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Clinical results in traumatic spinal cord injury elektrical stimulation.

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The attempts to use stimulation of the spinal cord as a curative method have been undertaken all over the world only for few years, so far. This method was firstly introduced by Shealy /21/ as a new way of treating pain syndromes. Its justification he based on Melzack and Wall "gate theory" which ascertained /12/ that stimulation of big quickly conducting myelinated fibres produces inhibition of the function of unmyelinated fibers which conduct pain stimuli. The rightness of this theory was confirmed experimentally by Shealy and co-workers, which a few years later /22/ published positive results of their first clinical attempts carried out in 6 patients with pain syndromes of different origin In these patients stimulators were implanted with electrodes sewed to dura mater. The method gain great interest and shortly a number of information appeared stating about positive results of using stimulation with both low as well as high frequency/13, 23/ - up to 200-250 cycles per second /1,10,15/.
Since 1970, Nashold and co-workers applied stimulation of cauda equina /14/aiming at obtainment in this way regulation of neurogenic bladder function. This technique was taken up by other authors /19,20/. The results obtained have become a basis for broader examination of indications for using spinal cord stimulation and of its influence on other tissues and body organs /2/, /3,4,16/. Cook /5,6/ found advantageous influence of spinal cord stimulation in patients with sclerosis multiplex consisting in improvement of motor functions, better coordination of movements, and lower level of spasticity. In the avallable literature

however, I could not find /except one case cited lastly by Vishnevski /24/ attempts of using spinal cord stimulation after injury.

Our own experiments.

In the Rehabilitation Institute at Konstancin /Poland/, since 1970, clinical observations have been carried out on the use of electrostimulation for controlling the function of paralyzed extremities in cases of spinal cord injuries in cervical segment with the use of technique of implanted stimulators /7, 8,16,17/. They demonstrated that stimulation of peripheral nerves leads to functional and strength improvement of paralyzed nervous and muscular complexes, as also revealed advantageous influence of this stimulation on injured segment of the spinal cord. As a result of this, we have advanced a conception of direct "bombardment" of the injured spinal cord segment with electric stimuli. We accepted that in this way there is possibility of both: preventing development of disadvantageous secondary changes arising in the spinal cord as a result of trauma, as also of improving conditions of its regeneration.
Since 1974, stimulating electrodes, or stimulators, have been implanted with a view to stimulating the spinal cord in 39 patients with spinal cord injury. Five persons were excluded from this analysis because they died in the early post-traumatic period. So, finally, 34 cases were analysed.

In the initial period of investigations we used electrodes with their wires led through the skin to the outside. They enabled us to use, apart from stimulation, DD current having anti-oedema and anti-inflammatory action and making possible applying of various kinds of courses of stimulating currents; we

could also measure parameters of stimulation /current voltage as well as impedance of stimulated tissues/. This method, however, had this shortcoming that wires led through the skin gave way in some cases to secondary infections of the surgical wound. After obtainment of necessery date we began to apply implanted stimulators with receiver placed most often in subcutaneous tissue of the chest. Age and sex of operated on patients are presented in Table I. Stimulators have been implanted most often in Young males operated on chiefly in the first days after cord lesion. Implantations were made in complete, as well as in incomplete injuries of the spinal cord /always, however, with a complete paralysis of muscle groups/ in cervical as also thoracic cord segment. These date were presented in Table II.

Symbol C denotes complete paralysis with abolition of all kinds of sensation; incomplete injuries were divided into three groups:

1. - complete paralysis with partial sensation /deep/ left,
2. - high degree of paresis,
3. - insignificant paresis impairing functions of extremities.

Technique of surgery.

Implantation of electrodes in the cervical part was made together with anterior decompression with a partial or total resection of the vertebral body. After elemination of the fragments of the shaft pressing upon the mening and after obtaining a bed in neighboring shafts /9,11/, electrodes of the stimulator were applied. They were placed under the vertebra bodies neighboring with the injured one, and next, an autogenic bony graft was anchored above them. In the case of using electrodes alone, their conduits were led through the skin - outside of the wound area - with the use of a big needle. When a stimulator was implanted, a canal in the subcutaneous tissue was made going down to the anterio-superior

surface of the chest in which receiver was introduced.

Introducing electrodes into thoracic segment was made during spring alloplasty by means of inserting them under vertebral arcs neighboring with the place of lesion or when postero-lateral decompression of the spinal cord is done. In such situation one electrode was put under meningeal sack from the side of vertebral body, and the second one - below and from dorsal side under the arc of vertebra.

Stimulation technical date.

Three kinds of voltage course were used in stimulation with implanted electrodes:

- rectangular impulses lasting 1 msec and having frequency of 45 cycles per sec;
- CP or DP straightened sinusoidal voltage of 50 cycles per sec;
- sinusoidal current of variable frequency of 7-14 kilocycles per sec, or 16-30 kilocycles per sec modulated by the voltage course, the frequency of which was automatically tuned from 50 to 400 cycles per sec with variable modulation factor from zero to 100% /automatically controled/.

Two types of implanted stimulators were used:

1. Avry Laboratories Inc.Med. Firm /in three cases/;
2. Worked out and made in the Rehabilitation Center, formerly used for stimulation of peripheral nerves. This stimulator operating on the principle of imparting energy in electric coupled circuits produces rectangular impulses the duration of which can be controlled within limits of 0.2-1.2 msec, frequency in the range of 30 - 80 cycles per sec, and amplitude from 0 to 20v.

In our previous investigations we implanted to 20 patients electrodes with wires led to the outside, and to 19 - implanted stimulators.

Stimulation method.

Stimulation was made with the use of a special programing arrangement. In the period of 5 min, 5-sec stimulating series with 30-sec breaks were used. After this period, there follows 30-min break, and next, successive 5-min stimulating seance. Daily training lasted 2-3hr.

In the case of stimulation with DD currents for 10min, DF current was used; for the next 10min CP and, in turn, DF currents were applied and in the last 10 min interrupted stimulation was used /RS/. In patients stimulated with modulated voltage of low frequency training was carried out twice a day for 14 min. Each time two different voltages, one after another of 7-min duration, were used. This program was applied using audiostimulator TD-100 with programing arrangement automatically switching the kind of stimulating voltage in 7-min intervals.

The values of voltages applied were dependent on individual reactions of patients, such as: muscle contractions, sensation in extremities or pain. These values ranges in limits of 0.6 to 2.8 v. Current amplitude was measured on the standard resistor, included in series to electrode circuit, and amounted from 2 to 9 mA.

Initial results of spinal cord stimulation.

It is difficult to assess results of treatment with the use of stimulation technique. This results both from not too great experience as yet, as also from the fact that stimulation was made in cases operated on in early post-traumatic periods. It is difficult to evaluate whether improvement is, and in what degree, the result of stimulation itself or operative decompression of the spinal cord. However, the fact remains that out of 34 patients with kinetic paralysis down from the place of injury ascertained

on admission, in 50% of cases distinct neurological improvement was obtained, which in 9 patients enabled them to walk indyvidually and brought about their full indepedence. Another incontestable achievement was regaining of bladder automatism in 6 weeks on the average. In analogical cases, treated differently, this result was obtained usually in 3-4 months after the injury. These two factors were a basis for evaluation the value of spinal cord stimulation. In Table III are given changes of neurological status in the group with electrodes led to the outside and with implanted stimulators. Table IV presents dependence of changes in neurological status on the height of spinal cord injury. It results from this table that somewhat better are stimulation results of cervical segment of the spinal cord. Out of 18 patients 9 improved in comparison with 5 cases of improvement out of 14 patients with injury of the lower segment of the spinal cord. This fact, however, does not result from the peculiarity of stimulation, but rather from the difference in anatomical conditions and pathophysiology of the spinal cord on these levels.

Table V presents time in which bladder automatism was obtained in the discussed group of patients. In this table, similarly as in Table III, there is a lack of data which can speak in favor of one of the two stimulation methods. It should be emphasized, however, that in80% of examined patients bladder automatism developed in the period of 8 weeks after trauma.

Taking the above into consideration, it seems that initial results of clinical examinations may be assessed positively. Further investigations are justified, which, maybe, will permit to specify indications for using this method and to choose the most advantageous stimulation parameters.

Table I

Age	sex		Total
	m	f	
up to 20	7	2	9
21 - 40	15	3	18
41 - 60	7	-	7
Total	29	5	34

Table II

Height of injury	Initial neurological status		Total
	0	1	
C_4 - C_7	7	9	16
D_1 - D_5	3	1	4
D_6 - D_{12}	11	3	14
T o t a l	21	13	34

Table III

Neurological status			stimulation type		Total
initial		after treatment	electrodes	stimulators	
0	-	0	8	8	16
0	-	2	2	2	4
0	-	3	1	-	1
1	-	1	-	1	1
1	-	2	1	3	4
1	-	3	4	4	8
T o t a l			16	18	34

Table IV

Neurological status initial	after treatment	Height of spine injury C_4-C_7	D_1-D_5	D_6-D_{12}	Total
C	C	6	1	9	16
C	2	1	1	2	4
C	3	-	1	-	1
1	1	1	-	-	1
1	2	2	1	1	4
1	3	6	-	2	8
T o t a l		16	4	14	34

Table V

Time: trauma-automatism	Type of stimulation electrodes	stimulators	Total
3 - 5 weeks	6	8	14
6 - 8	6	7	13
9 - 12	4	3	7
T o t a l	16	18	34

Since 1974 at the Konstancin Rehabilitation Centre electrodes or stimulators have been implanted in 39 patients to stimulate the injured spinal cord. 34 of the patients with complete or almost complete spinal lesion are presented.
The surgical technique and kind of electric currents used are described. The results obtained are satisfactory: in half of the patients neurological improvement was statee, 9 patients were able to walk by themselves and they were fully independent in daily living activities. It was also found that development of automatic bladder was promoted in stimulated patients. The assessment of whether the effects observed were due to stimulation or to spine early decompression is difficult

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