Research in Prosthetics In New Brunswick

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During the past few years, research in prosthetics has paid substantial dividends. Conventional prostheses have been improved both functionally and cosmetically. However, the most significant results have been in the area of externally powered prostheses. It wasn't until after the thalidomide tragedy that a concerted effort was put forth in Canada to develop methods of supplying external power for prostheses, which would be of benefit to the severely handicapped amputee. At present across Canada, there are four research centres, set up by the Federal Government, working primarily on the development and improvement of prosthetic devices. These are located in Winnipeg, Toronto, Montreal and Fredericton. My discussion will be confined to the research being done at the University of New Brunswick in Fredericton.

The Bio-Engineering Institute was established at the University of New Brunswick in 1965 for the purpose of facilitating interdisciplinary research on a broad range of topics of which the unifying theme is the interaction of man with modern technology. It had its origin in the activities of the Technical Assistance and Research Group for Physical Rehabilitation. This was an informal organization which had been conducting research in myo-electric control since 1962. (1)

The program at the Bio-Engineering Institute is divided into three separate projects. These are:

1. The investigation and development of myo-electric control systems.

2. Clarification of the roles of specific muscles in remedial and conditioning exercises and in sport skills.

3. The investigation of requirements for a satisfactory fit of lower extremity prostheses, and development of apparatus which will rapidly and automatically measure the stump, thus standardizing fitting techniques.

As an occupational therapist my chief concern is in the first project, that is myo-electric control systems.

From physiology courses in un-

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dergraduate days, you will recall that an electric potential is developed whenever a muscle is contracted. Although the current produced is very small, it can be amplified and used to activate relays which switch a motor on or off. A myo-electric control system, therefore, is one which uses the electric potential produced by voluntary contraction of a muscle to activate an output unit. The control system consists of a set of three electrodes, the control unit, and a battery to operate the unit. A second battery is required to supply power to the output unit. The type of output unit controlled is immaterial as far as the myo-electric system is concerned. It can be a prosthetic component such as an elbow or a hook, a dynamic splint, or perhaps a 'robot' used to perform tasks by a severely handicapped quadriplegic. The term myoelectric refers only to the system used to control the output unit.

For the sake of convenience, I will confine my references to amputees, as it is this group we have used to evaluate our controls.

The myo-electric system developed at the University of New Brunswick is a three-state system (2). That is it uses one muscle to provide on-off control of two functions. A slight contraction of the muscle activates one function, while a stronger contraction of the same muscle activates the second function. As an example you can consider a prosthetic elbow unit. With the three-state system, a weak contraction of the controlling muscle will produce elbow extension while a stronger contraction of the same muscle will produce elbow flexion. Thus, the number of control sites required is less than with the systems that require separate controlling muscles for each function. This can prove to be of vital importance to the high level amputee where control sites are limited.

Because the signal obtained from the muscle is greatly amplified, only a light muscle contraction is required to activate the device. It does not necessarily involve any physical motion of a body part. Consequently, a muscle which cannot produce any useful movement due to disease or injury may have sufficient electric output to serve as a control site for a myo-electric system. Also, as is the case with most high level amputees, it is easier to harness the electric output of a muscle than the corresponding physical movement it would produce.

One exciting development relating to the availability of potential control sites in the severely handicapped individual is the work being done in the control of single motor units. Dr. J. V. Basmajian at Queen's University (3) was the first to report the ability to produce voluntary contraction of a single motor unit. In his experiments, using normal subjects, he has shown that from one wire electrode in a muscle as many as three different motor units can be controlled voluntarily. These findings have since been verified in many laboratories including our own. However, this technique requires the use of an electrode in direct contact with the muscle.

The clinical application of this technique has been delayed due to the difficulties encountered in designing an electrode that can remain in a muscle at least semi-permanently. One approach to solving this problem is the development of a wireless transmitter which can be implanted permanently in the stump. This would transmit signals from the muscle to a control unit on the surface. The Bio-Engineering Institute will cooperate with the Manitoba Rehabilitation Hospital in the development of equipment and techniques for implanting a wireless myo-electric transmitter. This work will be carried out in Winnipeg this year under the direction of Professor Scott of the Bio-Engineering Institute and Dr. Tucker, an orthopedic surgeon at Manitoba Rehabilitation Hospital.

In this project, a transmitter will be implanted in the medullary canal of the humerus with two screws through the humerus. These screws will rest on the under surface of the muscle and act as electrodes to pick up the electric signal. Further reports on this project will be forthcoming at its termination within the next year.

Now let us consider the clinical application of myo-electric controls which, of course, is the area of primary interest to the occupational therapist. To date the U.N.B. myo-electric control system has been fitted to eight patients, all of whom are upper extremity amputees (1). It has been used to control electric components which were developed at the Prosthetic Research and Training Unit at the Ontario Crippled Children's Centre under the direction of Mr. Colin McLaurin. These are the two-fingered electric hook, the electric elbow, and the electric wrist rotator. In one case it was used to control a cable puller designed at Rancho Los Amigos Hospital in California. This was used to operate a standard Dorrance number 3 hand. The levels of amputation fitted were four below elbow, two above elbow, one complete phocomelia, and one forequarter amputation. All had unilateral involvement. Although we used below elbow amputees for evaluation purposes, it is generally agreed that mechanical control, that is, harnessing body motions to provide the power required to activate the prosthetic components, will remain the system of choice for the minimally involved amputee.

In the fitting and the training of patients using myo-electric control, it can be assumed that the occupational therapist will be most directly involved since most benefits will be derived by patients with upper extremity disabilities.

The occupational therapy program can be considered in four stages; these are:

1. Assessment of patients to determine their needs and recommending to clinics appropriate patients to be fitted with myo-electrically controlled prostheses.
2. Selection and training of muscles as control sites.
3. Functional prosthetic training after fitting has been completed.
4. Evaluation of the control system.

As I have already mentioned, myo-electric control and indeed external power is not suitable for all patients. Each individual must be carefully assessed and all his needs considered. The types of patients who can benefit most are the severely handicapped high level amputees. That is, those who do not have sufficient power and excursion to operate conventional appliances.

Once a patient has been considered for external power, the next decision must be on the type of control to provide. If a mechanical on-off switch can be used it is preferable because of its simplicity. However, it is usually not possible in a high level involvement to find switch locations to operate the number of functions that will be provided. In these cases myo-electric control should be considered either as the control for all functions or in combination with switches or mechanical controls.

In the selection of control sites there are some criteria that each control muscle must meet. First, it must be a superficial muscle whose primary function has been lost. Therefore, it is free to control a new function without interfering with normal activity. It is for this reason that in unilateral amputees muscles on the side of the loss are used in preference to control sites on the remaining arm. Second, the muscles chosen should not be accessory muscles for other functions such as turning the head, trunk movements, etc., as this will cause undesired activity in the controls. Contrary to the original idea, of only utilizing as control sites, the muscles normally associated with the function, it has now become evident that any muscle which can produce a useable signal is a potential control site. The function it controls is irrelevant.

Once suitable muscles have been chosen to control the unit, the patient must be trained to contract and relax these independently and at will. This is usually done with the aid of a "myo-electric trainer". This is a device which will indicate on a meter and by lights, the electrical activity in the muscle. Three surface electrodes are placed over the muscle. Two electrodes are used to pick up the signal and the third is a ground. These are connected to the trainer which provides the feedback during training. When the muscle is relaxed a green light is showing; with a weak contraction an amber light comes on and for a stronger contraction a red light is activated. With this feedback the patient can then, fairly quickly, learn to voluntarily contract and relax the muscles. Control is considered satisfactory when the patient can reach and hold all of the three levels of muscle tension on command, that is, complete relaxation, a weak contraction or a stronger contraction. The most difficult task is to go from a state of complete relaxation to a strong contraction without activating the function controlled with the weak contraction. A slight time delay is built into the control unit to facilitate this control.

Once good islolation of the controlling muscles has been achieved, the functional prosthetic training can begin. The methods used for this are similar to the established practices for any type of prosthetic training. Emphasis is placed on functional activities relating to everyday living, job skills and recreational or leisure time activities. Training concentrated on the functional use of the prosthesis, as opposed to drills, provides a more realistic picture of the demands that will be made on the components and will bring to light any problems that might occur.

Evaluation of the control system is the fourth aspect of the occupational therapy program. As this is not directly related to patient care, and is often time consuming, there is a tendency to neglect it. However, the therapist who is participating in the clinical evaluation of new equipment must realize that he is also a member of the research team, and, as such, has a contribution to make.

It is the therapist who is in daily contact with patients, knows their needs and knows how they react. This is information to which the engineers, who are responsible for design and development, do not have direct access but rely on the treatment personnel to provide.

In relation to myo-electric controls specifically, there are many questions yet to be answered. What is the ideal size and shape for the packaging of components? How sensitive must the units be to provide the optimum function? What is the maximum number of functions which a person can be expected to control myo-electrically? Which function has priority? Due to his close association with patients, the therapist can assist in supplying the answers to these questions.

First impressions often play a major role in final acceptance of something new. For this reason the packaging of the components can be a critical factor. Size, shape, weight, colour, placement of wires, etc., are factors to be considered when planning the final form of the control unit. To a great extent these aspects are not predetermined by the components used but can be tailored to suit the patients' needs. The therapist, therefore, can be of valuable assistance in providing information on these factors to the designers. One interesting case can be noted in which the patient was a teenage girl. She wore the package, which was covered in black plastic, on a belt around her waist. This did not present a problem except when worn under light coloured clothing. With the covering material changed to white it would be more acceptable from her point of view. Often small considerations such as these can make a difference in the patient's acceptance and use of a device.

The sensitivity of the units can also be varied to suit the patients' requirements. For example, the unit can be made very sensitive so that a signal of about 20 or 30 microvolts from the muscle will activate the control. However, if the unit is this sensitive, or in engineering terms, if the gain is this high, it will also be more sensitive to electrical activity in the environment such as 60 cycle (Hz.) electricity or signals from neighboring muscles. Therefore, there is a greater tendency for these extraneous signals to operate the control unit inadvertently. On the other hand, if the gain is too low, the strength of contraction required is greater and may be tiring for the patient who is using it all day. The optimum gain must be determined in order to achieve the best functional use of the prosthesis.

Another variable in the control system is the time constant. That is, the time delay between the contraction of the muscle and the initiation of the control sequence, or, in reverse, the delay between relaxation of the muscle and the cessation of activity in the output unit. This can be varied electronically to suit the requirements of the component being controlled. For instance, a device such as the electric hook which moves quite quickly, requires a fairly short time constant. Otherwise, it is difficult to accurately regulate the degree of opening because of the delay between relaxation and the end of the movement. In contrast, however, a slower moving component such as the electric elbow, is easier to operate if the time constant is a little longer.

Both of these variables, although essentially technical problems, can best be determined during functional training with the prosthesis. The therapist responsible for training and evaluation, therefore, must have a reasonable knowledge of the operation of the system and in addition must be able to communicate with the engineers in terms that are meaningful to both. Thus, it is important to provide the opportunity for treatment personnel to become familiar with the principles of myo-electric control and its applications.

The Bio-Engineering Institute has proposed an evaluation study of the functional applications of myo-electric control with particular reference to vocational rehabilitation. If the grant to cover this project is received, patients with potential for vocational rehabilitation, who have high level upper extremity involvement and would benefit from external power, will be selected from centres across Canada. The fitting, training and evaluation would all be carried out at the centre presently treating the patient.

A course would be given at the Bio-Engineering Institute for the staff member responsible for the treatment, which in most cases is the occupational therapist. This course would deal with principles of myo-electric control and its applications, selection of control sites, patient training, care and maintenance of equipment and evaluation procedures.

In addition to providing the foundation for our evaluation, this course would also give therapists in clinical settings an opportunity to become familiar with new developments in this area.

Although progress in any new field is slow, the developments during the past few years in providing external power for prosthetic and orthotic components have been encouraging. Use of myo-electric signals to control devices has proven to be functional. Already designers are working on more advanced and sophisticated control, as well as improving the reliability and packaging of present units. With continued research, the future in prosthetics looks optimistic.

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