PORTABLE CORRECTOR OF MOVEMENTS

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ABSTRACT

The use of above-knee and below-knee prosthesis, providing passive stability through articulated couplings, limits the recruitment of all stump muscles. Up to now, therapeutical physical exercises, massage, phantom-impulsive gymnastics, mechanotherapy were main means for maintenance of satisfying condition state of the truncated stump muscles. The studies carried out at our Institute, the CRIP, proved that electrical stimulation is an effective tool for preservation of muscles. As a result of this studies, medico-technical requirements were formulated for an electronic device intended for correction of the walking pattern. The corrector of movements makes possible simultaneous stimulation of two groups of muscles by monopolar pulses or one group of muscles - by bipolar pulses. In all our patients, after the course of artificial correction of movements (ACM), the gait speed was increased by 200/300 m/hour. Positive results of ACM, with the corrector developed at the Institute, permitted us to recommend it for regular clinical application.

KEY WORDS: corrector of movements, amputee, above-knee and below-knee stump, electrostimulation, prosthetic gait

INTRODUCTION

Special anatomical and physiological features of the amputated limb and expressed evidence of biomechanical pathology in prosthetics depend on several factors. The level of amputation determines the muscular mass deficit, thus the quality of the locomotor pattern. Preserved stump (truncated) muscles (both uni-articular and bi-articular), as well as muscles of above-located limb segments are only partially recruited, during the walk with a prosthesis, and that inevitably results in their progressive atrophy. With it non-natural and non-physiological loading of the shank and thigh soft tissue during the walk, doubles inevitable at amputation trophic and innervation damages. Besides, the walk using prosthesis, which design provides passive stability in articulated links, limits the recruitment of all stump muscles. Up to now,the therapeutical physical exercises, massage, phantom-impulsive gymnastics, mechanotherapy were the main means of maintenance of satisfactory condition of the truncated stump muscles. The studies carried out at the CRIP showed that electrical stimulation of

muscles for the gait correction on prostheses is an effective method. The general indication for artificial correction of movements in amputees is the deficit of functions of one or several muscles of a truncated limb, conditioning the damaged biomechanical structure. A conditions for artificial correction of movements are: absence of joint contracture and functional response of muscles to the electrical stimulation.

As a result of these studies medico-technical requirements were formulated for an electronic device intended for correction of the walk [1]. These requirements were satisfied, completely, with a development of the device presented by Feldman [2].

The corrector of movements is a small size, two-channel electronic device with autonomous power source and independent adjustments of delay time and sequence of stimuli duration. Synchronization of the work of the corrector channels with the step phases is performed from a common sensor. The corrector of movements permits simultaneous stimulation of two groups of muscles with monopolar pulses, or one group of muscles with bipolar pulses. Discrete adjustment of parameters of positive and negative semi-waves is built into the device. Clinical tests of the corrector of movements were carried out in amputees with a hip and shank stumps. In first case, tests were performed with one-channel bipolar stimulation of gluteal maximal, gluteal medial and posterior muscular group of the thigh. In the second case, we applied monopolar two-channel stimulation of gluteal muscles, thigh and shank muscles in different combinations (Table I). In all patients synchronization was controlled using a knee angle transducer.

From a total, of 16 patients ranged from 15 to 60 years of age. The amputation lesion was: in 9 patients in the middle third and on a border of the middle and lower third of their thigh; in 7 patients in the upper (2), middle (2) and on a border of the middle and lower third (3) of the shank. 13 of patients were prosthetized repeatedly, therefore artificial correction of movements (ACM) was performed while walking on the prosthesis suited their needs. In three patients initial prostheses was applied (temporary training prosthesis with a rigid socket (made of plastics, metal or gauze impregnated with plaster-of-Paris).

Gluteal muscles and posterior muscular group of a thigh in above-knee amputees were stimulated in the first half of a step stance phase. These muscles, i.e. posterior muscular group of a thigh, being truncated, perform the same function of extension at the hip joint as the gluteus maximus muscle.

While stimulating these muscles, an effect of the joint stabilization was achieved, a contact (fusion) of the stump with a prosthetic socket was improved because of the increase of the stump perimeter. Visually, this manifested in significant reduction of a compensatory bend of the trunk to the side of supporting prosthetized limb and in more confident support. Subjectively, the patients preferred more soft support on the prosthesis, without painful pressure in the area of sitting brim, and disappearance of the fear of the knee instability (bending of the knee joint). It allows the increase of the gait velocity because of faster movement of the leg and step.

In below-knee amputees biomechanical disturbances of the gait parameters were manifested less intensive. Clinically there was a marked weakening of the function of the knee and hip extensors as well as the below-knee truncated muscles. The weakened muscles have been stimulated in different combinations. In patients with a short below-knee stump gluteal and quadriceps muscles were stimulated. In the patients with a longer stump the gluteal and gastrocnemius muscles were stimulated

or quadriceps and gastrocnemius muscles. Visual manifestations of ACM were not so markedly expressed. Nevertheless, there was an improvement of "frontal stability", an increase of the gait velocity, a decrease of the stump piston movements in the socket during the weight bearing phase. Everything forenamed has been proved by judgement of amputees.

Level of amputation	Number of patients	Stimulated muscles	Time of stimulation
above-knee	9	Gluteus maximus Gluteus medius Posterior group of thigh muscles	0.3-0.4 s in the first part of stance phase
below-knee the upper third of the shank	2	Gluteus maximus Gluteus medius Quadriceps femoris	(same as above) 0.1-0.15 s at the end of the swing phase
below-knee the middle third	2	Gluteus maximus	0.3-0.4 s in the first half of the stance
		Gastrocnemius	0.3-0.35 s in the second half of stance phase
below-knee the border line ofmiddle and lower third	3	Quadriceps femoris	0.2 s at the beginning of a stance phase
		Gastrocnemius	0.3-0.35 s in the second half of stance phase

Table I. Some types of muscle stimulation in AK and BK amputees

15 patients have received a complete course of ACM consisting of 10-15 sessions of muscle ES. After determination of ES parameters, providing apparent active contraction of the stimulated muscle with an expected effect in a proper joint, after tuning a synchronizing transducer the patient was learned to use independently the corrector of movements - to set and fix electrodes and synchronize sensors in desired way, to regulate intensity of stimulating pulses. Donning takes about 30-40 minutes, in average.

At the beginning of ACM course, the duration of sessions was 30-35 minutes, and than gradually increased to 45-50 minutes, while the walking distance being covered increased from 0.6-0.7 km to 1-1.5 km.

14 patients were able to stand all the sessions and complete course of ACM without side effects. In process of carrying out the first two sessions one patient pointed out to unpleasant feelings at the head and weakness. With consideration a severe cranial- cerebral trauma in her anamnesis the course of treatment has been stopped. In the other patient, with a poor tolerance of electrical irritations, (in 1 or 1.5 hours after

the session he suffered a weakness) the duration of sessions was decreased to 20-25 minutes.

Correction of pathological disturbances of the prosthetic walking apparent in process of electrostimulation sessions were partially preserved clinically after finishing the ACM course that permits to conclude about the development of a correct gait pattern in prosthetized patients. The studies carried out in 10 patients have determined the force increment in the stimulated gluteal muscles (on the average this increment was 7 kg, i.e. 20-30% from initial data). These data have convincingly proved the efficiency of ES influence at ACM on the weakened muscles of a truncated limb.

Together with correction of the gait pattern in all the patients after the course being carried out the speed of walking on an above-knee prosthesis has increased by 200/300 m/h, mostly resulting from an increase of a step length and the number of steps in a minute (on an average - by 5%). Significantly less fatigue while walking is reported by all our patients.

Clinical estimation of the muscle function, undergone ES, has increased on the average by 0.5 mark (according to a 5-mark system of ratings).

The overall results of ACM are judged as positive. The developed corrector of movements applied in clinical trials during the walk of 15 patients (below-knee and above-knee prostheses), provided better walking pattern and decreased the over all fatigue effects. This device is considered for the regular clinical and home use for further improvement of the locomotion performance.

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2. Feldman O.E., Roganov V.A. Korrektor dvizhenij. Avtorskoje svidetelstvo SSSR No. 1466758 s prioritetom ot 30.07.87.

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