Rise2-Italy Project: Muscle FES after peripheral nerve lesion

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Abstract

One of the goal of the Rise2-Italy Project is to identify among the clinical cases of the Physical Medicine and Rehabilitation Unit of the University of Padua a group of subjects with permanent injuries (complete or incomplete) of arm/leg skeletal muscles aimed at extending the results of the European Project RISE [1-4]. Demonstration that a high-power electrical stimulator associated with large surface electrodes induces single (twitch) or sustained (tetanus) contractions in long-term denervated human muscles of paraplegics, open the opportunity to obtain trophic effect and some functional recovery of denervated muscle in patients with severe muscle atrophy secondary to peripheral nerve lesions. The eligible patients suffered traumatic injuries to plexus or single nerve (e.g., circonflessus or femoral nerve). At enlistment, shoulder or leg muscles of the patients do not respond to the clinical stimulation protocols for innervated muscle (twitch stimulation with 0.5 msec long impulse at 5-20 V/mAmp, or tetanising currents). Using an electrical stimulator for denervated muscle (i.e., with an adequate power) that discharges triangular waves 150-200 msec long at 20-80 mAmp to large surface wet electrodes (20x40cm, in lap case) the denervated muscle produces repeatedly single contractions (twitch training). Patient are revaluated monthly to verify if the denervated muscle partially recovers its excitability to a sufficiently short stimulations (duration <50msec), to be able to respond to short trains of impulse at 10-20 Hz frequency to perform tetanic contractions 2-3 sec long. This electrical stimulation protocol (5 times a week) will not replace, but complement the standard University of Padua Rehabilitation Unit protocol that includes passive and active functional rehabilitation. To monitor changes in thickness and tissue composition of trained muscles ultrasound scan are performed before and every three months during the 12 months of programmed treatment. Extent of innervation/reinnervation will be checked with periodic EMG. Our first observations suggest that this pilot study of the Rise2-Italy Project performed at the Padua Rehabilitation Unit could be extended to cases of peripheral denervation of skeletal muscles with clinically significant results.

Key Words: SCI, peripheral nerve lesions, traumatic injuries, twitch training, tetanic contractions, muscle ultrasound, electromyography, Functional Electrical Stimulation.

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Denervation of limbs occurs when there is a trauma to peripheral nerves and roots. The muscles lose mass rapidly, and much of the cross section becomes occupied by non contractile tissue, notably collagen and fat. The first goal of the Rise2-Italy Project is to identify among the clinical cases of the Physical Medicine and Rehabilitation Unit of the University of Padua a group of subjects with permanent injuries (complete or incomplete) of arm/leg skeletal muscles aimed at extending the results of the European Project RISE [1-4]. Demonstration that a high-power electrical stimulator associated with large surface electrodes

Fig. 1 *Clinical aspect of the right (denervated) and left (innervated) tibialis anterior. Atrophy of the right leg is evident. Voluntary dorsiflexion movements of the foot were completely absent more that one year after surgical removal of a portion of the sciatic nerve in the pelvis.*

induces single (twitch) or sustained (tetanus) contractions in long-term denervated human muscles of paraplegics, open the opportunity to obtain trophic effect and some functional recovery of denervated muscle in patients with severe muscle atrophy secondary to peripheral nerve lesions.

Materials and Methods

The eligible patients suffered traumatic injuries to plexus or single nerve (e.g., circonflessus or femoral nerve). At enlistment, shoulder or leg muscles of the patients do not respond to the clinical stimulation protocols for innervated muscle (twitch stimulation with 0.5 msec long impulse at 5-20 V/mAmp, or tetanising "Kotz currents"). Using an electrical stimulator for denervated muscle (i.e., with an adequate power) that discharges triangular waves 150-200 msec long at 20-80 mAmp to large surface wet electrodes (20x40cm, in Lap case) the denervated muscle produces repeatedly single contractions (twitch training). Patient will be revaluated monthly to verify if the denervated muscle partially recovers its excitability to a sufficiently short stimulations (duration <50msec), to be able to respond to short trains of impulse at 10-20 Hz frequency to perform tetanic contractions 2-3 sec long. This electrical stimulation protocol (5 times a week) will not replace, but complement the standard University of Padua Rehabilitation Unit protocol that includes passive and active functional rehabilitation. Extent of innervation/reinnervation will be checked with periodic EMG. To monitor changes in thickness and tissue composition of trained muscles ultrasound scan will be performed before and every three months during the 12 months of programmed treatment. In association the patient will do an echocolordoppler to observe the muscle perfusion and the change of the resistivity index (RI) before, during and after the stimulation. With this test is also possible to see the contraction of the muscle during the electrostimulation.

Results and Discussion

Rise2-Padova02-NB, a 46 years old woman, had suffered a right pelvic mass infiltrating the sciatic nerve that was partially sacrificed during surgery. Skin sensation and voluntary movements of the muscles of the anterior-external part of the leg (in particular Tibialis Anterior) were and remained absent after one year post-surgery, in spite of a progressive reinnervation of the thigh and posterior leg muscles. Electromyography confirms complete denervation of the tibialis anterior, and severe but partial denervation of the glutei and posterior muscles of the thigh. One year after surgery, Rise2-Padova02-NB commenced a training program which she done at the beginning in the hospital and than at home. One pair of electrodes with an area of 6x6cm was strapped to the anterior-external part of the right leg in proximal (negative one) and distal (positive one) position and to the glutei area. The electrical stimulator discharged triangular impulses 150 msec long at 18 mAmp producing repeatedly single contractions (FES twitch training). This training was delivered for 20 min per day, 5 days per week. After 6 months of stimulation the glutei muscles partial resumed his excitability (by reinnervation) and thus the training of this muscle was switched to a tetanising impulse protocol. In spite of permanent denervation, after one year of FES twitch treatment the excitability of tibialis anterior muscle fibers had recovered sufficiently to shorten the pulse duration to 70 msec. This allows delivering trains of 6 impulses that are able to induce dorsiflexion of the foot. Ultrasound imaging of the Tibialis Anterior (figure 2) show that the denervated muscle is still atrophic in comparison to the contra lateral innervated muscle, but that it responds with slow contractions to electrical stimulation.

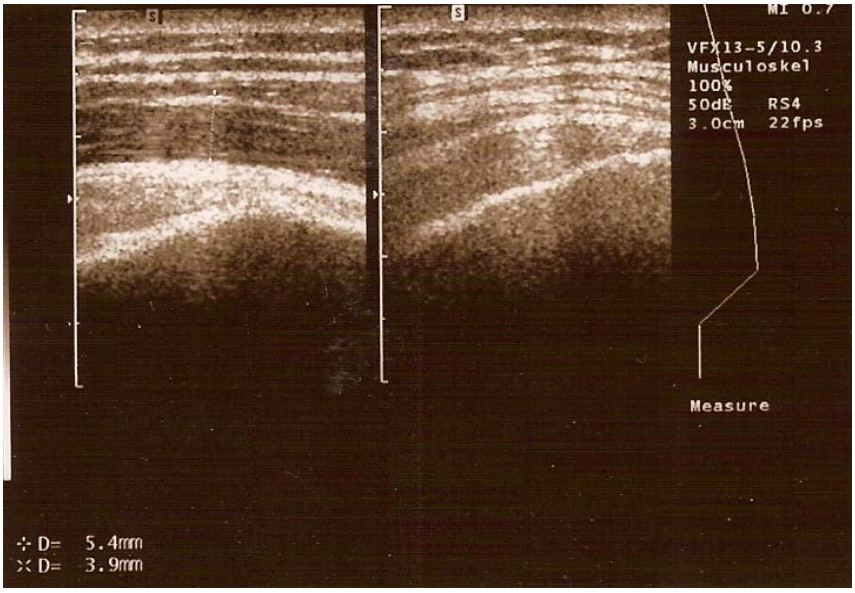

Fig. 2. *Ultrasound muscle images allow to measure at the neurovascular pole the thickness of the Tibialis Anterior 3.9 mm (right, denervated) and 5.4 mm (left, innervated).*

Functional Echomyography documents also a different perfusion behavior of the denervated TA, and that in the atrophic muscle the Resistance Index is modified by electrical stimulation-induced muscle contraction from 0.72 at rest to 0.8 during stimulation. Functional Echomyography show also a different mechanical response to electrical stimulation, in particular of the muscle relaxation phase (Manuscript in preparation).

Altogether preliminary observations of this pilot study of the Rise2-Italy Project performed at the Padua Rehabilitation Unit suggests that Therapeutic Electrical Stimulation of the lower motor neuron denervated skeletal muscle could be extended from the rare Conus Cauda Syndrome to more common cases of peripheral nerve lesions with clinically significant results.

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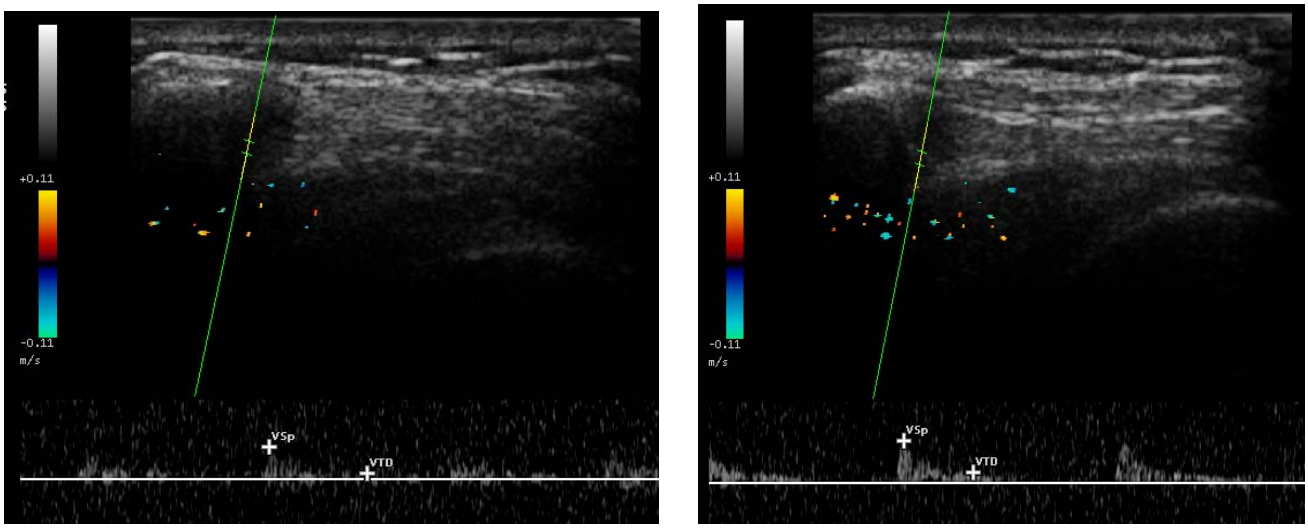

Fig. 3 *Functional Echomyography using colordoppler shows that the perfusion in the denervated muscle change characteristics during stimulation, from pathognomonic low resistivity index and diastolic perfusion to higher index, implying increase of the blood flow.*

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