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Role of Asleep Surgery for Supplementary Motor Area Tumors

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Abstract

Background The supplementary motor area (SMA) is involved in planning of voluntary motor activities. Tumors in SMA usually present with seizures and, rarely, motor deficits. Postoperatively, these patients may develop SMA syndrome. Patients with SMA tumors usually undergo awake craniotomy along with neuromonitoring for maximal safe resection, and some of these patients tend to have residual tumor.

Objective To completely excise the SMA region tumors under general anesthesia without causing any permanent neurological deficits.

Methods We operated upon four patients with SMA region tumor under general anesthesia (GA) with direct electrocortical stimulation (DES). Motor-evoked potential was used to monitor corticospinal tracts through corkscrew or strip electrodes. Intraoperative MRI was done to assess the tumor excision.

Results All four patients had complete resection of tumor and, postoperatively, all four developed SMA syndrome. All of them recovered completely over a period of time.

Conclusion SMA tumors can be excised completely under GA with DES, thereby increasing progression-free survival.

Keywords
- SMA tumor
- SMA syndrome
- GA-DES

Key message

One can achieve maximum safe resection or complete tumor excision with GA-DES for supplementary motor area (SMA) tumors.

Introduction

SMA controls the planning and execution of voluntary motor activities. Tumors of the SMA usually present with seizure and, rarely, motor deficits. Low-grade gliomas are the most common tumors of this region. Postoperatively, some of these patients may develop transient deficits like reversible SMA syndrome or, rarely, permanent motor deficits.[1,2]

Gliomas post a challenge for achieving complete tumor resection due to its infiltration along the white matter tracts. For functional preservation, awake craniotomy with mapping by direct electrical stimulation (DES) is practiced for SMA tumor resections.[2–4]

In awake craniotomy, resection of the tumor is performed as long as there are no deficits or till complete tumor excision. As the motor deficits/speech abnormalities appear, further resection is stopped, leaving some amount of residual tumor and decreased tumor progression-free survival (PFS).

In this article, we share our institutional experience of four patients with tumor involving SMA region with postoperative SMA syndrome. All these patients underwent tumor resection under general anesthesia (GA) along with DES.

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Table 1 Details of patients with tumors involving SMA region

	Case 1	Case 2	Case 3	Case 4
Age/sex	27/F	35/F	55/M	26/M
Symptoms	Seizure	Seizure	Headache	Seizure
Location of tumor	Right premotor region	Right prefrontal and premotor region	Left posterior frontal extending up to corpus callous	Left premotor region
Technique	GA-DES	GA-DES	GA-DES	GA-DES
Postresection MEP	Intact	Intact	Intact	Intact
IO-MRI	No residue	No residue	No residue	No residue
3 months MRI	No recurrence	No recurrence	Recurrence +	No recurrence
SMA syndrome	+	+	+	+
Recovery from SMA syndrome	Complete recovery	Complete recovery	Complete recovery	Complete recovery
Time of recovery from SMA syndrome	1 week	5 days	1 month	5 days
Histopathology	WHO gr 2 astrocytoma	WHO gr 2 astrocytoma	WHO gr 4 glioblastoma	WHO gr 2 astrocytoma
Postop RT/chemotherapy	No	No	Yes	No

Abbreviations: GA, general anesthesia; DES, direct electrocortical stimulation; MEP, motor-evoked potential; SMA, supplementary motor area.

Methods

We selected patients with SMA region intra-axial tumor. All the four patient's clinical histories and examinations were documented. Preoperatively, all these patients underwent MRI with tumor protocol, diffusion tensor imaging (DTI), functional MRI, and neuronavigation protocol (►**Table 1**).

All four patients were operated under GA with neuronavigation, transcranial motor-evoked potential (MEP) by corkscrew, mapping with strip electrodes, and DES. Intraoperative MRI (3T) was used to assess the extent of tumor resection. For baseline MEP, we used corkscrew stimulation with high-frequency train of seven stimuli, with current starting from 150 mA. Using strip electrodes, we mapped the central sulcus with somatosensory-evoked potential (SSEP) from contralateral shoulder; then, we mapped the cortical motor areas by DES. Motor mapping was done by anodal stimulation with a return electrode placed at the contralateral shoulder. High-frequency train stimulation with five pulses of 333 Hz and 500 us pulse width was used with increasing current intensity from 2 to 10 mA. After mapping the motor area, the tumor surface is also stimulated for any motor activity. Then tumor resection is started from the noneloquent area, that is, away from motor cortex, from anterior to posterior. As we went inferior and posterior, tumor resection was done along with DES. For subcortical mapping, the stimulation pattern was changed to cathodal stimulation with similar settings. Resection was done till we got positive stimulation with 6 to 8 mA or tumor was completely removed. Intermittently, we checked MEP with corkscrews or strip electrodes.

Results

We operated upon all four patients by this protocol, and we achieved complete tumor resection in all four patients, which was confirmed with intraoperative MRI. MEP was intact at the end of tumor resection, but all four patients developed SMA syndrome postoperatively, and all of them recovered completely. Two patients recovered by 5 days and one by a week. The patient who had dysphasia along with hemiparesis and left-sided, high-grade tumor recovered by 1 month (►**Figs. 1–3**).

Discussion

SMA syndrome is characterized by contralateral motor deficits with or without speech deficits (dominant side) following complete or incomplete resection of tumors involving SMA region. It is a disorder of executive function. SMA syndrome may be complete or partial by the extent of deficit developed following surgery. A complete or almost complete recovery of functions occurs within few weeks or months.[5]

The possible explanation for SMA syndrome is disruption of neuronal interconnections between the ipsilateral SMA and primary motor and sensory areas. The recovery of functions depends upon the interhemispheric connectivity between the contralateral SMA region with ipsilateral primary motor and sensory areas. This is best assessed by DTI; if the number of nerve fiber tracts is less than 8,000, then the recovery is delayed, that is, more than 7 days.[6]

Vassal et al did functional MRI in the patients with SMA region diffuse low-grade gliomas. After surgery, reorganization

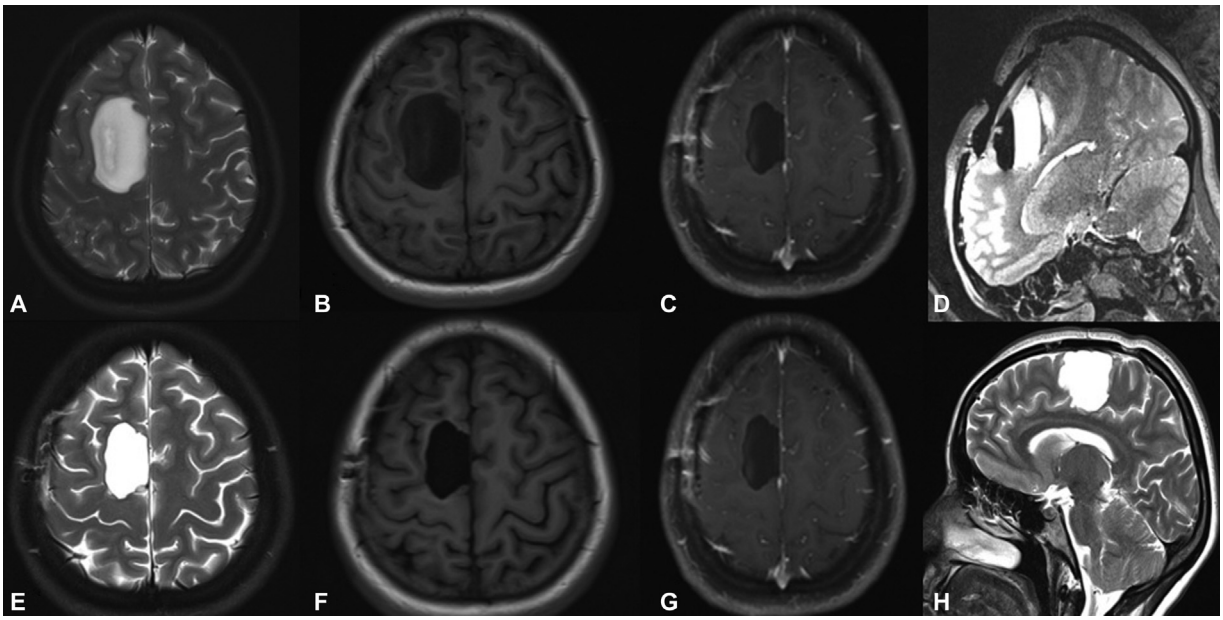

Fig. 1 Preoperative and postoperative MRI images of case 1. (**A–C**) are the preoperative images of T2 axial, T1 axial, and T1 postcontrast axial images, respectively, showing T2-hyperintense, T1-hypointense, and nonenhancing lesion in right posterior superior frontal gyrus and involving supplementary motor area (SMA) region. (**D**) is the intraoperative T2 sagittal image showing total excision of the tumor. (**E–H**) are the 3 months postoperative images of T2 axial, T1 axial plain, T1 axial postcontrast, and T2 sagittal images, respectively, showing no residual/recurrence of tumor.

of sensorimotor cortex was observed, which resulted in recovery of SMA syndrome. They demonstrated that interhemispheric connectivity is both inversely correlated to preoperative deficit and positively correlated with postoperative recovery in SMA syndrome.[7]

Awake craniotomy is preferred for SMA region tumors. Even though the SMA syndrome is transient, some patients are unable to execute complex movement or bimanual coordination, which may be detrimental. Awake mapping was done to identify and preserve these tracts. In awake mapping, when patient continuously moves the

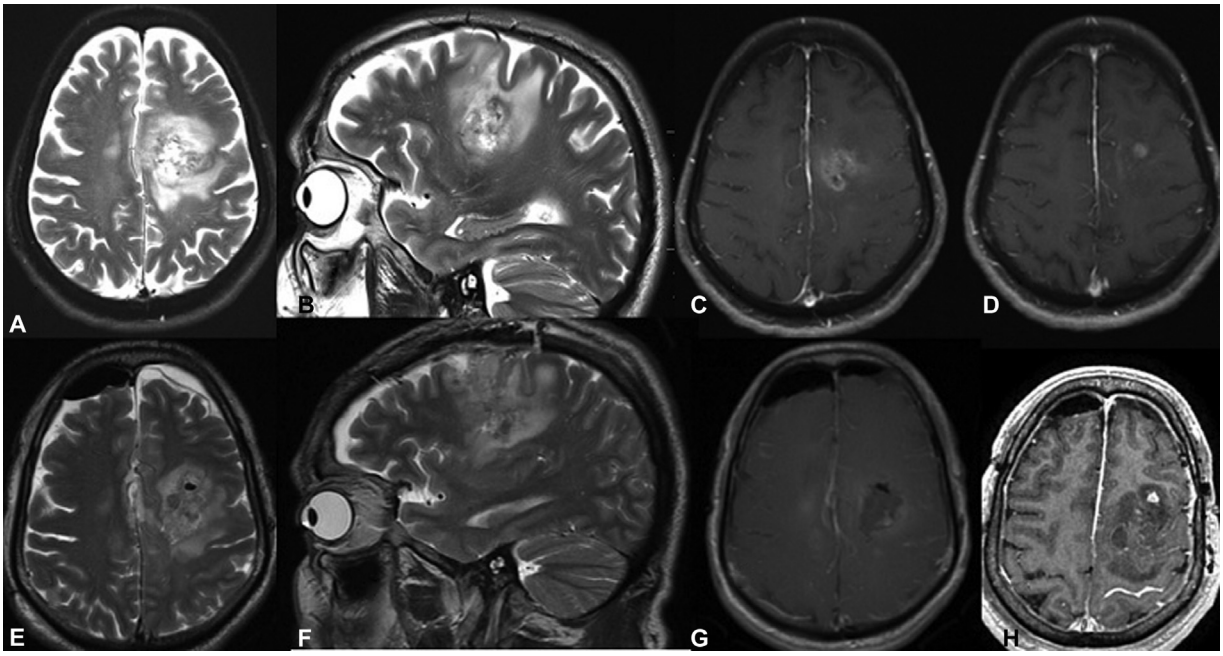

Fig. 2 Preoperative and immediate postoperative MRI images of case 3. (**A–D**) are the preoperative images. A—T2 axial, B—T2 sagittal, C and D are T1 postcontrast axial images showing T2-hyperintense, T1-hypointense and heterogeneously enhancing lesion in left posterior superior frontal gyrus with infiltration into supplementary motor area (SMA) region, cingulate gyrus and the corpus callosum. **E**—T2 axial, **F**—T2 sagittal, **G** and **H** are the T1 axial postcontrast immediate postoperative images showing no residual tumor. In this patient, fluorescence-guided surgery was performed.

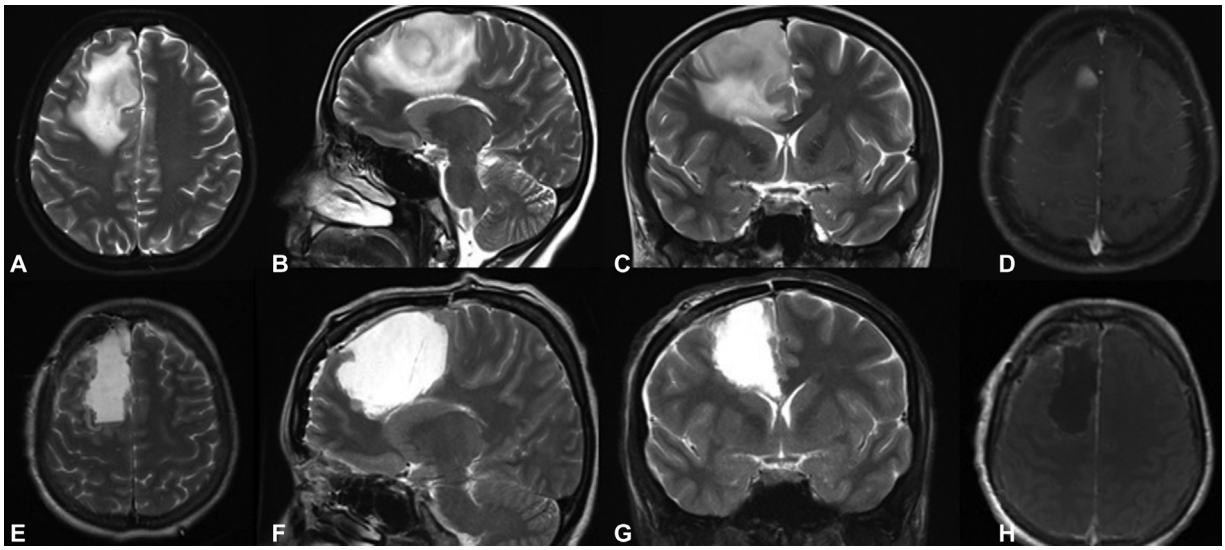

Fig. 3 Preoperative and immediate postoperative images of case 2. (**A–D**) are the T2 axial, T2 sagittal, T2 coronal, and T1 postcontrast axial images showing T2 heterogeneously hyperintense lesion involving right middle and posterior aspect of superior frontal gyrus, extending up to premotor region; lesion is hypo in T1 and showed a small nodular enhancement anteriorly and few areas of patchy enhancement posteriorly. (**E–G**) are the T2 axial, sagittal, and coronal immediate postoperative MRI images and **H** is the postcontrast T1 axial image showing complete resection of the tumor.

Table 2 Comparison of awake and asleep surgery in SMA tumors

Parameters	Awake	Asleep
MEP	Not possible	Possible
Cortical and subcortical mapping	Yes	Yes
Language assessment	Possible	Not possible
Assessment of complex executive function and bimanual coordination	Possible	Not possible
SMA syndrome	Yes	Yes
Endpoint of tumor resection	Onset of motor/ speech deficits	Resection continued till electrophysiological changes
Tumor residue	High chance of residue	Lesser than awake; if there is residue, it may be in lesser volume.

Abbreviations: MEP, motor-evoked potential; SMA, supplementary motor area.

contralateral side, stimulation induces an arrest or an acceleration of that movement. By this method, one can avoid deficits like bimanual coordination postoperatively.[8,9]

In awake craniotomy, we tend to prematurely stop resection when the patient develops weakness (motor or speech) intraoperatively, which may be due to SMA syndrome (likely to improve), thereby decreasing tumor PFS. There are other factors like patient cooperation, seizure, intraoperative bleeding, etc., which also come into play for achieving complete tumor resection (►**Table 2**).[4,10]

A complete resection of tumor increases the overall survival significantly in low-grade gliomas.[9] Tumor or the entire SMA region can be removed completely until the pyramidal tracts have been detected by DES and MEP. Under GA, MEP is possible, which gives us the real-time confirmation of intactness of corticospinal tracts during and at the end of procedure. But the information on bimanual coordination is not possible. In our series, complete resection of tumor was done, but all four patients developed SMA syndrome postoperatively despite intact MEP. We can reassure patients that their weakness is likely to be transient, which will improve over the period of time, based on the MEP information. All resections were limited only to the tumor area.

In patients having an occupation where bimanual coordination is essential, and in those tumors extending into primary speech area/cognitive connections, awake surgery with monitoring is mandatory.[8,9] In patients where tumor is limited to SMA area only and where bimanual coordination is not an issue, it may be wiser to do it under GA with monitoring to maximize the resection.

Conclusions

Under GA-DES with MEP for SMA region tumors, one may achieve maximum/complete safe resection, taking cognitive, language, and profession of the patient into consideration. This protocol needs to be evaluated in a large set of patients for better outcome.

Authors' Contributions

K.K.G. and C.C. contributed in concepts, design, definition of intellectual content, literature search, clinical studies, data acquisition, data analysis, manuscript preparation, manuscript editing, and manuscript review. A.B. and B.J.R. contributed in concepts, design, definition of intellectual content, literature search, clinical studies, data acquisition, data analysis, manuscript preparation, manuscript editing,

manuscript review, and as guarantors. N.M. provided definition of intellectual content; conducted literature search and clinical studies; and performed data analysis, manuscript editing, and manuscript review.

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Conflict of Interest
None declared.

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References

1 Nakajima R, Nakada M, Miyashita K, et al. Intraoperative motor symptoms during brain tumor resection in the supplementary motor area (SMA) without positive mapping during awake surgery. Neurol Med Chir (Tokyo) 2015;55(05):442–450
2 Zhang K, Gelb AW. Awake craniotomy: indications, benefits, and techniques. Rev Colomb Anestesiol. 2018;46:46–51
3 Szelényi A, Bello L, Duffau H, et al; Workgroup for Intraoperative Management in Low-Grade Glioma Surgery within the European Low-Grade Glioma Network. Intraoperative electrical stimulation in awake craniotomy: methodological aspects of current practice. Neurosurg Focus 2010;28(02):E7
4 Hervey-Jumper SL, Berger MS. Maximizing safe resection of low- and high-grade glioma. J Neurooncol 2016;130(02):269–282
5 Ulu MO, Tanriöver N, Ozlen F, et al. Surgical treatment of lesions involving the supplementary motor area: clinical results of 12 patients. Turk Neurosurg 2008;18(03):286–293
6 Oda K, Yamaguchi F, Enomoto H, Higuchi T, Morita A. Prediction of recovery from supplementary motor area syndrome after brain tumor surgery: preoperative diffusion tensor tractography analysis and postoperative neurological clinical course. Neurosurg Focus 2018;44(06):E3
7 Vassal M, Charroud C, Deverdun J, et al. Recovery of functional connectivity of the sensorimotor network after surgery for diffuse low-grade gliomas involving the supplementary motor area. J Neurosurg 2017;126(04):1181–1190
8 Duffau H, Mandonnet E. The “onco-functional balance” in surgery for diffuse low-grade glioma: integrating the extent of resection with quality of life. Acta Neurochir (Wien) 2013;155(06):951–957
9 Mandonnet E, Duffau H. An attempt to conceptualize the individual onco-functional balance: Why a standardized treatment is an illusion for diffuse low-grade glioma patients. Crit Rev Oncol Hematol 2018;122:83–91
10 Sokhal N, Rath GP, Chaturvedi A, Dash HH, Bithal PK, Chandra PS. Anaesthesia for awake craniotomy: a retrospective study of 54 cases. Indian J Anaesth 2015;59(05):300–305