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Application of intraoperative electrophysiological monitoring in vertebral canal decompression surgery for acute spinal cord injury

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Abstract

Objective: This study aimed to evaluate the joint monitoring of somatosensory evoked potentials (SEPs) and motor evoked potentials (MEPs) in vertebral canal decompression surgery for acute spinal cord injury.

Methods: Twenty-four patients, who were admitted to the hospital for the surgical treatment of spinal cord injury with SEP and MEP monitoring, were assigned to the intraoperative monitoring group (group I). In addition, 24 patients who were admitted to the hospital for the surgical treatment of spinal cord injury without SEP or MEP monitoring were assigned to the control group (group C).

Results: In group I, there were significant changes before and after decompression surgery in the P40 latency and amplitude, and in the latency of MEP in the abductor hallucis brevis (AHB), in patients with improved spinal nerve function following surgery. In contrast, there were no significant differences in the P40 latency or amplitude, or the latency of MEP in the AHB, in patients who showed no improvement after surgery.

Conclusion: In vertebral canal decompression surgery for acute spinal cord injury, the application of joint MEP and SEP monitoring can timely reflect changes in spinal cord function.

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Introduction

As a result of spinal canal epidural hematoma, tumor compression, stroke, or traumatic vertebral body laminar fractures, acute spinal cord injury and severe neurological dysfunction can occur. Emergency surgery for vertebral canal decompression is an effective treatment. Because the spinal canal space is narrow, injury and spinal cord postoperative complications can occur in the surgical treatment of spinal canal decompression and internal fixation.[1] To avoid these complications, the intraoperative monitoring of somatosensory evoked potentials (SEPs) and motor evoked potentials (MEPs) can effectively reveal the integrity of somatosensory and movement pathways.[2] SEPs are used to monitor the function of sensory nerve conduction in the spinal cord, while MEPs are used to monitor the function of motor nerve conduction in the spinal cord; SEP and MEP are often jointly monitored.[3] This study analyzed these intraoperative monitoring indicators in patients during surgery for acute spinal cord injury and evaluated the efficacy of this joint monitoring.

Materials and methods

Clinical data

Patients who were admitted to the hospital from January 2008 to December 2013 for the surgical treatment of spinal cord injury with SEP and MEP monitoring were assigned to the intraoperative monitoring group (group I). Patients who were admitted to the hospital from January 2002 to December 2007 for the surgical treatment of spinal cord injury without SEP or MEP monitoring were assigned to the control group (group C). All patients conformed to the neurosurgical diagnostic criteria published by the Ministry of Public Health in 2009. Satisfactory results were not obtained before opening the lamina during surgery. In addition, patients were excluded if they had postoperative severe heart, brain, or organ failure; a history of epilepsy, skull defects, or heart disease; or a pacemaker.

The evaluation of neurological function was performed using the McCormick Scale, and was evaluated before surgery and at 3 months after surgery.

This study was conducted in accordance with the declaration of Helsinki and approved by the Ethics Committee of the Affiliated Hospital of North China University of Science and Technology. Each participant gave written informed consent.

Surgical method

All patients underwent surgical treatment. The preoperative X line lesion-related sections of the spine vertebral plate were positioned and injected with methylene blue. After general anesthesia, patients were placed in the prone position and a posterior median straight incision was made, with the location determined using the markers as the center. The rear structure of the spine was then exposed, and the corresponding spinal section and lamina, or whole lamina, were removed for decompression. Next, the vertebral fracture was located, obviously compressed vertebral bodies were partially removed, and any necessary pedicle or lateral mass screw fixations were performed.

Monitoring methods

The present study used the Dantec Keypoint multifunction electromyography and evoked potential workstation (Natus Medical Inc., Pleasanton, CA, USA) and Cascade PRO intraoperative monitor (Cadwell Laboratories Inc., Kennewick, WA, USA) for the joint monitoring of spinal cord function using SEP and MEP. Because muscle relaxants and inhaled anesthetic ethers were used, nerve electrophysiological monitoring was inhibited.[4] The use of muscle relaxants was then suspended after the induction of anesthesia. Maintenance therapy was performed using propofol, and remifentanil was used for stability. The recording electrode installation positions for SEP monitoring were determined using the International 10/20 EEG system, on the C3, C4, Cz, and FPz sites. The stimulating electrodes (Xi'an Fude Electronics Co., Ltd., Xi'an, China) were then installed on the surface of the median nerve and posterior tibial nerve. For intraoperative SEP monitoring, the P40 wave of the lower extremity was recorded. For intraoperative MEP monitoring, transcranial electrical stimulation (TES) technology was used. Two stimulating electrodes were placed on C1′ and C2′. The recording electrodes were placed on the abductor hallucis brevis (AHB) of the lower limb muscle to record stimulus-driven compound muscle action potentials.

Preoperative observation points were located in the open lamina and spinal cord, and the postoperative observation points were located in the sutured muscle after decompression. The intraoperative baseline self-control settings before opening the vertebral plate were performed according to the 50/10 rule of the standard report. That is, for the intraoperative monitoring, an alarm was set off if the waveform latency increased by more than 10% or the amplitude decreased by less than 50% during the surgery.

Statistical methods

SPSS for Windows, version 11.5 (SPSS Inc., Chicago, IL, USA) was used. The SEP and MEP monitoring indexes are expressed as the $\bar{x} \pm$ standard deviation (SD), and were analyzed using the paired *t*-test. $P < 0.01$ was considered to be statistically significant.

Results

There were 24 patients in each surgical group. The control group had the same McCormick Scale distribution as the intraoperative monitoring group. See Table 1 for detailed patient characteristics.

In group I, 21 patients underwent total laminectomy, while the remaining three patients underwent corpectomy. Nine patients from group I were treated with internal fixation. In group C, 20 patients underwent total laminectomy, while four patients underwent corpectomy. Five patients from group C were treated with internal fixation. At 3 months after surgery, the two groups were followed up and their McCormick scores were monitored. In group I, spinal nerve function improved in 10 patients, did not change in 12 patients, and decreased in two patients. In group C, spinal nerve function improved in seven patients and did not change in 13 patients (Table 2).

For the 10 cases in group I whose spinal cord function improved following surgery, the SEP latency (or incubation period) and

Table 1. Patient demographics and clinical characteristics.

Group I			Number of patients
	Age (mean)	32 years (range 15–64)	
	Sex	Male/Female	19/5
	McCormick score	I	2
		II	7
		III	9
		IV	6
	Diagnosis	Spinal epidural hematoma	3
		Spinal canal tumor apoplexy	2
		Cervical spine trauma	8
		Thoracic trauma	5
		Lumbar trauma	6
Group C			
	Age (mean)	36 years (range 12–69)	
	Sex	Male/Female	16/8
	McCormick score	I	2
		II	7
		III	9
		IV	6
	Diagnosis	Spinal epidural hematoma	4
		Spinal canal tumor apoplexy	2
		Cervical spine trauma	7
		Thoracic trauma	6
		Lumbar trauma	5

Table 2. Preoperative and postoperative McCormick Scale score distributions in group I and group C.

		Postoperative rating			
Group	Preoperative rating	I	II	III	IV
Group I	I (n = 2)	2	0	0	0
	II (n = 7)	3	3	0	1
	III (n = 9)	1	1	6	1
	IV (n = 6)	1	1	3	1
Group C	I (n = 2)	2	0	0	0
	II (n = 7)	1	3	2	1
	III (n = 9)	0	2	6	1
	IV (n = 6)	0	1	3	2

amplitude and the MEP latency were compared before and after decompression. The recording period before decompression was before opening the lamina. The recording period following decompression was before suturing the muscle fascia. The P40 latency of SEP, P40 amplitude of SEP, and AHB latency of MEP were compared between the before and after decompression periods using the paired *t*-test. There was a

Table 3. Changes before and after decompression in the SEP P40 latency, SEP P40 amplitude, and MEP AHB latency.

	Spinal cord function improved			Spinal cord function unchanged		
	P40 latency (ms)	P40 amplitude (μV)	AHB latency (ms)	P40 latency (ms)	P40 amplitude (μV)	AHB latency (ms)
Before decompression	53.16 ± 1.93	–2.36 ± 2.08	50.49 ± 1.14	53.04 ± 2.08	–3.12 ± 1.02	49.87 ± 1.09
After decompression	48.32 ± 2.17	–6.75 ± 1.52	47.91 ± 2.16	51.67 ± 1.43	–2.78 ± 2.01	50.76 ± 2.43
Paired *t*-test	$P < 0.01$	$P < 0.01$	$P < 0.01$	$P > 0.05$	$P > 0.05$	$P > 0.05$

Values are given as $\bar{x} \pm$ SD. SEP, somatosensory evoked potential; MEP, motor evoked potential; AHB, abductor hallucis brevis; SD, standard deviation.

statistically significant difference in patients with functional improvement in the spinal cord; these patients had a significantly improved intraoperative electrophysiological index after decompression ($P < 0.01$, Table 3). Because the intraoperative monitoring of MEP amplitude fluctuation is volatile, no statistical analysis was performed on these measurements.

For the 12 cases in group I whose spinal cord function was unchanged following surgery, the SEP latency and amplitude and the MEP latency were compared before and after decompression. As determined using the paired *t*-test, there were no significant differences in these values (Table 3).

Discussion

Intraoperative monitoring technology is being continuously developed, and is thus being used in increasing numbers of spinal surgeries in an attempt to reduce complications.[5] With the use of the SEP or MEP methods alone, the monitoring results are somewhat one-sided. The intraoperative monitoring of SEP results cannot detect changes in motor function; therefore, although the intraoperative monitoring of SEP was normal, the motor function of patients may be damaged after the operation, resulting in "false negative" results.[6] In contrast, the joint monitoring of SEP and MEP can comprehensively reflect the function of spinal cord nerve conduction.

Decompression and internal fixation surgery may cause the destruction of spinal nerve conduction function, leading to postoperative nerve dysfunction.[7] In group I, for the intraoperative SEP and MEP joint monitoring, the 10/50 rule was used as an alarm to help surgeons identify and analyze the cause of any nerve injury, and take suitable measures. At the 3-month follow-up, we found that a greater number of patients in group I had an improved spinal cord function rating compared with patients in group C. However, there were more patients in group C with decreased spinal cord function compared with patients in group I. Hence, in surgery for acute spinal cord injury, and especially in pith vertebral canal decompression of spinal cord injury, SEP and MEP joint monitoring may reduce postoperative nerve dysfunction.

When we compared the electrophysiological monitoring indicators before and after decompression, patients with improved spinal cord function after decompression surgery had statistically significant differences between the before and after measurements of SEP latency, SEP amplitude, and MEP latency. In patients with unchanged spinal cord function after decompression surgery, there were no significant differences between the before and after measurements of SEP latency, SEP amplitude, or MEP latency. For the SEP and MEP joint monitoring index, the trends of the changes were consistent with the changes that occurred in spinal cord function in patients. Therefore, SEP and MEP joint monitoring may allow the timely detection of intraoperative spinal nerve function damage, and may also be useful to predict the prognosis of spinal cord function in patients.

Joint monitoring can eliminate external factors,[8] and may avoid interference in the surgical process. Furthermore, intraoperative monitoring operations should follow "the rule of parallel"; that is, the results of SEP and MEP in different limbs during the same time period should be used as references for one another. Joint monitoring of both SEP and MEP is superior to single monitoring in terms of both the comprehensive intraoperative detection of spinal nerve function damage, as well as the reduction in the occurrence of postoperative complications. The present study was limited by the small number of patients and its single-center design. The sample size should be expanded in future studies.

In summary, intraoperative joint monitoring can be used to comprehensively, timely, and effectively recognize spinal cord function in patients under anesthesia, and may reduce postoperative complications and improve patient prognosis.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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