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Research Article

Awake Surgery for Tumors of the Parietal Lobe: A Preliminary Experience with a New Protocol of Intraoperative Neuropsychological Test for the Monitoring of the Sensory Area Function

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Background. Nowadays, there is a lack of studies reporting techniques for the selective monitoring of the primary somatosensory cortex and the adjacent areas of the superior and inferior parietal lobules. We hypothesized a more specific and targeted test for awake surgery for monitoring the sensory area during resection of tumors involving it. *Materials and Methods*. We collected patients suffering from tumors involving the parietal areas and undergoing awake surgery for the resection. Intraoperative standard neurophysiological monitoring was performed, and we added a new intraoperative test. It consisted of a series of different objects with standard 3D conformations. The patient was asked to recognize the object shape using only the tactile sensibility, without seeing the object itself; in some cases, he was also asked to put the object in the corresponding hole, according to the shape. *Results*. We collected 6 patients. One patient with a right parieto-occipital lesion, at the stimulation of the anterior cortical margin of the surgical field, showed problems in naming the objects and collocating them in the corresponding spaces, while he was touching them with the left hand. Therefore, the areas of proprioception and perception of the objects were mapped and numbered. This deficit got better in the postoperative days with a total remission of the ideomotor apraxia and the psychomotor slowdown. The other 5 patients did not show an impairment with the new test. *Conclusions*. This is a preliminary study with the aim of enhancing the specificity of the neuropsychological test performed during awake surgery to allow the surgeon to monitor the neurological functions of the parietal cortex. More cases are needed to validate it.

1. Introduction

Intraoperative neurophysiological monitoring of the sensory area during surgery for parietal lobe tumors is considered very challenging. In the literature, there is a lack of studies reporting techniques for the selective monitoring of the primary somatosensory cortex and the adjacent areas of the superior and inferior parietal lobules. The parietal cortex has several important functions: spatial representations of objects in relation to themselves and to the body, visual guidance of motor behavior, and spatial perception and cognition [1].

During awake surgery, eloquent areas can be monitored through cortical-subcortical stimulations in order to guarantee the maximal resection of the tumor and to avoid postoperative neurological deficits. Indeed, in tumors involving primary sensory and surrounding areas, the standard neurophysiological monitoring could not be adequate, because these patients could develop neurological impairment undetected by MEPs and SEPs [2, 3].

Shinoura et al. [4] used preoperative tractography to detect the sensory tract in the corona radiata in nine patients undergoing surgical resection of S1 brain tumors. They evaluated eventual postoperative deficits of deep sensation, which occurred in two patients.

Functional MRI and tractography constructed by DTI [5, 6] may be useful for the surgical planning and the anatomical enhancement of the sensory fiber pathway; however, the anatomical distribution of subcortical fibers and cortical sensorial cells is sparse, and DTI could not be sufficient to avoid damage to the inherent complex neurological functions during surgery of parietal lobe tumors.

Moreover, intraoperative electrophysiological monitoring and mapping of sensitive subcortical and cortical pathways have a very low sensitivity.

McMullen et al. [7] recently published a technical note showing an intraoperative functional mapping technique with high-density electrocorticography to localize finger representations in the primary somatosensory cortex of a tetraplegic patient.

Nowadays, there are no standardized protocols for monitoring the epicritic tactile sensibility and the superficial or deep proprioceptive one during the surgical removal of parietal tumors. For this reason, we have developed more specific and targeted tests for awake surgery of sensory areas.

This is a preliminary study to enhance the specificity of the tests used in our cases treated so far.

2. Material and Methods

The local ethical committee approved the present study (119/2023/Oss/AOUFe).

2.1. New Neuropsychological Test. The study implied the administration of sensory tests to patients during awake surgery for brain tumors of the parietal lobe.

The tests are aimed at showing a specific deficit of sensory function through cortical and subcortical stimulations. In this way, we try to preserve eloquent sensory areas and connections.

Moreover, we test healthy patients to validate tests and scores.

The test consists of solid objects of different materials, shapes, and textures and a box with holes of different shapes (Figure 1).

Objects must be blindly manipulated and described by the patients.

We evaluate patients' manipulation of objects, around 40 minutes, during the surgery and at one-month follow-up. We compared changes in test response before, during, and after surgery to compare test performance between operated and nonoperated patients.

2.2. Patients. We collected patients suffering from tumors involving the parietal areas without motor pathway impairment and undergoing awake surgery for the resection.

We collected demographic, clinical, and radiological pre- and postoperative data.

Inclusion criteria were age over 18, good performance status, wish to participate to the study, and a newly diagnosed brain tumor in the parietal lobe eligible for awake surgery.

Patients under 18 years old, unfit for awake surgery, with bad general physical condition (KPS < 70), and with a sensory deficit in the preoperative evaluation (more than 20% of error) were excluded.

2.3. Preoperative Neuropsychological and Neurophysiological Tests. All patients underwent preoperative neuropsychological tests to recognize any deficits and to choose the specific ones to perform during surgery and at one-month follow-up. Different cognitive domains were covered, including language (comprehension, naming, and fluency), sensibility (tactile recognition and proprioceptive), memory (repetition), and complex sensibilities (somaesthesis, stereognosis, discrimination of right and left sides, and ability of writing, reading, and drawing).

(i) *Test 1 verbal recognition*: 20 repetitions of object manipulation with right and then with left hand and naming the shape of the manipulated objects

(ii) *Test 2 spatial recognition*: 20 repetitions of object manipulation with right and then with left hand and inserting in the corresponding hole of the manipulated objects

A wrong answer or a delay in the recognition over 6 seconds is considered as an error.

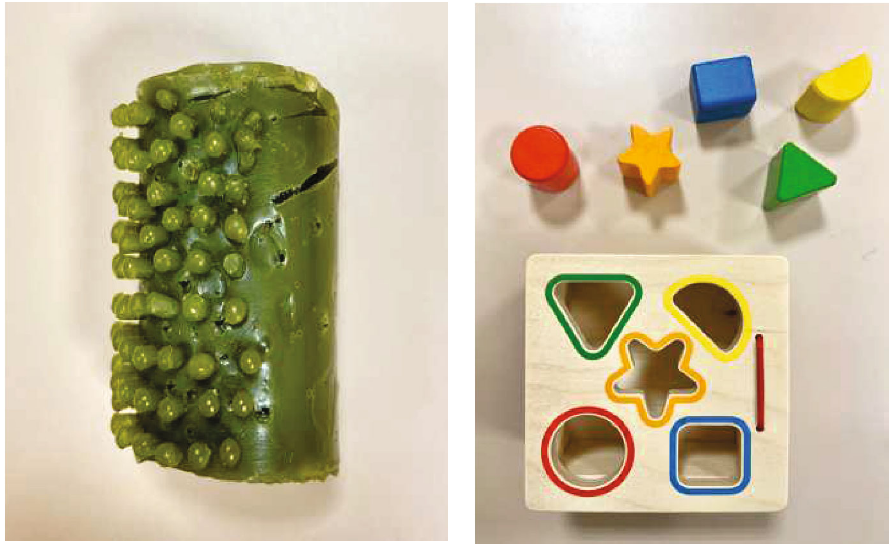
Tests 1 and 2 must be performed at least 12 hours before the surgery.

2.4. Intraoperative Neurophysiological Monitoring. All patients underwent asleep-awake-asleep surgery, to monitor neurological functions of the eloquent areas, with the SSEP phase reversal technique for identification of the primary sensory cortex. Anesthesiologists used *propofol* for sedation.

Bipolar anodal train-of-five stimulation (with 4 ms interstimulus interval and 0.5 ms pulse width and frequency of 250–500 Hz) was used to map the S1 area. After the central sulcus localization and the motor mapping, one strip electrode, positioned on the motor area, was used for eliciting MEPs with direct cortical train-of-five stimulation. The remaining electrodes were used for electrocorticography (ECoG) to detect epileptiform discharges and to confirm, with phase reversal, the location of the sensory cortex. We recorded SSEPs with a continuous stimulation of the left median nerve during the entire tumor resection.

2.5. Intraoperative Neuropsychological Test. Patients underwent standard neuropsychological tests for language (in cases of tumors in the dominant hemisphere) and motor monitoring.

To map the selective sensitive abilities and localize the sensory cortical and subcortical areas, we utilized new intraoperative tests (Tests 1 and 2).



(a) (b)

Figure 1: (a) The patient is asked to describe the surface of the object; (b) the patient is asked to put an object with a specific shape in the specific hole, just using tactile and proprioceptive information.

This test performed intraoperatively was recorded by a camera.

The tumor was resected under the constant bipolar cortical and monopolar cathodic stimulation, while the patient was performing this test. Errors could occur during the shape recognition phase (impairment of pure sensory function or agnosia) or during the placement in the corresponding hole (apraxia). If errors were evoked and confirmed after at least three stimulations in the same area, it was considered as "eloquent," and the tumor resection was stopped.

According to the patients' preoperative clinical conditions and their involved cortical regions, other examinations were performed during awake surgery, like denomination and repetition tests.

2.6. Surgical Technique. Patients gave their written consent for the surgical procedure, and the protocols were precisely explained to them. Patients also gave their written consent to video and audio recordings.

We used the standard asleep-awake-asleep protocol by propofol and remifentanil and anesthetic scalp blocks.

Patients were placed in a semisitting or lateral position. The tumor was identified with the aid of neuronavigation; then, the scalp incision was performed followed by a parietal craniotomy under general anesthesia. The dura was subsequently opened. The patient was awakened. Cortical mapping was performed (see Section 2.4). The posterior S1 cortical strip was explored. A multipolar electrode was placed over the cortical surface to allow MEPs, SSEPs and electrocorticography monitoring. Tumor resection was performed with the aid of CUSA while continuously stimulating with monopolar in the same position of the surgical maneuvers. Once a neurophysiological response was evoked, the resection was interrupted.

2.7. Postoperative Clinical Outcome. Patients underwent brain MRI with contrast on postoperative day 1, in order to evaluate radicality of the resection, possible residuals, or complications.

Postoperative clinical outcome was evaluated using the Karnofsky performance status.

Neuropsychological postoperative evaluation was performed a month after surgery through standard neuropsychological tests and Tests 1 and 2.

All patients with glioma WHO grade IV experienced a recurrence; the median time for recurrence was 7 months (min: 3.5 months, and max: 15 months). For patients with glioma WHO grade II (who underwent a partial resection), the residual remained stable at 18-month follow-up.

3. Results

3.1. Patients. We collected 6 patients, 2 women and 4 men. All of them suffered from tumors involving the parietal lobe (in 3 of them, tumors were extended also to frontal and occipital lobes), 4 on the left side and 2 on the right side.

Onset symptoms were nominal aphasia and dysarthria (2 patients), impaired vision (2 patients), cognitive impairment characterized by ideomotor apraxia and reduction of the functional autonomy (one patient), and partial seizures (one patient). The most common symptom was contralateral hypoesthesia, mainly on the upper limb. No patients had motor deficits.

Results of our preliminary study are summarized in the following tables (Tables 1 and 2).

3.2. Preoperative Neuropsychological and Neurophysiological Tests. Patients did not show preoperative cognitive or behavioral changes. One patient showed preoperative astereoagnosis in the left hand.

Table 1: Patients' and tumors' characteristics and postoperative neurological deficit evaluation.

	Handedness	Age (Y)	Sex	Preoperative neurologic deficit	Tumor location	Tumor histotype	Early postoperative deficit	Late postoperative deficit
1	R	52	M	Hypoesthesia/ quadrantanopia	Left parietal	Astrocytoma WHO grading II	None	
2	R	79	F	Spatial-temporal orientation deficit	Left parieto-occipital	Glioblastoma WHO grading IV	None	
3	R	62	M	Visual blurring	Right frontoparietal	Oligodendroglioma (WHO grading II)	Mild sensory and proprioceptive deficit in the left lower limb	Generalized seizures due to relapse of oligodendroglioma and mild hypoesthesia of lower limb
4	R	73	M	Anomia/ paraphasia and seizures	Left frontoparietal	Glioblastoma WHO grading IV		
5	R	56	M	Astereognosis of left hand and partial seizures	Right parietal	Glioblastoma WHO grading IV	Widespread hypoesthesia of left upper limb and mild dysarthria	Seizures in the left side due to regrowth of glioblastoma
6	R	52	F	Aphasia	Left parietal	Gliosarcoma (WHO grading IV)	None	

Table 2: Cortical and subcortical mapping results and extent of resection.

Case number	Cortical mapping	Subcortical mapping	Extent of resection
Patient 1	No somatosensory deficit	Tactile hypoesthesia/language disorders	Partial resection
Patient 2	No somatosensory deficit	No somatosensory deficit	Total resection
Patient 3	No somatosensory deficit/motor response of left lower limb	No somatosensory deficit/motor response of left lower limb	Partial resection
Patient 4	No somatosensory deficit	No somatosensory deficit	Total resection
Patient 5	Volumetric perception and shape recognition disturbances	Paresthesia/hypoesthesia	Partial resection
Patient 6	No somatosensory deficit	Sensory object recognition disorder	Total resection

3.3. Intraoperative Neuropsychological and Neurophysiological Monitoring and Mapping. During the intraoperative stimulation, 4 out of 6 patients presented errors in the denomination, one presented contralateral tactile hypoesthesia, while one patient, having lesions on the left frontoparietal region, presented language disorders.

Only one patient with right parieto-occipital lesion, at the stimulation of the anterior cortical margin of the surgical field, above the vein of Labbè, had problems in naming the three-dimensional objects and collocating them in the corresponding spaces, while he was touching them with the left hand; therefore, the areas of proprioception and perception of the objects were mapped and numbered. The other five patients with the lesions mostly on the left side were able to nominate the different three-dimensional objects and to collocate them in their corresponding space, considering their shape (see Table 3).

We evoked mainly negative sensory signs and symptoms, while one patient showed motor response to cortical and subcortical electrical stimulation mapping; none of the patients showed positive sensory perceptions during cortical and subcortical electrical stimulations.

3.4. Postoperative Clinical Outcome. At the postoperative MRI performed in the 1st POD, two patients showed a total resection of the lesion, while 3 showed a subtotal resection of the tumor.

Good clinical conditions were maintained in all six patients during the postoperative hospital stay (Karnofsky Performance Status 100); one patient showed hypoesthesia of the lower limb.

The patient who presented intraoperative neurological deficits in recognizing the three-dimensional objects got better in the postoperative days with a total remission of the ideomotor apraxia and the psychomotor slowdown.

4. Discussion

We report our experience with an additional intraoperative test to monitor sensory and proprioceptive functions during awake surgery for lesions involving the parietal lobe.

Out of 6 patients, only one (patient number 5) experienced errors in the tests proposed intraoperatively, which protracted postoperatively with the addition of widespread hypoesthesia of the left upper limb and mild dysarthria.

Table 3: Pre-, intra, and postoperative testing results for the new neuropsychological proposed tests (Tests 1 and 2).

Patient	Preoperative testing	Intraoperative testing	Postoperative testing
1	No errors	No errors	No errors
2	No errors	No errors	No errors
3	No errors	No errors	No errors
4	No errors	No errors	No errors
5	Error in shape recognition at Test 1	Error in shape recognition at Tests 1 and 2	Error in shape recognition at Tests 1 and 2
6	No errors	No errors	No errors

Several reports are available in the literature regarding the intraoperative monitoring of the motor cortex or the language areas; however, selective monitoring of the somatosensory cortex is rarely described [8–12].

The standard monitoring protocols take into consideration an ascending pathway, through the peripherical stimulations with electrodes to map the corresponding cortical surfaces, without considering the descending system. On the other hand, our protocol verifies through the cortical stimulation in the somatosensory area, while the patient is performing the different neuropsychological tests, any neurological deficits in the proprioception, stereognosis, sensibility, and spatial perception and cognition.

Tumor involvement of functionally eloquent areas has been gaining increasing importance in terms of the extent of surgical resection and the patient's quality of life. Intraoperative monitoring through awake surgery and adequate neuropsychological tests is nowadays mandatory. In fact, it is now recognized important for the integrity of somatosensory areas for the quality of life; otherwise, there could be a delay of motor function recovery; neurological deficits in picture naming, discriminating two points, or making calculations; or a visuospatial alteration.

Maldonado et al. [12] evaluated motor and language functions during awake surgeries in 14 patients with left inferior parietal lobe gliomas, and they were able to enhance the cortical somatosensory areas, to usually determine the anterior limit of resection. Their stimulation caused dysesthesias in the contralateral hemibody, and in some cases, subcortical stimulation permitted identification of the thalamocortical pathways as well.

In the literature, only few neurosurgical studies have described awake mapping for somatosensory functions when removing glioma in the parietal lobe, and these rare series mainly focused on spatial cognition [13].

We presented a preliminary experience with a neuropsychological test for the somatosensory areas during awake surgery with the aim of achieving total or subtotal resection of the lesion without experiencing permanent and severe postoperative neurological sensory deficits.

Considering the pathway of subcortical connections, we tried to differentiate patients with parietal lesion on the left side from those on the right side: to the first group (if the dominant hemisphere corresponds to the left one), we have asked to touch the three-dimensional wood objects without seeing them and to nominate their name according to their shape. Patients with lesion on the right side were asked to just indicate, without naming, the hole with the same shape of the solid figure after having received it on the contralateral hand.

These new, simple, and easily reproducible tests could be very important to better explore somatosensory eloquent areas, tributaries of functions as visuospatial representations of objects in relation to the patient, spatial perception and cognition, and protopathic and epicritic sensitivity. Moreover, Test 2 allows overcoming any language impairment, overcoming communication discrepancy as a language barrier. Despite the small number of cases collected, we consider such a test promising in order to detect cortical and subcortical sensory areas with a good level of sensitivity.

The limitation of the test is the patient's compliancy since the timing between the surgeon stimulation and the patient execution of the task required is fundamental.

Moreover, since the study of these new tests was preliminary, we followed a standard resection technique based on evaluation of SSEPs and MEPs or patient-referred (if awake) impairment of somatosensory or motor functions. New test results were only recorded, but not taken into consideration for surgical choices. These tests need a higher number of patients to be validated for surgical strategy guidance. For this purpose, we hope to collect a higher number of patients in the future and finally validate them. However, the choice between proprioceptive or sensory function preservation and extent of resection, especially in patients suffering from high-grade gliomas, could be very difficult and debated.

5. Limitations

Monitoring of complex functions, such as sensory and proprioceptive ones, is always challenging. We presented a new test that, as in all neuropsychological tests, relies on the compliance of the patient.

Moreover, the number of patients is small, but we are planning to extend it, since this test has been routinely adopted for all patients undergoing awake surgery for tumors located in the sensory area.

Patients did not undergo fMRI before surgery. It may surely enhance more details on the planning of the neuropsychological tests to monitor the parietal functions involved by the localization of the lesion. However, in our institution, we prefer to follow a "functional resection" based on intraoperative mapping and monitoring, and we rarely consider performing fMRI, because it does not change our operative planning.

6. Conclusion

This is a preliminary study with the aim of enhancing the specificity of the neuropsychological test performed during awake surgery which allows the surgeon to monitor the neurological functions of the parietal cortex, recognizing eloquent areas, and allowing a safe surgical resection. Awake surgery is shown to be a precise and useful technique to preserve very complex functions, such as the superficial, deep, and complex sensibilities. The addition of intraoperative performance allowed detecting sensory impairment otherwise undetected.

Abbreviations

DTI: Diffusion tensor imaging
SSEP: Somatosensory evoked potential
MEP: Motor evoked potential
MRI: Magnetic resonance imaging
fMRI: Functional magnetic resonance imaging
ER: Emergency room.

Data Availability

The data that support the findings of this study are available from the corresponding author.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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