Measurement of the action potential of the nerve for the isolation of the nerve in the operative field: An experimental study in rabbit

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Abstract: Background: Intraoperative neuromonitoring has been introduced to such surgery as head and neck, however, it is insufficient to predict the nerve function. In this study, we evaluate the nerve function by measuring the action potential directory in the operation field. Methods: Sciatic nerves of the rabbits were pulse stimulated electrically. The amplitude of the action potential of the nerve was evaluated on the nerve or surrounding tissue using by a custom-designed bio-amplifier. Results: Two different waveforms of electroneic spread and the saltatory conduction were recorded. The conduction velocity was 50 to 60 m/s. The amplitude of saltatory conduction on the nerve and surrounding tissue was measured approximately. Discussion: The saltatory conduction in the neighboring tissue was evaluated. It makes possible to detect the action potential derived from the nerve within 10 mm away from the nerve in the operative field.

Keywords: Intraoperative neuromonitoring, Measurement of the action potential of the nerve

1. Introduction
In the field of brain or head and neck surgery, intraoperative neuromonitoring (IONM) using electrical stimulation is important to prevent nerve injury and preserve nerve function [1-3]. However, several reports described that IONM has not contributed to the prevention of nerve injury [4, 5], it is insufficient to predict nerve function. There have been no reports regarding measurement of the action potential of the nerve in operation field. As search of the nerve, we evaluated conduction characteristics of the nerve and neighboring tissue by adding electrically stimulation to the nerve.

2. Methodology
A. Experimental procedure in the rabbit model
Seven New Zealand White rabbits aged 17-18 weeks were used. The experimental design was shown in the figure 1. The skin was incised 7 cm of length in dorsal thigh of the rabbit. Following incision, the sciatic nerve was exposed. A bipolar electrode for electrical stimulation was placed in the most proximal side of the exposed sciatic nerve. A bipolar electrode for detection was placed on the sciatic nerve or on the surrounding tissue away from the nerve. Electrical stimulation was used an electric stimulator and an isolator (NIHON KOHDEN Co., Tokyo). Amplitude of the conduction level was detected using an oscilloscope (TEXIO TECHNOLOGY Co., Yokohama) and a custom made amplifier [6]. An acceleration sensor (Akizuki Denshi Tsusho Co., Ltd., Tokyo) was attached to the foot of the stimulus side.

B. Measurement protocol of electrical conduction characteristic
The Sciatic nerve was stimulated by 1 to 3 electrical pulses of 100 µs duration. The stimulation intensity was the minimum level of acceleration sensor to react; around 0.1 mA in all cases.

A bipolar electrode for detection on the sciatic nerve was placed 10 mm, 20 mm, 30 mm, 40 mm, 55 mm, and 70 mm away from the electrode for stimulation. Then, a detection electrode on the surrounding tissue was placed 5 mm, 10 mm and 15 mm away from sciatic nerve in vertical direction from the sciatic nerve at 55 mm away from the electrode for stimulation.

3. Results
A. The conduction property of the nerve
Figure 2 shows the typical waveforms of the stimulation pulse, neuronal action potential, local field potential and motion of the foot at the point of 20 mm away from the stimulation. The top line (yellow) is the waveform of stimulation pulse. The second line (blue) is the detection waveform of 320 Hz - 3.4 kHz for neuronal action potential recorded (High channel; H ch) and the third line (pink) is the detection waveform of 1-340 Hz for local field potential (Low channel; L ch) [6]. The bottom line (green) is the waveform of acceleration sensor.

Two different waveforms of amplitude of conduction were shown in H ch. The first waveform shaped spike (electroneic spread) and the second waveform shaped gentle (saltyatory conduction) was evaluated the amplitude of conduction.

B. The conduction characteristics on the nerve and on the surrounding tissue around the nerve
The delay of the depolarization was positively correlated with the distance from the stimulus point (Fig. 3). Therefore, it was inferred from this study that the conduction velocity of the sciatic nerve was approximately 50-60 m/s.

The conduction waveforms on the neighboring tissue of the sciatic nerve were evaluated. The amplitude of saltatory conduction on the nerve and surrounding tissue 5 and 10 mm vertically away from the nerve was approximately 2000, 900 and 500 mV, respectively. The amplitude level of saltatory conduction is decreased in proportion to the increase of the distance from the sciatic nerve (Fig. 4).

4. Discussion
In this study, the conduction velocity is approximately 50-60 m/s. This matter is similar to previous report [7, 8]. Therefore, it is considered that the sciatic nerve is well isolated and appropriate condition for this experiments and the amplitude of the nerve was well evaluated.

The amplitude level of saltatory conduction on the surrounding tissue of the nerve is decreased in proportion to the increase of the distance away from the nerve. Therefore, Within 10 mm from the nerve, it was considered the action potential of saltatory...
conduction of the nerve could measure on the neighboring tissue of the nerve.

In this study, we developed a new method to measure the action potential of the nerve contactlessly in operative field and evaluated the function of the nerve by animal experiment.

5. Figures

Figure 1. The experimental composition of this study (schema).

Figure 2. The conduction waveform on the sciatic nerve 20 mm away from the electrode for stimulation.

Figure 3. The Delay from stimulation point of the sciatic nerve (mean ± S.E.).

Reference