Monitoring of Sensory Evoked Potentials During Surgery of Skull Base Tumours

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ABSTRACT: Despite advances in instrumentation and the use of microsurgical techniques, neurosurgical procedures involving extensive areas of skull base or other critical areas of brain still carry significant risk for neurological injury. The use of intraoperative recording of sensory evoked potentials (SEP) has been advocated to monitor neurologic function during these major neurosurgical procedures to reduce the risk of injury to neural structures.

This report summarizes our experience with intraoperative monitoring of SEP in over 200 patients, and details our findings in a group of 12 patients with skull base and posterior fossa tumours. Somatosensory evoked potentials (SSEP) were monitored in all patients, and brain stem auditory evoked potentials (BAEP) in five. While minor changes in BAEP and SSEP parameters were noted in most patients, significant changes occurred in five. Irreversible loss of BAEP in one patient was associated with complete hearing loss postoperatively. Marked, persistent alteration of both BAEP and SSEP was associated with postoperative brainstem dysfunction. No patient with stable BAEP and SSEP at the end of the procedure suffered additional neurological deficit.

We conclude that intraoperative SEP monitoring may be valuable in minimizing neural injury during major neurosurgical procedures.

RÉSUMÉ: Surveillance des potentiels évoqués sensitifs durant la chirurgie des tumeurs de la base du crâne Malgré les progrès dans l'instrumentation et l'emploi de techniques microchirurgicales, il existe encore d'importants risques lors des interventions portant sur la base du crâne. L'emploi peropératoire d'enregistrements des potentiels évoqués sensitifs lors de ces interventions neurochirurgicales a été préconisé dans le but de réduire le risque de lésions aux structures neuronales.

Le présent rapport résume notre expérience avec de tels enregistrements chez plus de 200 patients et explique nos observations chez 12 patients ayant des tumeurs de la base du crâne et de la fosse postérieure. Nous avons enregistré les potentiels évoqués somatosensoriels (SSEP) chez tous les patients et les potentiels évoqués auditifs du tronc cérébral (BAEP) chez cinq. Les modifications mineures des paramètres du BAEP et du SSEP furent notées chez tous les patients; elles sont importantes chez cinq. Une perte irréversible du BAEP chez un patient était associée à une perte complète de l'ouie après l'opération. Les variations importantes chez les autres patients étaient toujours associées à des dysfonctions postopératoires du tronc cérébral. Aucun malade dont le BAEP ou le SSEP étaient stables à la fin de l'opération ne devaient souffrir de lésions neurologiques additionnelles. Nous concluons qu'une surveillance peropératoire des potentiels évoqués sensitifs peut être utile et peut permettre de minimiser les lésions neurologiques lors de l'intervention.

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Important progress has been made in recent years in the treatment of tumours involving extensive portions of the skull base, deep midline structures, and other critical areas of the brain. Nevertheless, because of the depth of exposure and the degree of brain retraction often required, and because vital areas of the brainstem and major cranial nerves are often involved, surgery in these regions still carries an appreciable risk of producing neurological injury. One reason for this has been our inability to reliably monitor brain function in the anesthetized patient, and thus interpret the effects, beneficial or otherwise, of intraoperative manipulations. While monitoring cardiovascular and respiratory parameters is essential, they only indirectly

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reflect neurologic events and are unreliable as guides to the functional state of the central nervous system. Raw EEG activity, compressed spectral array, and cerebral blood flow have all been used to monitor the central nervous system during surgery, but these techniques are cumbersome, the results obtained not uniform and their reliability inconsistent. There is a need, therefore, to monitor brain function intraoperatively in a more direct and reliable manner to permit early detection of deteriorating neurological function and allow for corrective action before a permanent deficit occurs.

Monitoring of sensory evoked potentials (SEP) may prove useful in such a context;[1,2,3] it appears to satisfy a number of criteria required for a good CNS monitoring system. It allows monitoring of patients under anesthesia, independent of their level of consciousness, and recordings can be made continuously and safely by surface or needle electrodes. As direct electrophysiological responses of the nervous system to a specific external sensory stimulus, SEPs unlike spontaneous EEG activity, reflect the functional capabilities of specific neuronal pathways. SEP parameters also provide objective measurements that can be quantitatively and statistically analyzed.

This report summarizes our experience with intraoperative monitoring of SEPs and details our findings in a small group of patients with skull base and posterior fossa tumours.

Methods and Materials

From September 1982 to December 1984, SEPs were monitored intraoperatively in 205 patients undergoing a variety of neurosurgical procedures (Table 1). While our greatest experience to date has been in patients undergoing neurovascular procedures, SEPs were recorded during intracranial tumour surgery in 48 patients (36 supratentorial tumours and 12 infratentorial/basal tumours). While in the majority of patients with supratentorial lesions, somatosensory evoked potentials (SSEP) alone were monitored, patients with posterior fossa or basal tumours usually had both SSEP and brain stem auditory evoked potentials (BAEP) recorded.

The technique for intraoperative recording of SSEP was modified from that of Symon et al.[4,5] SSEPs are generated by stimulation of the median nerve at the wrist or posterior tibial nerve at the ankle. Square wave pulses of 0.15 msec duration were delivered at a rate of 4.1/sec using a constant current stimulator (Nicolet 1003). Stimulus intensity was sufficient to sustain thumb twitch. Recording electrodes were placed on the scalp over the areas of the right and left somatosensory cortex (C¾ positions of the international 10/20 EEG system), over the surface of the C2 vertebra and over Erb's point. With lower limb stimulation, recording was from a vertex electrode placed 2 cms behind Cz. The reference electrode was placed in the mid-forehead (FPz). Usually 128 or 512 responses were averaged and short latency (less than 50 msec) responses recorded simultaneously from over Erb's point (N9 — brachial plexus wave), C2 (N14 — dorsal column wave) and from the ipsilateral and contralateral cortex (N20 wave).

BAEPs were recorded using standard parameters.[2,3] A click stimulus of 100 microsecond duration at a rate of 10 Hz was presented monaurally via ear inserts at an intensity of 60 dBHL stimulus intensity and 35 dBHL broadbased masking noise presented to the contralateral ear. A sweep time of 10.24 msec was used with 1000 - 2000 repetitions per average. All electrode impedances were at or below 3000 ohms. In addition to the standard analysis of amplitude, wave form and latency of various waves, analysis of derived variables such as central conduction time (CCT), interpeak latencies and interhemispheric difference (IHD) was also measured (Figure 1). All recordings were carried out using a Nicolet CA 1000 system and data stored on floppy disks.

Patients to be monitored had preoperative recordings to obtain preanesthetic values and to document any pre-existing central or peripheral nervous system abnormality. A standardized anesthetic protocol was used whenever possible to minimize anesthetic and other drug variables. General anesthesia alone can significantly alter SEP parameters and one cannot compare values obtained intraoperatively with values from awake patients. It is recommended that normative data from control patients under baseline anesthetic conditions be obtained. Once anesthetic baseline values have been obtained, each patient acts as his own control by comparing one cerebral hemisphere to the other. Recordings are carried out almost continuously throughout the operative procedure including skin incision, bone removal,

Table 1: Intraoperative Monitoring of Sensory Evoked Potentials

		No. Cases
Cerebrovascular	— Endarterectomy	70
	— EC/IC Bypass	20
	— Aneurysm	49
	— A.V.M.	3
Tumours	— Cranial	48
	— Spinal	10
Interventional Neuroradiology		5
	Total	205

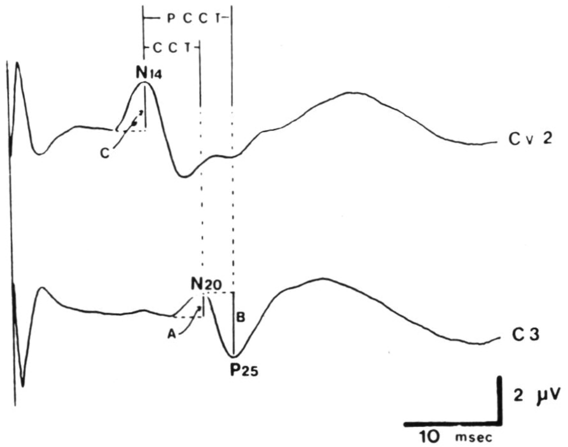


Figure 1 — Typical somatosensory evoked potential waves recorded from neck (CV2) and scalp (C3) following stimulation of contralateral median nerves. In addition to standard parameters of latency and amplitude, derived variables can be analyzed.

N14 — dorsal column nuclei wave; N20 — first negative cortical wave; P25 — first positive cortical wave; CCT — central conduction time = N20 - N14; PCCT - P25 - N14; IHD — interhemispheric difference; A = amplitude N20 wave; B = amplitude P25 wave; C = amplitude N14 wave; B/A, A/C, B/C — amplitude ratios.

dural opening, retractor placement, and during brain manipulation and wound closure. With experience, we have been able to record SEPs intraoperatively in a reliable and reproducible manner in over 90% of patients. The most frequent cause of failure is electrical interference. SEP monitoring prolongs the average surgical procedure by no more than 10 to 15 minutes.

Results

Some alteration in intraoperative SEP parameters was noted in the majority of patients. Minor variations in amplitude and latencies were most often related to changes in anesthetic concentration or alteration in cardiovascular and respiratory parameters such as blood pressure, arterial blood gases and temperature. More significant changes in amplitude and latencies were most commonly seen with temporary vessel occlusion and profound hypotension during cerebrovascular reconstructive procedures and aneurysm surgery.

Twelve patients with large posterior fossa or extensive skull base tumours were monitored. There were nine females and three males, ages 29 to 69 years. SSEPs were monitored in all patients. In addition, five patients also had BAEP recorded. While minor changes in BAEP and SSEP parameters from anesthetic baseline values were seen in all patients, significant alterations were noted in five. In three, specific action was taken by the surgeon in response to SEP alterations. In two cases, this involved release of brain retraction in response to prolonged CCT with subsequent improvement in conduction. In one case, tumour removal near the brainstem was interrupted on several occasions in response to marked attenuation of the SSEP cortical wave, with subsequent improvement. Irreversible loss of BAEP in one patient with a large acoustic neuroma was associated with complete loss of hearing postoperatively. Persistent marked attenuation of both BAEP and SSEP cortical wave was associated with postoperative brainstem dysfunction in a patient with a clivus meningioma. In two patients, tumour removal was associated with improvement in SEP parameters from preoperative and anesthetic baseline values.

Illustrative Cases

Case 1

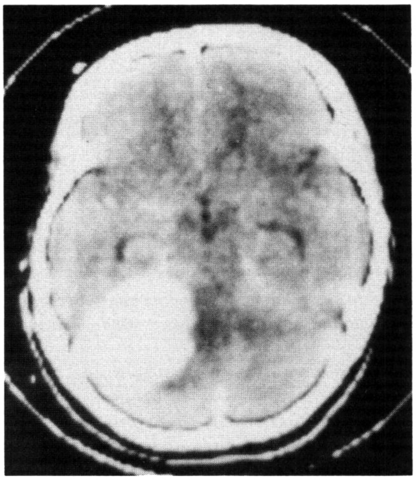
A 29 year old woman presented with headache, vertigo and ataxia. CT scan revealed a large enhancing mass in the left posterior fossa based on the posterior petrous ridge (Figure 2a). There was shift of the 4th ventricle and brainstem with associated hydrocephalus. Intraoperatively, both SSEP and BAEP were monitored. Prolongation of CCT bilaterally was noted during dural opening and tumour resection, with return to baseline values at closure (Figure 3). Typical changes in wave V latency and I-V interval of the BAEP are illustrated in Figure 3. The absolute latency of wave V and I-V interpeak latency increased bilaterally during cerebellar retraction and tumour manipulation. Tumour removal and release of brain retraction was associated with return of both SSEP and BAEP parameters to anesthetic baseline values. Total gross tumour removal was achieved with relief of hydrocephalus and no postoperative deficit (Figure 2b).

Case 2

A 48 year old woman presented with headache, facial paresthesia and papilledema. CT scan and angiography revealed a large left cerebellopontine angle and posterior petrous meningioma. Both SSEP and BAEP were monitored during surgery. Other than minor transient changes during dural opening, the SSEP recording remained stable throughout the procedure. However, the anesthetic baseline BAEP showed attenuation of the left-sided response, with increase in the latency of wave V and I-V interval. The waveform improved at the time of dural opening with subsequent return of normal response following tumour resection (Figure 4). Total gross removal was achieved with no added postoperative deficit.

Based on our initial experience in 50 patients, a grading system for SEP changes was developed in an attempt to better analyze the data and examine the prognostic value of the technique. The grading system for SSEP is based on CCT, amplitude and IHD. Table 2 shows the four grades used for SSEP. Note that all grades are references to anesthetic baseline values and not preoperative parameters. Experience with 69 patients monitored during carotid endarterectomy has shown a close correlation between SSEP grade at carotid clamping and the development of postoperative complications. No patient with Grade I/II changes developed postoperative deficit, regardless of whether a temporary bypass shunt was employed. Grade III/IV changes which could not be reversed by shunt placement or blood pressure manipulation were associated with an increased incidence of postoperative ischemic deficits.

Analysis of the findings in our group of basal tumours reveals that persistent Grade III or IV changes were associated with additional postoperative neurological deficits. No patient with normal BAEP and SSEP at the end of the procedure was found to have additional neurological deficit, with the exception of isolated cranial nerve palsy.



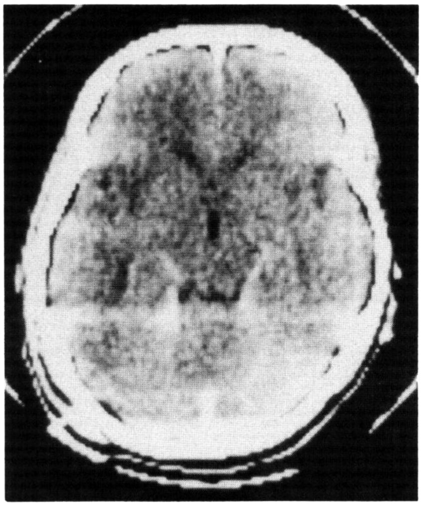


Figure 2 a) Pre-operative CT scan in Case 1 showing large enhancing mass in left posterior fossa and posterior petrous ridge. There is evidence of hydrocephalus with dilation of temporal horns and shift of 4th ventricle to right.

b) Post-operative CT scan showing total removal of tumour with return of 4th ventricle to midline.

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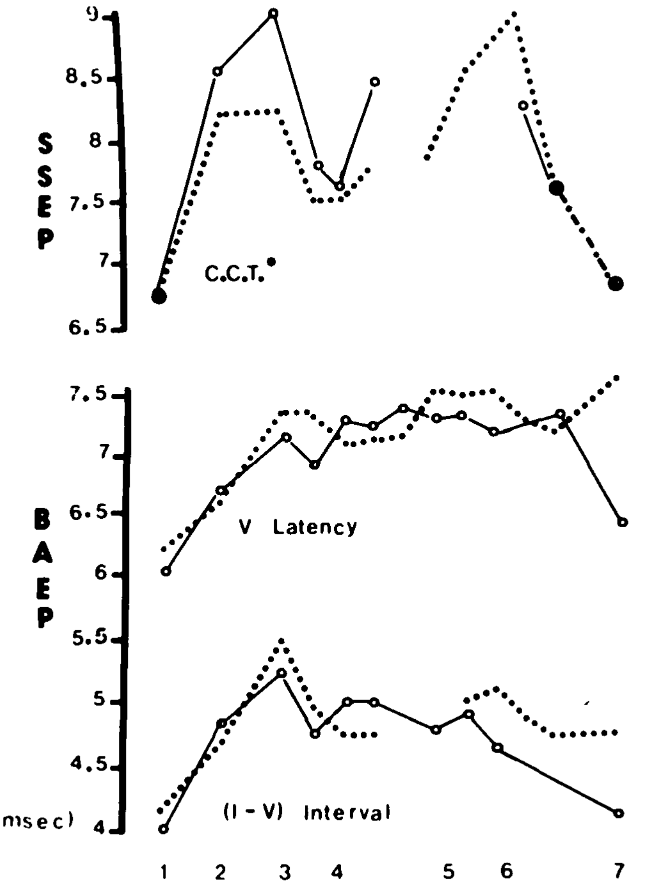

Figure 3 — Graphs (from Case 1) showing changes in central conduction time (CCT) of the somatosensory evoked response (SSEP) and latency of wave V and (1-V) interval of the brainstem auditory evoked response (BAEP) during various stages in the operative procedure in Case 1. Numbers at bottom refer to stages of operation as follows:

1. pre-operative baseline; 2. post intubation; 3. dural opening; 4. tumour resection; 5. release of retraction; 6. dural closure; 7. postoperative recording.

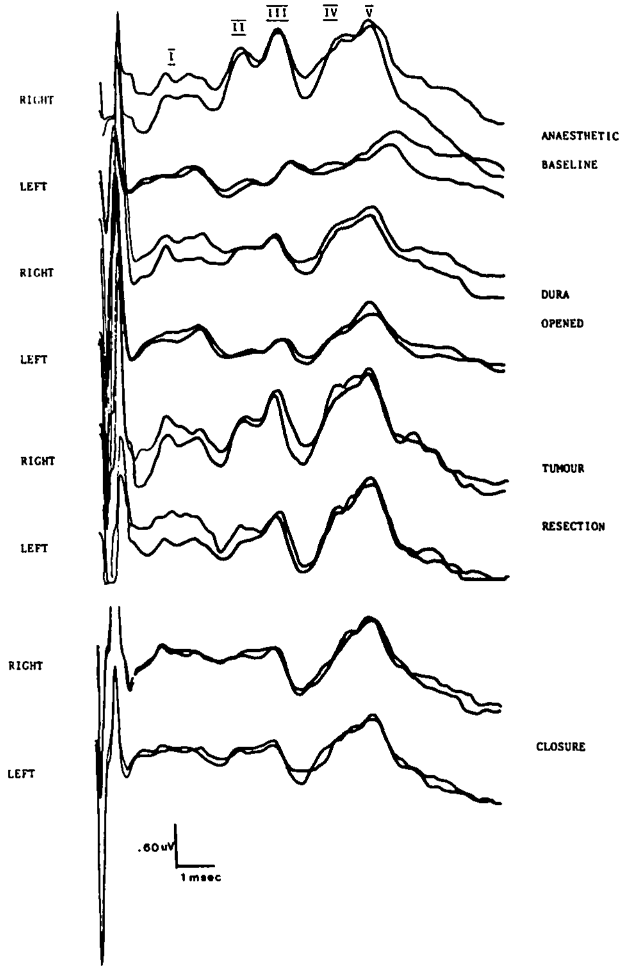

Figure 4 — Brainstem auditory evoked responses in Case 2 during various stages in operative procedure. Anesthetic baseline recording shows significant asymmetry in left sided response with prolongation of wave V and I-V interpeak latency and decrease in amplitude. Improvement in the left-sided response was seen on dural opening with bilateral normal responses following tumour removal.

Table 2: Grading of Intraoperative Somatosensory Evoked Potential Changes

Grade	Criterion
	(Changes from anesthetic baseline)
I	No change
II	↑ CCT < 1.0 msec. IHD < 0.5 msec. ↓ amplitude 50% (N_{20} wave)
III	↑ CCT > 1.0 msec. IHD ⩾ 1.0 msec. ↓ amplitude 50% (N_{20} wave)
IV	loss of N_{20} wave

CCT — central conduction time
IHD — interhemispheric difference

Discussion

With advances in instrumentation and microsurgical techniques, a more aggressive approach is being taken with many intracranial lesions. There is a need to monitor neurological function closely during such major neurosurgical procedures, to reduce the risk of injury to neural structures. The use of SEP monitoring offers promise in this regard.

To date, BAEP, visual and SSEP have been recorded intraoperatively. SSEPs have also been used during spinal operations and more recently, during neurovascular surgery.[6,7] BAEPs have been most frequently used during posterior fossa operations.[8,9,10] While dramatic results in individual cases have been reported, they remain anecdotal for the most part.

Our own experience in over 200 patients leads us to conclude that intraoperative monitoring of SEPs can be valuable in minimizing direct or ischemic injury to specific sensory pathways and adjacent structures. The development of a grading system for SEP changes has been important in determining quantitative tolerance limits for intraoperative SEP alterations.

Presently, we use changes in SSEP parameters as the only criteria for tolerance to carotid clamping and the need for temporary shunting during carotid endarterectomy. While our experience with the use of this technique in brain tumour surgery is limited, our results are encouraging. However, there are limitations in monitoring only one sensory modality.[11] In extensive tumours of skull base and posterior fossa, we now routinely monitor both SSEPs and BAEP. Measuring these two modalities simultaneously provides complementary information and improves the sensitivity of the technique.[11]

The important questions of whether intraoperative changes in SEP can accurately and reliably predict postoperative deficit in neurological function, and whether anesthetic or surgical action in response to SEP changes can prevent such deficits remain to be answered. Only with accumulation of further experience, large patient series and proper data analysis based on well-designed protocols will the ultimate role of this technique be defined.

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