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Electrical Stimulation to Maintain Functional Properties of Denervated EDL Muscles of Rats

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Understanding how long term electrical stimulation affects muscle properties underlies optimal usage of a neural prosthesis for functional electrical stimulation. Optimal stimulation of innervated muscle would avoid inducing progressive muscle damage and would maintain function and viability. Muscles might also be denervated for many months between initial neural deficit and final realization of the neural prosthesis system. Irreversible declines in the functional properties of the muscles during the period of denervation would limit functional outcome.

The purpose is to determine the ability of chronic electrical stimulation of denervated skeletal muscles to minimize the progressive loss of a) muscle mass, b) contractile force, and c) potential to regenerate and to become reinnervated.

The right EDL muscles of\ rats were permanently denervated and electrically stimulated by an implanted stimulator which generated a muscle contraction with 20 pulses at 100 Hz and 7-10 mA. The contractions were repeated at constant intervals such that 200 contractions were generated per day. The two electrode wires were looped around the EDL muscle being separated by at least 10 mm. The left EDL muscles were not denervated or stimulated and served as controls. The denervated muscles were stimulated for up to 7 months. Some of the denervated-stimulated muscles were grafted into a fresh innervation site in another rat to test the ability to regenerate and become reinnervated. To evaluate any of these EDL muscles, the muscles weres removed, weighed, and maximum tetanic isometric force was measured in vitro.

Current preliminary results indicate that compared with innervated control muscles, EDL muscles of rats denervated for 5 weeks retained only 35±1% of mass and 9±6% of force, but denervated-stimulated muscles retained 99±12% of mass and 87±11% of force. Longer term denervated and stimulated muscles retained less muscle mass and force, but always had higher values than denervated and unstimulated muscles. Muscles denervated and stimulated for 17 weeks retained 92±15% of force and 58±24% of mass. Muscles denervated and stimulated for 32 weeks retained 64±12% of mass and 29±16% of force.

Prolonged denervation leads to a progressive decline in recovery following reinnervation, such that EDL muscles of rats denervated for 32 weeks and grafted into an innervated site recover only 68% of mass and 37% of force compared with immediately reinnervated control grafts. It is not yet clear whether the se long term denervated and stimulated muscles that are then grafted have a greater ability to regenerate and become reinnervated than denervated and unstimulated muscles.

Denervated and stimulated EDL muscles of rats retain more muscle mass and force generating ability at time points ranger from 5 to 32 weeks. The preliminary data does not clearly show whether long term denervated and stimulated muscles retain a higher ability to regenerate and to become reinnervated. A failure to show this could be due to technical difficulties in maintaining constant stimulation over the longer duration, or it could show that the contractile activity generated by the electrical stimulation is not sufficient to suppress these progressive declines in long term denervated muscles.

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