assessed in the multivariate logistic regression model. $P < 0.05$ was considered statistically significant.

RESULTS

Patients and tumor characteristics

Sixty-four patients with perirolandic glioma underwent surgical resection using intraoperative cortical and subcortical mapping techniques between 2014 and 2019. Of these patients, 40 patients (62.5%) were operated with awake craniotomy, while 24 patients (37.5%) underwent surgery under GA. The mean age for awake group was 42.7 ± 14.5 years and 49.5 ± 15.5 years for GA group ($P = 0.08$). There were (65%) males in awake group and (41.7%) in GA group ($P = 0.69$). All patients had a KPS of 70 or more before surgery. The most presenting symptoms were headaches (75% awake group, 58.3% GA group; $P = 0.16$), seizures (47.5% awake group, 45.8% GA group; $P = 0.92$), and motor weakness (45% awake group, 58.3% GA group; $P = 0.3$) [Table 1].

Twenty-four patients of awake group (60%) had right sided lesion versus 14 patients (58.3%) in GA group. The mean

Table 1: Demographic and preoperative clinical characteristics of 64 patients underwent perirolandic glioma resection using intraoperative mapping techniques either awake or under GA.

Characteristic	Awake (n=40)	GA (n=24)	P-value
Age, mean (SD)	42.7 (14.5)	49.5 (15.5)	0.08
Sex, n (%)			
Male	26 (65)	10 (41.7)	0.69
Female	14 (35)	14 (58.3)	
Preoperative KPS, n (%)			
90	10 (25)	4 (16.7)	0.65
80	20 (50)	12 (50)	
70	10 (25)	8 (33.3)	
Preoperative presenting symptoms			
Headache	30 (75)	14 (58.3)	0.16
Seizures	19 (47.5)	11 (45.8)	0.9
Motor weakness	18 (45)	14 (58.3)	0.3
Sensory dysfunction	16 (40)	8 (33.3)	0.59
Cognitive deficit	6 (15)	6 (25)	0.32
Dysarthria	10 (25)	8 (33.3)	0.47

preoperative tumor volume for the awake group was 36.6 ± 17.3 cm³ and for the GA group was 45.3 ± 20.9 cm³ ($P = 0.07$). Glioblastoma multiforme GIV was the most encountered pathology in both groups and presented (37.5%) in awake group and (45.8%) in GA group ($P = 0.51$), [Table 2]. There was no statistically significant difference regarding patients' demographics and tumor characteristics between both groups.

The mean EOR in awake cases was 92.03% and 90.05% in GA cases ($P = 0.23$). GTR > 98% was achieved in 18 patients (45%) in awake group and 7 patients (29.2%) in GA group ($P = 0.2$). None of cases in both groups had PR below 50% [Table 2].

Intraoperative stimulation-induced seizures

In the awake group, the mean cortical stimulation intensity needed to evoke motor responses was significantly lower than the intensity in GA patients (4.9 ± 0.42 vs. 8.9 ± 1.2 mA, respectively, $P = 0.01$). Furthermore, subcortical stimulation threshold was statistically significant lower in awake patients (8.3 ± 0.62 vs. 12.1 ± 1.1 mA, respectively, $P = 0.01$) [Table 3].

Intraoperative cortical stimulation-induced seizures in 7 patients in both groups (10.9%), 4 patients in awake group (10%) experienced focal seizures, and 2 of them were controlled with only ice-cold ringer's lactate cortical irrigation while the other 2 patients needed small doses of sedation, but none of those patients had been converted to be operated under GA and further mapping was completed successfully [Figure 1]. From 24 patients in the GA group, 3 patients

Table 2: Tumor characteristics and surgical outcomes of 64 patients underwent perirolandic glioma resection using intraoperative mapping techniques either awake or under GA.

Characteristic	Awake (n=40)	GA (n=24)	P-value
Side, n (%)			
Rt side	24 (60)	14 (58.3)	0.89
Lt side	16 (40)	10 (41.7)	
Preoperative tumor volume			
Mean (SD)	36.6 cm ³ (17.3)	45.3 cm ³ (20.9)	0.07
Histopathology			
High grade glioma, n (%)			
Glioblastoma multiforme	15 (37.5)	11 (45.8)	0.51
Anaplastic astrocytoma G III	7 (17.5)	4 (16.7)	0.93
Anaplastic oligodendroglioma GIII	2 (5)	1 (4.2)	0.88
Low-grade glioma, n (%)			
Astrocytoma GII	11 (27.5)	5 (20.8)	0.55
Pleomorphic Xanthoastrocytoma GII	2 (5)	1 (4.2)	0.88
Oligodendroglioma GII	3 (7.5)	2 (8.3)	0.9
Extent of resection, mean (SD)	92.03 (3.1)	90.05 (3.9)	0.23
GTR>98%	18 (45)	7 (29.2)	0.2
NTR>90–98	14 (35)	8 (33.3)	0.89
STR 50–90%	8 (20)	9 (37.5)	0.13
PR<50%	0 (0)	0 (0)	n/a
Postoperative motor outcome, n (%)			
Worsened or new immediate deficit	15 (37.5)	11 (45.8)	0.51
Permanent deficit after 3 months	2 (5)	2 (8.3)	0.59

had intraoperative seizures (12.5%). Two of them had focal seizures during cortical stimulation which were controlled by cortical irrigation then mapping was resumed, while one patient developed secondary generalized seizure which was controlled by increasing sedation dose and resection was continued without further stimulation. Subcortical stimulations did not induce any seizures in both groups.

Postoperative characteristics

Eleven patients in the GA group (45.8%) encountered immediate postoperative worsened or new motor deficit, compared to 15 patients (37.5%) in the awake group ($P = 0.51$). At 3 months follow-up, only 2 patients (5%) of awake group had permanent deficit versus 2 patients (8.3%) who had operation under GA ($P = 0.59$). Postoperative seizures occurred in 9 awake patients (22.5%) and 8 GA patients (33.3%) ($P = 0.34$). Two patients in the GA group and 3 awake patients had small tumor bed hematomas which were treated conservatively, while only 1 patient in the GA group who developed postoperative large hematoma which required evacuation at the same operative day with subsequent good recovery. One patient from GA group had deep venous thrombosis and one had postoperative urinary tract infection. Three patients (4.7%) (2 awake and one from GA group) had postoperative wound infection which required conservative treatment with no further surgical interventions.

Predictors for intraoperative stimulation-induced seizures

Factors that might predict intraoperative seizures, while using cortical and subcortical stimulation mapping techniques were evaluated through logistic regression analysis. The univariate analysis revealed that patients who were treated preoperatively with multiple antiepileptic drugs (AEDs) ($P = 0.03$) and those with low-grade glioma ($P = 0.04$) were statistically significant predictors but did not show significance on multivariate analysis. Type of operation either awake or under GA, age, sex, preoperative KPS, preoperative seizure history, and preoperative tumor volume were not significant predictors [Table 4].

DISCUSSION

A large amount of retrospective data in the literature proved the value of maximum resection of glial-type tumors and suggested that the median survival time and time to recurrence are improved in patients who undergo aggressive resection either for low or high grade types,^[19,20,22,31,34,36,39] however, the price to pay for radical resection in perirolandic gliomas may be an increase in morbidity which negatively affects the overall outcome. Recently many advances in fMRI, DTI, neuronavigation, and other intraoperative imaging techniques that allow anatomic localization of eloquent areas had been achieved. However, due to interindividual variation, neuroplasticity, brain shift, and fallacies of fMRI

Table 3: Intraoperative stimulation-induced seizures and intraoperative electrophysiological mapping and monitoring values of 64 patients underwent perirolandic glioma resection using intraoperative mapping techniques either awake or under GA.

Characteristic	Awake (n=40)	GA (n=24)	P-value
Intraoperative stimulation-induced seizures, n (%)	4 (10)	3 (12.5)	0.76
Cortical stimulation threshold mA, mean (SD)	4.9 (0.42)	8.9 (1.2)	0.01
Subcortical stimulation threshold mA, mean (SD)	8.3 (0.62)	12.1 (1.1)	0.01

Table 4: Predictors for intraoperative stimulation-induced seizures using Univariate logistic regression model in 64 patients underwent perirolandic glioma resection using intraoperative mapping techniques either awake or under GA.

Variable	Odds ratio	95% CI	P-value
Mapping under GA	1.286	0.262–6.310	0.76
Preoperative seizure history	3.200	0.572–17.893	0.17
Multiple AEDs	5.000	0.983–25.437	0.03
Sex	1.042	0.213–5.086	0.96
Age	1.435	0.156–13.169	0.75
Preoperative KPS	1.500	0.258–8.711	0.65
Low-grade glioma	5.000	0.887–28.198	0.04
Preoperative tumor volume	1.773	0.195–16.088	0.61

and DTI,^[10,11,14,37] still intraoperative stimulation mapping techniques remain the gold standard to detect eloquent areas and create individualized map for every patient which facilitates maximum resection with decreased risk of morbidity.^[9,17,33]

Intraoperative motor mapping and monitoring can be performed while patient is awake or under GA, and still it is unclear which approach is preferable as little previous studies compared between both approaches.^[13,41] Continuous clinical monitoring of patient's voluntary movements is a valuable advantage during awake craniotomy but the fear of failed or aborted technique is limiting many surgeons, who prefer to do motor mapping under GA, and one of the most important failure causes is intraoperative seizures that might require endotracheal intubation and conversion to GA. In our institutes, we use both approaches when dealing with perirolandic gliomas according to specific inclusion criteria mentioned before, and in this study we retrospectively

collected 40 patients operated with awake craniotomy and 24 patients under GA. Positive motor mapping was detected in all patients then resection was employed. Mean EOR of 92.03% in awake cases and 90.05% in GA cases ($P = 0.23$) was achieved, which is obviously better than previous reports in the literature to patients with same lesions related to eloquent areas and operated without any mapping techniques,^[3,9,24] However, GTR > 98% was achieved more in awake group 45% compared to 29.2% in GA group ($P = 0.2$), also Eseonu *et al.*^[13] reported in their study that awake craniotomy allows for a higher frequency of 100% total resections. This is mostly attributed to the higher safety and surgeon confidence during awake craniotomy with continuous clinical assessment throughout the resection.

In the current study, immediate postoperative worsened or new motor deficit was reported higher in GA group (45.8% vs. 37.5% in awake patients) but was not statistically significant ($P = 0.51$), Zelizki *et al.*^[41] also reported better early postoperative motor outcome and shorter length of stay (LOS) in awake patients, but with no statistically difference between awake and GA groups at 3-month follow-up, and Eseonu *et al.*^[13] showed that awake craniotomy can be performed on perirolandic gliomas with better early postoperative KPS, and this could be explained by the higher incidence of vasoconstriction and hypoperfusion of the brain during GA as hyperventilation and diuretics can be used in order to keep brain relaxed and this might affect the early postoperative state.^[13,41]

Furthermore, Brallier *et al.*^[2] showed that serum lactate, which is a marker for cerebral ischemia and hypoperfusion, was elevated intraoperative in patients who had craniotomy under GA and was associated with new neurological deficits and longer LOS. The inhibitory effect of anesthetic agents on electrophysiological excitability and the relationship between MEP amplitude and depth of anesthesia was reported in previous studies,^[30,40] and we reported significantly lower mean cortical and subcortical stimulation thresholds to evoke motor response in awake patients than patients who were operated under GA ($P = 0.01$) and that also affects the immediate postoperative recovery.

Intraoperative stimulation-induced seizures may result in difficulties in further mapping and affect surgical outcome and EOR, and in awake craniotomy, either mild inconvenience to the patient and surgeon up to uncontrolled generalized seizures necessitating conversion to GA can happen. Intraoperative seizures occurred in 10% of our awake patients and 12.5% of GA cases; although it is statistically insignificant, the higher incidence in GA cases can be due to the higher cortical stimulation threshold needed to evoke motor response, we need further studies and higher patients number to confirm this point. Eseonu *et al.*^[13] in their study had intraoperative seizures in 7.4% of awake cases compared

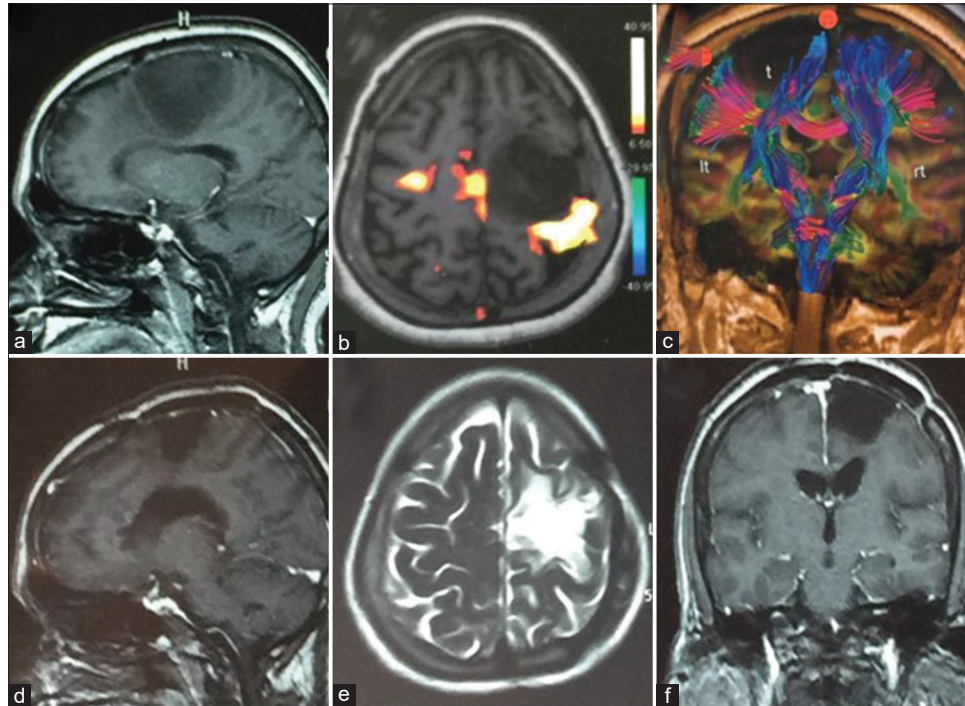


Figure 1: A case of left perirolandic fibrillary astrocytoma grade II operated by awake craniotomy and mapping techniques with occurrence of intraoperative stimulation-induced focal seizures controlled by ice-cold ringer's lactate irrigation and further mapping was successfully completed with gross total resection and postoperative uneventful recovery without new deficit. (a) preoperative MRI brain (sagittal T1 with contrast), (b and c) preoperative fMRI and DTI, (d-f) 3 months postoperative follow-up MRI brain with contrast.

to 16.1% of GA patients with no cases were terminated early. Serletis and Bernstein^[38] reported a seizure rate of 4.9% in a large cohort of 511 patients underwent awake craniotomy. Nossek *et al.*^[29] in their review of 477 patients with brain tumors who underwent awake craniotomy, the incidence of intraoperative seizures was 12.6% and 2.3% was reported as failed awake craniotomy. None of our awake cases who had intraoperative seizures were aborted or converted to GA and were controlled by cold ringer's lactate irrigation or small doses of sedation. The use of ECoG had been shown in previous studies to be linked with lower incidence and early detection of intraoperative seizures, and we used ECoG to detect afterdischarges in our protocol as mentioned. Boetto *et al.*^[1] reported 3.4% incidence of intraoperative seizures without ECoG use and concluded that it is not mandatory, also Nossek *et al.*^[29] in their study used ECoG in some patients and reported higher incidence of intraoperative seizures in those patients. In our study, ECoG was essential in our protocol to detect after discharges and used in all patients but intraoperative seizures can still occur with electrical stimulation mapping even if ECoG is used. Preoperative AEDs optimization, trained neuroanesthesia, neurophysiology, and ancillary teams, rapid communication, and proper intervention with the specific protocol are important factors to deal with such event without major morbidity or failed procedure.

Previous studies analyzed predictors for intraoperative stimulation-induced seizures and concluded that younger patients, low-grade glioma, history of seizures, positive cortical mapping, and preoperative tumor volume were significant predictors.^[12,29] In our study, we did not find a correlation between preoperative seizures and the incidence of intraoperative seizures as preoperative antiepileptic medications were carefully optimized, but patients who were partially intractable with multiple AEDs showed a significant predictor on univariate logistic analysis. Many studies reported that patients with low-grade glioma are more prone to present with seizures.^[23,35] We found significant correlation between low-grade glioma and intraoperative stimulation-induced seizures on univariate analysis but it did not show significance in multivariate model.

Study limitations

The limitations of this study are those inherent to retrospective nature with small populations. One of the inclusion criteria for awake craniotomy is the patient's acceptance to perform such technique which is source for a selection bias. This study does not account for the experience gained by the team and evolved by years for better deal with such cases.

CONCLUSION

Intraoperative cortical and subcortical mapping techniques increase safety and efficacy of perirolandic glioma resection either patient is awake or under GA with low incidence of stimulation-induced seizures which do not affect the procedure or further mapping. Low-grade glioma and previous use of multiple AEDs can be considered as predictors for higher incidence of stimulation-induced seizures. Awake craniotomy can be done safely in selected patients with continuous clinical assessment throughout the resection, lower stimulation intensities required for mapping and lower but statistically nonsignificant incidence of intraoperative seizures.

Declaration of patient consent

Institutional Review Board permission obtained for the study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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