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Continuous physical examination during subcortical resection in awake craniotomy patients: Its usefulness and surgical outcome

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ABSTRACT

Objectives: To evaluate the value of physical examination as a monitoring tool during subcortical resection in awake craniotomy patients and surgical outcomes.
Patients and methods: Authors reviewed medical records of patients underwent awake craniotomy with continuous physical examination for pathology adjacent to the eloquent area.
Results: Between January 2006 and August 2015, there were 37 patients underwent awake craniotomy with continuous physical examination. Pathology was located in the left cerebral hemisphere in 28 patients (75.7%). Thirty patients (81.1%) had neuroepithelial tumors. Degree of resections were defined as total, subtotal, and partial in 16 (43.2%), 11 (29.7%) and 10 (27.0%) patients, respectively. Median follow up duration was 14 months. The reasons for termination of subcortical resection were divided into 3 groups as follows: 1) by anatomical landmark with the aid of neuronavigation in 20 patients (54%), 2) by reaching subcortical stimulation threshold in 8 patients (21.6%), and 3) by abnormal physical examination in 9 patients (24.3%). Among these 3 groups, there were statistically significant differences in the intraoperative ($p = 0.002$) and early postoperative neurological deficit ($p = 0.005$) with the lowest deficit in neuronavigation group. However, there were no differences in neurological outcome at later follow up (3-months $p = 0.103$; 6-months $p = 0.285$). There were no differences in the degree of resection among the groups.
Conclusion: Continuous physical examination has shown to be of value as an additional layer of monitoring of subcortical white matter during resection and combining several methods may help increase the efficacy of mapping and monitoring of subcortical functions.

1. Introduction

In order to achieve a maximal resection of the pathology in the vicinity of eloquent areas and preserve cerebral functions, brain mapping and monitoring are used during resection. While cortical mapping usually provides a well-defined two dimensional boundary of safe zone that can be removed and used as a corridor to gain access to the deeper structures, subcortical mapping and monitoring are much more complex processes due to three dimensional intermingle axonal networks and constant anatomical changes during resection. A number of methods are used to map and monitor those subcortical neuronal functions including subcortical electrical stimulation [1–13], motor evoked potential (MEP) [7,10,14,15], physical examination [3,7,8,11,12,16–22].

Although physical examination is frequently mentioned in many reports of surgical removal of pathologies near the eloquent areas, data on its value and relevance are lacking [3,7,8,11,12,16–22]. Authors reported a series of continuous physical examinations during subcortical resection in awake craniotomy patients, its added value as a monitoring tool and surgical outcome.

2. Patients and methods

Authors retrospectively reviewed the data of 37 consecutive patients who underwent awake craniotomy with continuous phys-

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ical examination by single surgeon from January 2006-August 2015. Awake craniotomy with continuous physical examination was considered in patients with intrinsic pathology in the vicinity of eloquent areas such as language and somatosensory areas. Patients were excluded from this technique for the following reasons: uncooperative patient, potential respiratory issues, poor baseline neurological status despite dexamethasone administration (greater than 20 percent error of preoperative object naming test or motor strength of less than grade 3/5). All patients gave consent for the procedure. This study was approved by the institutional review board.

2.1. Preoperative period

All patients underwent detailed neurological assessments. Handedness was assessed by Edinburgh Handedness Inventory [23]. Preoperative imaging included MRI with a neuronavigation technique. Preoperatively, rationales of awake surgery, potential benefits, details of the procedure and what to expect during the surgery, were explained to each patient. This was done to lessen patient anxiety and gain full cooperation from patients during surgery. The tasks that would be done during the surgery, e.g. language and motor tasks were rehearsed. Anticonvulsant medication was administered preoperatively in all patients.

2.2. Anesthetic technique

All procedures were performed under local anesthesia with sedation. Monitoring included noninvasive and invasive blood pressure, electrocardiography, pulse oximeter, nasal cannula end tidal carbon dioxide sampling, skin temperature, urine output, arterial blood gas and blood glucose. Pneumatic compression device was applied on both lower extremities. All patients breathed spontaneously with oxygen supplement and without any tracheal or laryngeal airway. Nasopharyngeal airway was used in some cases if adequate airway control could not be achieved. Standard anesthetic technique included intravenous propofol by target controlled infusion at plasma level of 2–6 mcg/ml (Perfusor Space, B. Braun Melsungen AG, Melsungen, Germany) and fentanyl infusion of 0.5–1.0 mcg/kg/h. Depth of anesthesia was adjusted with the aid of Bispectral Index (Aspect Medical System, Inc., Natick, MA, USA) to maintain patient comfort, adequate spontaneous ventilation and stable vital signs. Dexmedetomidine supplementation was used in some cases with loading dose of 1 mcg/kg in 10 minutes and continued infusion with 0.4–0.7 mcg/kg/h. After the patient was sedated, a urinary catheter was inserted and circumferential scalp block was done by infiltrating 0.5% bupivacaine with 1:200,000 epinephrine to bilateral supratrochlear, supraorbital, zygomaticotemporal, auriculotemporal, great auricular, greater and lesser occipital nerves. Additional 1% xylocaine with 1:100,000 epinephrine was infiltrated along the incision site. Once the cranium and dura were opened, the anesthetic agent infusion was discontinued and the patient was allowed to gradually wake up until fully awake and cooperative with brain mapping and neurological assessment. If the patient felt any discomfort during the awake period, small bolus doses of fentanyl or additional local anesthetics were given as needed. At the end of the operation, after the resection was completed, hemostasis was satisfactorily attained and neurological status was reassessed prior to dura closure. The patient was re-sedated until the completion of craniotomy closure.

2.3. Positioning

Preferred position for awake craniotomy was lateral decubitus which lessened airway obstruction when the patient was sedated without an endotracheal tube. However, supine position with neutral head orientation was chosen when the pathology was located near the midline. A rigid head holder was used in all cases. Authors used transparent sterile drape as it allowed better illumination and visualization of patient responses by surgeon and anesthesiologist teams during the operation.

2.4. Cortical mapping

After the cortical surface was exposed to cover the desired area, a bipolar electrode with a 5 mm spaced tips was used for cortical stimulation (Ojemann stimulator, Radionics, Inc., Burlington, MA, USA). Stimulation parameters were as follow: constant current square wave, biphasic pulses of 500 μs duration and frequency of 50 Hz. Amplitude of stimulation was initiated at 2 mA with 2 mA increments until either the clinical response was observed, 10 mA amplitude was reached or clinical seizure occurred. Stimulation was applied for 4 s at each site. The site would be considered eloquent if at least 2 out 3 clinical responses were obtained from non-consecutive stimulations. Speech mapping was done by stimulating the cortex while the patient was performing an object naming task. Mapping of motor areas was done by observing the motor response of the contralateral extremities and face. Sensory area mapping was done by instructing the patient to report any new appearing sensory phenomenon during stimulation with a “no stimulation” control. Intraoperative ECoG and EMG were not used. If seizure occurred, the cortex would be irrigated with cold saline which was made available before the beginning of cortical mapping. The area that caused the seizure was not re-stimulated.

2.5. Resection phase

Once all the desired areas had been mapped, the area of cortical resection was then outlined. Authors aimed for maximal resection with minimal neurological deficit in all cases. The margin of resection to the eloquent area was normally 5 mm. The tumor boundary which was closest to the eloquent areas was resected last. During the resection, monitoring was performed concurrently by two methods. The first method was continuous examination of speech function and/or motor strength depending on the nearby eloquent areas. The patient was tested for motor strength of the contralateral extremities and language functions (object naming, conversation, simple command comprehension, finger identification). If impairment occurred, the resection would be stopped and motor and/or language functions were re-assessed. If the impairment was confirmed and did not improve within 5 minutes (and other factors of impairment have been excluded) the resection would not be resumed. If the impairment subsided, however, continuation or termination of the resection was solely dependent on surgeon discretion according to surgical goals, nature of deficit and prior discussion with the patient. The second method was subcortical stimulation. The full details of subcortical stimulation have been described elsewhere [24]. In brief, once the subcortical white matter was reached, in addition to physical examination, subcortical stimulation was periodically applied as the resection progressed during which the patient was performing language tasks. If no speech disturbance and no motor-sensory response (eg. twitching, dystonic, paresthesia) occurred, the resection resumed with re-stimulation of subcortical white matter every 3–5 mm of resection. No further resection was made when the stimulation threshold reached 4 mA.

Therefore, resection was concluded if 1) planned resection volume had been achieved by visual inspection with the aid of neuronavigation system, or 2) subcortical stimulation threshold had reached 4 mA, or 3) physical examination demonstrated functional impairment. Neurological status was assessed as a post resection baseline before the dura closure and patient was then sedated