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Impact of different perioperative intraluminal shunt insertion methods on final patient outcomes after carotid endarterectomy in a sample of 250 patients

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SOUHRN

Úvod a cíl: Karotická endarterektomie (CEA) je v současné době častým a z hlediska prevence cévní mozkové příhody (CMP) účinným výkonem. Operace v celkové anestezii jsou prováděny ve většině případů za elektrofyziologické peroperační monitorace pacienta s využitím somatosenzorických evokovaných potenciálů (SEP). Standardně se za monitorace SEP při poklesu amplitudy N20/P25 o více než 50 % při třech a více po sobě následujících souborech zavádí zkrat. Operace s použitím zkratu je spojena s vyšším rizikem poškození cévní stěny a s možnou centrální embolizací. Ve snaze minimalizovat počet pacientů se zavedeným intraluminálním zkratem jsme modifikovali kritéria načasování jeho zavedení při monitoraci SEP a tímto způsobem jsme operovaný soubor vyhodnotili.
Metodika: Do studie bylo retrospektivně zařazeno 250 pacientů (171 mužů, 79 žen, průměrný věk 67 let ± 8,55 SD, max. 86 let, min. 45 let) indikovaných k CEA. Zkrat jsme zaváděli až po kompletním vymizení odpovědí SEP bez reakce na anesteziologickou intervenci. Vyhodnotili jsme soubor pacientů operovaných s modifikovaným načasováním zavedení zkratu. Byly zaznamenány a porovnány neurologické komplikace (měřeny změnami v National Institute of Health Stroke Scale [NIHSS]).
Výsledky: V našem souboru bylo operováno 85,51 % pacientů pro symptomatickou stenózu vnitřní karotické tepny (ICA) s dosažením 2,80% 30denní mortality a morbidity (2,0% a 0,8%, tedy 5 a 2 pacienti). Tyto hodnoty jsou z hlediska publikovaných výsledků standardní. Nebyl zaznamenán statisticky významný rozdíl perioperačních neurologických komplikací mezi skupinou SEP pozitivních a SEP negativních pacientů (2,9 % v SEP pozitivní skupině vs. 2,7 % v SEP negativní skupině pacientů, $p = 0,79$). Z tohoto pohledu nejsou SEP jediným faktorem, který dokáže predikovat výsledný neurologický pooperační nález. Pokles odpovědí SEP jsme pozorovali u 68 pacientů (27,2 %). Kompletní vymizení odpovědí s nutností zavedení zkratu jsme zaznamenali v pěti případech (2,0 %).
Závěr: Operace s modifikovaným načasováním zavedení zkratu vedla ke standardním výsledkům. Vzhledem k výše uvedeným skutečnostem a riziku, které je spojeno se zavedením zkratu, je vhodné zabývat se v budoucnu podrobněji načasováním zavedení zkratu ve vztahu k monitoraci SEP a přizpůsobit optimální načasování zavedení zkratu individuálnímu průběhu operace.

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ABSTRACT

Background and purpose: Carotid endarterectomy (CEA) is a common and effective surgical method of stroke prevention. The procedure is performed under general anesthesia and is usually accompanied by simultaneous intraoperative somatosensory evoked potential (SEP) monitoring. If a more than 50% decrease in N20/P25 SEP wave amplitude in 3 or more recordings occurs during surgery, a shunt is inserted. Shunt surgery is associated with higher risk of vessel wall injury and possible central embolization. In an effort to minimize the number of shunted patients, we modified shunt insertion timing criteria according to intraoperative SEP changes and reviewed a sample of patients for whom this modified approach was utilized.

Methods: 250 patients (171 males, 79 females, mean age = 67.00 years ± 8.55 SD, max. 86, min. 45) indicated for CEA were retrospectively enrolled in the study. Shunting criteria included long-term loss of SEP that was not affected by full anesthesia with elevated mean arterial pressure and increased sedation. Neurological complications (measured as changes in NIHSS) were recorded and compared.

Results: The overall incidence of perioperative adverse events (i.e. stroke/death) following CEA was 2.8% (2.0 and 0.8% in 5 and 2 patients, respectively). A drop in SEP was observed in 68 cases (27.2%). Early persistent declines in cortical response amplitude that developed into complete persistent SEP amplitude loss resulted in shunt placement in 5 cases (2.0%). Perioperative neurological complications were observed in all patients and independently of intraoperative SEP response development (2.9% in patients with SEP loss vs. 2.7% in the remainder of the sample, $p = 0.79$)

Conclusion: Surgery with modified shunt insertion timing demonstrated standard results. Due to the potential for vessel wall injury and embolization it is crucial to pay attention to shunt insertion timing in accordance with the individual course of surgery and intraoperative SEP development.

Keywords:
Carotid artery shunting
Carotid endarterectomy
Periprocedural stroke
Somatosensory evoked potentials

Introduction

Carotid endarterectomy (CEA) remains the gold standard treatment for symptomatic internal carotid artery stenosis [1–3]. In an effort to reduce the incidence of adverse events, various approaches to minimize CEA surgical morbidity have been developed [4]. Somatosensory evoked potentials (SEP) appear to be the most cost-effective intraoperative brain monitoring method for use during CEA [5,6]. Pathological intraoperative responses indicate a decline in regional blood perfusion [7]. This usually leads to changes in surgical strategy and, sometimes, shunt placement [8]. Intraoperative use of an intraluminal shunt may reduce the risk of stroke by reducing the compromise of cerebral blood flow. Unfortunately, shunt insertion itself is associated with significant risk of atherosclerotic arterial wall damage and subsequent stroke during carotid endarterectomy [9–11]; even uncomplicated and early shunt insertions can lead to cerebral hypoperfusion and risk of new structural brain lesions [9,10].

Previously published studies have demonstrated the risks associated with shunt insertion [9–12]; thus, we modified timing criteria of the procedure in relation to decreased SEP and evaluated a sample of patients for whom this modified approach was utilized.

Materials and methods

The study includes 250 patients who underwent CEA (171 males, mean age = 67.00 ± 8.55 SD, max. 86, min. 45). Indications for CEA were based on current guidelines [3] with the majority (85.51%) had been indicated for symptomatic stenosis following a stroke. Patient neurological status was evaluated by an independent neurologist through use of the National Institute of Health Stroke Scale (NIHSS) with assessments performed upon admission, the day prior to CEA surgery, upon discharge, and at 30 days postoperatively.

All surgical procedures were performed under general anesthesia. Intravenous heparin (200 IU/kg) was administered at the time of carotid occlusion, and heparin reversal with protamine sulfate was carried out during wound closure. All endarterectomies were microsurgical and were performed by the lead author (P.H.). Somatosensory evoked cortical response to peripheral nerve stimulation was used during all surgeries. SEP stimulation and registration methods were adopted from previous studies [6]. Baseline SEPs were recorded after patients were anesthetized, but prior to the initial incision. SEPs were recorded at one-minute intervals thereafter.

A transient decrease of 50% in the N20/P25 wave (cortical response) amplitude did not trigger a "warning" for the surgeon, whereas a continuous amplitude drop did. If the amplitude continued to decline, an "alarm" was triggered for both the neurosurgeon and anesthesiologist. Following such an "alarm," all possible safety measures were undertaken (i.e. mean arterial pressure was increased to 110 Torr using intravenous ephedrine or norepinephrine and deeper sedation was achieved through increased anesthetic delivery). A persistent loss in cortical response occurring more than five minutes prior to the expected artery declamping resulted in shunt placement. Patients were categorized according to SEP development in SEP positive (warning and alarm patients) or SEP negative groups (patients without a significant SEP decrease).

The study was approved by the institutional review committee and patients gave informed consent prior to CEA. For statistical analysis, a repeated-measures analysis of variance was used with a post-hoc Bonferroni test (ANOVA, Statistica® 7.0; Statsoft, Tulsa, OK, USA). The threshold for significance was set at $p = 0.05$.

Results

SEP monitoring was successful in all 250 patients. The overall incidence of perioperative adverse events (i.e. stroke/death) following CEA was 2.8% (2.0 and 0.8% in 5 and 2 patients, respectively).

The SEP positive group comprised 68 (27%) patients. A "warning" associated with a change in the N20/P25 wave amplitude occurred in 40 (16%) cases, and "alarms" were issued in 28 (11.2%) cases.

In 23 (9.2% of all patients) of the aforementioned "alarm events" declamping was completed less than 5 minutes after the change in SEP. Early persistent declines in cortical response amplitude that developed into complete persistent SEP amplitude loss resulted in shunt placement in 5 cases (2.0%).

Two patients in the SEP positive group suffered from peri-procedural strokes. The first patient developed a change in NIHSS score of +4 points, while the second patient had a change of +2; both changes were still observed at 30 days postoperatively.

In the normal SEP group, 2 patients (0.80%) had early severe post-op neurological signs that persisted more than 30 days after surgery (NIHSS changes of +3 and +8). Two patients (0.80%) suffered from reperfusion syndrome with deep hemispheric bleeding (1 patient died; 0.40%). One patient (0.40%) died after cardiac failure on the tenth postoperative day. The incidence of peri-procedural adverse events was not significantly different between the groups (2.9% in SEP positive vs 2.7% in SEP negative, current effect ANOVA of NIHSS compare: p = 0.79)

Discussion

Opinions regarding intraluminal shunt insertion during carotid endarterectomy in relation to intraoperative SEP monitoring differ according to department preferences. Some surgical groups do not shunt under any circumstances, while other surgical groups do [12–15].

Published study results have clearly shown that intraluminal shunt insertion is associated with high perioperative morbidity. During surgery, the vessel wall can be damaged and central embolization with a greater number of ischemic lesions can occur [9–12]. The prolonged length of the surgery could also be associated with higher risk of neurological complications. On the other hand, surgery without intraluminal shunt insertion and inadequate collateral circulation may cause hemispheric hypoperfusion on the side of the temporarily-clamped ICA. In such cases, use of an intraluminal shunt is a reasonable approach to minimize the risk of neurological deficit. As a result, the majority of neurosurgery departments use intraluminal shunts selectively [9,10]; our department prefers the same method when carotid endarterectomies are performed. The question remains, however, of how to recognize patients for whom shunt insertion would be beneficial in relation to perioperative morbidity. During operations performed under conduction anesthesia, consciousness levels and neurological functions are monitored directly by testing the conscious patient in a verbal manner. During operations performed under general anesthesia, this is not possible. Therefore, various monitoring techniques have been developed, such as back pressure measurement, transcranial Doppler ultrasonography, and electrophysiological monitoring [6,8,16–18]. At present, the most common method is evoked potential monitoring, primarily with SEP of the median nerve [5,6]. The predictive value for neurological deficit risk is a more than 50% decrease in N20/P25 amplitude in 3 or more consecutive records [16,17].

Although carotid endarterectomy is a standardized method, differences in approach exist among departments. Following the common approach, after internal carotid artery clipping, at our department we used to wait 4 minutes for evoked potential monitoring results and, if the amplitude is decreased by more than 50% and is unresponsive to anesthesiologic intervention, we inserted an intraluminal shunt. Since published study results have demonstrated the risks associated with shunt insertion [12,15], we have partially modified the surgical criteria of shunt placement timing. We begin the arteriotomy immediately after internal carotid occlusion, and insert the shunt in cases of complete amplitude loss that is resistant to anesthesiologic intervention. From the point of shunt insertion, various situations may occur during the surgery and different approaches should probably be considered. If SEP signals are lost after plaque removal while suturing the vessel during an uncomplicated carotid endarterectomy, it is preferable to finish surgery without shunt insertion and recover vessel perfusion as soon as possible. If atheromatous plaque extirpation is more complicated or is performed in an unfavorable anatomical region (long and highly located stenosis in the neck with anatomic variants), an intraluminal shunt is inserted during a continuous SEP decrease that is unresponsive to anesthesiologic intervention. Conversely, if absolute loss of SEP occurs during ICA preparation, surgery is cancelled and another intervention can be attempted in the future.

Observations regarding perioperative morbidity were based on major studies conducted at the end of the previous century [19–21]. At present, most neurosurgery departments report improved results [6,9,10]. Previous observations of 6% mortality and morbidity in symptomatic patients and 3% mortality in asymptomatic patients are too high in relation to recently published results. Perioperative morbidity and mortality of 3% of the patients in mixed cases of asymptomatic and symptomatic stenosis, in patients who underwent surgery better reflects the current situation. In our patient sample, 85.51% had symptomatic ICA stenosis and a 2.80% 30-day mortality and morbidity was achieved. This is standard in terms of results published in the literature. No difference was observed in our sample between SEP positive and SEP negative patients with recognized neurological complications (2.9% in SEP positive vs. 2.7% in SEP negative, p = 0.79). For this reason, SEP is not the only factor that can predict final outcomes in post-op neurology patients.

Conclusion

This study demonstrated that is it possible to achieve published results even if shunt insertion timing is modified. We realize that our small patient sample provides limited information and further research is needed. The importance of intraoperative SEP monitoring during carotid endarterectomy is unquestionable. Given the results presented in this study, we suggest a greater focus on

the criteria of shunt insertion timing. The impact of a decrease in SEP amplitude during different phases of surgery, hypoperfusion velocity, and other aspects that could determine shunt insertion timing more precisely must be studied further to develop a truly patient-specific approach during CEA.

Conflict of interest

The authors declare no financial or other conflicts of interest.

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Ethical statement

Authors state that the research was conducted according to ethical standards.

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