FUNCTIONAL ELECTRICAL STIMULATION OF THE EXTERNAL URINARY SPHINCTER AND FATIGUE OF THE SPHINCTER

P. Šuhel, S. Rakovec, C. Godec, M. Benedik, T. Jegliě, E. Vavken, M. Janko, B. Kralj, and S. Grobelnik

Summary

The experimental study is focused on preventing incontinence in paraplegic patients. In a number of patients exhibiting incontinence external electrical stimulation succeeded in stoping urinary flow and in preventing incontinence. Thus far we have got some interesting experiences with long term electrical stimulation of the external sphincter. Decreasing excitability of the external sphincter has been established as well as fatigue of the sphincter. Electrofatiguing of the sphincter followed by stimulation of the detrusor is expected to produce complete or almost complete emptying of the bladder. We intend to measure the duration of the electrical stimulus which can tire the sphincter to such an extent that the urinary flow from bladder would not be disturbed. It is also necessary to find out the optimal time needed to reinstitute activity of the sphincter.

For more than a decade functional electrostimulation (FES) has been used for dysfunctions of the urinary bladder /1/. There have been various results from treatment. FES of the detrusor creates a serious problem by spreading stimuli to neighboring antagonist muscles /4/. Application of FES in treatment of incontience, esspecially stress incontience has led to better results then when it has been used to treat lesions of the sphincter following prostate operations. So far, such treatment of neurogenic dysfunctions of the incontinent bladder has not been satisfactory /2/. Hence, up until now, our research has been limited to the study of incontinence among neurogenic dysfunctions. It is our opinion that FES can be successful in treatment of this form of incontinence, but only in cases when the muscles controlling continence are not denervated. Such cases occur by lesions of the spinal cord which are located over the spinal reflex center for the bladder. In order to obtain clarity and limit complications, those cases have been chosen for our research which most nearly approximate transverse suprasegmental lesions of the spinal cord and which are neurologically, as well as clinically, relatively well researched.

To achieve the maximum effect, FES for urinary incontinence must be permanent, except for periods of voluntary emptying of the bladder.

This investigation was supported by the Foundation "Boris Kidrič" in Ljubljana

In this regard two questions arise, how does a muscle respond to permanent stimulation and is permanent FES at all possible. Our attention was drawn to a report by Mogil and colleagues about experiments with dogs in which more successful emptying of the bladder was achieved by preceeding electrostimulation of the detrusor with electrostimulation of the proximal part of the urethra /6/. Mogil asserts that this result is a consequence of fatigue, caused by the closing of the bladder muscles which is followed by relaxation. Although these experiments had the primary purpose of preventing, or at least weakening, the spreading of electrical stimuli to the urethral structure related to continence, some doubts arose about the possibility of permanent stimulation. Recently a member of our research group, Rakovec, as a guest of Professor N. A. Lopatkin in Moscow /5/, had the opportunity to observe a patient with neurogenic dysfunction of the bladder. In order to maintain retention of urine, two receivers were implanted in his body: one for stimulating the detrusor and the other for stimulating the closing muscles of the bladder. First, for a few seconds, the patient electrically stimulated the closing muscles and then, following the short interval, stimulated the detrusor. This effected a prompt emptying of the bladder. In this case fatigue of the closing muscles should also enable more successful emptying of the bladder. There are various opinions about the possibility of muscle fatigue. K.P.S. Caldwell, who over a period of ten years has used permanent electrostimulation for urinary incontinence, claims to have not noticed the fatigue of muscles, but to the contrary, their strengthening /3/. In order to thoroughly study the fatigue of muscles, our research has been directed toward observation of the reaction of muscles subjected to long term external electrostimulation and of patients with permanently implanted electrostimulators.

Selection of patients: Seeking patients with known lesions of the spinal cord, we had to choose from among a large group of paraplegics. Some routine neurophysiological and urodynamic methods were used for precise diagnosis of these lesions. The length and degree of lesion of motor paths in the spinal cord were determined by polyelectromyography. Analysis of somatosensoric evoked cerebral potentials provided data about the length and degree of lesions of ascendent paths in the spinal cord.Electromyography of the pelvic muscles indicated peripheral motor innervations of these structures.

In order to achieve highly precise diagnosis of lesions umong our patients, the following urodynamic parameters were examined:

intravesical pressure, intraabdominal or extravesical pressure, differential pressure, vesical volume and residual urine, intensity or integrity of the closing muscles at the bladder exit, and the passing of urine from the bladder through the urethra.

Intravesical pressure was examined using a special cystometry, whereby the activity of the detrusor was defined by measuring the functional dependence of pressure on volume. For this task, ordinary cystometers are too insensitive. Therefore, esspecially designed equipment incorporating a highly sensitive pressure transducer, called "Pitran", was used. This equipment measures the hydraulic transmission through the "Pitran" of intravesical pressure changes. These changes are then electrically amplified and recorded.

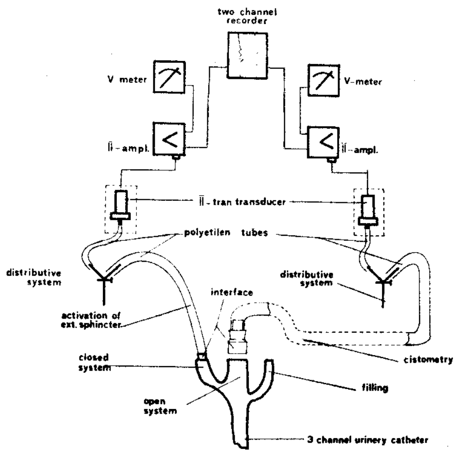

Fig. 1.

Figure 1 illustrates the measuring system for cystometry, which is connected to the right channel of a Foley catheter. A "Pitran" transducer registres the hydraulic transmission of this channel. Using a special balloon, inserted in the rectrum, abdominal pressure and the strength of second degree urinary expulsors were determined. The differential pressure was calculated by subtracing the intraabdominal pressure from the intravesical pressure.

Cystourethroscopy, using a prograde optic, determined morphological and some useful urodynamic information about the bladder and proximal urethra, as well as the vesical volume and residual urine.

The measurement of activity in the closing muscles of the urinary bladder was restricted to the muscles of the pelvic floor, the contraction of which indicates the extent to which the closing mechanism is still under the voluntary control of the patient. The system for measuring this activity is also illustrated in Figure 1. It consists of a mechanical sensor, representing a balloon filled with liquid, which is attached to the closed system of the left channel of the Foley catheter. Information is transmitted in the same way as for the right channel. Mechanical pressures provoked by the muscles of the closing mechanism are transmitted through the tube to a "Pitran" transducer and from there electrcal signals through the compensator to the amplifier and finally to the recorder. This system can be regulated by adjusting the amount of fluid in the measuring balloon. In this way, it is possible to compare the activity of these muscles with various lesions.

The system for measuring activation of the urethral closing mechanism records activity reflextively provoked by assistance of electrostimulation of the pelvic or sphincter muscles. For these tests the same channel is used as that for measuring the activity of the closing muscles. The measuring balloon is located in area of the closing system. The methods of measurement are shown in Figure 2.

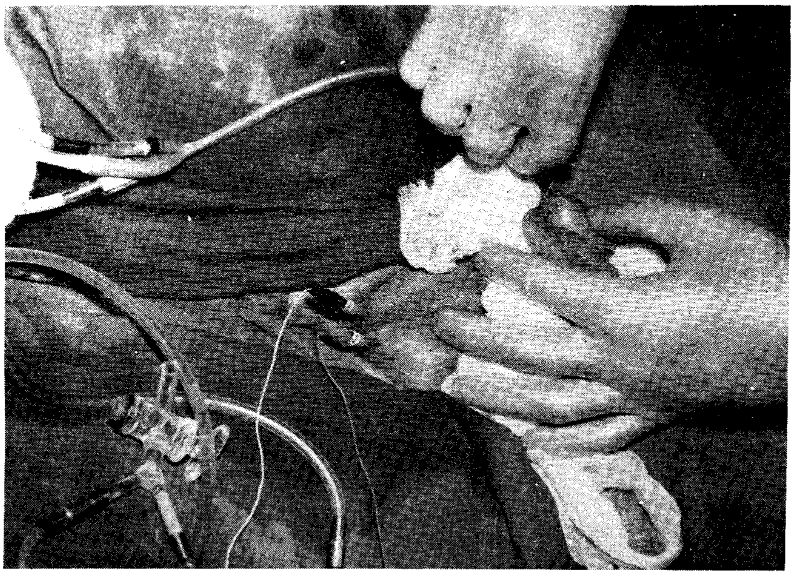

Fig. 2.

Cinecystourethrography enables observation of the dynamic passing of urine from the bladder and the funnel shaped opening of the muscles of the pelvic floor as well as its contraction provoked by electrostimulation. The simultaneous lifting of the pelvic floor and the bladder provides additional information about activation of these structures.

On the basis of routine urological and neurophysiological examinations 12 patients were selected as subjects for our research. Among all these patients urodynamic and neurophysiological parameters were determined 23 times.

Using the above methods, not a single patient was found who had only a lesion of the spinal cord above the spinal reflex center for micturition. In addition to spinal lesion all patients had peripheral denervation of some muscles in the pelvic floor.

Although pure forms of a transverse suprasegmental lesion were not found, several of these patients, nonetheless, were chosen for further research. It is known, namely, that denervation of muscles is usually only partial. Clinical experiments using percutaneously inserted needle electrodes produced a positive response among these patients. While measuring the activation of the pelvic floor, the most noteworthy phenomenon was encountered. Following successive electrostimulations, the contraction of the urogenital diaphragm became progressively weaker, although the same stimulus with an amplitude of 8 V, with of 1 msec. and frequency of 25 cycles, was used. This is shown in Figure 3.

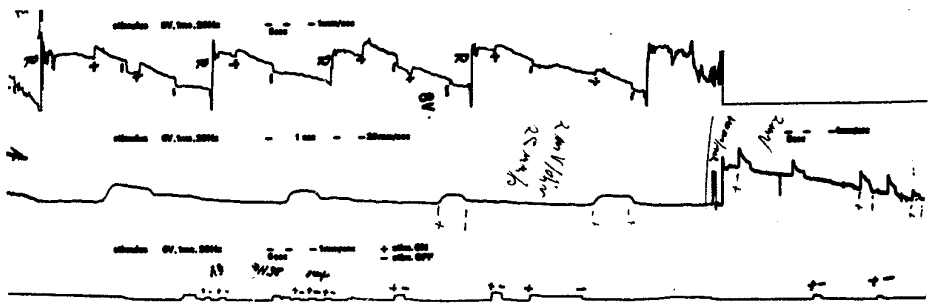

Fig. 3.

We are aware that examination of the urinary tract using instruments can themselves be the source of various artifacts. It is known, for example, that by itself the insertion of the catheter can cause contractions of the urogenital diaphragm which are also recorded. Therefore, when the above phenomenon was apparent, measurement was repeated several times. However, after several recurrences of the same phenomenon, we considered its clarification through various interpretations and eventually additional research.

For the patient with an implanted electrostimulator (schematically shown in Figure 4) it was possible to promptly interrupt micturition with electrostimulation. Before, during and after stimulation an attemption was made to observe the electromyographic activity of the patient´s external urethral sphincter. During the period of measurement unchanging electromyographic activity was observed. Even after stimulation with needle electrodes inserted into the muscles of the pelvic floor, it was impossible to provoke a response of the external urethral sphincter. During stimulation needle electrodes, the EMG of the anal levator showed response with a latency of 40 msec.

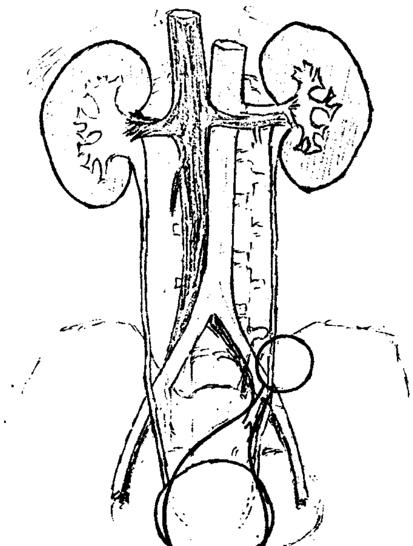

Fig. 4.

Our research concerning the fatigue of muscles with FES remains too limited for final conclusion to be drawn. However, our observation, by itself, concerning the electromyographic of the anal levator is most interesting.

It is difficult to explain such a long latency. It is possible that this latency is caused by damaged nerve fibers which transmit impulses very slowly. Namely, in the anal levator indications of insufficient peripheral motor innervations were discovered. Another explanation for this long latency can be that afferent fibers were stimulated and hence, the impulse reached the muscle via the medulla spinalis.

These findings lead one to think that not only the motor nerve paths, but primarily the afferent paths are provoked by FES. Hence, impulses travel via the reflex center to the motor paths. Electrostimulation is therefore not direct, but rather, afferent. In addition, it has been observed that stimulus of a greater amplitude than that used by us, is required for direct stimulation and is strong enough to damage muscle tissue at the point of electrode insertion. Finally, we would like to share an observation about our patient with the reflex bladder, which was made during the implantation of electrodes on both sides of the apex of the prostata. This is shown by the X-ray in Figure 5.

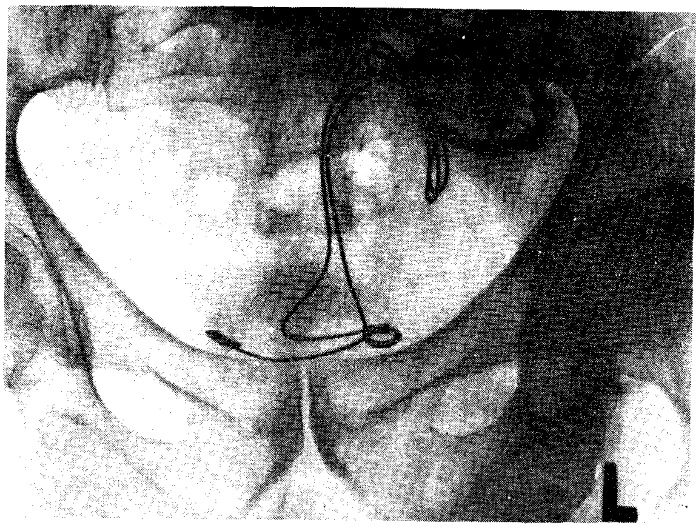

Fig. 5.

An especially strong contraction of all muscles of the pelvic floor was observed and recorded during electrostimulation with a train of impulses having an amplitude of 6 v., width of 1 msec., and a frequency of 25 cycles. It is our opinion that response of muscles in such an extended area can only be explained by reflex transmission of the stimulus, whereby stimulation of a confined area is conveyed via the interneuron system to a larger group of muscles. Such a reflex mechanism is more effective, requires less stimulus and therefore would be preferable. Of course, our experience is too limited for us to form any hypothesis. In so far as observations and possible mistakes are subject to various explanations, so are those of certain authors who explain in terms of muscle fatigue, and easier emptying of the bladder which is achieved with electrostimulation of the detrusor following that of the closing muscles. So far, such muscle fatigue has not been precisely investigated. The hypothesis about the reflex mechanism of stimulation even excludes the possibility of muscle fatigue.

With our experiments in stimulation, it was not possible to prove fatigue of the electrostimulated muscles of the bladder´s closing mechanism. Our work led to the thought that it is possible to stimulate the afferent part of the reflex arc and not the motor nerve fibers.

References

/1/ Bradley, W., Timm, G., and Chou, S. in *Urol Int.*, 26: 283-303, 1971.

/2/ Caldwell, K. in *Ann. Roy. Coll. Surg. Eng.*, 41: 447-459, 1967.

/3/ Caldwell, K., personal communication, 1972.

/4/ Hald, T., Meier, W., Khalili, A., Agrawal, J., Benton, J., and Kantrowitz, A. in *J. Urol.*, 97: 73-78, 1967.

/5/ Lopatkin, N., personal communication, 1971.

/6/ Mogil, R., Paxton, D., and Svenberg, H. in *J. Urol.*, 105: 388-391, 1971.