NOTE *Surgery*

Effectiveness of Intraoperative Somatosensory Evoked Potential Monitoring During Cervical Spinal Operations on Animals with Spinal Cord Dysfunction

Seiichi OKUNO[1)], Amane NAKAMURA[1)], Takayuki KOBAYASHI[1)] and Kensuke ORITO[2)]

[1)]*Animal Clinic Kobayashi, 715–1 Sakai, Fukaya, Saitama 366–0813 and* [2)]*Department of Veterinary Pharmacology, School of Veterinary Medicine, Azabu University, Fuchinobe, Sagamihara, Kanagawa 229–8501, Japan*

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ABSTRACT. We conducted somatosensory evoked potential (SEP) monitoring on 3 dogs with cervical spinal cord dysfunction caused by various diseases throughout operative procedures to examine whether the intraoperative SEP monitoring was effective for prediction of spinal cord conductive function. The SEP was recorded on the scalp via stimulation of the ulnar nerve. Stable SEP was recorded in all animals examined. Its amplitude was decreased by surgical manipulations of the regio vertebralis, but the amplitude gradually recovered once the manipulations were halted. The latency showed small variation throughout the operations. This evidence suggests that intraoperative SEP monitoring may provide continuous and instantaneous information regarding the functional integrity of the central nervous system.

KEY WORDS: canine, somatosensory evoked potential (SEP), spinal disease.

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Somatosensory evoked potential (SEP) is elicited by stimulation of peripheral sensory nerves in limbs and recorded over the scalp [3, 8, 13, 14]. Since SEP reflects conduction of the afferent volley primarily along the myelinated dorsal columns, through the medial lemniscal pathways, to the primary somatosensory cortex, it has often been used for examinations of the sensory tract and spinal cord functions, not only to diagnose neurological diseases, but also to monitor conductive function during spinal surgery in humans [2, 3, 5–7, 10, 15]. In fact, a 50% decrease in SEP amplitude is generally considered to be a sufficient cause for alarm during spinal operations in humans [15]. Early detection of the alarm level for spinal conductive functions contributes to safe surgery. However, there are no reports on spinal cord functional examinations utilizing SEP during spinal surgery in veterinary medicine. Surgical complications in cases of cervical spinal disease may lead to paresis or paralysis [1, 12]. Thus, intraoperative monitoring of conductive function is necessary to avoid surgical complications.

It has been possible to record SEP on the scalp when electric stimulation is given to the peripheral nerve in dogs. The waveforms of SEP recorded in dogs are considered to reflect the activities of the somatosensory cortex, although short-latency SEP recorded on the scalp with peripheral nerve stimulation has several waveforms, which are elicited in the peripheral nerve, spinal cord, brainstem, and cerebral somatosensory cortex in humans [8, 13, 14]. Waveform amplitude is decreased by experimentally induced spinal cord compression and blockage of the blood supply to the spinal cord in dogs [4, 11]. These reports have suggested that an intraoperative SEP examination would be very useful in veterinary practice for understanding the spinal cord functions during surgery. In the present study, we performed intraoperative SEP monitoring on three dogs requiring spinal surgery, and investigated the changes in SEP amplitude and latency resulting from surgical manipulations.

We examined intraoperative SEP monitoring in the following 3 dogs in which neurological abnormalities were found using neurological examination, including postural reactions, spinal reflexes, and acral pain sensations, and radiographic examination involving myelography. In hematological examination, the complete blood count (CBC) was obtained, and a serum biochemical analysis was conducted. Informed consent of the owners was obtained prior to participation of the animals in the present study. All animals in this study were managed in accordance with the specifications of the Azabu University Guide for the Care and Use of Laboratory Animals, April 2000.

Case 1: A 9-year-old female Pomeranian had severe neck pain and tetraplegia caused by traumatic luxation at C5-C6, which was confirmed by radiography. Neurological examinations revealed the impossibility of voluntary movement, hyper-reflex of four limbs, and the existence of pain sensation in all limbs. Increased creatine phosphokinase (650 IU/L) and alanine aminotransferase activities (380 IU/L) were recognized from the serum biochemistry. We performed a fixation of the spinous processes of C5 and C6.

Case 2: A 9-year-old male Beagle had severe pain in the neck and showed ataxia caused by an intervertebral disk hernia, considered to be Hansen Type II, between C2 and C3, which was confirmed by myelography. Neurological examinations showed upper motor neuron sign in four limbs. Decreased conscious proprioception and superficial acral pain sensation were recognized in both hind limbs. No abnormalities were found in hematological examinations that included CBC and serum biochemistry. This dog underwent a decompression operation, making a ventral slot at C2-C3.

Case 3: A 12-year-old female Golden Retriever had severe neck pain and tetraplegia caused by an extradural tumor in the vertebral canal of C3, which was confirmed by myelography. Neurological examinations revealed the impossibility of voluntary movement, hyper-reflex of four limbs, and decreased superficial pain sensation in all limbs. No abnormalities were recognized in hematological examinations, which included CBC and serum biochemistry. We performed a hemilaminectomy at C3, and extracted the tumor. A pathology laboratory considered this to be a soft tissue malignant tumor.

In all animals examined, atropine sulfate was subcutaneously injected, and anesthesia was induced by IV administration of thiamylal sodium (Isozol injection, Mitsubishi Pharma, Osaka, Japan). Anesthesia was maintained throughout the examination period by inhalation of isoflurane (Isoflu, Dainippon Pharmaceutical, Osaka, Japan). Rectal temperature was monitored to maintain body temperature above 37°C using circulating water-heating pads (Micro-Temp Pump SMS-1000, Seabrook Medical Systems, Ohio, U.S.A.). A system for the measurement of evoked potentials (Neuropack MEB-5508, Nihon Koden, Tokyo, Japan) was used in all recordings.

Surface disk-electrodes were used as recording and reference electrodes. The recording electrode was placed at the juncture of the coronal and sagittal sutures, which was considered to be adjacent to the somatosensory area, and the reference electrode was placed on the spinous process of the axis, following the method of Uzuka *et al.* [13]. The electrical stimuli lasted 0.2 msec, and rectangular waves at a rate of 3 Hz were applied to the ulnar nerve. The needles were inserted percutaneously, and placed on the ulnar nerve immediately distal and lateral to the carpometacarpal joint. The cathode of the electrode was placed proximally about 1 cm from the anode. Intensity was adjusted to produce visible flections of a digit. A total of 500 responses were averaged with low- and high-pass filters at 0.5 and 3,000 Hz, respectively.

The SEP examination began after the induction of anesthesia. The stable SEP elicited repeatedly before the incision served as the baseline SEP. Initial positive and negative waves were identified in the SEP waveform. The SEP amplitude was determined as the peak-to-peak amplitude of initial positive and negative waves (Fig. 1). Latencies from the stimulation artifact to the peak of the first positive wave were recorded simultaneously (Fig. 1). The SEP examination was performed to monitor the spinal cord conductive functions during surgical manipulations, such as skin incision, retraction and removal of muscles, hemilaminectomy, and making a ventral slot. When the SEP amplitude was decreased, surgical manipulations were briefly halted, and any change in the SEP waveform was observed.

Stable SEP responses were recorded throughout the surgery in all cases examined. Table 1 shows changes in SEP amplitude and latency in all cases.

Case 1: The peak-to-peak amplitude of the baseline SEP was 4.40 μV, and decreased during retraction of multifidus muscles and spinalis cervicis muscles from the dorsal spinous processes and laminae of the vertebrae. At the end of muscle removal, the amplitude was 2.25 μV (the minimum amplitude throughout these operations). The amplitude recovered to 3.10 μV about five minutes after halting a manipulation, and was 3.00 μV at the end of the surgery. The latency of the first positive wave of baseline SEP was 12.8 msec, and the latency remained unchanged even when the amplitude exhibited the minimum value. Furthermore, it shortened to 12.3 msec after the surgery was completed. This dog was able to stand unassisted three days after the operation (Fig. 2).

Case 2: The baseline SEP amplitude was 1.20 μV, and gradually decreased when the disk space was exposed and the ventral slot was made using a pneumatic drill. A transient decrease in SEP amplitude to 0.40 μV, which was the minimum amplitude throughout this operation, was recognized while making a ventral slot. Five minutes after halting the surgical manipulation, the amplitude gradually recovered to 0.76 μV. The final SEP amplitude was 0.80 μV. The SEP latency, on the other hand, was stable at 19.0 msec throughout the operation. This dog showed no signs of neck pain and dysbasia the day after the operation.

Case 3: The baseline SEP amplitude was 1.43 μV, and the latency of the first positive wave was 17.5 msec. The amplitude gradually decreased to 0.83 μV during removal of the bivente cervici muscles. A minimum amplitude of 0.60 μV was identified when the tumor was extracted, after

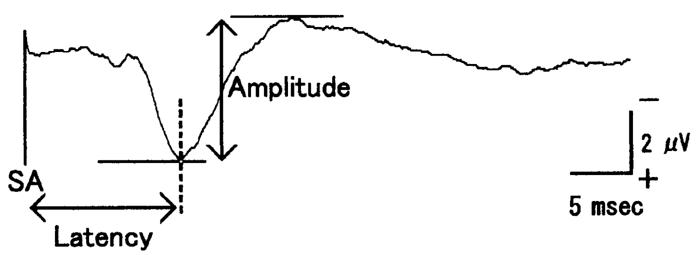

Fig. 1. A typical intraoperative somatosensory evoked potential (SEP) recorded on the scalp by ulnar nerve stimulation (Case 1). Negative polarity is indicated by an upward deflection. The amplitude is measured from the peak of the positive wave to the peak of the following negative wave. The latency is the delay from the stimulus artifact (SA) to the peak of a significant positive wave.

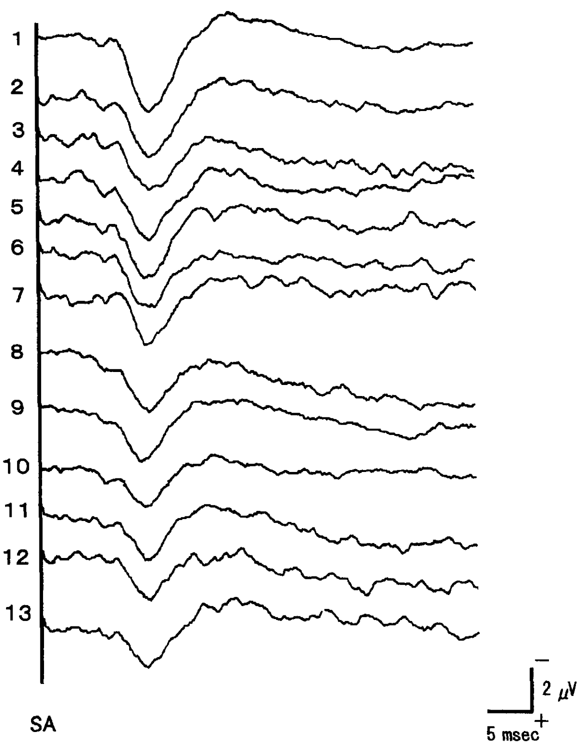

Fig. 2. SEP traces during a cervical vertebrae fixation surgery (Case 1). Trace number 1 is the baseline SEP of this dog, which was 4.40 μV. Trace number 6 is the response during retraction of multifidus muscles and spinalis cervicis muscles from the dorsal spinous processes and laminae of the vertebrae; the amplitude was 2.30 μV. Trace number 8 is the response during fixation of the spinous processes of C5 and C6 by wire. The amplitude was 2.25 μV, which was the minimum amplitude throughout this surgical procedure. Trace number 13 is the final SEP at the end of this surgery; the final SEP amplitude was 3.00 μV. The latency from the stimulus artifact (SA) to the peak of a significant positive wave was 12.8 msec before the operation, and the latency at the end was 12.3 msec.

Table 1. Changes in SEP amplitude and latency during surgery

A. Amplitude (μV)

	Case 1	Case 2	Case 3
Baseline	4.40	1.20	1.43
Minimum	2.25	0.40	0.60
Final	3.00	0.80	1.61

B. Latency (msec)

	Case 1	Case 2	Case 3
Baseline	12.8	19.0	17.5
Minimum SEP amplitude[a)]	12.8	19.0	17.5
Final	12.3	19.0	15.0

a) Minimum SEP amplitude: latency when the minimum SEP amplitude was identified.

which the amplitude recovered to 1.05 μV within 10 min. The latency remained 17.5 msec when the minimum amplitude was identified. The latency began to shorten after the tumor extraction. The final amplitude increased to 1.61 μV, and the latency shortened to 15.0 msec, respectively. This dog recovered autokinesis and acral pain sensation in all four limbs 3 days after the operation.

In the present study, stable intraoperative SEP responses were recorded in all cases. SEP amplitude decreased following surgical manipulations, i.e., retraction and removal of muscles from vertebral bodies, reduction of vertebral bodies, cutting a slot into vertebral bodies, and inserting instruments into the vertebral canal. The amplitude gradually recovered when the surgical manipulations were halted, suggesting that surgical manipulations of the spine affect the conductive function of the spinal cord. Some surgical procedures of the dorsal cervical muscles affected cervical spinal cord function without manipulation of nerves directly. The spinal cord was overstretched by laxation of the vertebrae in Case 1. It was compressed by the tumor in the vertebral canal in Case 3. Manipulation of the cervical muscles might facilitate the vertebral movement that worsened these existing spinal cord injuries. In humans, a 50% decrease in recorded amplitude is determined to be the level below which there may be damage to spinal function [15]. Intraoperative SEP monitoring has been effectively performed to prevent functional impairment associated with surgical manipulations in human medicine because it correctly reflects the present situation of spinal cord function. If a reliable alarm level of SEP is determined in veterinary medicine, it will be a very useful aid to performance of safe spinal surgery.

The SEP latency was not largely affected by surgical manipulation, even when the SEP amplitude was decreased maximally. This evidence indicates that SEP amplitude is more sensitive to changes in the conductive function of the spinal cord than to changes in latency. This is consistent with the report of Poncelet *et al.* They revealed that scalp recorded SEP latency did not change significantly in association with mild lesions, although the SEP amplitude changed with lesions of intermediary severity in dogs with naturally acquired spinal cord disease [9]. There arises a question as to why the latency of SEP is less sensitive than amplitude. Considering that SEP latency is proportional to distance [8], the change in latency due to surgical manipulations may be too small when using scalp recording SEP with stimulation of a nerve in a forelimb.

An average number of at least several hundred would be necessary to arrive at a reliable average waveform of SEP responses recorded on the scalp. A shorter interval of stimulation would be helpful in producing evoked potentials more quickly. However, accelerating the stimulation generally produces lower amplitude potentials, making monitoring more difficult. Moreover, other stimulus conditions such as intensity, duration, and site can alter the waveform evoked. Recording filters are also an important factor in achieving useful evoked potentials. A narrow-band pass filter (i.e., 30 Hz-100 Hz) would be helpful in producing rapid and smooth responses, but at a lower amplitude with an unclear wave peak. On the other hand, a wide-band pass filter (i.e., 0.1 Hz-3,000 Hz) would be helpful in producing high amplitude responses with a clear peak of evoked waves, although it is susceptible to background noise [6]. Further studies are necessary for standardizing and utilizing intraoperative SEP monitoring more effectively in veterinary medicine.

In summary, SEP provides continuous and instantaneous information regarding the functional integrity of the central nervous system. Thus, intraoperative SEP is a useful parameter to identify present conditions in the central nervous system.

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