CORTICAL STIMULATION OF LANGUAGE FIELDS UNDER LOCAL ANESTHESIA

Optimizing removal of brain lesions adjacent to speech areas

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Abstract – Objective: The main objective when resecting benign brain lesions is to minimize risk of postoperative neurological deficits. We have assessed the safety and effectiveness of craniotomy under local anesthesia and monitored conscious sedation for the resection of lesions involving eloquent language cortex. **Method:** A retrospective review was performed on a consecutive series of 12 patients who underwent craniotomy under local anesthesia between 2001 and 2004. All patients had lesions close to the speech cortex. All resection was verified by post-operative imaging. Six subjects were male and 6 female, and were aged between 14 and 52 years. **Results:** Lesions comprised 7 tumour lesions, 3 cavernomas and 1 dermoid cyst. Radiological gross total resection was achieved in 66% of patients while remaining cases had greater than 80% resection. Only one patient had a post-operative permanent deficit, whilst another had a transient post-operative deficit. All patients with uncontrollable epilepsy had good outcomes after surgery. None of our cases subsequently needed to be put under general anesthesia. **Conclusion:** Awake craniotomy with brain mapping is a safe technique and the "gold standard" for resection of lesions involving language areas.

KEY WORDS: cortical mapping, awake craniotomy, tumor, speech area.

Mapeamento cortical da fala com o paciente acordado: optimização para ressecção de lesões intracranianas localizadas próximas à área da fala

Resumo – Objetivo: O presente estudo visa discutir as vantagens e as limitacões do uso da técnica de mapeamento cortical da área da fala com o paciente acordado. **Método:** Esta é uma revisão retrospectiva dos casos em que foi realizado monitoramento cortical intraoperatório em cirurgias para ressecção de lesões intracranianas localizadas próximas à área da fala. Todos os pacientes foram submetidos a avaliação neuropsicológica no pré e intra-operatório. O grau das ressecções foi verificado através de exames de imagem pós-operatórios. Foram avaliados um total de 12 pacientes. Destes, 6 eram do sexo masculino e 6 do feminino. **Resultados:** 7 lesões eram tumorais. A ressecção total foi atingida em 66% e ressecção subtotal nos remanescentes. Apenas 1 paciente apresentou déficit motor permanente no pós-operatório e todos os pacientes com quadro prévio de epilepsia refratária obtiveram bom controle das crises no pós-operatório. Em nenhum caso houve necessidade de conversão da anestesia para geral. **Conclusão:** O mapeamento funcional intraoperatório na craniotomia com o paciente acordado otimiza a extensão da ressecção da lesão minimizando morbidade permanente. Esta é uma técnica eficaz no manejo de lesões em íntimo contato com o córtex eloqüente, que outrora, seriam designadas inoperáveis.

PALAVRAS-CHAVE: mapeamento cortical, craniotomia acordado, tumor, área da fala

Cortical locations corresponding to neurological functions can vary significantly among individuals and some brain lesions are able to distort the anatomy, hindering the localization of certain key intra-operative points. Determining the exact functional area is essential for safe and effective resection[1,2].

As the extent of tumor lesion resection is directly related to outcome, the surgeon should attempt to maximize the extent of removal without compromising the patient's quality of life.

In this study, we aimed to evaluate the safety of intraoperative cortical stimulation in the awake patient, to

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analyze how the application of this technique allows total resections, and to determine to what extent cortical mapping can prevent postoperative deficits.

METHOD

Twelve patients, with brain lesions in close proximity to language-specific cortex, operated from 2001 to 2004, were studied. Of these, 6 were female and 6 male. Age varied from 14 to 52 years (mean 35.4 y). The patients were submitted to a protocol where age, clinical symptomatology, the Karnofsky scale (KPS) and radiological findings through computed tomography (CT) and magnetic resonance (MRI) were analyzed.

A neuropsychological evaluation composed by the Boston Diagnostic Aphasia Examination-III was conducted at bedside to identify patient characteristics in order to optimize subsequent language testing in the operating room.

All were submitted to a left craniotomy under sedation and local anesthesia without muscular relaxation. A three-pin head holder was placed after head block using 0.5% lidocaine, 0.25% bupivacaine with epinephrine (1:200,000) and saline (Fig 1). Surgical incision and skin flap base were anesthetized with the same solution. In half of the surgeries, sedation was achieved using midazolam, fentanil and propofol. The main anesthetic for sedation in six procedures was dexmedetomidine at a loading dose of 3 mg/Kg/h over 20 minutes, maintained with 0.5 mg/Kg/h (Almeida et al.). The anesthesist and the prinicpal surgeon were the same in all surgeries (S.I. and A.N.A., restrospectively).

Cortical stimulation was carried out to identify the eloquent areas. Intraoperative stimulation was carried out using a monopolar probe (Grass Stimulator) in 11 patients (Figs 2 and 3), while in one patient a bipolar probe was applied (Micromar). The current for stimulation varied from 3–13 mA, with single pulse of 1 millisecond and frequency of 60 Hz.The safety limit adopted in this study was the adjacent pia mater of the functional cortex with preservation of the intersulcal vessels. The resection type was graded into total, subtotal (>80%), partial (< 80%) and biopsy, according to postoperative radiological findings (contrasted CT scan and MRI). The surgeries were accomplished in an oncologic view when applicable, in a bid to achieve both maximum lesion removal and treating the epileptic condition, present in the vast majority of patients.

After surgical procedures, all patients were submitted to a CT scan within 6 hours. An MRI was performed after 3 to 9 months to evaluate the resection extent compared to previous exams.

Fig 1. Positioning. (A) The surgeon view. See the head fixed by three-pin head holder and the skin exposion. (B) The anesthesiologist view: free airway. Note that is important to expose the face to motor and neupsychological assessment and the contralateral hand.

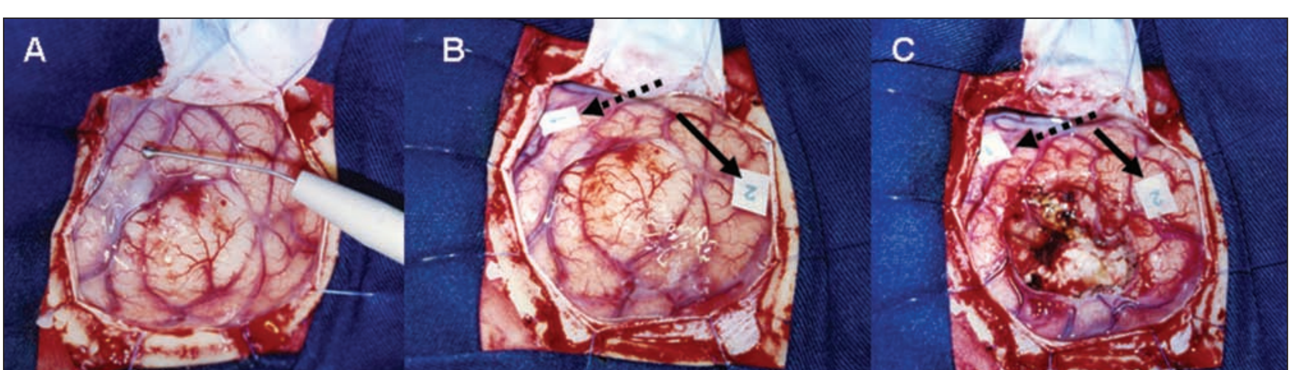

Fig 2. (A) Intraoperative cortical stimulation with electrode monopolar; (B) identification of 2 speech areas in posterior temporal lobe (black dotted narrow and black narrow) and (C) satisfactory exeresis of the lesion preserving the functional cortex.

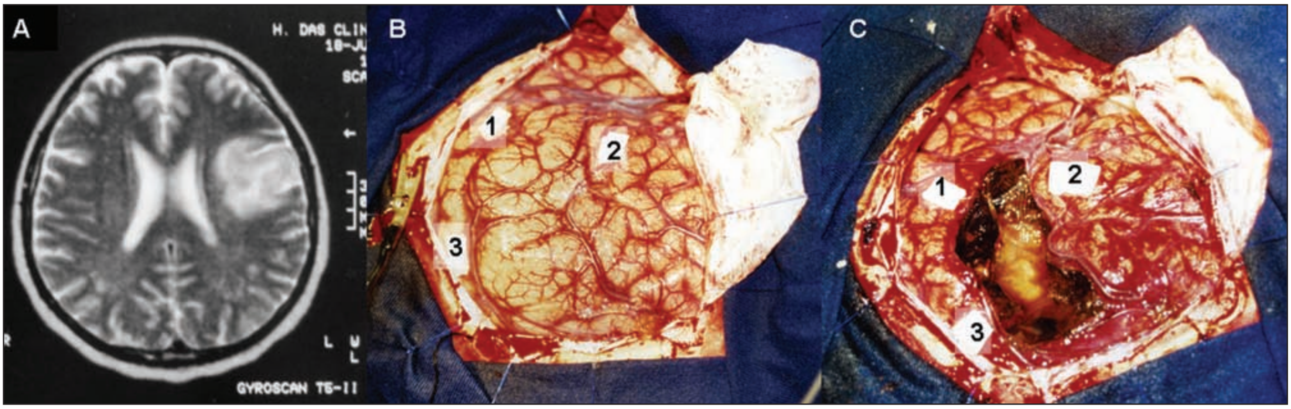

Fig 3. (A) Patient with close tumoral lesion to the motor and speech area evidenced by MRI (B) Intraoperative field showing the lesion adjacent to the eloquent cortex with probably infiltration. Cortical stimulation revealed two speech areas (1 and 2) and the motor gyrus (3). (C) After resection the tumor. At the end of surgery the patient had motor aphasia and there was no sign of movements in contralateral hand. He did not recover the deficits.

Table. Patients characteristics included in the study.

	Sex	Age (y)	Symptoms of presentation	KPS	Lesion	Localization	Resection	Postoperative deficit	Recover	Neurological compl.	Local compl.	Systemic compl.
1	M	50	Refractory crisis	100	Oligodendroglioma	Frontal	Subtotal	Motor aphasia + hemyplegia	No	Permanent deficit	Wound infection	No
2	F	38	GTC crisis	100	Oligodendroglioma	Medium frontal gyrus	Total	SMA	Yes	Transitory deficit	No	No
3	M	21	Refractory crisis	nda	Gliosis	Frontal-opercular	Total	No	Yes	No	No	No
4	M	36	Refracory tonic crisis	100	DNET	Frontal-opercular	Total	No	Yes	No	No	No
5	F	36	Refractory CPC	100	Xantoastrocytoma	Posterior temporal lobe	Total	No	Yes	No	No	No
6	M	40	Refractory GTC	nda	Dermoid cyst	Frontal-opercular	Total	No	Yes	No	No	No
7	F	14	Refractory CPC	100	Ganglioglioma	Medium temporal gyrus	Subtotal	No	Yes	No	No	No
8	M	28	Headache + GTC crisis	nda	Cavernous angioma	Supramarginal gyrus	Total	No	Yes	No	No	No
9	F	45	Comprehension aphasia + SPC	nda	Cavernous angioma	Angular gyrus	Total	No	Yes	No	No	No
10	M	35	GTC crisis	nda	Cavernous angioma	Frontal-opercular	Total	No	Yes	No	No	No
11	F	30	GTC crisis	100	Oligodendroglioma	Frontal	Subtotal	No	Yes	No	No	No
12	F	52	GTC crisis	100	MGB	Frontal	Subtotal	No	Yes	No	No	No

GTC, generalized tonic-clonic; SPC, simple partial crisis; CPC, complex partial crisis; KPB, Karnofsky Scale; nda, do not apply; DNET, disembryoblastic neuroepithelial tumor; MGB, multiform glioblastoma; AMS, supplementary motor area syndrome.

The postoperative complications were classified into neurological, regional or systemic and median follow up was 6 months.

RESULTS

All the patients presented with seizures. Half of these presented with refractory seizures non-responsive to clinical treatment. Just one patient presented speech disturbance in the preoperative neurologic exam (fluent aphasia). No patients had motor deficits in the preoperative clinical evaluation. Headache was the initial symptom in one patient, who presented a cavernous angioma with signs of bleeding. All patients harboring tumorous lesions had Karnofsky scale (KPS) 100.

Most lesions were located in the inferior left frontal lobe (8), followed by the left posterior temporal lobe (2) and inferior parietal lobe (2). We identified the language areas in 11 patients. Patient 1 exhibited 2 areas where stimulation provoked aphasia (Fig 3). We were unable to locate the speech area in patient 5.

Of the identified lesions, 7 were tumorous, 6 of which were low grade tumors. The five benign lesions were cavernous angiomas (3), dermoid cyst (1), and gliosis (1) in a patient who underwent craniotomy due to brain contusion and was admitted with refractory epilepsy.

Concerning grade of resection, 8 patients (66%) had total gross resection whereas 4 patients underwent subtotal resection. In patient 2 the number of speech disturbances decreased postoperatively.

Two out of the six patients submitted to conscious sedation using dexmetadomidine presented focal seizures during surgery. Patient 1 had two focal and one generalized seizure. All of the episodes were transitory and ceased upon application of cold crystaloids (NaCl 0.9%) to the cerebral cortex. Patient 1 presented three seizures during the procedure, one before dural opening and two during cortical stimulation. The other patients had seizures during cortical stimulation.

Six patients (50%) underwent sedation with dexmetomidine (patients 1,2,6,8,9,10) as this was deemed by the anesthesiologist and patients to be the most comfortable anesthetic. However, no fits occurred under the other anesthetic scheme.

One patient, harboring an oligodendroglioma, had a postoperative transitory motor deficit that receded by the second postoperative month, while only 1 patient developed permanent deficit characterized by hemiplegia and expression aphasia. The same patient presented with meningitis due to cerebrospinal fluid leakage and deceased 4 months later. Control of epilepsy was achieved in all patients with refractory episodes through the surgical procedure. Subsequent reduction of anti-epileptic drugs resulted and 1 patient had total withdrawal of drugs after 6 months (Table).

DISCUSSION

In mapping studies performed by Ojemann et al. on 117 patients[2], 67% had more than one distinct essential language area and 24% had three or more distinct areas subserving the language function in the dominant hemisphere peri-Sylvian region. Thus, in lesions that invade the language centers the surgical procedure to achieve total gross resection becomes progressively more difficult. The gold standard for identifying cortical function remains the direct cortical stimulation at surgery time in the awake patient[3,4], despite the several techniques such as functional MRI, magnetoencephalography which have been described recently[5-7]. Given intraoperative cortical stimulation can identify eloquent areas, many authors routinely adopt this technique to guide brain lesion resections and to maintain integrity of the functional pathways[8]. Vitaz et al.[9] compared the use of local anesthesia with general anesthesia in patients submitted to resection of lesions adjacent to eloquent cortex and reported a higher success rate of stimulation in awake patients (100% versus 50%) who required a significantly lower stimulation current (5 mA versus 13 mA, $p<0.0001$). A recent randomized prospective study compared general anesthesia with awake surgery and found that better tumor cytoreduction and neurological improvement was seen in the former, demonstrating that this topic remains controversial[10]. In our series, it proved impossible to identify the speech area in patient 1, although this did not affect the postoperative outcome. This can be explained by the fact that speech area can often be located in different regions and may be as small as 2.5 cm^2. The stimulation current ranged from 3 mA to 13 mA. Gross total resection was achieved in 66% of our series, similar to the rate to found by other authors ranging from 37.5 to 62%[4,11,12]. Neurological worsening in the immediate postoperative period followed by recovery within several weeks coincides with other series reported in the literature (27 to 83%)[13,14]. This worsening could be related to edema caused by surgical manipulation, to the effect of traction on eloquent areas or due to transgression of certain safety margins in mapping. Danks et al.[4] found a rate of 4% for permanent deficit postoperatively, similar to the 8% found in our study.

Surgical procedures performed under local anesthesia allow evaluation of certain intra-operative cerebral functions, such as the language area, and to avoid the risks attributed to general anesthesia, besides reducing length of stay in intensive care units[3,13]. Danks et al.[4] found some anesthetic complication in 45% of the procedures, where pain represented the main cause (10%), with epileptic episodes occurring in 7.6%. In their series of 122 patients there was a need to resort to general anesthesia in one patient. In the present study, the high frequency of seizures did not represent increased morbidity or length of hospital stay. The seizures lasted some seconds and were controlled quickly using cold isotonic solution on the cortex. None of our cases called for general anesthesia.

For a satisfactory procedure we ideally require an awake, cooperative patient capable of undergoing neurocognitive tests[13-15]. Different anesthetic combinations, including neurolept, propofol with or without opioid infusions, and asleep-awake-asleep techniques, have been reported for awake craniotomy. In all these techniques, respiratory depression has been reported as a complication[14,16]. There was no respiratory complication in our series when using propofol, midazolam and fentanil. Dexmetomedine provided the best neurological feedback during lesion is resected and did not produce agitation. Seizures occurred in two out of six patients who used a dexmetomedine anesthetic agent. Experimental studies have demonstrated the proconvulsant effect of dexmetomedine[17,18], but this has yet to be confirmed in humans.

In the majority of series, surgical resection is recommended to within 0.5 to 2 cm of the functional cortex. However, the technique used by the authors was subpial resection, adjacent to the sulci that delimits the functional cortex. There was no significant increase in postoperative deficits employing this technique. We believe that using motor mapping in awake patients the neurosurgeons can feel safer nearing the functional cortex in this type of resection.

In conclusion, brain mapping by cortical stimulation allows the extent of resection to be optimized thereby minimizing postoperative deficits. Awake surgery is a safe technique that allows the direct physiologic feedback of patients in the operating room. Association with cortical mapping optimizes resections in close contact with eloquent areas, allowing similar results to those achieved for surgical procedures carried out in less critical areas.

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