

Effect of tension on force of contraction of muscle and nerve conduction velocity of the repaired nerve in a rat model

Pramod Devkota,¹ Wang Lei,² Zeng Bing-fang,² Tang Jian-fei² and Fan Cun-yi²

¹Department of Orthopaedic Surgery, Patan Hospital, Lagankhel, Lalitpur, Nepal

²Department of Orthopaedic Surgery, Shanghai Sixth People's Hospital, Shanghai 200233, P R China

Corresponding address: Dr. Pramod Devkota, Department of Orthopaedic Surgery, Patan Hospital, Lagankhel, Lalitpur, Nepal.

ABSTRACT

To investigate the effect of tension on the contractive force of muscle and nerve conduction velocity of the repaired nerve, this study was designed. Fifty-four Sprague-Dawley (SD) rats were randomly divided into 3 groups. The left gastrocnemius muscles of the rats were dissected with the neurovascular pedicles intact; the tibial nerves were cut and immediately repaired by epineurial suture. Then the Achilles tendons were isolated and treated accordingly; the Achilles tendon was lengthened by 0.5 cm in lengthened group, shortened by 0.5 cm in shortened group and left alone in normal (control) group. In the 2nd, 4th and 8th weeks after operation, the isometric twitch contractive force of both the right and the left gastrocnemius muscles and the nerve conduction velocity (NCV) of the tibial nerve were measured. The shortened group showed greater isometric twitch contractive strength of the bilateral gastrocnemius muscles than those in the normal and lengthened groups in all the postoperative periods. The nerve conduction velocity (NCV) in the shortened group showed greater than other groups. A proper high tension of the muscle can increase the contraction of the muscle and may improve the nerve conduction velocity of the repaired nerve.

Keywords: Muscle tension Isometric twitch contractive force nerve conduction velocity (NCV).

INTRODUCTION

A neurovascularized free muscle transfer is an ideal solution to the reconstruction of a devastated skeletal muscle or a paralyzed extremity,^{1,2} But, there are lots of factors that govern the functional outcome of free muscle transfer and the reconstructive surgeons emphasized the need of placing the transferred muscle in an optimal tension. It remains unknown how a skeletal muscle responds towards the tension in terms of contraction and how muscle tension responds towards nerve conduction velocity of the repaired nerve. Further research is therefore needed to give an answer to this question and this study is thus designed.

MATERIALS AND METHODS

Fifty-four Sprague-Dawley (SD) rats were used in the experiment. The left gastrocnemius muscles of the rats were dissected with only the neurovascular pedicles intact; the tibial nerves were cut and immediately repaired by epineurial suture. Then the Achilles tendons were isolated and treated accordingly. The rats were randomly divided into 3 groups with 18 rats in each, based on the manner of the Achilles tendon treatment. In group A (the normal group), the Achilles tendons were just isolated without cut, in group B (the shortened group), the Achilles tendons were cut and sutured back with a shortening of 0.5 cm, and in group C (the lengthened group), the Achilles tendons were divided with stair cut and sutured back with their length increased by 0.5 cm. The wounds were then closed and the rats allowed to move freely. (Fig 1 shows the animal model)

At 2nd, 4th and 8th weeks after operation, 6 rats from each group underwent measurement of isometric twitch contraction of both right and left gastrocnemius muscles and nerve conduction velocity (NCV) of the tibial nerve. When measured, the rats were anaesthetized by injecting ketamine into the abdomen and put in prone position. The left and right gastrocnemius muscles were exposed and connected to the tension transducer with 5-0 suture. The tension of suture was adjusted to keep the muscle in its initial length. Multipurpose physiological stimulator device (voltage 15v, frequency 90Hz, wave length 2ms) was used to stimulate the gastrocnemius muscle and the isometric twitch contraction of gastrocnemius was recorded with a two-channel physiological recorder (sensitivity 10 mv/cm, time constant 0.25, filtered frequency 100 Hz). The ratios of isometric twitch contraction of the bilateral gastrocnemius were calculated (as shown on Fig 2). In

measuring nerve conduction velocity, the tibial nerve exposed and Neuropack Electro-physiological device was used to measure nerve conduction velocity (NCV).

All the data were analyzed by the software SPSS 11.0 for Windows.

RESULTS

Isometric twitch contraction ratio: The change of the isometric twitch contractive strength of the bilateral gastrocnemius muscles was the lowest at the fourth postoperative week. The isometric twitch contractive strength ratio is shown in Table-1, its differences between the lengthened group and the shortened group was statistically significant with P value being 0.003 at the second week, 0.002 at the fourth week and 0.0017 at the eighth week. Eight weeks after operation, the differences in the isometric twitch contractive strength ratio between the shortened and lengthened groups, the normal and the shortened groups, the normal and the lengthened groups were statistically significant with a P value of 0.017, 0.0023 and 0.0013, respectively.

Nerve Conduction Velocity: As the time went on, the cut and sutured tibial nerve generated gradually, its conduction velocity increased subsequently, the NCV of the different groups at different time period is shown on Table-2. In comparison between the experimented groups at the same period, the conduction velocity of the tibial nerve in the shortened group was quicker than any of the other groups. The difference in the conduction velocity of the tibial nerve between the shortened group and the lengthened group was significant in all periods with the P value being 0.002 at 2 weeks after operation, 0.003 at 4th weeks, and 0.0012 at 8th weeks. The differences in the conduction velocity of the tibial nerve were not significant in the comparison between all the other two groups, except that between the normal group and the lengthened group at 8th weeks after operation, in which the P value was 0.0011.

DISCUSSION

The skeletal muscle is characterized by its ability to contract. Isometric contraction is the muscle contraction without shortening its length. Tetanus contraction is a continuous contraction movement of the muscle; it depends on the continuous stimuli and excitation on the cell membrane of muscle cell. Measuring the force of contraction of reinnervated muscle one can assess the functional outcome of nerve regeneration.³ In this study the isometric twitch contraction ratio of the bilateral gastrocnemius muscles was measured to assess the function of the muscles before and after the repair of nerves innervating them. In the same group the isometric twitch contractive strength ratio increased as the time went on. At the same period, the isometric twitch contractive strength ratio in different groups showed some tension related difference. At all the time the isometric twitch contractive strength ratio in the shortened group was always greater than that in the lengthened group, the difference being statistically significant ($P < 0.005$). At the eighth postoperative week the differences in the isometric twitch contractive strength ratio showed obvious significance between every two groups, demonstrating that under the higher tension the muscles had the greater isometric twitch contractive strength ratio. Tension increases the number and length of sarcomeres, the contraction unit of muscle, in new muscle tissue.^{5,6}

The rate of conduction of a signal, calculated from the latency and the distance and expressed as meter/seconds (m/s) is nerve conduction velocity (NCV). Slow conduction may occur either segmentally or diffusely through the course of the nerve. Segmental or focal slowing suggests a localized lesion such as nerve compression or entrapment.⁶ The dystrophy of myofiber also results the changes of NCV.⁷ If the NCV returned to normal the skeletal muscle also regains its normal function.⁸ A decrease in NCV indicates the dystrophy of the myofiber and proliferation of the connective tissue.⁹ That there is relationship between the morphology of the skeletal muscle and NCV and function of the skeletal muscle and NCV has been reported.⁵ An increase of tension on the nerve remarkably impeded nerve regeneration resulting low NCV.¹⁰ In comparison between groups at the same time, the NCV of the tibial nerve in the shortened group was quicker than any of the other groups. The difference in the NCV of the tibial nerve between the shortened group and the lengthened group was significant in all periods with the P value being 0.002 at 2nd weeks after operation, 0.003 at 4th weeks, and 0.001 at 8th weeks. The differences in the NCV of the tibial nerve were not significant in the comparison between all the other two groups, except that between the normal group and the lengthened group at 8th weeks after operation, in which the P value was 0.001.

This shows that there exists some relationship between tension of muscle and NCV of repaired nerve but it needs further research for clear understanding.

This study has revealed that tension of the muscle can influence the contractive force of the muscle and nerve conduction velocity of the repaired nerve. A suitably high tension on the muscle can increase its isometric twitch contractive force and also increases the nerve conduction velocity of the repaired nerve. It is therefore suggested that, in order to make the functional recovery better, a transplanted muscle should have proper high tension intraoperatively, and an injured limb should be immobilized in such a position that a high tension can be put on the paralyzed muscle after its nerve repair.

REFERENCE

1. Doi K, Hattori Y, Kuwata N *et al.* Free muscle transfer can restore hand function after injuries of the lower brachial plexus. *J Bone Joint Surg [Brit]* 1998; 80 B: 117-20.
2. Chuang DCC, Carver N, Wei FC. Results of functioning free muscle transplantation for elbow flexion. *J Hand Surg* 1996; 21A: 1071-77.
3. Tham S, Dowsing B, Finkelstein D *et al.* Leukemia inhibitory factor enhances the regeneration of transected rat sciatic nerve and the function of reinnervated muscle. *J Neurosci Res* 1997; 47: 208-15.
4. Friden J, Ponten E, Lieber RL. Effect of muscle tension during tendon transfer on sarcomerogenesis in a rabbit model. *J Hand Surg* 2000 25 A: 138-43.
5. Day CS, Moreland MS, Floyd SS Jr *et al.* Limb lengthening promotes muscle growth. *J Orthop Res* 1997; 15: 227-34.
6. Iyer VG. Understanding nerve conduction and electromyographic studies. *Hand Clinics* 1993, 9: 273-87.
7. Hilburn WJ. General principles and use of electrodiagnostic studies in carpal and cubital tunnel syndromes. *Hand Clinics* 1996, 12: 205-21.
8. Asami A, Morisawa K, Tsuruta T. Functional outcome of anterior transposition of the vascularized ulnar nerve for cubital tunnel syndrome. *J Hand Surg Brit* 1998 23: 613-6
9. Ericson U, Ansved T, Borg K. Charcot-Marie-Tooth disease: muscle biopsy findings in relation to neurophysiology. *Neuromuscul Disord* 1998, 8:175-81
10. Cruz J, editor. Neurologic and neurosurgical emergencies. (1st Ed), WB Saunders; Harcourt Publishers Limited 2001. 353.