CHANGES AND LIMITATIONS TO ELECTRICAL STIMULATION OF FLACCID PARALYSES

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Paralyses are motorical disturbances of function deriving from either the central nervous system,the spinal cord,the peripheral nerves or the muscle itself.In nervous defiencies we distinguish between spastic and flaccid paralyses depending on the paralysed muscle still being connected with its peripheral nerve or not.

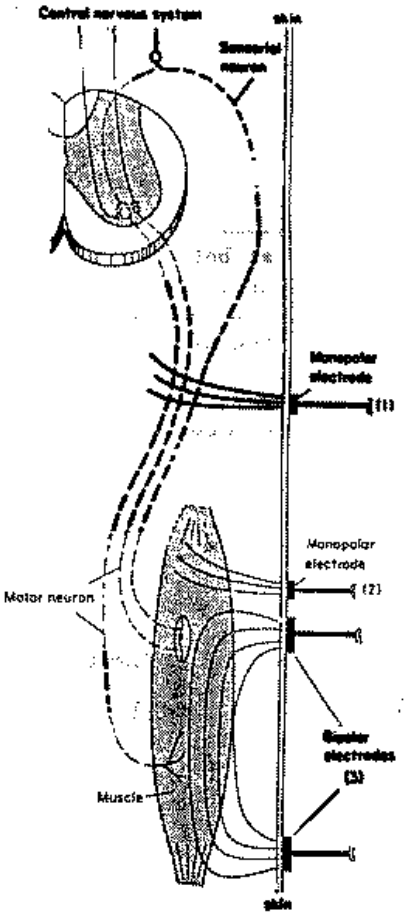

Figure 1 Indirect and direct muscle stimulation

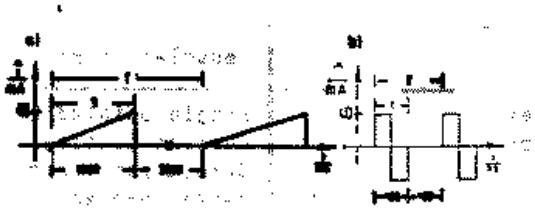

Figure 2 Stimulation for the treatment of flaccid muscles
a) Triangular or Exponential
b) Bidirectional

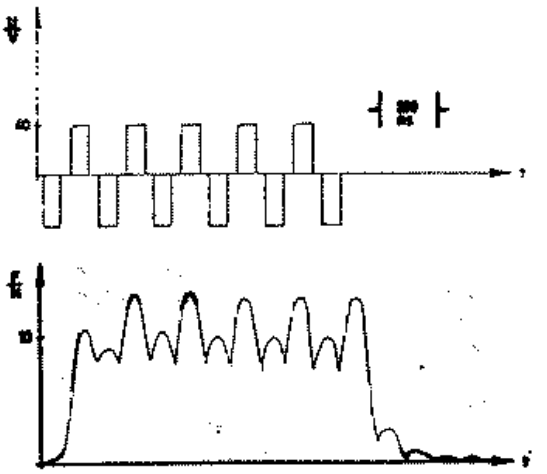

Figure 4 Stimulus voltage and mechanical force of m. biceps femoris

In the first case reflex circles of efferent and afferent nerves and the paralysed muscles are still working.The basic tonus often is rather higher then reduced, due to lacking blocking signals from the central nervous system.

Paralyses	Central Spastic	Peripheral Flaccid	
stimulation	indirect monodirectional	direct exponential	direct bidirectional
pulse duration	5 - 20 ms	800 - 1000 ms	10 - 100 ms
current intensity	5 - 20 mA	80 mA	20 - 40 mA
puls/period duration	1 : 20	1 : 5	1 : 1
fusion frequency	40 - 150 Hz		15 Hz
stimulus conductivity	nerve: 70 m/s muscle: 5 m/s	-	-
excitation process	single pointed by current density depolarisation of nerve membrane	spatial by current field, direct release of calcium ions	
arrangement	monopolar on motor point	bipolar at both ends of the muscle belly	
target	maintenance or substitution of function	maintenance of muscle or extremity	

Table 1

Blood circulation and trophism are quite good, which is proved by the condition of skin and bones.The muscles can rather easily be stimulated indirectly via the nerves.The spectacular successes of Functional Electrical Stimulation are achieved to spastic paralyses tries to at least partially regain the disturbed function by means of external or implanted stimulators / 10, 9 /.

Peripheral nerves and muscle fibres do not only form a functional unit but also a trophic one.A division leads to an atrophy of the muscle fibres with destruction of the contractile substance and an eletro-physiological change of the membrane. Above all the muscle membrane loses its capacity of spreading irritations, because of enforced inactivity and of the trophic influence of nerves on muscle fibres.In addition to the loss of function secondary damages appear due to reduced metabolism. Such damages are, for example, subnormal temperature, susceptibility to infections and contractures because of immobility. Extended paralyses, such as transverse lesions of the cord, cause permanent failures of posture (scoliosis). Insufficient trophism and continuous sitting in a wheel chair will develop decubital ulcers. In paralysed extremities bones change their structure and lose substance, which often implies contractures. The formation of residual urine in a paralysed bladder leads to chronic infection. In incomplete paralyses the interaction between bladder and sphincter is disturbed. A manually supported voiding of the bladder may increase pressure and in the long run this may cause damage to the kidney.

All attempts to counterbalance the damages by electro-therapy turned out rather unsuccessful. Therapy with exponential currents (fig.2), though considered most suitable, is only indicated for patients, where re-innervation can be expected / 3 / Degeneration of muscles can only be retarded, but cannot be prevented.

Our working group / 4,5 / was able to demonstrate that when applying bi-directional currents (fig.2), a suitable mode of proceeding and a special technique in electrodes, it was possible to maintain and even restore flaccid paralysed muscles. This requires a regular training for several times a day. In the course of therapy pulse duration should be shortened down from 100 ms in the beginning to 20 ms, which then made initial single twitches of the muscle turn over to tetanic contractions. The fusion frequency is lower than in the innervated skeletal muscle and ranges between 8 - 12 Hz. As a denervated muscle cannot spread excitations, it can only contract in an area of sufficient current density in direction of the muscle fibre. On the other hand current density must not be too high in order to avoid damages to skin. According to our opinion the necessary quasi-homogeneous current fields can only be produced with surface electrodes the diameters of which have to be adapted to the cross-section of the muscle in question (fig. 1). As implanted electrodes must necessarily be smaller the induced current density will either not be sufficient for stimulation or will destroy the tissue in the immediate environment of the electrodes.

Table 1 shows the differences between indirect and direct muscle stimulation. Flaccid paralysed muscle can only be restored by applying sufficiently long pulse durations and bi-directional currents. This can directly be deduced from fig. 3a and fig. 3b showing the development of force measured by a bending beam in a denervated trained m. biceps femoris under mono-directional and bi-directional currents. Fatigue which is typical for direct muscle stimulation can only be avoided with bi-directional currents. This effect can certainly be attributed to the fact that the current lines enter and leave the muscle fibres at many points. When current changes direction the virtual anodes and cathodes change place, so that finally varying parts of this muscle are contracting. This is also shown in fig.4. The different maxima can clearly be assigned to the positive and negative current pulses.

This process is at least similar to the normal excitation of the innervated muscle, in which the motor units change permanently for avoiding a quick fatigue.

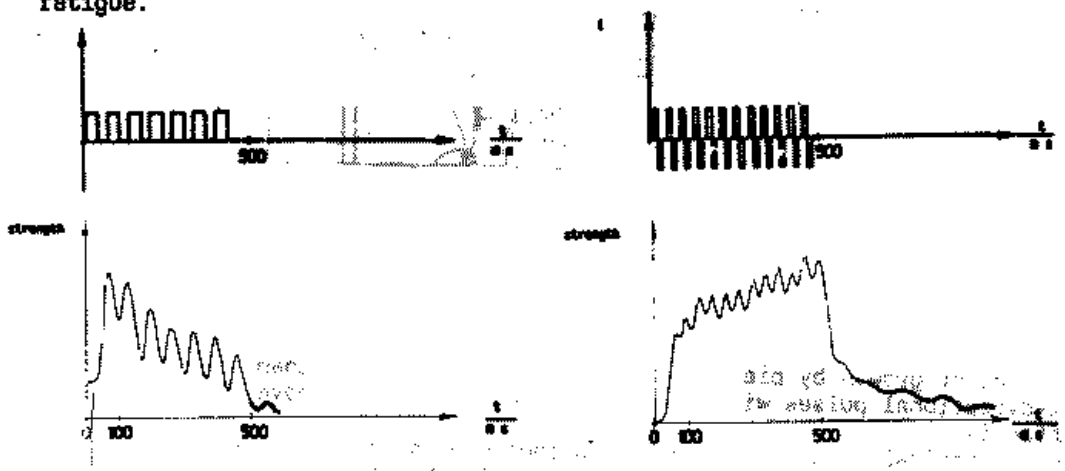

Figure 3 Dynamic strength development in flaccid paralysed muscle
a) with monodirectional impulse b) with bidirectional impulse

Minimum demands to a therapy are two or three one-minute tetanic contractions

per day for maintaining a muscle in a stable condition / 4,5 /. The thus obtained forces, however, are not sufficient for a functional support of movements. Special stimulation devices have been developped which can be used as home stimulators by instructed laymen /Eichhorn/. If both legs are paralysed, treatment of the main muscles takes about one hour. Depending on the rate of degeneration of muscle current intensities may amount up to 60 mA. The possibilities of this therapy are restricted due to the large amount of time and to the high current intensities already causing current pains to patients with restricted sensibility.For intensification of therapy multi-channel stimulators have been developped permitting to perform an automatic treining. Moreover multi-channel stimulation offers new chances which to some part imply immeasurable extensions for the time being. Some ideas are outlined in the following.

A first approach should bre the rebuilding of force chains which after having performed a sufficient treining will permit the passing over to functional electrical stimulation. Suitable support for reaching this target is certainly given by the selective stimulation of a muscle, with more than two electrodes. The forces produced by stimulation take effect on bones and joints via ligaments, and thus exert a positive influence on the growth of bones and the flexibility of joints. With multi-channel devices these effects can purposively be utilized, especially if several muscles are interacting simultaneously. For this, muscles and joints are pasively placed into defined positions and fixations, for example in standing bars (fig.5). This usual passive therapy is now supported by the planned activity of paralysed muscles. Going one step further innervated muscles can be stimulated via nerves as in scoliosis therapy to work against unvoluntary evasive movements.

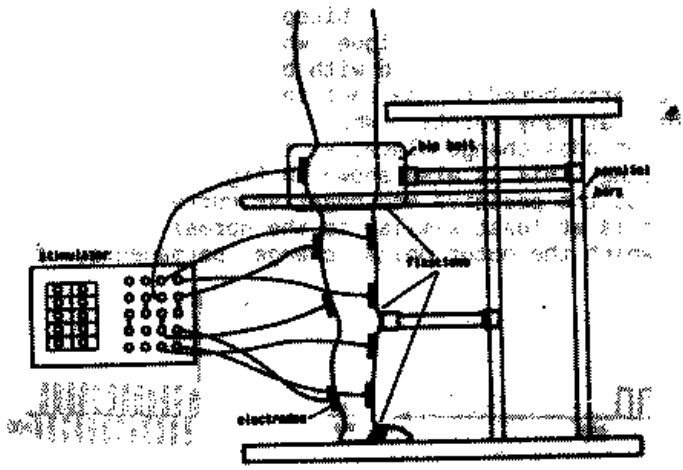

Figure 5 Isometric stimulation in parallel bars for standing upright

From clinical investigations we know the (direct) stimulation of bones, permitting to support the growth in bones after fractures by applying low current intensities. It is supposed, that stimulation replaces the normal control of growth by piezo-electricity depending on mechanical charge. Thus bi-directional pulses with walking frequency (0,7 Hz) prove to be especially effective.

The mechenical load can as well be produced by stimulated muscles. In first examinations on a isometric treiner it shall therefore be tried to achieve a quantitative influence not only on muscle growth, but also on growth in bones and on flexibility of joints.

The vesical wall has unstriped musculature losing its shape in flaccid paralyses and forming extroversions which can however be reformed by a treatment with long-lasting bi-directional pulses (T > 200 ms, keying ratio 2, I 30 mA) which make contract the unstriped musculature.
Current is applied via four electrodes attached on the abdominal wall directly above the bladder. Fig.6 shows, that depending on the circuit four arrangements of current density can be set each flowing through different muscle fibres in longitudinal direction and stimulating them. Examinations with ultra sonic prove that by applying such an arrangement itis possible to give back to the bladder its original shape and thus to eliminate sites of infection.

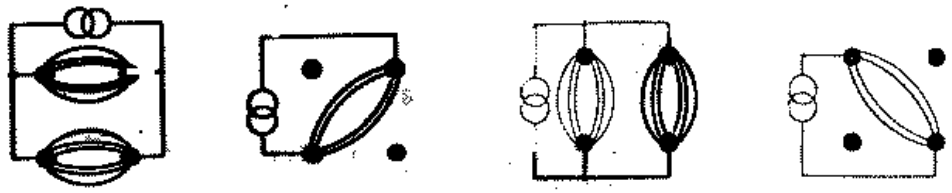

Figure 6 Arrangement of electrodes to stimulate the bladder

The other mentioned problems being quite similar to each other, e.g. pain reduction and the planned inhibition of a muscle by electrical anesthesia, are still unsolved.In literature many suggestions can be found on this behalf / 3,6 /. These are mostly based on higher placed neronal connections and can therefore at least not easily be transferred to the problems mentioned before.Theoretical possibilities for solution are offered by the sodium and potassium channels of the nerve membrane which may be retained in an open or closed position by means of direct currents or medium frequency currents. / 7 /. We have built special two-channel stimulation and measuring systems for generating synchronous stimulating signals between 0 and 50 kHz and for measuring the mechanical responses and the evoked potentials. We are looking forward to give a report on application of these systems and on the results in due course.
Finally there exists a problem, which cannot clearly be assigned to either the medical or the technical area, but which is placed inbetween. It deals with acceptance and correct application of such systems.Experiences with one channel devices show, that apart from emotional reservation treatment often fails, because therapists do not master either the accurate application of electrodes or the electro-diagnostics for obtaining the suitable stimulation parameters.It is therefore indispensable to improve education and collaboration and at the same time create suitable user's support and mechanical feedbacks up to knowledge based systems.

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