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Original Article

Assessment of the Benefit of Intraoperative Cortical Stimulation in Patients with Lesions within Eloquent Brain Regions

Avaliação do benefício da estimulação cortical intraoperatória em pacientes com lesões em áreas cerebrais eloquentes

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Abstract

Objective The present study sought to evaluate the benefits of intraoperative cortical stimulation (CS) for reducing morbidity in neurosurgery.

Method A total of 56 patients were submitted to neurosurgical procedure with the aid of CS. Initially, surgical exposure and planned resection were based on anatomy and imaging exams, which were followed by CS. According to the findings, the patients were divided into two groups. In group 1 the previous surgical strategy had to be altered, while in group 2 the surgical planning did not suffer any interference. Patients were also divided into subgroups according to the underlying disease: gliomas or other etiologies. Transient and definitive deficits occurrence were compared between groups 1 and 2 and subgroups of etiologies. The real benefit of CS technique was calculated by a specific formula.

Results There were 20 patients (37.5%) whose surgical strategy was changed based on CS findings. Furthermore, 65% of group 1 patients had transient deficit, in comparison to 30.5% of patients in group 2 ($p = 0.013$). As for the definitive deficit, it occurred in 15.0% of group 1 patients versus 8.3% of patients in group 2 ($p = 0.643$). Definitive deficits with no statistical difference ($p = 0.074$) were found in 17.2% of patients with gliomas, while none were found in the other etiologies subgroup. The rate of real benefit of intraoperative CS was 30.4%. Considering the subgroups of gliomas and other etiologies, the benefit rates were 25.7% and 38.1%, respectively.

Conclusions The surgical decision was influenced by CS in 35.7% of the cases and prevented definitive deficit in 30% of patients.

Keywords
- intraoperative neurophysiological monitoring
- gliomas
- brain mapping
- neuronal plasticity
- surgery
- direct electrical stimulation

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Resumo

Objetivos O presente estudo procurou avaliar os benefícios da estimulação cortical (EC) intraoperatória na redução da morbidade em neurocirurgias.

Métodos Um total de 56 pacientes foram submetidos ao procedimento neurocirúrgico com ajuda da EC. Inicialmente, a exposição cirúrgica e o panejamento da ressecção eram baseados nos achados de anatomia e imagem, que eram seguidos pela EC. De acordo com os achados neurofisiológicos, os pacientes foram divididos em dois grupos. No grupo 1, a estratégia cirúrgica teve que ser modificada, enquanto no grupo 2, o planejamento cirúrgico não foi alterado. Os pacientes foram ainda divididos em dois subgrupos de acordo com a doença subjacente: gliomas ou outras etiologias. A ocorrência de déficits transitórios e definitivos foram comparadas entre os grupos 1 e 2 e entre os subgrupos de etiologias. O benefício real da técnica de estimulação cortical foi calculado por uma fórmula específica.

Resultados A estratégia cirúrgica foi alterada em 20 (37,5%) pacientes após a estimulação cortical. Além disso, 65% dos pacientes do grupo 1 tiveram déficits transitórios, em comparação com 30,5% dos pacientes do grupo 2 ($p = 0{,}013$). Quanto ao déficit definitivo, este ocorreu em 15% dos casos do grupo 1 contra 8,3% dos pacientes do grupo 2 ($p = 0{,}643$). Déficit definitivo sem diferença significativa ($p = 0{,}074$) foi observado em 17,2% dos pacientes com gliomas, enquanto nenhum foi encontrado no subgrupo de outras etiologias. A taxa de benefício real da EC intraoperatória foi de 30,4%. Considerando os subgrupos de gliomas e outras etiologias as taxas de benefício foram 25,7% e 38,1%, respectivamente.

Conclusões A EC influenciou a decisão cirúrgica em 35,7% dos casos. Embora 90% dos pacientes não tenham cursado com déficits a longo prazo, a estimulação cortical preveniu tais déficits em cerca de um terço deles.

Palavras Chaves
- monitorização neurofisiológica intraoperatória
- gliomas
- mapeamento cerebral
- plasticidade neuronal
- cirurgia
- estimulação elétrica direta

Introduction

Studies have shown that quality of life and mean survival correlate with the extent of lesion resection, especially in gliomas.[1–4] However, the aim is to dry out the lesion as much as possible, taking care to preserve cortical functions. Identification of eloquent areas in the cerebral cortex is important to minimize the morbidity associated with resection of abnormal brain tissue. Techniques used for this localization have been adapted over the years for epilepsy, tumors, and vascular surgeries involving the eloquent cortex and subcortical white matter.[1,5,6]

The treatment for these lesions involves proper preoperative planning, imaging exams, and functional identification during surgery. Techniques for identifying eloquent areas are varied, with an emphasis on direct intraoperative cortical stimulation. The use of cortical electrical stimulation in neurosurgery began in 1930 with Forster, then Penfield described the motor and sensory homunculus in 1937.[5] Then, it spread across America and Europe.[7,8] The principle of this technique is based on depolarization of local neurons, inducing excitation or inhibition.[6] This technique is efficacious, cost-effective, and easy to apply, being recommended for tumors, cavernomas, arteriovenous malformations, and epilepsy. Furthermore, it has changed the concept of "inoperable lesion" by reducing the sequelae rate described in the literature from 6.5 to 17%.[9]

Cortical and subcortical electrical stimulation allow resection to the point where functional response occurs.[6,10] This technique can be used to identify descending subcortical motor fibers when resection extends below the cortical surface, such as during resection in additional motor areas or insular regions. It is believed that intraoperative cortical stimulation has contributed to a wider and safer removal of lesions, improving patient survival, and preserving the functional area. Nevertheless, there are no randomized and controlled studies that determine the impact of this technique concerning surgical safety and survival of patients. Most of the published articles present case series without comparative groups. On the other hand, metanalyses reinforce assumption that it is difficult, if not impossible for ethical reasons, to recruit a control group of patients with infiltrative lesions in eloquent areas of the brain to undergo resection surgery without intraoperative cortical stimulation.[1,6,11–15]

The present study aimed to evaluate the benefit of this technique in surgical resection of brain lesions in eloquent areas of the brain.

Method

From 2002 to 2016, 63 patients were operated at the Hospital das Clínicas of the Federal University of Minas Gerais (Belo Horizonte, Brazil), for presenting brain lesions near or involving

Table 1 Degree of resection and histological findings of 56 patients

Degree of resection	N	%
Total	34	60.7%
Partial	22	39.2%
Etiology		
Low-grade gliomas	25	44.6%
High-grade gliomas	10	17.8%
Metastasis	5	8.9%
Cortical dysplasia	3	5.3%
Radionecrosis	3	5.3%
Lymphomas	2	3.5%
Neurotoxoplasmosis	2	3.5%
Meningiomas	1	1.8%
Ependymoma	1	1.8%
Dysembryoplastic tumor	1	1.8%
Abscess	1	1.8%
Cavernoma	1	1.8%
Vascular malformation	1	1.8%
Total	56	100%

one or more brain eloquent areas, such as motor, sensory, or language. All of them were submitted to intraoperative cortical stimulation. Of this total, 7 patients were excluded due to having a follow-up period lower than 3 months or because of incomplete medical record data. Thus, 56 patients were selected and retrospectively evaluated. There were 31 men (55.3%) and 25 women (44.6%), with a mean age of 39 years, ranging from 9 to 79 years. After chart review, patients were called for a new consultation, and their data were checked and updated. Furthermore, a new neurological examination was done, and the imaging exams were analyzed. Patients were followed for a mean of 228.4 months (3 to 120 months). ►**Table 1** presents the degree of resection and lesion etiologies.

All patients were operated by the same surgeon, using the same technique. If only motor stimulation was necessary, the patient underwent general anesthesia. In cases where language and/or sensory stimulation were necessary, sedation alone was used at the beginning of the series to obtain satisfactory arousal during neuropsychological tests. As anesthetic technique improved, the "asleep-awake-asleep" strategy was applied, in which the patient undergoes general anesthesia, the airway is protected with a laryngeal mask or orotracheal tube, and patient is awakened during the tests after airway clearance. After cortical stimulation, patients were submitted again to general anesthesia with the laryngeal mask and the surgical procedure was completed as usual. Craniotomy was used to expose the entire lesion (►**Fig. 1C**) as well as the adjacent cortex. For that purpose, preoperative images, craniometric references, stereotactic system (for small lesions), neuronavigation, intraoperative ultrasound, and electrocorticography (for refractory epilepsy cases) were used (►**Table 2**). Once the lesion was delimited (►**Fig. 1D**, **2B**, **3B**, **4B**), the area to be resected or incised was marked with a silk thread. These anatomical parameters alone were used, and when the functional register was not possible, and a photographic record was made. Then, the cortical stimulator equipment (biphasic current, 60 Hz, 1 millisecond, starting from 2A and increasing based on the response) was used to perform stimulation over the adjacent cortex and the area to be operated. Once the eloquent area was identified, the medical professionals decided if the previous planning would be modified or not. The alternatives were reduction (►**Fig. 2C**) or increase in the area to be removed (►**Fig. 4C**), or incision on another topography (►**Fig. 3C**). A new photographic record was made at this point, as well as at the end of the main surgical procedure (►**Fig. 1F**, **2D**, **3D**, **4D**).

Considering cortical stimulation findings, patients were divided into two groups, with (group 1) and without (group 2) changes in surgical strategy due to cortical stimulation . The changes in surgical tactics for group 1 were increasing or reducing the area to be resected, or alteration in corticectomy. The patients were further divided into two subgroups according to the underlying disease: gliomas and other etiologies. They were also compared for transient and permanent deficit, as well as for change in surgical strategy. Furthermore, patients were periodically monitored and reevaluated; the rates of transient and definitive neurological deficits were recorded and compared statistically. Transient deficits were defined as those that appeared or suffered aggravation during postoperative period but regressed up to the date of the last clinical evaluation. Permanent deficits, regardless of magnitude, were those neurological deficiencies that did not exist during preoperative period and remained up to the last clinical evaluation.

The real benefit of the cortical stimulation technique was calculated by dividing the number of patients who needed a change in strategy after mapping and who did not present late deficit by the total of patients multiplied by 100. This assessment was also performed for the etiology subgroups.

To estimate homogeneity among the groups, regarding the variables of this study, and to compare the deficits between the groups, the Fisher exact and the Chi-square tests were used.[16] The software employed in the analysis was R (R Foundation for Statistical Computing, Vienna, Austria) version 3.3.2. The statistical significance level established was 5%. A p-value lower than 0.05 generates evidence for rejection of the null hypothesis of the test.

The present study was approved by the university's ethics and research committee (CAAE - 53468716.5.0000.5149). The free and informed consent form was signed by all patients, ensuring the secrecy and confidentiality of collected data. When a patient was considered unable to sign the consent form, this function was delegated to a caregiver or family member.

Results

Regarding the surgical technique and stimulation variables (►**Table 2**), it is important to note that most of the individuals

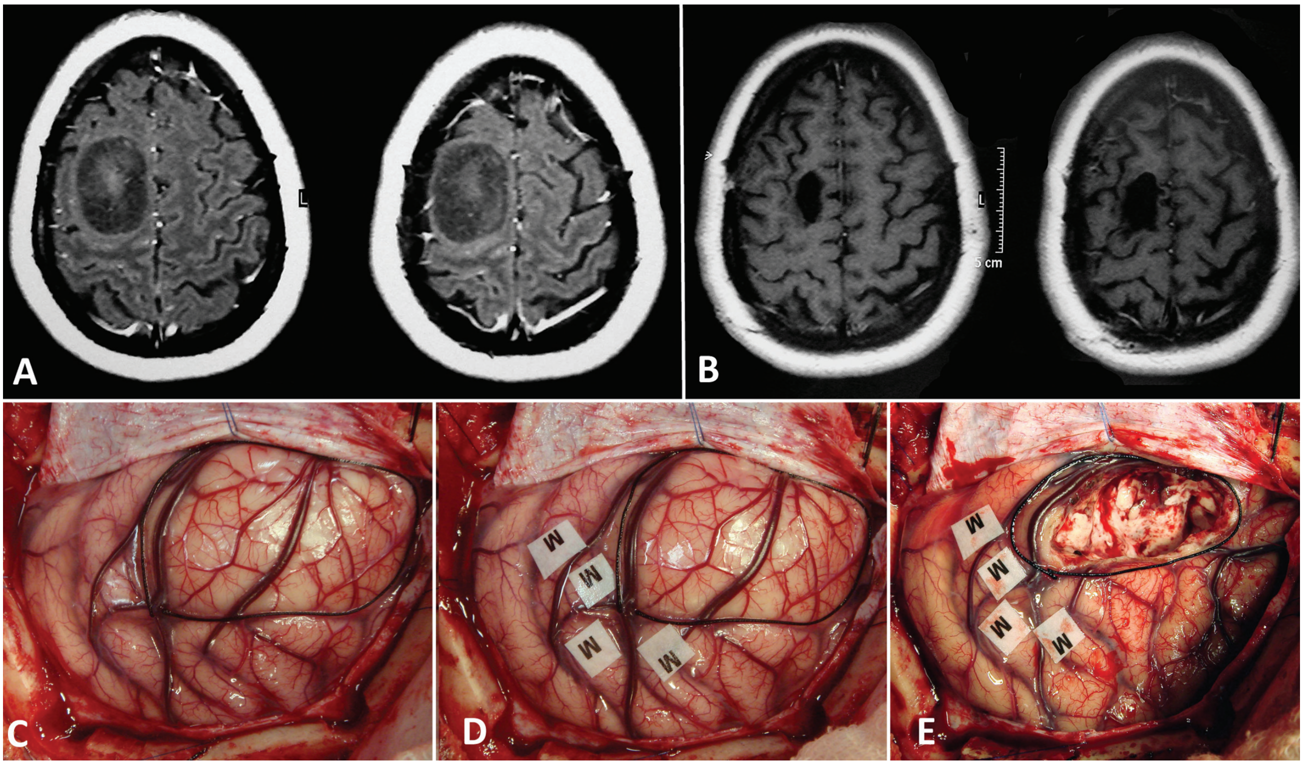

Fig. 1 (**A**) Preoperative, contrast-enhanced T1-weighted MRI: Hypointense, fairly enhancing, slightly insufflated image located in the right frontal region whose posterior border is close to or encompassing the motor area. (**B**) Postoperative, contrast-enhanced MRI showing complete lesion resection. (**C**) Intraoperative photo: Wide craniotomy with exposure of the cortex infiltrated by the disease and a silk thread demarcating the planned resection area. (**D**) Intraoperative photo after mapping: motor cortex (M) is outside the planned resection area. (**E**) Intraoperative photo: final appearance after tumor resection, demonstrating that initially planned surgical strategy was performed without the influence of cortical stimulation.

Table 2 Absolute and relative descriptive frequency of variables

Variables		N	%
Anesthesia	General	35	62.5%
	Awake	21	37.5%
Identification method	MRI	51	91.7%
	Ultrasonography	17	30.3%
	Stereotactic	8	14.2%
	Electrocorticography	7	12.5%
	CT scan	5	8.9%
	Neuronavigation	2	3.5%
Stimulation	Motor	53	94.6%
	Language	13	23.2%
	Sensitive	9	16.1%

Abbreviations: CT, computerized tomography; MRI, Magnetic resonance image.

(62.5%) underwent general anesthesia. More than one localization method was used in most patients, and magnetic resonance imaging was used in 91% of the cases. Motor stimulation was the most frequent modality (94.6%).

Among the patients who presented a surgical strategy change, this alteration occurred in three ways: resection was smaller or larger than planned, or the corticectomy site was modified. These changes occurred in 20 of the 56 cases, making up 35.7% of surgical interventions. Among the 20 patients who had the surgical tactics altered due to intraoperative cortical stimulation, 16 (80.0%) obtained a smaller resection than expected (►**Table 3**).

There was a significant difference in transient deficit ($p = 0.013$) between the groups: 65.0% of group 1 patients had transient deficit, compared with 30.5% of those in group 2. Regarding definitive deficit, it is possible to say, with no statistical difference ($p = 0.643$), that it occurred in 15.0% of group 1 patients versus 8.3% of group 2 patients (►**Table 4**).

The subgroups were divided by underlying disease etiologies. The group of patients with gliomas had 83.4% of transient deficits ($p = 0.005$) and all late deficits (►**Table 5**). Furthermore, when the surgical strategy changed, the transitory deficits rate was 83.3% ($p = 0.024$) for this subcategory (►**Table 6**).

Permanent deficits, with no statistical difference ($p = 0.074$), were observed in 17.2% of the patients with gliomas and in none of those in the other etiologies subgroup (►**Table 5**).

The real benefit rate of intraoperative cortical stimulation was obtained by dividing the number of patients with technique changes and without long-term deficit[17] by the total of patients (n = 56), and the result was multiplied by 100, thus obtaining a value of 30.4%. In the gliomas subgroup, this result was of 25.7%, and in the other etiologies subgroup it was of 38.1%.

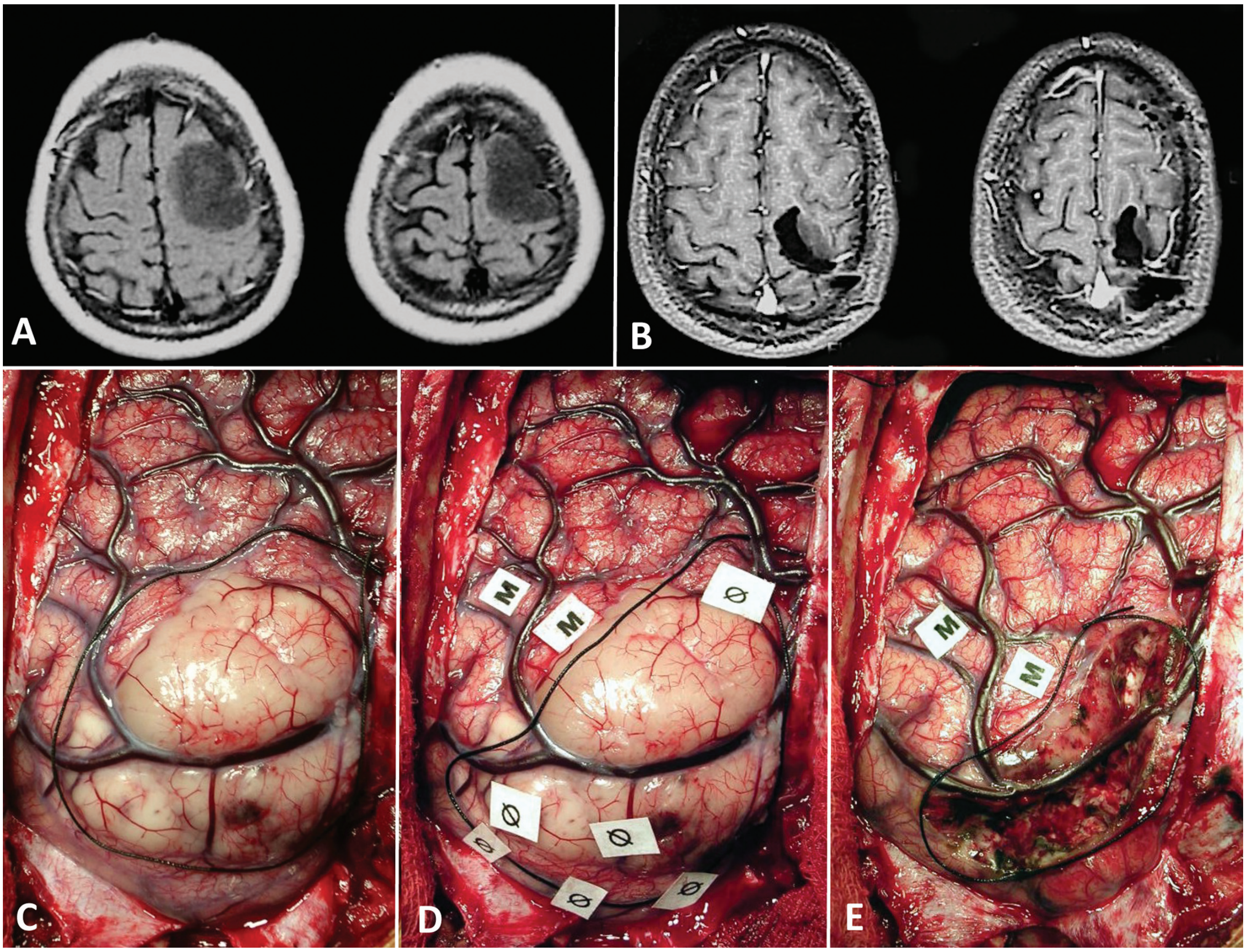

Fig. 2 (**A**) Preoperative, contrast-enhanced T1-weighted MRI: Hypointense, no-enhancing, slightly insufflated image located in the left frontal region whose posterior border is close to or encompassing the motor area. (**B**) Postoperative, contrast-enhanced MRI showing incomplete lesion resection. The tumor residue site corresponds to the motor strip (hand). (**C**) Intraoperative photo prior cortical stimulation: a silk thread demarcates the planned resection area based on anatomical and imaging data. (**D**) Intraoperative photo after mapping: motor response (M) was obtained at anterior and lateral border of the lesion. The silk thread had to be moved medially. Ø represents areas of no response. (**E**) Intraoperative photo after lesion resection. It is observed that the final resection was smaller than the initially planned one. The patient had no definitive deficit.

In regards to the relation between development of neurological deficits and anesthetic strategy, there was no significant difference ($p > 0.050$) in any of the variables (►**Table 6**).

Discussion

The present study sought to verify the effectiveness of direct cortical stimulation in postoperative outcomes, mainly regarding the presence of transient and permanent deficit stratifying patients among comparable groups regarding the alteration or not of the previously outlined surgical strategy (as result of the stimulation). The results were then analyzed considering two diseases subgroups: gliomas and other etiologies.

Aiming to compare results between two groups, in which all patients were submitted to direct cortical stimulation, a control group (group 2) was simulated, with patients whose surgical strategy was not altered as a function of the experimented technique. This control group was then compared with group 1, in which stimulation altered the surgical strategy.

The comparison performed in the present efficacy evaluation study is unprecedented, with most of the available literature constituting case series.[5,10–12] Scientific literature, in general, does not provide data for comparative calculations. Most published studies are case series without control groups. Furthermore, assembling a patient control group and submitting them to surgery without intraoperative cortical stimulation goes against medical ethics, since the benefit of the technique is considered relevant despite the absence of class 1 studies.

Mapping by cortex stimulation procedures can be performed under general anesthesia or while the patient is awake. In this study, motor stimulation was performed in 94.6% of the patients and in association with stimulation of the language area in 17.8% of them.

The motor stimulus evaluation can be performed under general anesthesia and in awake patients. The adopted anesthetic strategy did not affect surgical planning changes or the resection degree in the present study. Therefore, when the

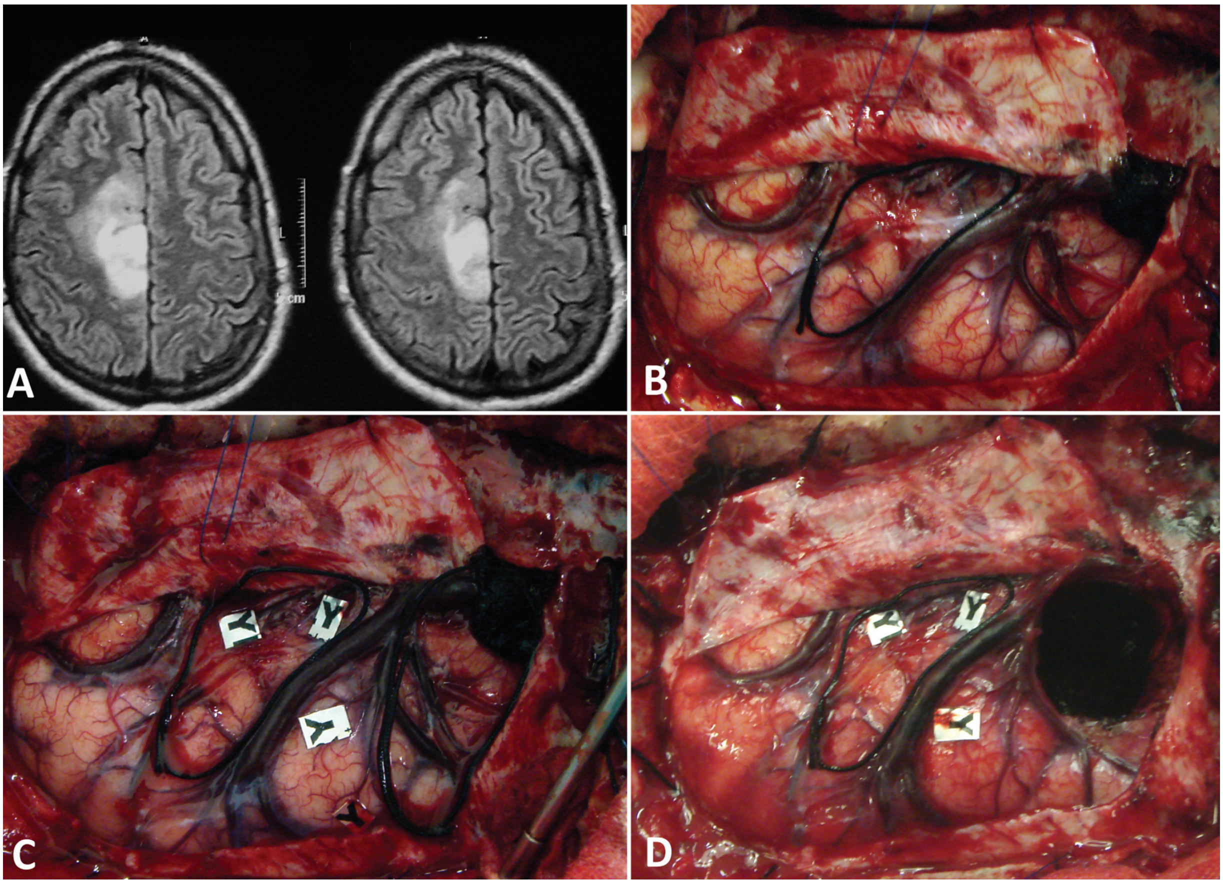

Fig. 3 (A) Preoperative Flair-sequenced MRI revealing an irregular, hyperintense right frontoparietal lesion. (B) Intraoperative photo: Exposure and planning of the resection before mapping. (C) Intraoperative photo: cortical mapping with functional areas detected inside the surgical planning site. (Y; motor stimulus areas). (D) Intraoperative photo: site of the corticectomy and lesion approach was moved anteriorly due to intraoperative cortical stimulation.

motor area is being evaluated alone, the plan with general anesthesia and airway protection should be prioritized, since it is safer and has a similar efficacy. However, mapping with the patient awake is fundamental in language evaluation, being the only strategy capable of evaluating this brain function. Language stimulation was performed in 23.2% of the patients, as its deficit (evaluated during intraoperative stage) can have different nuances. Both speaking and understanding language involve complex interface mechanisms and distinct association pathways, and specific neuropsychological tests are needed to detect each language deficit. Coordination between surgeon and neuropsychologist demands technical knowledge to identify semantic, phonological, phonetic, phonemic, and visual paraphasias, as well as to adapt the nature of the test applied to the patient intraoperatively with the surgical site and the more probabilistically resection-damaged path of association.[14]

A meta-analysis published by Hamer et al. showed that, in 75 publications, the rate of patients without permanent neurological deficit of any severity after resections of low-grade gliomas in eloquent areas was of 92.9% with the use of direct cortical stimulation.[12] The present study, although not exclusively composed of patients with gliomas, obtained a similar result (89.3%). In another study involving 8,091 adult patients with supratentorial infiltrative gliomas, the use of direct cortical stimulation mapping resulted in a 3.4% incidence of definite neurological deficits , and 8.2% without its use.[15] However, these analyzes did not managed to consider the number of patients who would be successful in surgery even without the utilization of the technique.

In the group of patients with a resection area unaltered by cortical stimulation (group 2), it is speculated that stimulation had no benefit in the direction of resection. For patients whose strategy was modified by stimulation findings (group 1), but presented deficits, it can be also considered the technique did not bring benefits. Thus, it is inferred that only those who did not have long-term deficits and whose stimulation findings altered the surgical strategy benefited. Therefore, to calculate the benefit rate, we divided the number of benefited patients (those who had changed strategy and no deficit) by the total of participants multiplied by 100. By this formula, there was a 30.4% overall benefit rate of the cortical stimulation technique. When gliomas alone were analyzed, this rate is reduced to 25.7%, whereas at the other etiologies subgroup the benefit rate was 38.1%. All calculations were made using the same formula.

According to the literature, cortical stimulation allows resection of more extensive areas in 74.9% of the cases.[12] However, when the results obtained in the present study are analyzed, among the group of patients who underwent a

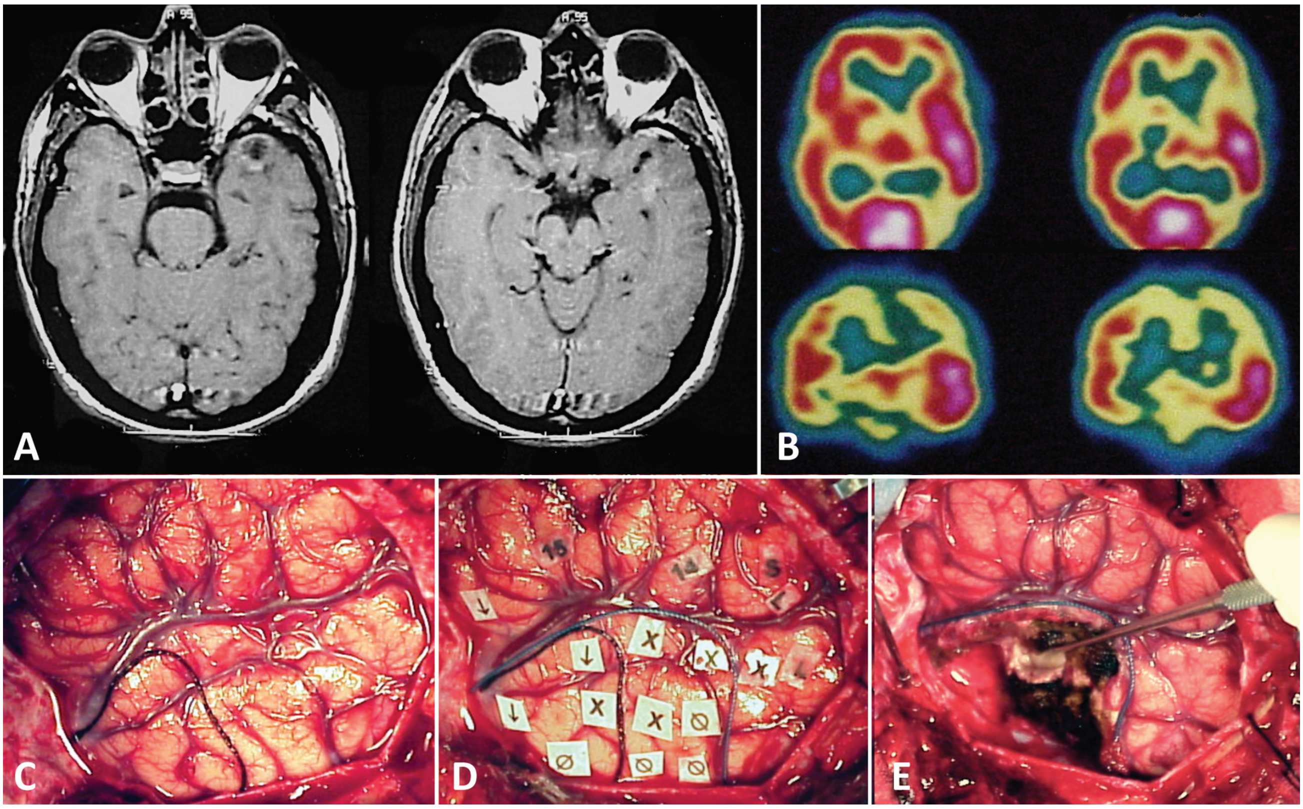

Fig. 4 (**A**) Preoperative, contrast-enhanced T1-weighted MRI reveals hypointense lesion in left temporal lobe pole of patient with refractory epilepsy. (**B**) Ictal aspect scan showing a bright area at the left temporal lobe. (**C**) Intraoperative photo: Exposure with delimitation of the area to be resected with silk thread. (**D**) Intraoperative photo: After electrocorticography registry was performed, discharges (X) were noted beyond the tumor site. Since the language areas (L) were more posterior, a 5 cm temporal cortex resection could be made from its pole. ↓: attenuation; Ø: normal electrographic tracing. (**E**) Intraoperative photo: final aspect, revealing an increase of the resected area compared with the initial planning. The patient became seizure free with no transitory or definitive deficit.

Table 3 Number of patients whose surgical strategy changed and type of alteration

Change	Number of cases (%)	Type of change	Number of cases (%)
No	36 (64.3%)		
Yes	20 (35.7%)	Minor resection	16 (80%)
		Major resection	1 (5%)
		Corticectomy site	3 (15%)

Table 4 Neurological deficits frequencies according to change on surgical strategy after cortical stimulation

Change (N)	Transitory deficit number (%)		Definitive deficit number (%)	
	Yes	No	Yes	No
No (36)	11 (30.6%)	25 (69.4%)	3 (8.3%)	33 (91.7%)
Yes (20)	13 (65.0%)	7 (35.0%)	3 (15.0%)	17 (85.0%)
Total (56)	24 (42.9%)	32 (57.1%)	6 (10.7%)	50 (89.3%)
p-value	0.013		0.643	

[a]Chi-square test.

Table 5 Comparison of deficits in relation to gliomas subgroups and other etiologies

Transitory deficit (N)	No (%)	Yes (%)	Value-p[a]
Gliomas (35)	15 (46.9)	20 (83.4)	0.005
Other etiologies (21)	17 (53.1)	4 (16.6)	
Definitive deficit (N)	**No (%)**	**Yes (%)**	**Value-p[a]**
Gliomas (35)	29 (58.0)	6 (100.0)	0.074
Other etiologies (21)	21 (42.0)	0 (0.0)	

[a]Fischer exact test.

surgical strategy change as a function of cortical stimulation (group 1), the results conflicted with those in the literature. These patients were subdivided into three other categories according to the nature of the alteration obtained through cortical stimulation: corticectomy change (15%), minor resection (80%), and major resection (5%). This evidence shows that cortical stimulation, when surgical procedure was changed, was not responsible for a larger than expected resection, but a smaller one. This data confronted the literature in countless works.[10–12,17]

The use of cortical stimulation usually assists in obtaining total or subtotal resections in 75% of patients using the technique, whereas this rate falls to 58% without its use.[12,18]

Table 6 Comparison of transitory and definitive deficits in relation to the studied pathology etiology, stratified by the change or not of the surgical strategy:

	Transitory deficit	Change in surgical strategy		p-value[a]
Gliomas		No (%)	Yes (%)	
	No	13 (56.5%)	2 (16.6%)	0.0238
	Yes	10 (43.5%)	10 (83.3%)	
Other etiologies	No	11 (84.6%)	6 (75.0%)	0.586
	Yes	2 (15.3%)	2 (25.0%)	
	Definitive deficit	Change in surgical strategy		p-value[a]
Gliomas		No (%)	Yes (%)	
	No	20 (87.5%)	9 (75.0%)	0.391
	Yes	3 (12.5%)	3 (25.0%)	
Other etiologies	No	13 (100.0%)	8 (100.0%)	1.000
	Yes	0 (0.0%)	0 (0.0%)	

[a]Fischer exact test.

Table 7 Comparison between the anesthetic technique and the presence of transitory or definitive deficits:

VARIABLES / ANESTHESIA		Awake	General	p-value[a]
		N (%)	N (%)	
Transitory deficit	No	13 (61.9%)	19 (54.3%)	0.604
	Yes	8 (38.1%)	16 (45.7%)	
Definitive deficit	No	19 (90.5%)	31 (88.6%)	0.801
	Yes	2 (9.5%)	4 (11.4%)	

[a]Chi-square test.

The most accepted theory that explains such findings is that functional areas of the brain diverge topographically as a function of individual variations in physiological-cortical organization and anatomical distortion caused by injury—as well as by neuroplasticity, which is especially present in slow-growing lesions such as low grade gliomas.[18,19] This phenomenon occurs through a functional reorganization of motor areas and language, or through a recruitment of latent neuronal circuits.[20]

In their series of cases, Southwell et al. observed neuroplasticity in 33.3% of patients, through stimulation of eloquent cortical points in repeated oncologic surgeries.[20] In a 2017 study, Sanai et al. reported that the change in positive cortical focus for function in repeated surgeries of low-grade gliomas, occurred in 40.9% of cases.[18] The detection of this change in functional area through direct cortical stimulation would allow the resection of areas infiltrated by neoplasia, but considered (by the classic studies) eloquent in “nondiseased” brains. Larger resections are facilitated by his technique, so that surgery would be interrupted only when positive cortical stimulation points are identified intraoperatively, instead of being based on anatomical knowledge alone.[13,19,21,22]

As this is a retrospective study, where events occurred in the past, there were difficulties related to data collection, most of which sums up to medical record errors and information losses in physical records. In an attempt to minimize these pitfalls, patients were called to the clinic and a new interview with neurological examination and image analysis was performed. At this point, the limitations of some patients were observed in thoroughly describe facts that had occurred at the time of diagnosis and the instituted surgical treatment (memory bias). Furthermore, the allocation of different etiologies with different oncological behaviors (such as metastases and gliomas) at a single group, as well as to generalize the results from the cortical stimulation benefit rate, was another considerable limitation. To exclude this bias, the groups were stratified according to the underlying disease etiology (gliomas and other etiologies), and the rate was calculated individually for the described subgroups.

Conclusions

The present study concludes that the real benefit rate of the intraoperative cortical stimulation technique for the mapping of eloquent areas in brain lesion surgeries was 30.4%.

Cortical stimulation influenced the surgical decision in 35.7% of the cases. For the most part, the change in strategy was for a smaller resection of the lesion. Although almost 90% of patients had no long-term deficits, it is believed that intraoperative cortical stimulation prevented it in one third of them. This number is sufficiently important to justify the adoption of this operative technique.

The anesthetic strategy had no influence on patients’ final evolution, since there was no significant difference in definitive deficit between awake patients or those submitted to general anesthesia.

Conflict of Interests
The authors have no conflict of interests to declare.

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