FES as a rehabilitation tool for orthopaedics and neurological patients
(view from Russia)

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Abstract

FES systems in Europe and North America are generally used only as assistive devices. For the last 30 years a number of rehabilitation methods utilizing basic FES principles were developed in Russia. However, FES usage for rehabilitating patients with orthopaedic and neurological pathology has its own important points, including the usage of specific equipment and methods. By now our experience is based on the treatment of more than 6000 patients with different motion abnormality. Therefore FES usage is effective for patients with no pathology of central and peripheral nervous system as well.

1 A survey and practice

The general conclusion concerning development of the FES in Europe and in the North America is that it stopped methodically many years ago (sorry if this viewpoint is inconvenient). This is in spite of well sophisticated hardware progression and new investigations of motion programs for able-bodied and damaged central nervous system (CNS) [1, 2, 3]. At present the FES systems are used mainly only as assistive devices or prosthesis of motion management system CNS. Central Prosthesis Institute in Moscow, Russia, continued research into using FES as primary rehabilitation tool for the last 30 years. A number of experimental works were dedicated to neurophysiological aspects of influence of electrical impulses on human muscles [4]. These investigations made it possible to suggest new methods of synchronizing electrical stimulation impulse to muscle’s motion cycle. The effectiveness of methods was examined experimentally and improved at the next stage according to the achieved results. A number of different FES systems were developed by this time. The practical usage of FES in Russia is also different from that abroad. Instead of stimulating nerves, as done abroad, Russian researchers prefer to stimulate body of muscles. The second difference is the contingent of patients. These are not only patients with hemiplegia or spastic spinal-cord-injured subjects, but also different orthopedic and neurological patients with normal CNS or almost saved peripheral nervous system. This practice includes lower extremity prosthetic patients, low back pain and scoliosis patients, patients with consequences of poliomyelitis, cerebral palsy, stroke, occlusive diseases of arteries of lower extremity. The FES method proved to be good for all kinds of above described pathologies [4].

The neurophysiological and biomechanical investigations of the FES treatment results show the global effect of the FES therapy [5, 6]. One of the main results is reprogramming the muscle automatic program in the walking cycle. This effect stays for a period from half a year to a year or longer, depending on the decease. Other experimental works helped to invent a new method of diagnosing the insufficient muscle function.

The survey of current FES systems that are manufactured in the world is shown. There are many different FES systems represented at the world market. In spite of this it is hard to find any adoptable system for multichannel surface muscles stimulation while walking or any another repeatable motion whole body or extremities which could be usable in clinical practice. Only experimental systems exist in specific Labs or clinics. Some of them use basic principles of FES, but not always correctly.

2 Criteria

Analyzing the history of FES systems development in the world and in Russia, and taking into consideration experimental and practical results (including mistakes, inconveniences and other non-lack outcomes of FES), it is possible to point out several main criteria for building rehabilitation FES systems. Such systems could follow these guidelines:
time programming accuracy must not be less than 1/100 of walking or any another motion cycle,

- each patient’s side should have its own synchronization device,
- synchronization should be achieved by using motion of different basal joints (hip, knee, shoulder, elbow joints) or footswitches for heel and toe of the foot,
- synchronization program should use different types of motion patterns and adequate settings for each type of synchronization devices,
- synchronization program must follow definite patient’s motion pattern parameters,
- wide ranges of stimulation impulse amplitude, frequency, pulse width, time of beginning and finishing the stimulation package along with high accuracy.

All principles written above of using FES in clinical practice as a rehabilitation tool, are based on conclusions approved by our clinical application.

At first, we need to make a biomechanical investigation of the patient’s motion before prescribing FES rehabilitation. It has six main goals:

- detailed functional diagnostics of patient’s motion pathology and abnormal motion patterns of the patient,
- which repeatable motion pattern needs to be used (walking, bicycling, etc),
- determine, which muscles should be stimulated,
- which time program needs to be used for each selected muscle,
- what kind of synchronization device is required to be applied for each patient’s side (left and right),
- what type of synchronization algorithm will be adequate for the selected synchronization device and given patient.

We can make several conclusions at this point.

The first is that each patient should have a biomechanical investigation before FES is used as a rehabilitation tool. Depending on the patient's problem a locomotion for FES should be selected by using a biomechanical investigation, that might include gait analysis or examination of any another cyclic motion at lower or upper extremity. At this point the physician makes a decision concerning the motion pattern for FES. For example, if a patient shows a deep abnormal and nonrhythmic pattern of walking the bicycling exercising could be used for FES. Another important question is what type of synchronization device is necessary to use for a particular patient and what would be the criterion for defining the motion cycle. For this aim it's better to use a biomechanical transducer which shows the most stable process with good quality of motion repetition. For example, if we have an unstable pattern of walking cycle for the knee joint at the affected side and a stable pattern for hip joint at the same side, we could use a goniometer for the hip joint as a synchronization device.

The detailed motion analysis with obligatory utilization of multichannel surface EMG recording could help determining which muscles group needs to be stimulated at the beginning of FES treatment and the following stages. Often it's possible to find the general answer to this question by a routine clinical examination. However, surface EMG investigation should increase the accuracy of the decision.

Preliminary biomechanical and EMG exploration are necessary for the most important assessment – what should be the time program of FES? If the motion pattern is far from normal we could not use for the first trials normal time program, because it is not to be synchronized with abnormal pattern. For example, walking pattern of patients with cerebral palsy or after stroke or after a long time of immobilization has a time shift of muscle program from normal. Some patterns have very complicated time disturbances for different muscles on each extremity.

At our experience [5, 6] the rehabilitation procedure of FES could take from 20 minutes to one hour for a patient each day. The whole number of FES procedures is usually from 10 to 20. During FES it is necessary to have a complete information concerning work of stimulation channels and synchronization transducers. Often when the patient has a serious motion pathology it would be convenient for the physician to get more biomechanical information from the patient. Therefore the best way to use FES for
rehabilitation is to have on-line control of biomechanics data and parameters of stimulation procedure. The most important stimulation parameters are the beginning and the end of stimulation impulses relatively to the patient’s motion cycle. On-line biomechanics data makes it possible to get information about what kind of motion correction the patient has as a result of FES. Consequently, the appropriate FES rehabilitation system should register necessary biomechanical data with its own hardware devices.

3 Possible solution

According to the criteria written above we have created a new 8-channel FES-rehabilitation system called “STIMUL". The system includes: the system unit which is placed on a patient with a special belt; synchronization devices: goniometers for hip and knee joints, footswitches (for heel and toe); a number of differently sized electrodes, the system cable (with a length of 30 meters or more), a computer with the WINDOWS operation system, specific software and additional attachments. The cable connection was chosen basing on a long experience, because a patient needs to have organized distinct and limited walkway and biomechanical and stimulation parameters should be controlled the whole time during FES. Our experiments show that any system with connection between the patient and the physician’s computer by the radio channel is limited. We found that it's possible to use this type of systems only for patients with slight degree of motion disturbance.

In software a physician could find different FES methodic or create one with existing options and software instruments. During a FES procedure a physician could see at one-line regimen work of synchronization devices and stimulation channels. It is also possible to change the function condition of each device or stimulation channel options. When the procedure is over the software could save all data and create a complete report (biomechanical data are included).

The clinical investigation of the system shows that the system is more convenient for patients as well as physicians. Except that it is possible to use it for different types of cyclic locomotion as for lower as for upper extremity. A big number of synchronization devices and synchronization algorithms makes it possible to adopt FES procedure for different types of patients including high degree disability.

4 Discussion and Conclusions

The viewpoint written above is based on a long experience of rehabilitating more than 6000 patients with different types of motion abnormalities. The main aim of this paper is to invite researchers and physicians outside Russia to use FES not only as assistive devices, but also as a rehabilitation method for patients with motion disabilities such as: cerebral palsy, stroke, poliomyelitis, after bones and spinals column fractures, low back pain, endo and exso prosthesis for leg and upper extremity, occulsive vascular deceases, and many others. At this time the general usage of FES systems in the world is usually limited to treating paralyzed patient on the one hand and sport and fitness (i.e. able-bodied) persons on the other hand. But it is almost anybody between them.

However, the most important effect of rehabilitation FES is reprogramming automatic muscle action, which is also useful when central nervous and peripheral nervous system is not damaged.

Probably this is a good source for future development of FES in rehabilitation industry.

References


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