HELP FOR THE DISABLED

Dow Dorcas, P. Eng.*
Halifax, Nova Scotia

In 1962 a voluntary group, the Technical Assistance and Research Group for Physical Rehabilitation (TARGPR), was organized in Fredericton, New Brunswick. This group was formed to provide the opportunity for persons skilled in applied science and technology to contribute to the welfare of the physically handicapped. The purpose of the group was: "to assist the medical profession in the diagnosis, treatment, and rehabilitation of the disabled, with particular reference to the rehabilitation of the physically handicapped."

Among the sixteen members of this voluntary group were five electrical engineers, three medical doctors, two civil engineers, one chemical engineer and one mechanical engineer and one kinesiologist. A majority of the members were on the staff of the University of New Brunswick or the Forest Hill Rehabilitation Centre Inc. Original financial support was received from the New Brunswick Co-ordinating Council for the Handicapped and from private donations.

Modern medical techniques have made long life possible for those handicapped through congenital malformations, trauma or disease. This has presented a challenge to the engineering profession to provide powered assistive devices for the physically handicapped. These devices include prostheses, such as artificial limbs, and orthoses, such as functional splints. These devices require activation by other body parts to be functional. For example, a conventional artificial hand may be operated by cable and shoulder harness.

TARGPR began research and development of control systems which use electrical input signals originating in the human body. The input signal is derived from the muscle action potential (EMG) in a muscle which the patient can contract voluntarily. This potential accompanies all muscle contractions. An important advantage of myo-electric control is that no motion of the muscle is required; an EMG system can be controlled by muscle contractions too slight to activate any other controller. Fatigue in the controlling muscle is thus greatly reduced. No mechanical harness is required, and problems of frequent readjustments, inherent in other systems, are eliminated.

The first demonstration of a working myo-electric control system ready for use outside the laboratory, was given in Moscow in 1960, by a Russian research team headed by A. Ye. Kobrinskiy. Today, at least four research groups claim to have such systems in use or undergoing final trials, and at least four other groups have built laboratory prototypes.

The Russian system as well as others used one muscle signal to control one function. A system developed by the University of New Brunswick represented an attempt to use more efficiently the operator's capability by controlling two functions from a single muscle. Slight contraction of the muscle activates the first function, for example, the closing of an artificial hand. A stronger contraction turns off the first function and activates the second, the opening of the hand. With the muscle relaxed both the functions are off and the hand remains fixed in the desired position. This system was designed to work with any electrically powered appliance. At present it has been used with a motor-driven hook, elbow unit and wrist rotator all developed by C. McLaurin of the Ontario Crippled Children's Centre in Toronto. It has also been used with a cable-pulling device developed by Rancho Los Amigos

---

*Second year medicine, Dalhousie University.

Hospital, Inc., in Downey, California.

Research into many other aspects of myo-electric control was also begun in addition to the electronics work. Five major lines of investigation were followed: control sites, electrodes, signal processing, coding and operator training. The control site requires that voluntary control of the muscle be possible, that the muscle not be contracted involuntarily during activities of the operator while the system is in use, and that the muscle be accessible for electrical connection to the control equipment. Finding adequate control sites can be quite a problem. For example, in an upper limb amputation, the higher the level of amputation, the more functions you must provide the patient, but the number of muscles available for control sites decreases. In a paralysed patient very few muscles may remain under the voluntary control of the patient. This prompted studies into infrequently-used muscles such as perineal muscles and those which wiggle the ears.

Making adequate electrical contact between the patient and the electrical equipment poses many problems. The skin is a fairly good electrical insulator. The conventional electrode is one situated on the surface of the skin over the muscle. Here electrical contact varies with skin conditions and physical motion. In conjunction with the space program some very good surface electrodes have been developed which minimize these problems. Another problem is that of fixing the electrode to the patient's body. The repeated attachment must not damage the patient's skin. Satisfactory results have been achieved by building the electrodes into the shell of a prosthesis or by attaching them with an elastic bandage around the limb. The feasibility of constructing semi-permanent electrodes from very small wires inserted through the skin was investigated at the University of New Brunswick. No practical electrode design was achieved due to problems of electrode breakage and the lack of an adequate miniature electrical connector.

Signal processing involves the selection of some characteristic of the myo-electric signal which is controllable by the operator. Electronic analogue computer studies are being carried out to determine which characteristic of the signal gives the best performance and to determine the optimum values of design constants for the system.

Two types of coding are possible in myo-electric systems. A sequential coding system is analogous to the dial telephone. This has been used in a controller designed at the Stoke Mandeville Hospital in Aylesbury, England. At the University of New Brunswick a hybrid system was developed to control an arm splint with six degrees of motion. The desired function was selected by having the patient aim a light on a helmet at a particular photocell in a control panel in front of him. After selecting the function the appliance was activated from a myo-electric signal. This type of coding is slow and requires continued conscious attention by the patient. Parallel coding in its simplest form requires the simultaneous contraction of a specific set of muscles to initiate a particular function. This has been extended by the recently developed pattern recognition techniques, which minimize the need for extensive operator training.

Experiments were carried out to determine to what extent the human operator could voluntarily control the myo-electric activity in two or more muscles. University students were used as subjects. First four muscles, the biceps brachii, deltoid, pectoralis major and trapezius were used in simple on-off control. Nearly all subjects could voluntarily activate any desired combination of the four muscles, quickly and reliably, after only eight short practice sessions. Next, proportional control was studied. Here a two co-ordinate positioning system was used to control the position of a spot on an oscilloscope screen. Contraction of one muscle caused vertical deflection of the spot and contraction of the other, horizontal. In the final experiments an attempt was made to measure the ability to control six muscles independently. A combination of two muscles was used for the two co-ordinate positioning, the remaining four being monitored and the experiment being declared invalid if any activity was detected in them. This experiment demonstrated the feasibility of multi-channel control.

After its organization in 1962 the Technical Assistance and Research Group for Physical Rehabilitation conducted an expanding program of research. At first the

informal, unincorporated Group was a satisfactory administrative structure. It enjoyed the cooperation of the University and the Forest Hill Rehabilitation Centre, and had an annual operating budget of less than five thousand dollars. However, in 1965, the annual operating budget on a grant for research into application of myo-electric control to the victims of the thalidomide tragedy had risen to fifty thousand dollars, a sum too large for the existing organization. The University was approached with the suggestion that a facility be provided for this work, rather than attempt to modify the original group for that purpose. Thus emerged the University of New Brunswick Bio-Engineering Institute as the answer to that specific problem and as a means of fostering other interdisciplinary research at U.N.B. The present Executive Director is R. N. Scott, Associate Professor of Electrical Engineering.

Initially the Institute had only one project, the Myo-Electric Control Systems investigation taken over from TARGPR. For work on this project the Institute was corecipient, with the Ontario Crippled Children's Centre, of the 1965 Annual Rehabilitation Award, given by the Reader's Digest Association (Canada) Ltd. This award is granted at the recommendation of the Canadian Council for the Rehabilitation of the Disabled, for "distinguished service in developing and expanding community rehabilitation programs for the handicapped."

Several new projects were initiated by the Institute. The main objective of the first is to assist the evolution of prosthetics from an art to a science. At present, the artistic skill of the prosthetist is relied upon to create a comfortable socket. This project is an investigation of the requirements for satisfactory fit of lower extremity prostheses, involving the development of an apparatus for rapid and automatic characterization of stump dimensions in digital form. It has as its ultimate objectives the improvement of standards of fitting and extension of the concepts of socket prefabrication developed by the Prosthetics/Orthotics Research and Development Unit at the Manitoba Rehabilitation Hospital.

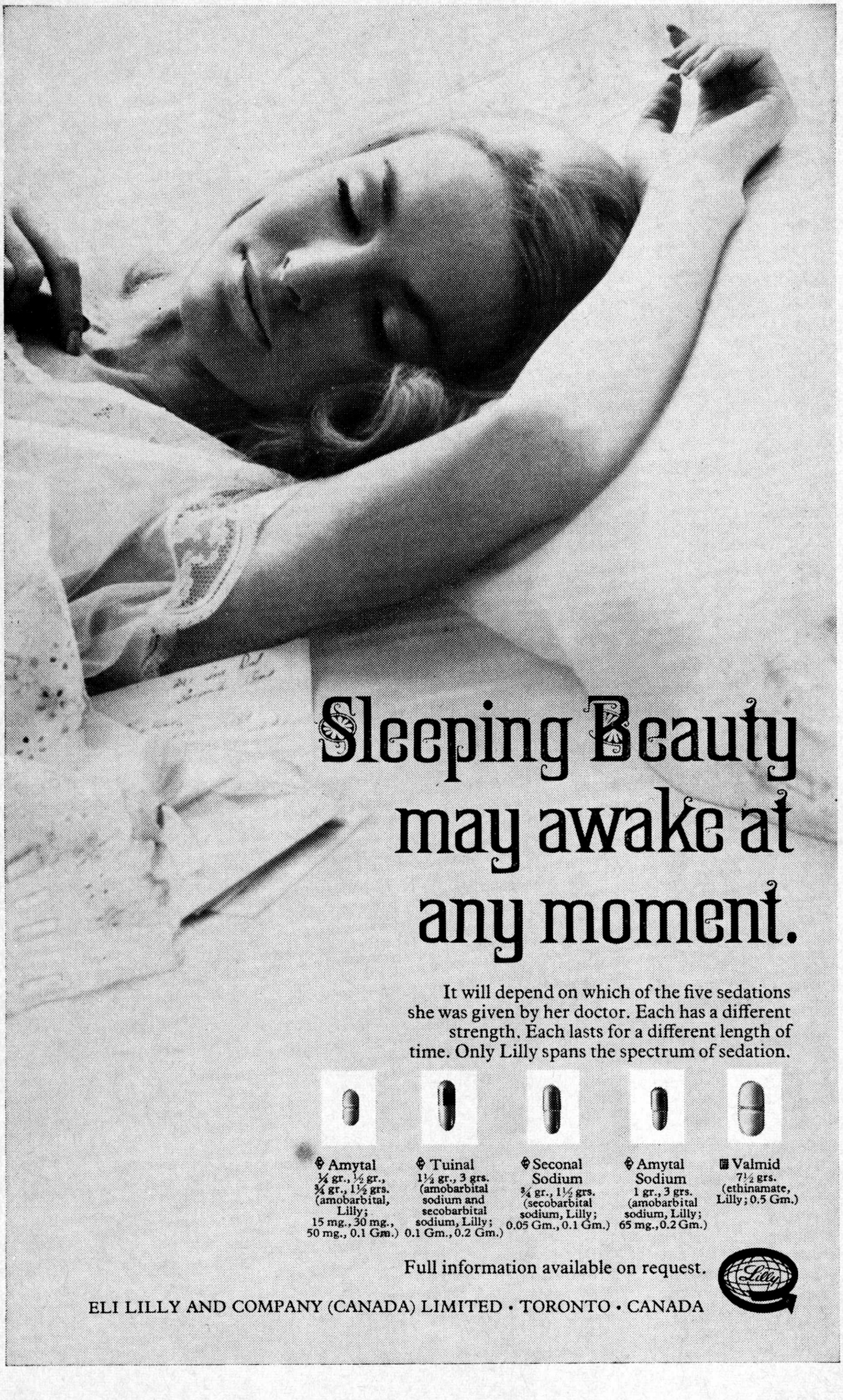
In a second program, development of improved instrumentation and measurement techniques will be followed by a careful study to clarify the roles of certain muscles in remedial and conditioning exercises and sports skills.

A promising solution to the limitations on the use of myo-electric control due to the lack of suitable control sites is the use of a single motor unit in the muscle as a control site. Dr. J. V. Basmajian of Queen's University published on this topic and research was begun by a number of research groups. Voluntary control of single motor units in skeletal muscle has been shown possible. Dr. William McLeod began work at Highland View Hospital, Cleveland, and this is being continued at the Institute.

Studies carried out by the Prosthetics and Orthotics Research and Development Unit at the Manitoba Rehabilitation Hospital have shown that optimum alignment of a below-knee pylon prosthesis is achieved when both the anterior-posterior and medial-lateral bending moments on the pylon are minimized. Originally the Winnipeg group used direct wire connections from the strain gage assembly on the prosthesis to the measuring apparatus. The trailing cable is very undesirable. The Institute designed and constructed a more convenient electronic device. The equipment consists of a small two-channel telemetering transmitter which is attached to the prosthesis and a receiver and display equipment which is not connected to the patient. It is hoped that when perfected this technique will expedite lower extremity prosthesis alignment.

Recently various centres have shown considerable interest in the possibility of powering orthotic systems by direct electric stimulation of paralyzed muscles. In light of this fact the Institute is preparing a comprehensive annotated bibliography on the subject of electric stimulation of paralyzed muscles. While emphasis is placed chiefly upon restoration of motor function in paralyzed limbs, literature dealing with restoration of voluntary bladder control is included. This information in a readily accessible form should greatly facilitate work on functional electric stimulation both at the Institute and at other centres.

During the summer of 1967 the first attempt was made to fit a patient with two powered functions utilizing myo-electric control from two control sites. The patient had undergone a forequarter amputation due to osteogenic sarcoma. She was provided with


Sleeping Beauty may awake at any moment.

a powered elbow unit which provides flexion-extension, and with a powered hand covered with a cosmetic glove. The two control sites selected were upper trapezius and latissimus dorsi. The wrist unit provides passive supination-pronation and the shoulder unit passive flexion-extension, abduction-adduction, and rotation. Two types of control are utilized. The hand is normally closed and opens on contraction of the controlling muscle. It remains open as long as the contraction is held. After relaxing the muscle the hand returns to the normal closed position. Flexion or extension of the elbow is controlled from the other muscle control site. A slight contraction flexes the elbow while a harder contraction causes extension. The elbow can be left in any position simply by relaxing the controlling muscle at the desired position. This system is still functioning well and its successful fitting significantly advanced the state of the art of myo-electric control at the Institute.

In addition to continuing the research described above, the Institute is participating with the Manitoba Rehabilitation Hospital in the development of equipment and techniques of implanting wireless myo-electric transducers within the body. Myo-electric signals will be transmitted from within the body to a receiver in the control unit situated on the artificial appliance, thus eliminating the electrical connection between the patient and the control unit. During the first half of 1967 preliminary work was carried out at the Institute. In September, 1967, Professor Scott and two candidates for the M.Sc.E. degree moved to Winnipeg to partake in an intensive one-year experimental program. The feasibility of locating the implanted transmitter in the medullary cavity of the humerus of an above-elbow amputee is being investigated.

It is hoped that this report will point out some of the fascinating work being carried out in the field of interdisciplinary research at the University of New Brunswick. All the work described illustrates that many research projects are more effectively dealt with by joint efforts of persons of two or more disciplines than by individual effort. This is particularly true in the application of complex instrumentation to studies of human biology, health, or behaviour,

References

1. Scott, R. N., "*Myo-Electric Control*", Science Journal, Vol. 2, No. 3, pp. 53-59; March 1966.
2. Dorcas, D. S., and Scott, R. N.: "*A Three-State Myo-Electric Control,*" Medical and Biological Engineering, Vol. 4, No. 4, pp. 367-371; July, 1966.
3. Scott, R. N., and Thompson, G. B.: "*Orthotic Systems Research, Progress Report No. 3*", Research Report 64.2, Department of Electrical Engineering, University of New Brunswick, Fredericton, N. B.: June 1964.
4. Dorcas, D. S., Scott, R. N., and Thompson, G. B.: "*Orthotic Systems Research, Progress Report No. 4,*" Research Report 65.1, Department of Electrical Engineering, University of New Brunswick, Fredericton, N. B.; May, 1965.
5. Scott, R. N.: "*Myo-Electric Control Systems, Progress Report No. 5,*" Research Report 65.3, Bio-Engineering Institute, University of New Brunswick, Fredericton, N. B.; December, 1965.
6. Scott, R. N.: "*Myo-Electric Control Systems, Progress Report No. 6,*" Research Report 67.1, Bio-Engineering Institute, University of New Brunswick, Fredericton, N. B.; January, 1967.
7. Basmajian, J. V.: "*Conscious Control of Single Nerve Cells,*" New Scientist, Vol. 20, pp. 662-664; December, 1963.
8. Ivey, W.: "*Use of Electronics to Align the Below-Knee Pylon Prosthesis,*" Report No. 7, Prosthetics and Orthotics Research and Development Unit, Manitoba Rehabilitation Hospital, Winnipeg, Manitoba; January, 1966.
9. Dunfield, V. A.: "*An Electronic Aid for the Alignment of the Below-Knee Pylon Prosthesis,*" M.Sc.E. Thesis, (unpublished), University of New Brunswick, Fredericton, N. B.; October, 1967.

> *Reason commands us far more imperiously than a master; for in disobeying the one we are unfortunate, and in disobeying the other we are fools.*
>
> *–Pascal*