Intraoperative Monitoring with Cortical Estimulation: Gliomas Postoperative Clinical Evaluation in Motor and Supplementary Motor Area

Monitorização com Estimulação Cortical Intrao-peratória: Avaliação Clínica Pós-Cirúrgica de Tumores Gliais em Área Motora e Motora Suplementar

Henry Koiti Sato1
Maurício Coelho Neto2
Erasmo Barros da Silva Jr3
Luis Fernando Moura da Silva Junior2
Ricardo Ramina4

ABSTRACT

Introduction: Resection of gliomas in eloquent areas such as motor and supplementary motor areas has always been a main challenge for the surgeon due to the risk of severe neurological sequelae. An important tool used during the procedure to avoid postoperative neurological deficits is the intraoperative cortical stimulation of eloquent areas as a safe option of functional area mapping.

Methods: In this study, authors examined 50 patients with gliomas located in the motor and supplementary motor area that have undergone surgery with cortical stimulation, using clinical assessment of muscle strength in the pre- and immediate postoperative assessments and three months after surgery as parameters. Results: There was significant difference (p<0.001) between the preoperative and immediate postoperative assessments regarding the occurrence of severe neurological deficit, demonstrating a worsening of the neurological status after surgery. Concerning the comparison between the immediate postoperative period and the assessment performed three months after surgery, it was observed that all the patients who had severe deficit (11 cases) improved (p<0.001). No statistical difference was found between the malignancy grade and the evolution of the neurological deficit in the assessments performed in the three evaluated periods. Conclusion: In the immediate postoperative period following surgical resection of glial tumors in the motor and supplementary motor areas with intraoperative cortical monitoring, most patients have significant alterations in their muscle strength. However, three months after surgery there was significant improvement of these neurological deficits and no patient had severe sequelae.

Key words: Glioma; Cortical stimulation; Intraoperative monitoring

RESUMO

Introdução: A ressecção de gliomas em áreas eloquentes como as áreas motora e a motora suplementar sempre foi um dos principais desafios para o cirurgião, devido ao risco de sequelas neurológicas graves. Durante o procedimento, uma importante ferramenta utilizada para evitar déficits pós-operatórios é a estimulação cortical intraoperatorária de áreas eloquentes como uma opção segura de mapeamento de área funcional. Métodos: Neste estudo, os autores examinaram 50 pacientes, com gliomas localizados nas áreas motora e motora suplementar que foram submetidos à cirurgia sob estimulação cortical, através de avaliação clínica de força muscular nos períodos pré-operatório e pós-operatório imediato e três meses após a cirurgia como parâmetro. Resultados: Houve diferença significativa (p < 0,001) entre as avaliações pré-operatória e pós-operatória imediata com relação à ocorrência de déficit neurológico severo, demonstrando uma piora da condição neurológica após a cirurgia. Sobre a comparação entre o período pós-operatório imediato e a avaliação realizada três meses após a cirurgia, observamos que todos os pacientes que apresentavam déficit severo (11 casos) melhoraram (p < 0,001). Nenhuma diferença estatística foi encontrada entre o grau de malignidade e a evolução do déficit neurológico nos levantamentos realizados nos três períodos avaliados. Conclusão: No período pós-operatório imediato, seguinte à ressecção cirúrgica, de tumores gliais nas áreas motora e motora suplementar com monitorização intraoperatorária cortical, a maioria dos pacientes apresentou alterações significativas em sua força muscular. No entanto, três meses após a cirurgia houve melhora significativa destes déficits neurológicos e nenhum paciente teve sequelas graves.

Palavras-chave: Glioma; Estimulação cortical; Monitorização intraoperatorária

1MD, MSc, Neurologista, Instituto de Neurologia de Curitiba, Serviço de Neurologia, Curitiba, Paraná, Brazil
2MD, Neurocirurgião, Instituto de Neurologia de Curitiba, Serviço de Neurocirurgia, Curitiba, Paraná, Brazil
3MD, PhD, Neurocirurgião, Instituto de Neurologia de Curitiba, Serviço de Neurocirurgia, Curitiba, Paraná, Brazil
4MD, PhD, Neurocirurgião, Instituto de Neurologia de Curitiba, Chefe do Serviço de Neurocirurgia, Curitiba, Paraná, Brazil

Received Aug 2, 2016. Accepted Mar 8, 2017.
Introduction

Resection of gliomas in eloquent areas such as the motor and supplementary motor area has always been a main challenge for the surgeon due to the risk of severe neurological sequelae\textsuperscript{1,2}. Despite the surgical risk, the complete removal of the tumor is an important factor in the prognosis of most brain tumors\textsuperscript{3,4}. In high and low grade gliomas, the presence of tumor residue identified in postoperative magnetic resonance imaging (MRI) is an important prognostic factor for recurrence and malignancy\textsuperscript{5}.

Imaging diagnosis with computerized tomography scan\textsuperscript{6,7} and MRI\textsuperscript{8} allows the location of brain tumors, and with tractography and functional MRI enables to provide a better surgical planning and risk assessment of motor neurological sequelae. However, in case of tumor growth, the motor area becomes distorted, and the conventional anatomy is modified, preventing a reliable assessment\textsuperscript{9}. Moreover, the precise location of the neurological function may vary considerably among normal individuals\textsuperscript{5,10}.

Intraoperative cortical stimulation of eloquent areas has been described in the literature as a safe option of functional mapping in surgeries that involve risk to important brain areas\textsuperscript{11,12}. It has the advantage of being performed during the surgery facilitating the identification of important functional areas, with or without the presence of tumor\textsuperscript{13}.

Despite the fact that the intraoperative cortical stimulation is considered the golden standard for functional monitoring\textsuperscript{14}, some patients may present postoperative neurological sequelae\textsuperscript{15}.

Therefore, so far, there is not a totally safe method for tumors resection in eloquent areas. Consequently, further studies are needed to investigate new techniques of brain mapping associated to brain tumors, in order to obtain total resection of tumor without causing severe neurological sequelae.

In the present study, we have examined patients with gliomas located in the motor and supplementary motor area that have undergone surgery, with the assistance of cortical stimulation, through clinical assessment of muscle strength in the preoperative and immediate postoperative assessments and three months after surgery as parameters.

Methods

Fifty patients with glial tumors in the motor and supplementary motor area without alteration of muscular strength or mild dysfunction were examined. The data collected were obtained from April 2009 to February 2016. The patients had an average age of 44.5 years with male predominance (68%). The most frequent histological type was astrocytoma grade II (40%), followed by glioblastoma (36%) and anaplastic oligodendroglioma (12%). When the tumors were grouped by their malignancy grade, it was found that there was homogeneity between the high-grade tumors (52%) and the low-grade tumors (48%). Most tumors were located in the left supplementary motor area (64%).

The presence of intracranial glioma in the motor or supplementary motor area in patients over the age of 18 years was the inclusion criteria for this study. Patients with any of the following alterations: cerebral ischemia, radiation damage, central nervous system infection, non-glial tumor, and traumatic brain injury were excluded from this study.

Preoperative Evaluation

The patient was admitted to the hospital on the day before the surgery for preoperative tests, and for neurological and anesthesia evaluation.

The neurological examination consisted in an evaluation of muscle strength according to the scale of the Medical Research Council\textsuperscript{16}. After muscle strength assessment, the data obtained were classified into\textsuperscript{17}:

- No deficit: when the predominant muscle strength in the limb was equal to V.
- Mild deficit: when the predominant muscle strength in the limb was equal to IV.
- Moderate deficit: when the predominant muscle strength in the limb was equal to III.
- Severe deficit: when the predominant muscle strength in the limb was equal to III, II, I and zero.

The lower grading value of muscle strength in any limb was used as a reference for the classification of the deficits. Afterwards, the patient was subjected to brain MRI.
All patients underwent 1.5 tesla MRI at sequences of high resolution for the topography of the motor and supplementary motor area. The images were obtained in the coronal, axial and sagittal planes, according to the following order: T1-weighted spin-echo, fluid acquisition inversion recovery (FLAIR), T2-weighted fast spin-echo, T2-weighted gradient-echo (T2*), diffusion and 3D volume with gadolinium. Diffusion tensor tractography was performed to show the relationship between tumor and neighboring white matter tracts. Also, patients with tumor near Broca or Wernicke area underwent functional MRI to allow individual localization of speech-eloquent regions.

**INTRAOPERATIVE TECHNIQUE**

Microscopic surgery under general anesthesia for the removal of the injury was performed in all patients. Neuronavigation with T1-weighted post-gadolinium (in high-grade gliomas) and T2/FLAIR (in low-grade gliomas) sequences were used for intracranial orientation and tumor location.

After anatomical identification of motor cortex and tumor borders, the intraoperative mapping of the eloquent area was performed according to the techniques described in the literature. The distance between the electrodes was 3 mm with a constant biphasic square-wave current in the predetermined frequency of 60 Hz. The initial current was 3 mA with increments of 0.1 mA and the final current was up to 10 mA; increments were performed according to the motor response required until the predetermined limit. The initial pulse was 1.2 ms with an activation time of the pulse of 5 seconds.

Before stimulating the cortex, the electrode was used to depolarize the adjacent muscle in order to assure that the patients were not paralyzed with these drugs. The location of the primary motor area was performed based on the central sulcus. The electrode was positioned in contact with the cortex parallel to the assessed rotation, and resection was performed at 0.5 cm of the primary motor cortex. The stimulated areas were marked with sterile filter papers that corresponded to the movements obtained with the mapping. In case of deviation of the structures caused by the tumor, the preoperative MRI image of the non-affected brain hemisphere was used as reference of stimulation marks.

Initial resection of the tumor borders was performed in small tumors. For large tumors, there was a debulking followed by lesion resection. The removal of the affected brain cortex was performed avoiding all the positive sites identified in brain monitoring. The resection considered the anatomical limits defined in the preoperative image studies. The main goal was to attempt a complete resection of T1-enhanced area (high-grade gliomas) or T2/FLAIR abnormalities (low-grade gliomas). The same team of neurosurgeons performed the tumor resection of all cases. The craniocaudal extent of the tumor was never exceeded, and at the end a white substance with normal characteristics was visible. Serial biopsies on the surgical cavity borders were obtained after resection. In case of residual tumor that did not infiltrate into the motor area, the resection was expanded.

In cases of seizure during the surgery, irrigation with cooled lactated Ringer’s solution was the treatment of choice.

**POSTOPERATIVE ASSESSMENT**

The patients with high-grade gliomas confirmed by histology were subjected to chemotherapy with temozolamide and radiotherapy in the postoperative period.

In the immediate postoperative assessment and three months after surgery was performed the clinical evaluation of the motor function. Neurological examination was always performed by the same neurologist.

Comparisons of the neurological deficit according to the four categories (no deficit, mild deficit, moderate deficit and severe deficit) were made between the preoperative assessment, immediate postoperative assessment and three months after surgery. Then, the patients with severe deficit and the other categories together were compared.

On the first postoperative day a brain MRI was performed in all patients for detection of possible complications and residual tumor. New images were requested three and six months after surgery.

Total resection was obtained in all the patients in the immediate postoperative assessment according to the pre-established grading4,18:
The results of the quantitative variables were expressed by mean, medians, minimum values, maximum values and standard deviations, and the results of the qualitative variables were expressed by frequencies and percentages. Binomial test was used to assess the effect of the surgery using intraoperative cortical monitoring on the assessment of the neurological deficit. The comparison between high and low-grade tumors in relation to the neurological deficit was performed using Fisher exact test. Values $p<0.05$ were considered as statistical significance.

**RESULTS**

The neurological assessments were performed in the preoperative period, in the immediate postoperative period and three months after surgery according to the pre-established classifications of neurological deficit (Figure 2). It was found that in the preoperative period most patients had no neurological deficits, and in the immediate postoperative assessment 44% of the patients had important deterioration in their clinical status. However, at the end of the third month after surgery, there was no case of severe neurological deficit.

In the present study, from the 50 examined cases, 18 (36%) did not show neurological deficit in the preoperative assessment, which persisted in the two postoperative assessments. Two patients (4%) had mild deficit in the preoperative assessment and no deficit three months after surgery. One
patient had mild deficit and another one had no deficit in the immediate postoperative assessment.

Twenty-nine (58%) had become worse after surgery when assessed in the immediate postoperative period. In the assessment performed three months after surgery, among the patients with aggravation of their neurological condition, 11 patients (22%) were found to have regained their initial (preoperative) neurological status, 10 patients (20%) had a decrease of one point in the level of their neurological status and 3 patients (6%) had a decrease of two points in the level of their neurological status compared to the preoperative assessment.

**CLINICAL ASSESSMENT IN TWO SUBGROUPS**

Table 2 presents the frequencies of the cases according to the preoperative and immediate postoperative assessments. Immediate postoperative and three months after surgery (Table 3) and preoperative and three months after surgery (Table 4) are shown according to the deficit classifications: no deficit / mild deficit / moderate deficit (no deficit/mild/moderate) and severe deficit.

The null hypothesis was tested whether the percentage of cases with severe deficit in the preoperative assessment was equal to the percentage of cases with severe deficit in the immediate postoperative assessment or the assessments ended in different percentages. Also, comparisons between the group assessed in the immediate postoperative period and the group assessed three months after surgery were done.

In Table 2 can be observed that from all patients enrolled in this study, 18 patients were classified as having severe deficit in the immediate postoperative assessment. The result of the test indicated rejection of the null hypothesis ($p<0.001$). Therefore, there is a significant difference between the preoperative and immediate postoperative assessments regarding the occurrence of severe neurological deficit, demonstrating a worsening of the neurological status after surgery.

Concerning the comparison between immediate postoperative period and the assessment performed three months after surgery, it is observed that all the patients who had severe deficit (18 cases) improved and were classified in the grouped deficit category. The result of the test indicated the rejection of the null hypothesis ($p<0.001$) confirming the existence of a significant difference between the assessments in the immediate postoperative period and three months after surgery regarding the occurrence of severe neurological deficit.

### Table 2. Comparison of the neurological deficit grouped in the preoperative and immediate postoperative assessment.

<table>
<thead>
<tr>
<th>Preoperative assessment</th>
<th>Immediate postoperative assessment</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No deficit / mild / moderate</td>
<td>32 mild / 18 moderate / 0 severe deficit</td>
<td>50</td>
</tr>
<tr>
<td>Severe deficit</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>50</td>
</tr>
</tbody>
</table>

### Table 3. Comparison of neurological deficit grouped in immediate postoperative assessment vs. three months after surgery.

<table>
<thead>
<tr>
<th>Assessment carried out three months after surgery</th>
<th>No deficit / mild / moderate</th>
<th>Severe deficit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No deficit / mild / moderate</td>
<td>32</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>Severe deficit</td>
<td>18</td>
<td>0</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>0</td>
<td>50</td>
</tr>
</tbody>
</table>

### Table 4. Comparison of grouped neurological deficit in the assessments performed in the preoperative period and three months after surgery.

<table>
<thead>
<tr>
<th>Preoperative assessment</th>
<th>Assessment carried out three months after surgery</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No deficit / mild / moderate</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Severe deficit</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>0</td>
</tr>
</tbody>
</table>
All 50 patients who participated in this study were classified as having no deficit/mild/moderate in the preoperative assessment and showed the same status in the assessment performed three months after surgery (Table 4). Thus, no difference was found between the preoperative assessment and the one performed three months after surgery.

EVALUATION OF THE ASSOCIATION BETWEEN THE MALIGNANCY GRADE AND NEUROLOGICAL DEFICIT

For each assessment period, the null hypothesis of the probability of severe deficit is equal for high and low grade tumors compared to the alternative of different probabilities according to the histological type.

Table 5. Number of cases and percentage of neurological deficit grouped in the preoperative assessment of low and high-grade tumors.

<table>
<thead>
<tr>
<th>Preoperative assessment</th>
<th>Tumor grade</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>No deficit / mild / moderate</td>
<td>24</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>Severe deficit</td>
<td>100%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

*p value: --- (Test not applicable. However, it was found no difference between the groups concerning the percentage values).

Table 6. Number of cases and percentage of neurological deficit grouped in the immediate postoperative assessment in high and low-grade tumors.

<table>
<thead>
<tr>
<th>Immediate postoperative assessment</th>
<th>Tumor grade</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>No deficit / mild / moderate</td>
<td>14</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Severe deficit</td>
<td>58.33%</td>
<td>53.85%</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>24</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

*p value = 1

Table 7. Number of cases and percentage of neurological deficit grouped three months after surgery in high and low-grade tumors.

<table>
<thead>
<tr>
<th>Assessment three months after surgery</th>
<th>Tumor grade</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>No deficit / mild / moderate</td>
<td>24</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>Severe deficit</td>
<td>100%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

*p value: --- (Test not applicable. However, no difference between the groups concerning the percentage values was found).

In Tables 5, 6 and 7 the frequencies and percentage values of the cases, for each type of tumor, are presented according to the deficit classifications grouped in relation to the following periods: preoperative, immediate postoperative and three months after surgery, respectively.

No statistical difference between the malignancy grade and the evolution of the neurological deficit in the assessments performed in the preoperative period, in the immediate postoperative period and three months after surgery was found. Thus, it is demonstrated that the histological type does not correlate with a greater risk of neurological sequelae.

Discussion

Profile of Patients

In the United States, the ages of patients with low and high-grade gliomas ranged from 30 to 40 years and 45 to 75 years, respectively, and both tumors are more common in men. In the present study, 68% of the patients were men and the mean age of patients with low and high-grade tumors was 40 and 55.7 years, confirming the high incidence of benign tumors in young individuals. Only two patients, aged less than 40 years, were found to have high-grade glioma.

Several studies demonstrate that seizure is one of the most common neurological manifestations in patients with brain tumor. The findings of the present study have shown that 64% of the patients had seizure at the time of the diagnosis and 42% had symptoms related to the alteration in neurological examination (paresis, paresthesia and apraxia), corroborating the description found in literature. These findings can be...
explained by the compression and infiltration of the tumor at the motor and sensitive cortex.

**Evaluation of the Glioma**

Glioblastoma is the histological type most frequently found in glial tumors, accounting for 54% of the cases. Histological evaluation showed that most patients had astrocytoma grade II (40%). The authors believe that the reduced incidence of malignant lesion was due to the location of the tumor and its early diagnosis.

The gliomas, mostly the low-grade tumors, are located in eloquent brain areas, particularly the supplementary and insular regions. Duffau and Capelle postulated that cytoarchitectural, neurochemical and metabolic alterations in these areas cause the major incidence of these tumors in the region. The most common site of incidence of gliomas was the left premotor area, with 64% of the cases.

**Evaluation of the Brain Monitoring**

According to Kim et al., the negative response in the mapping of eloquent areas provides a safety margin for surgical resection of brain tumors and reduce the incidence of neurological deficits in the postoperative period and one month after surgery. The authors reported that there was no risk of sequelae, because the resection site was probably located far from important functional areas. Danks et al. studied 122 patients, and only 4% of them had severe neurological deficit.

Evaluation of the response during surgery showed a positive response (location of the motor area) in 72% of the study patients. No comparisons were made between the postoperative neurological deficit and the positive response in the location of the motor area. Nevertheless, no patient had severe neurological deficit in the postoperative assessment, and 24% evolved to moderate deficit. Despite the controversy, the authors believe that there were no serious complications, because the surgeon observed the preoperative marking and the response obtained in the monitoring. Besides, Kim et al. reported cases of language monitoring.

**Evolution of Neurological Deficit**

The correct surgical planning for radical resection of gliomas allows a better quality of life and increases patient survival. However, there is a potentially high risk of permanent sequelae, particularly when the tumor is located within eloquent brain regions. Such risk is the main allegation against surgery with wide resection of gliomas associated to important functional regions.

Nevertheless, many studies describe postoperative safety of radical surgery in tumors in the motor and language brain areas. According to several authors, intraoperative cortical monitoring can identify the limits of the tumor and the function of the eloquent structures, leading to significant reduction in postoperative neurological deficits.

Danks et al., in their study with patients with tumors adjacent to eloquent areas, found that 31% of the patients had severe neurological deficit in the immediate postoperative period, but in most cases the patients recovered within one month, and only in 4% of the cases, this deficit persisted. According to these authors, the persistence of neurological deficits can be explained by brain edema without resolution.

In order to attempt to demonstrate the efficiency of brain stimulation, Duffau et al. performed a retrospective study comparing the surgical procedure performed with and without intraoperative monitoring (IOM) by the same surgical team. In the group that had no monitoring, 17% of the patients had severe permanent deficit three months after surgery, and in 52% of the cases partial resection was performed. As for the group under monitoring, 6.5% of the patients persisted with severe deficit and the index of partial resection was 20.6%.

Kim et al. performed a retrospective study of 309 patients with brain tumor in eloquent areas using IOM. In the immediate postoperative period the authors found that 111 patients had a worsening of their neurological deficit, but 57% of the patients regained their preoperative neurological status.

Abel et al. demonstrated recurrent supplementary motor area (SMA) syndrome occurring in patients undergoing repeat resection of tumors involving the SMA.

In the present study, the patients had a significant worsening in the immediate postoperative period, with 36% of them presenting severe deficit. However, three months after surgery most patients recovered from the initial sequelae and there
was no case of severe deficit. In the comparison to evaluate the occurrence of severe deficit, the IOM demonstrated that the patients had a satisfactory evolution, since there was no significant difference between the preoperative group and late postoperative group (three months). Six patients in this study improved their neurological status and had no neurological symptom three months after surgery. Eight patients persisted with moderate deficit, and a Karnofsky index above 80. At the end of three months, all patients resumed their usual social and laboral activities, without restriction to their quality of life.

There are many theories on the neurological recovery of patients who have undergone surgery on the central lobule. For Peraud et al.17 neurological recovery can be related to the location of the low-grade gliomas in the SMA. After the removal of the tumor in the SMA, in the immediate postoperative period the patient evolves to paresis, decreased reflexes and akinesia of the affected limb. There is significant recovery in a variable postoperative period. The postoperative evolution is known as the syndrome of the supplementary area. Of a total 24 reported cases, 20 patients had severe neurological deficit in the immediate postoperative period. However, within a week there was an improvement in the muscle strength of 14 of these patients. For high-grade tumors, the evolution seems also favorable, according to Russell and Kelly31.

Recent research seems to indicate that the SMA has a somatotopy that is found in the primary motor cortex32-35. In their study, Fontaine et al.36 describe motor and language alterations according to the degree of resection of the supplementary motor area. Eleven patients with tumor in the supplementary motor area, as well as their postoperative evolution, were evaluated. When the authors removed the most anterior portion of the left SMA, the patient had genuine motor aphasia. When the resection extended posteriorly, aphasia was associated to the involvement of the upper limb, and in case of complete resection of the SMA, the patient had aphasia and hemiparesis. In the present study, all the patients have completely recovered from their preoperative neurological deficits. It was found that in 84% of the patients the tumor was located in the SMA and no patient had severe neurological deficit three months after surgery.

For Duffau et al.37 other factors can also be related to the postoperative neurological improvement of patients. According to the authors, the inexistence of preoperative deficit, despite the tumor growth in eloquent regions, can be explained by a compensation of other areas around the tumor. Thus, even after the removal of an eloquent area, there is postoperative compensation of the regions adjacent to the lesionectomy. Another hypothesis for the recovery is that the surgery itself may induce compensation by increasing the hyperexcitability of injured neurons. The hyperexcitability would be generated by alterations in the GABAergic receptors and NMDA, as previously described in other types of brain lesion38,39. These recovery phenomena are related to the theory of neuroplasticity.

Brain edema is considered an important factor in the postoperative evolution of neurological deficits. There are reports of improvement of the muscle strength following the resection of tumors in an eloquent area40. In the present study, three cases of edema in the immediate postoperative period were identified by MRI. During the follow-up of these patients, clinical improvement was accompanied by radiological improvement of the edema, and after three months, the patients had no neurological deficits. In the other cases no edema was detected by MRI. The authors believe that local manipulation may cause metabolic alterations, which could lead to edemas not always visible on an MRI scan.

**Conclusion**

Analysis of the results allows concluding that in the immediate postoperative period following surgical resection of glial tumors in the motor and supplementary motor area with intraoperative cortical monitoring, most patients have significant alterations in their muscle strength. However, after three months of surgery there was significant improvement of these neurological deficits and no patient had severe sequelae.

**References**


**CORRESPONDING AUTHOR**

*Henry Koiti Sato*
**MD, MSc, Neurologist**

**Neurologist**

**Instituto de Neurologia de Curitiba (INC)**

**Rua Jeremias Maciel Perretto, 300**

**Curitiba - PR**

satoHenry@gmail.com