State-of-the-art equipment for functional electrical stimulation and functional monitoring of denervated muscles – technical developments of the EU-project RISE

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Abstract

Non-invasive functional activation of denervated muscles and assessment of muscle function require novel stimulation and measurement techniques. Stimulation equipment must be safe enough for home-based training though the applied electrical parameters raise critical safety issues. Assessment of biomechanical and electrophysiological parameters is provided by oscillation tonometry, twitch and m-wave measurements.

Key Words: human muscle, permanent denervation of the lower extremity, FES, muscle recovery, prevention of secondary diseases.

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Traditional functional electrical stimulation (FES) targets neural structures and indirect control of muscle contraction. The EU project RISE has demonstrated the feasibility and effectiveness of the novel application FES of denervated muscles.
The main difference between nerve and direct muscle stimulation is the required impulse width of the applied stimuli. Nerves are stimulated with less than 1 ms, muscles with 30 to 200 ms at comparable intensity levels. The resulting charge per impulse and average electrical power levels are critical in applications of both surface electrode based and implantable stimulation systems. In non-invasive systems up to 30 mC of impulse charge and 25 W of power may occur. To minimize the risk of skin damage a large contact surface and holohedral current distribution are essential in design and handling of the electrodes.

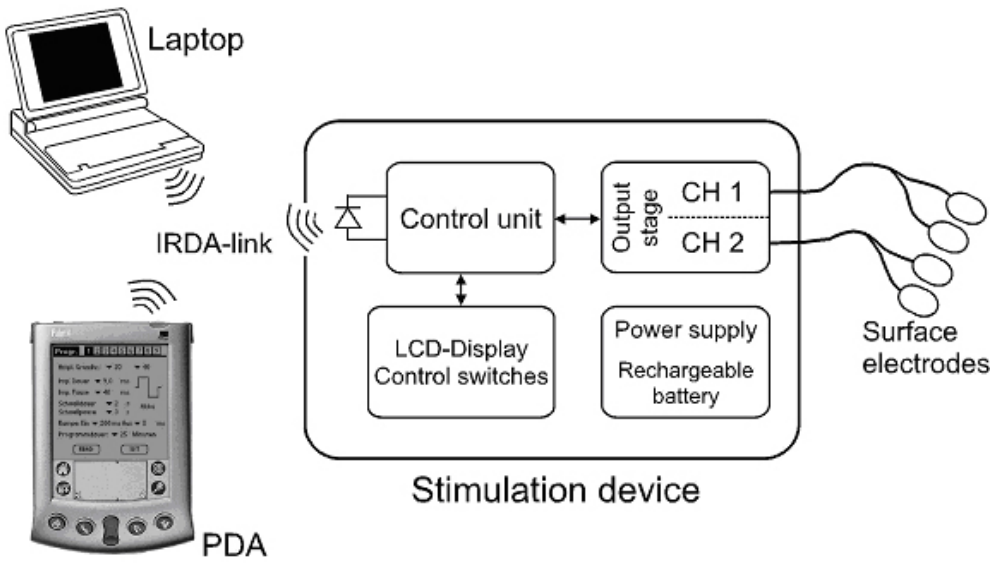

Figure 1. *Diagram of the 2-channel surface electrode based stimulator for denervated muscles, details in [4].*

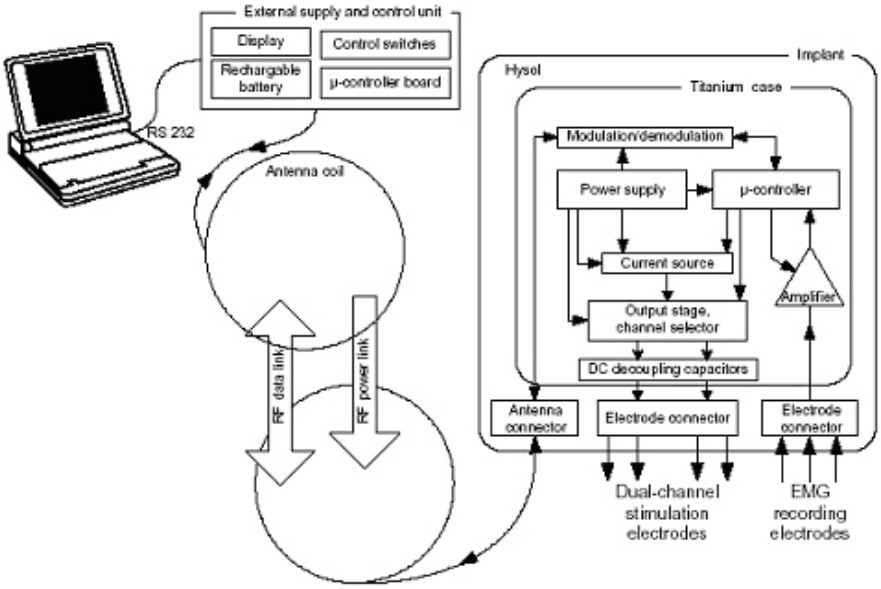

Figure 2. *Diagram of the RF-powered 2-channel implant for denervated muscles, details in [4].*

Stimulators must guarantee charge balance and zero DC at the outputs and must include all thinkable safety monitoring, operation and handling features to avoid failures in daily home based routine treatment.A suitable dual-channel system was developed in RISE and successfully tested in a patient study for a period of more than 2 years (Fig. 1). Implanted systems are not yet developed to a level that justifies clinical application. Various problems with the required size of the electrode being an extensive foreign body in moving tissue, electrochemical and mechanical stress and the power supply are not solved satisfactory. Nevertheless preliminary solutions where demonstrated in animal experiments (Fig. 2) [1]. FES of denervated muscles requires not only novel stimulation but also but also alternative measurement solutions. A new oscillation tonometry method, where the oscillation frequency and the decay curve of the freely swinging lower leg are assessed provides sensitive parameters for even minimal muscle reactions [2]. A second biomechanical method measures the contraction twitch of quadriceps femoris via a sensor at the patella sensor quantifying the contraction dynamics (time to peak, half relaxation time). Not at least single fibre M-wave recordings provide sound data on conduction velocity and recovery of the muscle fiber's membrane [3]. With the end of the RISE project we are able to provide both stimulation equipment for the patients' home based training and measurement equipment for the supervising outpatient clinic. Further efforts will address further refinement of the developed solutions, but will also aim in the development of implantable solutions that promise clear benefits in selectivity and safer and easier application [4].

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References

[1] Zrunek M, Bigenzahn W, Mayr W, Unger E, Feldner-Busztin H. A laryngeal pacemaker for inspiration controlled direct electrical stimulation of denervated posterior cricoarytaenoid muscle in sheep. *Eur Arch Otorhinolaryngol* 1991; 248(8):445-448.

[2] Gallasch E, Rafolt D, Kinz G, Fend M, Kern H, Mayr W. Evaluation of FES-induced knee joint moments in paraplegics with denervated muscles. *Artif Organs* 2005; 29(3):207-11.

[3] Hofer C, Forstner C, Modlin M, Jager H, Mayr W, Kern H. In vivo assessment of conduction velocity and refractory period of denervated muscle fibers. *Artif Organs* 2005; 29(6):436-9.

[4] Mayr W, Bijak M, Rafolt D, Sauermann S, Unger E, Lanmueller H: Basic design and construction of the Vienna FES implants - existing solutions and prospects for new generations of implants. *Medical Engineering and Physics* 2001; 23:53-60.