Neuroanesthesia and Intensive Care

Posterior tibial nerve and median nerve somatosensory evoked potential monitoring during carotid endarterectomy

[Le monitorage du potentiel évoqué somato-sensitif du nerf tibial postérieur et du nerf médian pendant l'endartériectomie de la carotide]

Pirjo Manninen MD FRCPC,* Roger Sarjeant BS CNIM,† Mital Joshi BSCH MSc*

Purpose: Somatosensory evoked potential (SSEP) monitoring using the median nerve (MN) modality during carotid endarterectomy is well established. This study assessed the usefulness of monitoring the posterior tibial nerve (PTN) SSEP as an adjunct to MNSSEP for detection of cerebral ischemia and as an indicator for the insertion of a shunt in patients undergoing a carotid endarterectomy.

Methods: All patients undergoing carotid endarterectomy during three years who had routine bilateral MNSSEP were also monitored with bilateral PTNSSEP. Patients received a shunt if there was a significant change (> 50% decrease in amplitude of cortical peak (N20) in the MNSSEP after cross clamping. The incidence, timing, and duration of all PTNSSEP changes were compared to MNSSEP changes.

Results: One hundred fifty-three patients were studied. Significant changes in MNSSEP after cross clamp lead to insertion of a shunt in six patients. Changes in PTNSSEP occurred at almost the same time in three patients, four minutes before MNSSEP in one, three minutes later in one and no change in one patient. Good quality baseline tracings were obtained in 99% MNSSEP as compared to 88% PTNSSEP ($P < 0.05$). New postoperative neurological deficits occurred in four patients (2.6%), only one had significant evoked potential changes.

Conclusion: Monitoring of PTNSSEP is feasible and may be considered for an adjunct to MNSSEP or as an alternative modality if there are difficulties with MNSSEP. However, there may be a greater incidence of poor quality baseline tracings for PTNSSEP.

Objectif : *Le monitorage du potentiel évoqué somato-sensitif (PESS) selon la modalité du nerf médian (NM) pendant l'endartériectomie de la carotide est bien connu. Nous voulions évaluer l'utilité du monitorage du PESS du nerf tibial postérieur (NTP) comme complément au PESSNM pour la détection d'ischémie cérébrale et comme indicateur pour l'insertion d'un shunt pendant une endartériectomie de la carotide.*

Méthode : *Pendant trois ans, les patients devant subir une endartériectomie carotidienne et qui avaient un PESSNM de routine ont aussi eu un PESSNTP bilatéral. Ils ont reçu un shunt s'il y avait un changement significatif (> 50 % de diminution de l'amplitude du pic cortical (N20) du PESSNM après le clampage carotidien. L'incidence, l'ordre de déroulement et la durée des changements de PESSNTP et de PESSNM ont été comparés.*

Résultats : *L'étude a porté sur 153 patients. Des changements significatifs de PESSNM survenus après le clampage croisé ont mené à l'insertion d'un shunt chez six patients. Des changements de PESSNTP sont survenus presque au même moment chez trois patients, quatre minutes avant le PESSNM chez un patient, trois minutes après chez un autre et aucun changement n'a été noté chez un troisième. Des tracés de base de bonne qualité ont été obtenus chez 99 % des PESSNM comparés à 88 % de PESSNTP ($P < 0,05$). De nouveaux déficits neurologiques postopératoires ont été observés chez quatre patients (2,6 %) dont un seulement présentait des changements significatifs de potentiel évoqué.*

Conclusion: *Le monitorage du PESSNTP est faisable et peut être considéré comme complément du PESSNM ou comme une modalité de remplacement devant des difficultés de PESSNM. Toutefois, il pourrait y avoir une plus forte incidence de tracés de base de pauvre qualité pour le PESSNTP.*

From the Departments of Anesthesia* and Neurosciences,† Toronto Western Hospital, University Health Network, University of Toronto, Toronto, Ontario, Canada.

Address correspondence to: Dr. Pirjo Manninen, Department of Anesthesia, Toronto Western Hospital, 399 Bathurst Street, Toronto, Ontario M5T 2S8, Canada. Phone: 416-603-5118; Fax: 416-603-6494; E mail: Pirjo.Manninen@uhn.on.ca

Sources of financial support: none.

Accepted for publication April 7, 2004.

Revision accepted August 2, 2004.

THE use of somatosensory evoked potential (SSEP) monitoring during carotid endarterectomy is well established in many institutions.[1–17] SSEP monitoring helps to assess the adequacy of collateral circulation during cross clamping of the carotid artery and the need for insertion of a shunt. Median nerve SSEP (MNSSEP) reflects the activity of the primary sensory cortex, which is supplied by the middle cerebral artery. As occlusion of the carotid artery will affect the blood supply to this area, the SSEP modality used during carotid endarterectomy has traditionally been the MN.[1–17] During a transient ischemic attack (TIA) or a stroke, patients usually exhibit neurological deficits involving the upper extremity but may also have deficits of the lower extremity. Posterior tibial nerve SSEP (PTNSSEP) monitoring has been used as a monitor of the anterior cerebral artery territory.[18] This area may also be affected during the occlusion of the carotid artery. The purpose of this study was to assess the usefulness of monitoring the PTNSSEP as an adjunct to MNSSEP for detection of cerebral ischemia and as an indicator for the insertion of a shunt in patients undergoing a carotid endarterectomy.

Methods

With the approval of the local Ethics Board, all patients undergoing a carotid endarterectomy during a three-year period (2000–2003) were studied. In our institution it is standard practice to monitor all patients during their carotid endarterectomy with bilateral MNSSEP. A shunt is inserted if there is a greater than 50% decrease in the amplitude of the cortical N20 peak after cross clamping of the carotid artery. The surgical procedure was conducted in a standard fashion as determined by each surgeon. In addition to bilateral MNSSEP all patients were monitored with bilateral PTNSSEP. No clinical action was taken based on the PTNSSEP monitoring.

All patients received a general anesthetic as determined by the attending anesthesiologist. In addition to standard monitors, an intra-arterial catheter was used for blood pressure measurements. The anesthetic management included the induction of anesthesia with fentanyl, propofol, and rocuronium. Maintenance consisted of nitrous oxide, fentanyl, rocuronium, and isoflurane, sevoflurane, or desflurane. Muscle paralysis was maintained. Blood pressure was maintained at the patient's preoperative normal level and any hypotension was treated with vasopressors, (phenylephrine, ephedrine) and bradycardia was treated with atropine. The temperature and $PaCO_2$ of the patient were both maintained within a normal range.

A trained technologist performed all evoked potential monitoring. The equipment used was an Axon Epoch 2000 neurophysiological recording system (Axon Systems, Hauppauge, NY, USA). This monitor allows for simultaneous asynchronous stimulation and recording of both the MNSSEP and PTNSSEP. Standard parameters were used for both recording and stimulating the upper limb and lower limb SSEP. Subdermal needle electrodes (Rochester Electro-Medical Inc., Tampa, FL, USA) were inserted after the induction of anesthesia and used for both stimulating and recording. The electrode impedance was maintained below 5.0 k ohms and the inter-electrode impedance below 1.0 k ohms. The MNSSEP was stimulated at the wrist with a 250 μsec duration square wave pulse of 20 to 30 mA intensity, 3.1 pulses·sec^{-1}. The PTN was stimulated at the ankle (posterior to the medial malleolus) using the same stimulation parameters. Baseline recordings were acquired soon after the induction of anesthesia and subsequent, comparative recordings were obtained continuously during the procedure. The MNSSEP was recorded from the brachial plexus (Epi-Epc), the upper cervical spine (Cv2-Fpz), and the sensory cortex (CPc-Fpz). The PTNSSEP was recorded from the upper cervical spine (Cv2-Fpz), and the sensory cortex (CPz-Fpz, CPc-Cpi). A common ground electrode was placed on the patient's sternum.

Patient demographic information was documented including the neurological history, reason for surgery and the immediate preoperative neurological status. SSEP data recorded included the measurements of the amplitude and latency of the cortical peaks (N20, P37) for baseline evoked potentials after induction of anesthesia and prior to cross clamping of the carotid artery. The incidence of any changes occurring during the procedure and especially after cross clamping of the carotid artery were documented. The incidence of shunting was documented. The patients were examined on emergence from anesthesia for any change in their neurological status and new postoperative neurological deficits were noted. The incidence, the timing, and the duration of all PTNSSEP changes were compared to MNSSEP changes. Chi-square testing was performed for statistical analysis of the raw data.

Results

All 153 patients who underwent a carotid endarterectomy were included in this study. The mean age ± SD was 68 ± 9 yr, weight 76 ± 14 kg, ASA III (median), range 2 to 4, and there were 54 female and 99 male patients. The indications for surgery included TIA (n = 91), stroke (n = 52) and asymptomatic carotid stenosis (n = 10). The degree of stenosis of the ipsi-

TABLE Onset and recovery times of significant somatosensory evoked potential (SSEP) changes

Case #	*Time of significant change after cross clamp* *MNSSEP*	*PTNSSEP*	*Time of complete recovery after shunt insertion* *MNSSEP*	*PTNSSEP*	*Neurological deficits*
# 15	8 min	4 min	5 min	25 min	
# 49	5 min	No change	3 min		
# 91	3 min	3 min	15 min	15 min	48 hr
# 108	3 min	3 min	6 min	8 min	
# 136	3 min	6 min	1 min	1 min	
# 148	3 min	1 min	2 min	2 min	
# 151*	18 min	18 min	21 min*	21 min*	

*No shunt was inserted. Cross clamp was removed at 21 min. MNSSEP = median nerve somatosensory evoked potential; PTNSSEP = posterior tibial nerve somatosensory evoked potential.

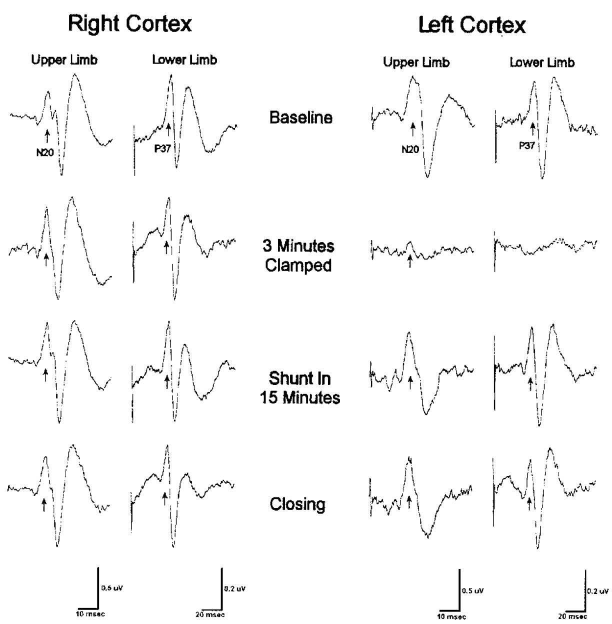

FIGURE 1 Evoked potential tracings during carotid endarterectomy in a 64-yr-old female (# 91) with a history of transient ischemic attack and a 90% stenosis of the left carotid artery. Three minutes after cross clamping of the left carotid artery there was an almost simultaneous and significant change in both cortical tracings of the ipsilateral median and posterior tibial nerves. Both changes recovered slowly after insertion of a shunt. The patient had a new postoperative neurological deficit, weakness of her right arm, which gradually recovered over two days.

lateral carotid artery was 86 ± 11%, 14 patients had previous surgery on the opposite side and 16% had documented bilateral disease. The duration of cross clamping of the carotid artery was 52 ± 18 min.

Good quality bilateral MNSSEP baseline tracings after the induction of anesthesia were obtained in 99% of the patients. In two patients there was absence or poor quality of the MNSSEP waveform on one side due to a previous stroke [ipsilateral to side of surgery (one), contralateral (one)]. In contrast good quality bilateral PTNSSEP baseline tracings were present only in 135 patients [88% ($P < 0.05$)]. Absent or poor baseline tracings occurred bilaterally in 14 patients. The reasons included technical problems (seven), diabetes (four), peripheral vascular disease (two) and leg edema (one). As well in four patients only one side PTNSSEP was useful for monitoring [technical problems ipsilateral (one), contralateral (one); previous amputation, ipsilateral (one), and prepping of the leg for a vein graph, ipsilateral (one)].

Significant MNSSEP changes (a greater than 50% decrease in the cortical peak (N20) after cross clamping of the carotid artery occurred in seven patients (Table). Six of these patients had a shunt inserted by the surgeon. Significant PTNSSEP changes also occurred in five of these patients. No patient had only a PTNSSEP change. The time of onset of each SSEP change varied greatly. In two patients the PTNSSEP changes occurred before there was a change recorded in the MNSSEP. After the insertion of the shunt the SSEP changes recovered rapidly in five patients, but in one patient they persisted for 15 min and this patient had a transient deficit on awakening. In one patient there was a significant SSEP change in both modalities after 18 min of cross clamping, however the procedure was then quickly finished and the evoked potentials recovered immediately with release of the cross clamp at 21 min. The patient had no deficit. In another patient with no SSEP changes the surgeon decided to shunt prophylactically based on the patient's clinical history and the fact that technical problems with the evoked potential monitoring had developed 30 min into the procedure. Examples of the time of onset of the SSEP changes are shown in Figures 1 and 2.

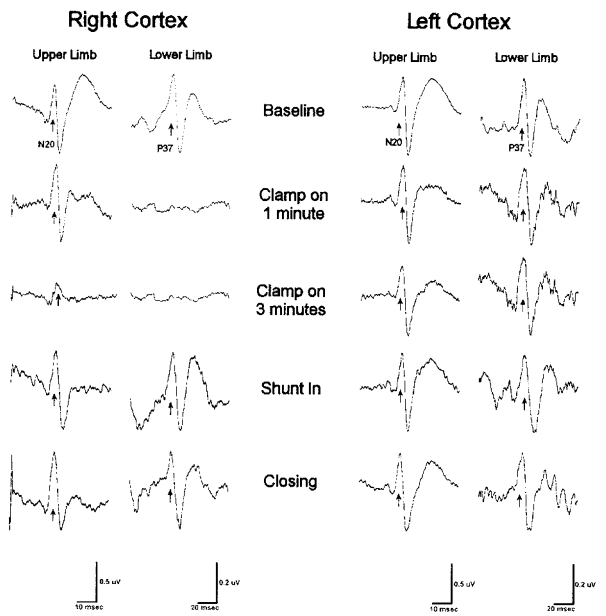

FIGURE 2 Evoked potential tracings during carotid endarterectomy in a 75-yr-old male (# 148) with a history of stroke and a 90% stenosis of the right carotid artery. At one minute after cross clamping of the right carotid artery there was a significant change in cortical tracing of the ipsilateral posterior tibial nerve and at three minutes the median nerve evoked potential changed. Both recovered after the insertion of a shunt. The patient had no postoperative neurological deficits.

Other SSEP changes occurred in seven patients but were classified as non-significant as the decrease in amplitude of the cortical peak (N20 or P37) was less than 50% but greater than 30%. These changes occurred on the side ipsilateral to surgery. Following cross clamping of the carotid artery, three patients had ipsilateral MNSSEP changes that recovered when the patient's blood pressure was increased. In two other patients both MNSSEP and PTNSSEP changes occurred immediately with cross clamp, both recovered when the blood pressure was increased. Two patients with very labile blood pressure had repeated decreases in amplitude in both ipsilateral MNSSEP and PTNSSEP whenever the blood pressure was low, but had rapid recovery with elevation of the blood pressure. None of these patients had any postoperative neurological deficit.

New postoperative neurological deficits occurred in four patients. One patient who had received a shunt and had prolonged changes in both MNSSEP and PTNSSEP woke up with a deficit that persisted for 48 hr. Two patients who had transient deficits (lasting less than 24 hr) had had no intraoperative SSEP changes. One other patient who had no significant evoked potential changes woke up with a major persistent deficit (hemiplegia and aphasia). Patients were discharged from hospital at two days (median), (range 1–32). Overall the outcome of the patients at discharge from hospital was good for all except three who had cardiorespiratory complications and one patient who died from intracranial hemorrhage that occurred on day three postoperatively.

Discussion

In this study we found that monitoring of the PTNSSEP was feasible and potentially useful as an adjunct to MNSSEP. We did however find that there were more difficulties with the use of PTNSSEP than with MNSSEP. The usefulness of SSEP monitoring depends on the ability to have good baseline tracings for each patient from which to interpret any changes during the procedure. We had more technical difficulties with PTNSSEP. The reason for this in all patients was not clear though the influence of medical diseases, such as peripheral vascular disease, and neuropathies associated with diabetes, was clearly an issue for some patients and may have been an additional factor for others.

Though there is an associated risk of cerebral ischemia during carotid endarterectomy, there is controversy regarding the need for monitoring and there is no consensus on the most appropriate monitor.[1–14] The decision to insert a shunt during cross clamping of the carotid artery is also controversial and each surgeon or institution has its own criteria.[1,4–13,15,16] Even when using SSEP monitoring, there are no universally recognized criteria for a significant change.[2–5,7–16] However, the most commonly accepted and used is a greater than 50% decrease in amplitude of the cortical peak (N20) of the MN. In our study, the patients received a shunt on the basis of this change in MNSSEP. The number of patients with a significant change requiring a shunt was small (3.9%). All of these patients also had a change in their PTNSSEP except one. The time of onset of a MNSSEP change following cross clamping as well as the recovery of the changes after shunting when compared to the PTNSSEP changes varied. Most changes were close in time, though in one patient there was a very definite earlier change in the PTNSSEP. Some of the explanations of the variation in onset time include the state of collateral circulation and intracranial disease of each patient, as well as the technical aspects of evoked potential monitoring. Even with the use of sophisticated equipment to do simultaneous monitoring of different modalities, interferences may occur causing artifacts that impede monitoring.

SSEP changes were classified as non-significant when the decrease in amplitude of the cortical peak (N20 or P37) was less than 50% but greater than 30%. These changes were ipsilateral to the side of surgery and mostly related to decreases in blood pressure. The change occurred only in the MNSSEP in half of the patients. Because the blood pressure was treated immediately it could be that the change in the PTNSSEP did not have time to develop. As well it is not known whether these changes would have progressed to a significant change if the blood pressure had not been aggressively treated. The influence of anesthetic agents cannot be completely eliminated. However anesthetic agents should affect both ipsilateral and contralateral sides. In our practice whenever there are SSEP changes that occur bilaterally, the anesthetic management of the patient is examined and adjusted if needed.

We did not attempt to assess the relationship of an intraoperative evoked potential change to the occurrence of a postoperative deficit. All patients received a shunt whenever there was a significant evoked potential change after cross clamping, and any other changes of lesser severity were treated by increasing the patient's blood pressure. This could influence the outcome. Overall, new postoperative deficits occurred in four patients (2.6%), only one of whom had significant SSEP changes.

In conclusion the monitoring of PTNSSEP is feasible and may be considered for an adjunct to MNSSEP or as an alternative modality if there are difficulties with MNSSEP during carotid endarterectomy. However there may be a greater incidence of absent or poor quality baseline tracings for PTNSSEP due to the common medical problems that are present in patients undergoing a carotid endarterectomy.

References

1 *Markand ON, Dilley RS, Moorthy SS, Warren C Jr.* Monitoring of somatosensory evoked responses during carotid endarterectomy. Arch Neurol 1984; 41: 375–8.

2 *Schweiger H, Kamp HD, Dinkel M.* Somatosensory-evoked potentials during carotid artery surgery: experience in 400 operations. Surgery 1991; 109: 602–9.

3 *Lam AM, Manninen PH, Ferguson GG, Nantau W.* Monitoring electrophysiologic function during carotid endarterectomy: a comparison of somatosensory evoked potentials and conventional electroencephalogram. Anesthesiology 1991; 75: 15–21.

4 *Haupt WF, Horsch S.* Evoked potential monitoring in carotid surgery: a review of 994 cases. Neurology 1992; 42: 835–8.

5 *Amantini A, Bartelli M, de Scisciolo G, et al.* Monitoring of somatosensory evoked potentials during carotid endarterectomy. J Neurol 1992; 239: 241–7.

6 *Fava E, Bortolani E, Ducati A, Schieppati M.* Role of SEP in identifying patients requiring temporary shunt during carotid endarterectomy. Electroencephalogr Clin Neurophysiol 1992; 84: 426–32.

7 *D'Addato M, Pedrini L, Vitacchiano G.* Intraoperative cerebral monitoring in carotid surgery. Eur J Vasc Surg 1993; 7(Suppl A): 16–20.

8 *Fiori L, Parenti G.* Electrophysiological monitoring for selective shunting during carotid endarterectomy. J Neurosurg Anesthesiol 1995; 7: 168–73.

9 *Horsch S, Ktenidis K.* Intraoperative use of somatosensory evoked potentials for brain monitoring during carotid surgery. Neurosurg Clin N Am 1996; 7: 693–702.

10 *Prokop A, Meyer GP, Walter M, Erasmi H.* Validity of SEP monitoring in carotid surgery. J Cardiovasc Surg 1996; 37: 337–42.

11 *Schwartz ML, Panetta TF, Kaplan BJ, et al.* Somatosensory evoked potential monitoring during carotid surgery. Cardiovasc Surg 1996; 4: 77–80.

12 *Guérit JM, Witdoeckt C, de Tourtchaninoff M, et al.* Somatosensory evoked potential monitoring in carotid surgery. I. Relationships between qualitative SEP alterations and intraoperative events. Electroencephalogr Clin Neurophysiol 1997; 104: 459–69.

13 *Wöber C, Zeitlhofer J, Asenbaum S, et al.* Monitoring of median nerve somatosensory evoked potentials in carotid surgery. J Clin Neurophysiol 1998; 15: 429–38.

14 *Pedrini L, Tarantini S, Cirelli MR, Ballester A, Cifiello BI, D'Addato M.* Intraoperative assessment of cerebral ischaemia during carotid surgery. Int Angiol 1998; 17: 10–4.

15 *Linstedt U, Maier C, Petry A.* Intraoperative monitoring with somatosensory evoked potentials in carotid artery surgery - less reliable in patients with preoperative neurologic deficiency? Acta Anaesthesiol Scand 1998; 42: 13–6.

16 *Manninen PH, Tan TK, Sarjeant RM.* Somatosensory evoked potential monitoring during carotid endarterectomy in patients with a stroke. Anesth Analg 2001; 93: 39–44.

17 *Sbarigia E, Schioppa A, Misuraca M, et al.* Somatosensory evoked potentials versus locoregional anaesthesia in the monitoring of cerebral function during carotid artery surgery: preliminary results of a prospective study. Eur J Vasc Endovasc Surg 2001; 21: 413–6.

18 *Sako K, Nakai H, Kawata Y, Takizawa K, Satho M, Yonemasu Y.* Temporary arterial occlusion during anterior communicating or anterior cerebral artery aneurysm operation under tibial nerve somatosensory evoked potential monitoring. Surg Neurol 1998; 49: 316–23.