Unexpected Changes of Contractile Properties in Denervated Muscle Following Long-Term Bidirectional Rectangular Electrical Stimulation (LIB-Stimulation)

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Abstract

In previous studies, LIB-stimulation has proved effective in maintaining and restoring muscle contraction force in fast muscles of rabbit and man. The present study has been done to investigate the influence of stimulus parameters on contractile properties of denervated muscle when using a special type of electrotherapy (LIB-stimulation).

Thirty adult white New Zealand rabbits were denervated reaching a complete sensory-motor loss of the right hindlimb. Electrical stimulation was performed 2x9 min/d over a period of three months. In a final experiment the group of plantar flexors (F), the slow soleus muscle (SOL), the group of extensors (E) and the fast tibialis anterior muscle (TA) were investigated.

The greatest effect on preservation of force was seen in TA following electrotherapy with 40 mA/25 Hz with a right/left ratio of 86%. No significant effect was seen in SOL after stimulation with 20 or 40 mA. Unexpectedly, contraction time of fast muscles increased no only without stimulation but even following the therapeutic regimes with 10 msec impulses, more with 50 than with 25 Hz, while it decreased with 20 msec, 25 Hz. Fatigue resistance of SOL and TA was best after therapy with 20 msec, 25 Hz, 40 mA, and the twitch/tetanus-ratio increased less in this stimulation group.

Obviously not only frequency and total amount of stimulation influence the contractile properties, pulse duration also proved to be important in a quite interesting way which might be of some clinical importance in therapeutic stimulation. When trying to perform a functional electrical stimulation in denervated muscle, the muscle should react promptly and, on the other hand should work with the lowest possible fatigue. Thus, stimulation parameters are of great importance.

1. Introduction

In previous studies, electrical stimulation with balanced bidirectional rectangular impulses of high intensity and long pulse duration (LIB-stimulation) has proved to be effective in maintaining and restoring, resp., muscle contraction force in fast muscles of rabbit and man. Additionally, the morphological sequelae of denervation atrophy could be stopped and muscle bulk can even be restored.

The influence of different stimulus patterns on contractile properties of innervated muscles has been investigated for many years. Frequency was found to be most important for dynamic changes in the muscle according to its "plasticity". This finding was thought to be valid in denervated muscle, too, and there is also some experience in estimating the effects of different stimulus patterns on the contractile properties muscle following denervation. Those results, however, come from experiments, where no major effects were found on maintenance of contraction force.

So far, it was not known, in which manner a muscle would react on different stimulus patterns of a type of electrotherapy, which is able to avoid atrophy. This special type first was described in the early eighties, and it is now known as LIB-stimulation, using rectangular long
impulses that are bidirectional and balanced.

The present study has been done to investigate the influence of stimulus parameters on contractile properties of denervated muscle when using this special type of electrotherapy.

**Previous Work**

Design/Methods:
Animals/Denervation:
Thirty adult white New Zealand rabbits were denervated reaching a complete sensory-motor loss of the right hindlimb by transection of the sciatic nerve, femoral nerve, obturator nerve and the lateral cutaneous nerve of the thigh. Care was taken that no reinnervation occurred.

Electrical stimulation:
A painless electrical stimulation was performed twice daily with a total stimulation time of 9 minutes each via surface electrodes over a period of three months. The usual regime was a tetanic contraction of 30 seconds, followed by a break of 2.5 minutes. The impulse was of a bidirectional rectangular shape which was balanced in charge, with a duration of 20 ms, followed by a break of the same length, according to a frequency of 25 Hz.

Evaluation:
In a final experiment the group of plantar flexors (F), the slow soleus muscle (SOL), the group of extensors (E) and the fast tibialis anterior muscle (TA) were investigated. Measurements were made on the isolated muscle, with the blood supply intact, at a constant temperature of 19 °C. Parameters of evaluation were twitch and tetanic contraction, fatigue resistance and the twitch/tetanus ratio (steady state), the time of contraction (t/c) and the half relaxation time (R/2).

Results:
Contraction force:
The greatest effect on preservation of force was seen in TA following electrotherapy with 40 mA/25 Hz with a right/left ratio of 86%. No significant effect was seen in SOL after stimulation with 20 or 40 mA.

Contractile properties:
Unexpectedly, contraction time of fast muscles increased not only without stimulation to 1.03 of normal, but even following the therapeutic regimes with 10 msec impulses, more with 50 (1.21) than with 25 Hz (1.17), while it decreased with 20 msec, 25 Hz (0.89). Fatigue resistance of SOL and TA was best after therapy with 20 msec, 25 Hz, 40 mA, and the twitch/tetanus-ratio increased less in this stimulation group.

2. Summary and Conclusions

The present results show distinctly that not only frequency and total amount of stimulation may influence the contractile properties following denervation, pulse duration also proved to be important in a quite interesting way which might be of some clinical importance in therapeutic stimulation. When trying to perform a functional electrical stimulation in denervated muscle, the muscle should react promptly and, on the other hand should work with the lowest possible fatigue. Thus, stimulation parameters are of great importance.

Acknowledgment

The author wishes to acknowledge the financial support of the Deutsche Gesellschaft für Elektrostimulation und Elektrotherapie e.V. (GESET)

References