THE EXPERIMENTAL STUDY ON PERIPHERAL SYMPATHETIC NERVE ACTIVITY OF LOWER LIMBS USING THERAPEUTIC ELECTRICAL STIMULATION (TES).

INTRODUCTION

Therapeutic electrical stimulation ("TES") is clinically applied to the patients with spinal cord injury ("SCI") for recovery of voluntary movement and muscle strength as well as for prevention of spasticity and pressure sore. The action mechanism of TES in the peripheral sympathetic nerve that dominates thermoregulation and peripheral blood circulation involved in the spasticity and pressure sore prevention has yet to be clarified. As a method to investigate the sympathetic nerve activity, Hagbarth et al. directly captured human skin sympathetic nerve activity ("SSA") by microneurography. It is possible to lead the action potential of single nerve fiber in the peripheral nerve trunk by this microneurography. It is a direct analysis method of sympathetic nerve activity that cannot be captured on the basis of effector activity or by noradrenaline determination.

Using a SCI model prepared by cordotomy, we took the time course record of nerve potential of SSA and muscle sympathetic nerve activity ("MSA"), and investigated the action mechanism of TES in the peripheral sympathetic nerve. The results are reported in the following.

SUBJECTS

For preparation of SCI model, 6 Japanese white rabbits weighing 1.0-1.5 kg were used. This study was conducted in compliance with the standards related to the rearing and preservation, etc. of experimental animals.

METHODS

1. Preparation of SCI model
   In a room kept at 26-28°C temperature, the animals were anesthetized by intravenous administration of pentobarbital sodium (25 mg/kg) and immobilized in prone position on the fixator. Laminectomy of the twelfth thoracic vertebra was performed by posterior approach to expose the spinal cord, and the spinal cord at T12/L1 level was completely transected with a knife. Then, the sciatic nerves were exposed.

2. Stimulation method
   Functional electrical stimulation ("FES") electrodes (GE, SES114) were placed at the motor point of gastrocnemius. Using a portable long hour stimulator specially prepared for this purpose (Unique Medical ON200-044), continuous stimulation of 20 Hz cycle and 7 - 8V intensity was applied to the gastrocnemius for 48 hours from immediately after cordotomy.

3. Potential recording method
   As to the microneurography, a tungsten microelectrode (Unique Medical, UJ3002B) with the tip diameter of 1 mm and impedance of 3 - 5W was inserted into the cutaneous branch of right and left sciatic nerves to lead SSA, and to the muscular branch to lead MSA.

SSA and MSA were led by 500 - 5 KHz amplifier (Nihon Koden, MEMH104). The electrocardiogram ("ECG") was monitored using a bedside monitor (Nihon Koden, BSM8302).

Using an electrostimulator (Medelec, USC6), rectangular wave electric stimulation of 15 mA strength and 0.2 msec duration was applied through stimulation electrodes on the forehead and SSA, MSA and ECG obtained by stimulation were recorded immediately after, and at 24 and 48 hours after cordotomy.

BIMUTAS (Kissei) was used for analysis. After the full-wave rectification of potential, the integral waveform was obtained to calculate the time rest integral in 60 seconds.

4. Statistic analysis method
   One-way analysis of variance was employed for integral comparison, and the difference in the mean value between the groups was assayed by Scheffe's method. Differences with a probability of less than 5% were considered to be statistically significant (p<0.05).

RESULTS

The integrals (mean±SE) of SSA on TES side immediately after, and at 24 and 48 hours after cordotomy were 8.7±1.9 (×10³mV·sec), 18.3±2.5 (×10³mV·sec) and 11.0±4.9 (×10³mV·sec) respectively, and those on the non-TES side were 7.7±1.8 (×10³mV·sec), 10.7±3.9 (×10³mV·sec) and 5.1±1.2 (×10³mV·sec) respectively, indicating no significant difference between the TES and non-TES sides.

The time course changes in the TES and non-TES sides did not show any specific tendency.

The integrals (mean±SE) of MSA on TES side immediately after, and at 24 and 48 hours after cordotomy were 43.1±10.6 (×10³mV·sec), 36.8±9.1 (×10³mV·sec) and 53.1±12.8 (×10³mV·sec) respectively, and those on the non-TES side were 36.0±11.7 (×10³mV·sec), 26.7±13.9 (×10³mV·sec) and 4.1±0.7 (×10³mV·sec) respectively. Compared with the value on non-TES side, the integral obtained on TES side at 48 hours after cordotomy was significantly larger (Fig. 1). The time course changes in the TES showed a tendency of increase on TES side while a tendency of decrease was observed on the non-TES side.

DISCUSSION

The complications such as orthostatic hypotension, autonomic hyperreflexia, which can be prevented by retaining the sympathetic nerve activity for the SCI patient, are abounding. In this regard, rehabilitation approach would be very important to preserve the sympathetic nerve activity. The time course increase in MSA integral was observed by TES in this experiment. TES is expected to be an effective therapeutic approach in maintaining the vascular smooth muscle activity in the skeletal muscle and skin.

The function of MSA that dominates the vascular smooth muscle in the skeletal muscle and that is involved in the vascular resistance and metabolic control is regulated by the increase and decrease of signal input from chemoreceptors, nociceptors and skeletal muscle receptors as well as by the influence from the central nervous system ("CNS"). The direct influence of TES on the receptors promote continuous release of carbon monoxide and lactic acid accumulated in the contraction muscle to persistently stimulate the receptors, thereby increasing the signal input.

As to the control from CNS, it is necessary to find a pathway of influence in a site distal from spinal cord because of the absence of control to correspond to the stimulation that is input from the dorsal root to the spinal cord due to the disappearance of spinal reflex below the injury during the spinal shock.

The axon collateral of the G III-IV that are involved in muscular sensation input extend from dorsal root ganglion to sympathetic ganglion for synapse binding to the sympathetic nerve system and adjusts sensitivity of somatic nerve at the sympathetic ganglion level.

The G III-IV are important as somatic nerve that connect to the postganglionic sympathetic nerve fibers. In this regard, an increase in input transmission to the G III-IV is considered to be closely related to the promotion of MSA.

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