Journal of Clinical Neuroscience 21 (2014) 1891–1894

Contents lists available at ScienceDirect

Journal of Clinical Neuroscience

journal homepage: www.elsevier.com/locate/jocn

Clinical Study

Pediatric awake craniotomy and intra-operative stimulation mapping

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ARTICLE INFO

Article history:
Received 2 July 2014
Accepted 6 July 2014

Keywords:
Awake craniotomy
Cortical stimulation
Epilepsy
Functional mapping
Language
Neuropsychological
Tumor

ABSTRACT

The indications for operating on lesions in or near areas of cortical eloquence balance the benefit of resection with the risk of permanent neurological deficit. In adults, awake craniotomy has become a versatile tool in tumor, epilepsy and functional neurosurgery, permitting intra-operative stimulation mapping particularly for language, sensory and motor cortical pathways. This allows for maximal tumor resection with considerable reduction in the risk of post-operative speech and motor deficits. We report our experience of awake craniotomy and cortical stimulation for epilepsy and supratentorial tumors located in and around eloquent areas in a pediatric population (n = 10, five females). The presenting symptom was mainly seizures and all children had normal neurological examinations. Neuroimaging showed lesions in the left opercular (n = 4) and precentral or peri-sylvian regions (n = 6). Three right-sided and seven left-sided awake craniotomies were performed. Two patients had a history of prior craniotomy. All patients had intra-operative mapping for either speech or motor or both using cortical stimulation. The surgical goal for tumor patients was gross total resection, while for all epilepsy procedures, focal cortical resections were completed without any difficulty. None of the patients had permanent post-operative neurologic deficits. The patient with an epileptic focus over the speech area in the left frontal lobe had a mild word finding difficulty post-operatively but this improved progressively. Follow-up ranged from 6 to 27 months. Pediatric awake craniotomy with intra-operative mapping is a precise, safe and reliable method allowing for resection of lesions in eloquent areas. Further validations on larger number of patients will be needed to verify the utility of this technique in the pediatric population.

1. Introduction

It is well recognized that awake craniotomy with intra-operative electrical brain mapping represents a reliable method to minimize the risk of permanent deficit during surgery for lesions within eloquent areas [10,32,35]. Non-invasive functional mapping can guide surgical resection of tumors near eloquent cortex. Positron emission tomography, functional MRI (fMRI) and magnetoencephalography are all valuable tools utilized in localizing motor, sensory, and language function pre-operatively [6,8,13–15,18,19,21,25,26,28,30,31,34]. However, these techniques have limitations when used in young children to define ictal foci, which may limit their usefulness as a guide to resection in eloquent areas [23]. Furthermore, fMRI identifies cortical regions activated during specific tasks, rather than regions critical to these functions. Thus, it often overestimates the area of functional cortex for a given task, which may limit the extent or accuracy of resection [11].

There have been previous reports in the literature of awake craniotomy in the pediatric population [1,17,24,29,36,38,39] with fewer reports where awake craniotomy was combined with intra-operative stimulation. We report a series of children who underwent awake craniotomy with intra-operative electrical stimulation to demonstrate our management, approach, outcomes and recommendations in the pediatric population.

2. Materials and methods

Research ethics board review approval was obtained for this study (REB No. 1000028839). We performed a retrospective chart review of all the patients who had awake craniotomy, neuronavigation, and intra-operative neuromonitoring at The Hospital for Sick Children, Toronto, between January 2009 and February 2013. Demographic information of each patient including the age at

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http://dx.doi.org/10.1016/j.jocn.2014.07.013
0967-5868/

surgery, sex, presenting symptoms, indication for awake craniotomy, pre-operative work up imaging, intra-operative events, post-operative complications and recovery was evaluated.

2.1. Surgical technique

Routine intravenous prophylactic antibiotics were administered along with dexamethasone and anti-convulsants as indicated in each patient. The patients were positioned in the supine or lateral position. Prior to head immobilization in the Sugita head holder for rigid fixation, the pin sites were infiltrated with 0.25% bupivacaine with epinephrine. The asleep–awake–asleep technique was employed using a combination of propofol and fentanyl/remifentanyl [27]. All patients bar two had an appropriate sized laryngeal mask airway (LMA) placed. All patients had an arterial line and a Foley catheter inserted. Once the incision was marked, sterile draping was performed with the neuroanesthetist and neuropsychologist well positioned to interact with the patient. The scalp incision was infiltrated with 0.25% bupivacaine and epinephrine in a regional block fashion [37]. Intra-operative neuronavigation (Brainlab AG, Munich, Germany) and intra-operative ultrasound (Hitachi Aloka, Tokyo, Japan) was used in all cases.

2.2. Mapping

The propofol infusion was discontinued, and the LMA removed prior to cortical mapping. After the craniotomy was performed and the dura opened, the patient was awakened by discontinuation of the propofol infusion, and removal of the LMA. Intra-operative cortical stimulation was then performed using bipolar electrodes with stimulation duration of 100 microseconds pulse width at 60 Hz frequency. Stimulation intensity started at 3 milliamps to a maximum of 14 milliamps. A neuropsychologist was present in the operating room for speech mapping which included naming and counting. Motor mapping was done with the patient moving specific parts of the limbs to instructions. Resections of tumors, lesions, and epileptic foci were performed in eloquent areas with the patient awake and communicating and following the instructions of both the neuroanesthetist and the neuropsychologist. Upon completion of the resection, the propofol infusion was restarted, the LMA was repositioned, and multi-layer closure was undertaken in the usual fashion.

3. Results

There were 10 patients who had awake craniotomy during this period (Table 1). The male to female ratio was 1:1. Their ages ranged from 11–17 years with a mean age of 14.6 years. The main presenting symptom was seizures. Three patients had epilepsy surgery while the rest had craniotomy for tumor excision. The indication for awake craniotomy was the location of the tumor, or epileptogenic foci, in an eloquent region. Of the two patients who were left handed, one had a left hemispheric dominance while the other had language localized to both hemispheres. Two patients did not have any pre-operative functional imaging; one was a patient with a recurrent tumor and the other had imaging features of a high-grade tumor necessitating urgent intervention. The patients tolerated the procedures well with resections completed as planned in all of the patients, although Patient 6 became combative and uncooperative with speech mapping during the latter part of the procedure necessitating abandonment of the awake craniotomy portion of the procedure. Patient 1 was not initially scheduled to have LMA insertion but developed intra-operative apnea necessitating her airway be secured. She eventually settled and was cooperative with speech mapping. Two (20%) patients had speech arrest during mapping with consequent subtotal resection of the tumor in one patient so as to spare language. All the tumors we operated on were gliomas with World Health Organization grades from I–IV. The procedure time (anesthesia and surgical time) ranged from 115–264 minutes with a mean time of 212 minutes. The follow up period was 6–27 months and this was influenced by the graduation of some of the patients to the care of the local adult neurosurgery center. We recorded a worsening neurologic deficit in one patient (Patient 8) with tumor over the anatomical language area. This patient's word finding problem worsened post-operatively but this progressively improved and

Table 1
Summary of patient demographics, lesion/tumor location, surgical procedures and pathology

Patient	Sex, handedness	Age, years	Symptom	Tumor location/ seizure focus	Pre-operative functional imaging	Intra-operative neurophysiology monitoring SSEP/MEP	Extent of resection	Pathology	Complications
1	F, right	17	Seizures	Left frontal opercular	fMRI, MEG	Yes	GTR	Anaplastic astrocytoma	Intra-operative apnea
2	M, right	17	Seizures	Left frontal	MEG, fMRI	Yes	STR	Low grade glioma	None
3	F, right	15	Seizures, H/A	Left frontal	None	Yes	GTR	Recurrent GBM	None
4	M, right	16	Seizures	Right posterior frontal	MEG, fMRI	Yes	GTR	DNET	None
5	F, right	17	Seizures	Right posterior STG	MEG, fMRI		GTR	PXA	None
6	M, left	13	Seizures	Left temporal	Wada, MEG, fMRI	Yes	Seizure surgery	Gliosis with microcalcification	Combative and uncooperative with speech mapping
7	M, right	13	Seizures	Left temporal + mesial structures	MEG, PET, fMRI	Yes	Seizure surgery	Neocortex	None
8	F, right	16	Seizures	Left frontal	MEG, PET, fMRI	Yes	Seizure surgery	Gliosis	Post-operative word finding
9	F, left	11	Seizures, dysphasia, H/A	Right temporal	fMRI	Yes	GTR	Residual ganglioglioma	None
10	M, right	11	Seizures	Left frontal lobe	None	Yes	GTR	Anaplastic astrocytoma	None

DNET = dysembryoblastic epithelial tumor, F = female, fMRI = functional magnetic resonance imaging, GBM = glioblastoma multiforme, GTR = gross total resection, H/A = headaches, M = male, MEG = magnentoencephalography, MEP = motor evoked potentials, PET = positron emission tomography, PXA = pleomorphic xanthoastrocytoma, SSEP = somatosensory evoked potentials, STG = superior temporal gyrus, STR = subtotal resection.