Evoked potential monitoring during posterior fossa aneurysm surgery: a comparison of two modalities

Pirjo H. Manninen MD FRCPC,
Steven Patterson MD FRCPC, Arthur M. Lam MD FRCPC,
Adrian W. Gelb MB ChB FRCPC, William E. Nantau BSc

The purpose of this study was to compare and assess the ability of two different evoked potential (EP) modalities, median nerve somatosensory evoked potentials (SSEP) and brainstem auditory evoked potentials (BAEP) in monitoring for cerebral ischaemia and in predicting neurological outcome during posterior fossa aneurysm surgery. During 70 procedures, patients were monitored with both SSEP and BAEP. Temporary occlusion of an artery was used in 52 patients and permanent occlusion in 21 patients. A change was defined as a greater than 50% decrease in amplitude and/or an increase in latency greater than 1 msec of the N20 (cortical waveform) for SSEP monitoring and of the fifth peak for BAEP monitoring. Neurological assessment of the patient was performed immediately on emergence, after 24 hr and at the time of discharge. In total, 14 patients had an SSEP change which predicted a neurological deficit in eight patients (57%). Ten patients had a change in BAEP; six had a neurological deficit (60%). Five patients had a change in both, two had a deficit (40%). The incidence of false negative results (a neurological deficit but no EP change) for both modalities was 20% (SSEP 47%, BAEP 60%). The incidence of false positive results (an EP change but no deficit) was 13% overall (SSEP 11%, BAEP 7%). All patients who had a permanent EP change developed a neurological deficit. We did not find a difference in the ability of SSEP compared with BAEP in predicting neurological deficits but, using both modalities, the incidence of false negative results was decreased. In conclusion, dual modality monitoring should be used whenever possible as neither modality alone was better than the other in detecting cerebral ischaemia and in predicting neurological deficits.

Cette étudè vise à évaluer et comparer la capacité de deux méthodes de mesure des potentiels évoqués (EP) pour le monitorage de l'ischémie cérébrale et pour la prédiction du pronostic neurologique pendant la chirurgie de la fosse postérieure: les potentiels évoqués somatosensoriels du nerf médian (SSEP) et les potentiels évoqués auditifs du tronc cérébral. Au cours de 70 interventions, on monitorise à la fois les SSEP et les BAEP. L'occlusion temporaire d'une artère est réalisée chez 52 patients et l'occlusion permanente chez 21 patients. Un changement est défini comme une baisse de l'amplitude de plus de 50% avec ou sans une augmentation de la latence de 1 msec de N20 (forme d'onde corticale) pour le moniteur de SSEP et du cinquième pic pour le moniteur de BAEP. Une évaluation neurologique est faite dès le réveil, après 24 h et au moment du congé. Au total, 14 patients ont montré des SSEP altérés qui ont permis la prédiction d'un déficit neurologique chez huit patients (57%). Dix patients ont montré des altérations de BAEP; six avaient un déficit neurologique (60%). Cinq patients avaient des altérations des deux; deux patients avaient un déficit (40%). L'incidence de faux négatifs (un déficit neurologique sans altération d'EP) pour les deux méthodes était de 13% (SSEP 11%, BAEP 7%). Tous les patients avec un changement permanent de l'EP ont eu un déficit neurologique. Nous n'avons pas trouvé de différence entre la capacité des SSEP comparativement aux BAEP, pour la prédiction des déficits neurologiques, mais l'utilization concomitante des deux méthodes permet de diminuer l'incidence des faux négatifs. En conclusion, pour détecter l'ischémie cérébrale, comme une des méthodes seule est meilleure que l'autre, les deux méthodes devraient être associées lorsque possible.

Key words
ANAESTHESIA: neurosurgical;
MONITORING: evoked potentials, somatosensory, brainstem auditory;
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From the Department of Anaesthesia, University Hospital, London, Ontario.

Address correspondence to: Dr. Pirjo H. Manninen, Department of Anaesthesia, Toronto Western Division, The Toronto Hospital, 399 Bathurst St., Toronto, Ontario, Canada M5T 2S8.

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During posterior fossa aneurysm surgery, surgical manipulation may result in ischaemic insults to the brainstem. Evoked potential monitoring reflects the functional integrity of the neuronal pathways monitored and has been used to monitor for cerebral ischaemia.[1-3] Early detection of cerebral ischaemia may be beneficial in allowing implementation of therapy or alteration of surgical approach to prevent neurological deficits. Somatosensory evoked potentials (SSEP) have been shown to be feasible during aneurysm surgery but it has been questioned whether they are helpful during posterior fossa aneurysm surgery as ischaemia may occur in areas that are not monitored by this pathway.[4-7] In contrast, brainstem auditory evoked potentials (BAEP) have been reported useful during basilar and vertebral artery aneurysm surgery.[8] The surgical treatment of many aneurysms includes temporary and occasionally, permanent occlusion of a major feeding artery.[9,10] The duration of temporary occlusion is often very short, and with evoked potential monitoring, there may be time to test only one modality. Thus, the purpose of this study was to compare two different evoked potential modalities, median nerve SSEP and BAEP, during posterior fossa aneurysm surgery to determine if one modality was better in monitoring for cerebral ischaemia and in predicting neurological outcome.

Methods

Approval was obtained from the institutional ethics review board. Evoked potential monitoring was routinely performed on all patients undergoing cerebral aneurysm surgery whenever equipment and technical help were available. Sixty-seven patients undergoing posterior fossa surgery for treatment of an aneurysm of the basilar vertebral circulation during 1985–1991 had both SSEP and BAEP monitoring and were included in this study. There was a total of 70 procedures as three patients underwent two separate procedures each.

The patients were all unpremedicated. Induction of anaesthesia was achieved with fentanyl 2–5 $\mu g \cdot kg^{-1}$ or sufentanil 0.5–1 $\mu g \cdot kg^{-1}$, thiopentone 4–6 $mg \cdot kg^{-1}$ and lidocaine 1–1.5 $mg \cdot kg^{-1}$. Tracheal intubation was facilitated with succinylcholine 1–1.5 $mg \cdot kg^{-1}$ or a nondepolarizing muscle relaxant. Maintenance of anaesthesia consisted of 50% nitrous oxide, 50% oxygen or air/oxygen (FIO_2 of 0.5–0.6), isoflurane, supplemental narcotics and muscle relaxants. All patients received 1–2 $g \cdot kg^{-1}$ mannitol 20%. Routine monitors included an ECG, intraarterial, central venous, and urinary catheters and temperature monitoring by an oral pharyngeal or oesophageal probe. Patients were monitored with an end-tidal capnogram and a pulse oximeter when this became available. Arterial blood gases were measured in all patients to ensure adequate oxygenation and appropriate $PaCO_2$. A lumbar subarachnoid catheter was inserted for the drainage of cerebral spinal fluid where indicated by the surgeon. Isoflurane-induced hypotension was used in some patients during dissection of the aneurysm or for clipping but was not used during temporary arterial occlusion.

A Nicolet CA 1000 averager or a Pathfinder 1 was used to obtain the evoked potentials. Standard stimulating and recording variables were used.[6,8] Scalp electrodes were placed according to the International 10–20 system for electroencephalographic monitoring. During monitoring, physiological factors such as temperature, blood pressure, depth of anaesthesia, and $PaCO_2$ were maintained in a steady state as much as possible. Control readings were taken after induction of anaesthesia and during stable anaesthesia. Bilateral recordings were obtained for both median nerve SSEP and BAEP. Each patient served as his or her own control for comparison of any intraoperative changes. Both modalities were monitored throughout the periods of dissection, temporary occlusion of the feeding artery and clipping of the aneurysm. Duplicate tracings were performed to ensure reproducibility of the waveform and of changes. The amplitude and latency of N20 (the first negative peak on the cortical waveform) and N13 (the first negative peak of the peripheral waveform) were measured. For analysis of SSEP recordings, both the amplitude and the central conduction time (CCT) (N20–N13) were used. The SSEP changes that were considered to be important in our study included a decrease in the amplitude of N20 greater than 50% and/or an increase in CCT of greater than 1.0 msec. For analysis of BAEP recordings, the amplitude and latency of all the peaks were measured. The BAEP changes considered to be important included a decrease in amplitude of the fifth (or fourth-fifth complex) peak greater than 50% and/or an increase in latency of the fifth peak or of the interpeak latency (1–5) greater than 1 msec. Changes in SSEP and BAEP could be unilateral or bilateral since it was difficult to predict if one or both sides were affected by the occlusion or manipulation of the brainstem. The changes were further classified as permanent if the change persisted to the end of the procedure, and transient if the change recovered with release of retraction or temporary occlusion. The neurological outcome of the patient was assessed postoperatively in the recovery room, 24 hr after surgery and at the time of discharge from hospital and this was correlated with the evoked potential results. The neurological assessments were performed by both the neurosurgeon and the nurse and documented in the patient's chart. The neurosurgeons, but not the nurses, were aware of any intraoperative evoked potential changes. Any new neurological deficit that was not present preoperatively was documented and described as transient if the patient recovered

TABLE I Location of aneurysms

Arterial location	*Number of patients*
High	
Basilar bifurcation	23
Superior cerebellar	9
Mid	
Basilar trunk	5
Low	
Vertebral-basilar junction	18
Anterior inferior cerebellar	2
Posterior inferior cerebellar	13
	70

TABLE II Evoked potential changes and neurological outcome

Evoked potential changes	*No deficit*	*Neurological deficits*	
		Transient	*Permanent*
SSEP			
Transient ($n = 11$)	6	3	2
Permanent ($n = 3$)	0	0	3
BAEP			
Transient ($n = 8$)	4	3	1
Permanent ($n = 2$)	0	0	2
*Both**			
Transient ($n = 4$)	3	1	0
Permanent ($n = 1$)	0	0	1
No EP change ($n = 51$)	48	2	1

*These patients are also included in the separate SSEP & BAEP groups.

completely within 24 hr of surgery and permanent if the same deficit was present at the time of discharge. A false negative result occurred when there was a new neurological deficit immediately postoperatively but no intraoperative evoked potential change. A false positive result was defined as the patient awakening with no new neurological deficits despite the occurrence of an evoked potential change intraoperatively. Chi square analysis and the Fisher's exact test were used to assess statistical significance. $P < 0.05$ was considered to be significant.

Results

A total of 70 procedures where both SSEP and BAEP monitoring were used were included in this study. The locations of the aneurysms are shown in Table I. The mean age of the patients was 50 ± 11 yr (range 21–75 yr). There were 46 female and 24 male patients. Temporary occlusion of the feeding artery was used in 52 patients with a total of 86 separate occlusion episodes with an average duration of 4.5 ± 5.4 min, (range 0.5 to 35 min). The surgical treatment of the patients included clipping of the aneurysm in 44 patients, permanent occlusion of a major artery in 21 patients, and in five patients no treatment was possible. Two patients had abnormal control SSEP tracings which made interpretation difficult. In some patients, the BAEP was abnormal on one side due to neurological deficits preoperatively such as brainstem compression by a giant aneurysm but in all patients, at least on one side the BAEP was adequate for monitoring. In many patients there was insufficient time to perform both evoked potential modalities during each temporary occlusion. As there usually were multiple temporary occlusions in these situations, the other modality was done during the subsequent occlusion.

Postoperatively, 15 patients had a new neurological deficit (Table II). Seven patients had transient hemiparesis. Eight patients had permanent deficits which consisted of hemiplegia (four patients), brain stem deficits (loss of the gag reflex) in two patients and both hemiplegia and loss of gag reflex in two patients.

SSEP changes

In total, 14 patients had SSEP changes (Table II). An SSEP change predicted a neurological deficit in eight patients (57%). The type of change that predicted a neurological deficit included amplitude ($n = 3$), CCT ($n = 3$) and both amplitude and CCT ($n = 2$). There was no difference between the types of change. All patients who had a permanent SSEP change developed a neurological deficit. When the patients were classified according to the anatomical location of their aneurysm (see Table I), the SSEP changes predicted a neurological change in 57% of the high, 66% of the mid and 50% of the low location aneurysms. Calculations of the relative sensitivity and specificity of SSEP and BAEP in their ability to detect postoperative neurological deficits are shown in Table III.*

BAEP changes

Ten patients had a change in their BAEP. Six (60%) of these patients developed a neurological deficit postoperatively. All patients who had a permanent BAEP change had a permanent neurological deficit. The changes in

*Sensitivity and specificity are standard analytical methods used to assess the validity of any diagnostic test in comparison with a gold standard.

$$\text{sensitivity} = \frac{\text{true positives by gold standard}}{\text{true positives + false negatives}}$$

$$\text{specificity} = \frac{\text{true negatives by gold standard}}{\text{true negatives + false positives}}$$

TABLE III Sensitivity and specificity of evoked potential changes to predict a neurological deficit – classified according to the location of aneurysm

	High $n = 32$	*Mid* $n = 5$	*Low* $n = 33$	*All* $n = 70$
SSEP				
Sensitivity	50%	100%	40%	53%
Specificity	88%	67%	93%	89%
BAEP				
Sensitivity	25%	50%	60%	40%
Specificity	92%.	100%	93%	93%

BAEP consisted of a decrease in amplitude and increase in latency of the fifth peak. The incidence of neurological deficits that were predicted by a BAEP change according to the anatomical location of the aneurysm is for high 50%, mid 100%, and low aneurysms 60%. Table III shows the sensitivity and specificity of BAEP changes in predicting a neurological deficit. There were no significant differences.

SSEP and BAEP changes

Five patients had a change in both SSEP and BAEP. These patients are also included in the two groups above and shown in Table II. Two patients (40%) had neurological deficits.

Temporary occlusion of the feeding artery was used in 52 patients. This involved the basilar artery for the high and mid location aneurysms ($n = 36$) and one or both of the vertebral, the anterior inferior cerebellar or the posterior inferior cerebellar arteries for the low basilar or vertebral artery aneurysms ($n = 16$). Of the 17 patients who did not have temporary occlusion at any time, four patients had changes in their evoked potentials during retraction of the brainstem. This included transient SSEP changes in three patients, of whom two developed transient neurological deficits and one permanent SSEP change that was associated with a permanent deficit.

Discussion

Monitoring of SSEP and BAEP, especially during the temporary occlusion of a major feeding artery, was both feasible and useful during posterior fossa aneurysm surgery in our study. It has been shown that SSEP are affected when the cerebral blood flow decreases below a critical threshold.[1] The surgical technique for treatment of aneurysms frequently includes the temporary arterial occlusion of a feeding vessel to create regional hypoperfusion rather than the use of induced systemic hypotension. Some aneurysms can not be clipped and the treatment may involve the permanent occlusion of the feeding artery. In our series 21 patients were treated in this fashion. In these cases monitoring of evoked potentials was used to assess the safety of permanent occlusion.

Intraoperative SSEP monitoring during temporary occlusion has been shown to be beneficial in predicting neurological outcome for aneurysms in the anterior circulation, but their value in posterior fossa surgery is unclear. Little *et al.* monitored 16 patients with posterior circulation aneurysms:[4] ten had both BAEP and SSEP monitoring. Monitoring with SSEP and BAEP failed to identify a neurological deficit in four patients (25% false negative results). The authors concluded that evoked potential monitoring was not helpful in reducing morbidity during basilar aneurysm surgery as the ischaemic event may involve a small area that is not in the neural pathway being monitored. One patient in their study with a basilar bifurcation aneurysm had a 35 min occlusion of the basilar artery. This patient showed transient changes in SSEP but not in BAEP and woke up with a neurological deficit. This difference could be explained on the basis of the anatomical location of the arterial supply of the two pathways at the mid-brain level.

Friedman *et al.* also found SSEP and BAEP monitoring unhelpful during basilar aneurysm surgery.[5] The authors used BAEP monitoring for four basilar, one anterior inferior cerebellar and one posterior inferior cerebellar artery aneurysm. Three patients had neurological deficits that were not predicted by a change in their BAEP (50% false negative result). The authors concluded that the vascular distribution at risk for basilar bifurcation aneurysms does not reliably include either the BAEP or the SSEP pathway and that during arterial occlusion the affected distribution is determined by many other factors including collateral blood supply and blood pressure.

Schramm *et al.* found that there were limitations to the use of SSEP in certain anatomical locations.[7] They had seven patients with a basilar and six patients with posterior inferior cerebellar artery aneurysms. False negative results occurred in two patients (15%) with basilar bifurcation aneurysms. Another patient developed repeated transient SSEP changes during temporary clipping of the basilar artery and woke up with a neurological deficit.

In a previous study, we also found that monitoring SSEP during temporary occlusion in aneurysm surgery in the basilar vertebral circulation predicted only 38% of the neurological deficits.[6] This was in contrast to a 75% prediction rate for aneurysms of the middle cerebral and carotid artery. In another report from our institution, we found BAEP monitoring to be useful during basilar vertebral aneurysm surgery especially for assessing the safety of permanent occlusion.[8]

In this series, both monitoring modalities were used in all patients, but a criticism of our study is that frequently, due to time limitations, we were unable to perform both modalities during one temporary occlusion. Many of our temporary occlusion times were of one minute or less in duration. Due to the lack of suitable technical equipment, we were unable to perform both modalities at the same time. Thus, we may have missed changes in one modality. This is particularly true for transient changes. However, with a change that persisted, both modalities would have been performed repeatedly and significant changes ascertained.

A false negative result may occur when the ischaemic zone is not directly monitored by the pathway of the modality of the evoked potential being used or if ischaemia develops after the monitoring has been stopped. The overall incidence of false negative results (there was no change in either SSEP or in BAEP) was 20% in our study. For SSEP changes alone the incidence was 47%, and for BAEP it was 60%. Thus it may be useful to use dual modality monitoring to increase the ability of evoked potentials to predict neurological deficits.

False positive results need to be considered with respect to the duration of the evoked potential changes. The total incidence of false positive results in our study was 13% (for SSEP alone 11% and BAEP alone 7%), but all were transient. All patients who had a permanent evoked potential change developed a neurological deficit. Frequently, there were intraoperative changes that occurred during temporary occlusion but recovered with the release of the occlusion. Likewise changes may occur during retraction of the brainstem and recover with the release of retraction. The duration of ischaemia that results in an evoked potential change predictive of a neurological deficit postoperatively is unknown. There is the potential for existence of an ischaemic state where blood flow is inadequate for electrical function but enough to sustain viability should normal blood flow be restored in time.[1] Thus, a transient change cannot be used to predict a definite neurological deficit postoperatively.

The purpose of our study was to assess which of the modalities would be better able to detect cerebral ischaemia and predict postoperative neurological deficits in posterior fossa surgery. We divided the aneurysms anatomically into three groups as temporary occlusion would involve different arteries, and thus affect different areas of the brainstem. For clipping of the high location aneurysms, mostly at the basilar bifurcation, the basilar artery was occluded. This was in contrast to the low aneurysms that were located either on the vertebral system or at the vertebral basilar junction and in all these patients, the temporary occlusion was performed by occluding one or both vertebral arteries. The five patients that were classified mid location had aneurysms of the trunk of the basilar artery. We did not find a difference in the ability of SSEP compared with BAEP to predict neurological deficits in any of the three groups. There was a tendency for the low aneurysms to have a higher sensitivity for BAEP monitoring in predicting neurological deficit in contrast to the SSEP monitoring having a higher sensitivity for monitoring of the high location aneurysms, but this was not statistically significant. This may be accounted for by the small number of patients in our study who had evoked potential changes (19), or who developed a neurological deficit (15).

In our study, the changes in SSEP and BAEP, whether they were of amplitude or latency, did not show a difference in their ability to predict neurological outcome. Thus, we are unable to conclude from our study which type of change is the better monitor.

Anaesthetics affect evoked potential monitoring and this has been well studied.[11] In all our patients, we attempted to keep a steady state of anaesthesia and physiological factors at all times of monitoring, especially immediately before and during temporary occlusion so that the patient could act as his or her own control. Whenever a change in the evoked potentials occurred, if the surgical intervention could not be stopped, the anaesthetist would ensure that blood pressure was in the normal range, but there was no attempt made to increase blood pressure pharmacologically.

In conclusion, monitoring of both modalities is possible during posterior fossa aneurysm surgery. A limitation is the time factor during temporary occlusion as one is unable to do both modalities at the same time. This technical handicap can be resolved with newer equipment that allows simultaneous dual modality monitoring. Which modality better predicts a neurological deficit and thus is most useful in monitoring the patient, cannot be definitely stated from our study. Both techniques were associated with false positives and false negatives but using both modalities should help to decrease the incidence of false negative results.

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