Canadian Experience with the Soviet Myoelectric Upper-Extremity Prosthesis

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Presented at the 1966 AOPA Assembly,
Palm Springs, California

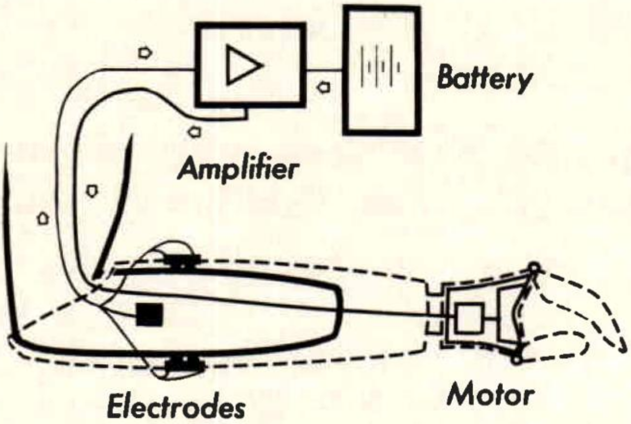
The prosthetic requirements of the upper extremity amputee are quite often extensive and complex in terms of functionality. Furthermore, the higher the level of amputation, the more body functions are needed to power a conventional prosthetic device while at the same time, the number of available controlling muscles decreases. Artificial effectuators may be used to produce mechanical functions in prosthetic systems, supplied from an external source of energy in the form of electricity or compressed gas. Combining humans and machines in this way requires a control system to interconnect the two, if the human and technical elements are to operate compatibly. Using muscle action potentials for control signals provides an excellent means of establishing communication between man and machine.

Several laboratories on this Continent and elsewhere experimented with external power in connection with myoelectric control for prosthetic devices. However, a group of Soviet researchers produced the first practical device. Perhaps their greatest merit is due to their decision that myoelectric control was practicable. The device is a simple hand prosthesis, performing the function of fingertip prehension. The control signals are provided by two muscles of the forearm, preferably one of the finger extensors and one of the flexors. The servo-mechanism loop is completed through the visual observation of the amputee-operator.

To date, the Rehabilitation Institute of Montreal has equipped 12 below-elbow amputees, 11 male and one female adults of various amputation history, with the Soviet device. Three of these amputees are bilateral cases. Working with this prosthesis provided the Institute with immediate clinical experience, greatly reducing the time delay required by independent research.

The Rehabilitation Institute of Montreal, responsible for the care of more than 30 thalidomide children, followed the developments and the literature on myoelectric control. A team travelled to Moscow to visit the Central Prosthetic Research Institute, and in the fall of 1964, through a grant from the Province of Quebec, purchased the manufacturing rights and ten prototypes. The purpose of this undertaking was to evaluate the possibilities of the Soviet device with a view of applying myoelectric control to prostheses for congenital amputees.

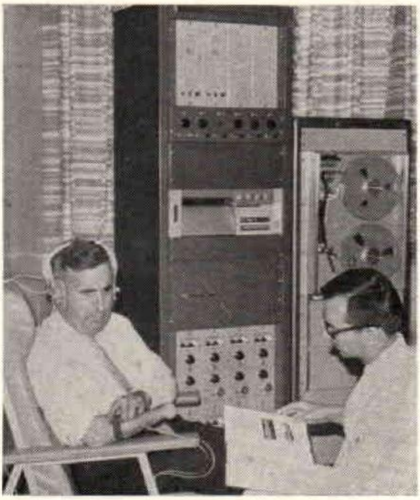
The functional components consist of a hand shell made of plastic material, housing the drive motor in the metacarpal area. The fingers and thumb are hinged corresponding to the metacarpo-phalangeal joint. The interphalangeal joints are fixed in a slightly flexed position. In the Soviet prototype, spring loaded electrode cups containing abrasive electrolytic paste



1. Diagram of the prosthesis with external power and myoelectric control.

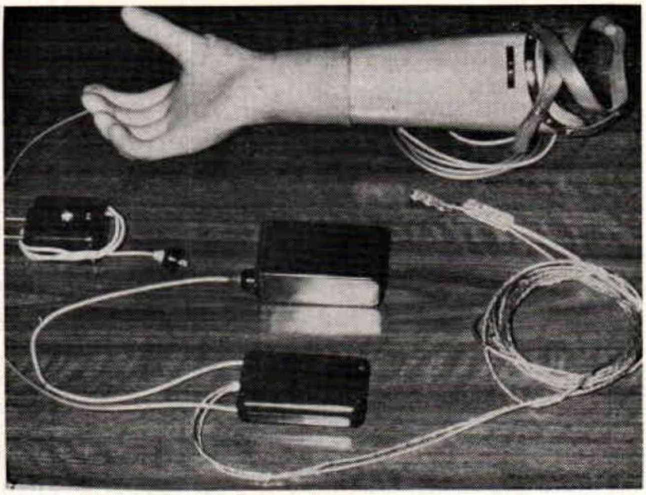
are installed over selected control muscles. Movement of the fingers and the thumb is caused by a lever, one end of which is connected to a slider block. The latter is driven back and forth by a leadscrew.

The system is powered by a rechargeable battery of 13.75 volts weighing 320 grams. The capacity of the battery is sufficient to sustain operation of the hand for 15 hours depending on the frequency of use. A small charger restores energy to the battery overnight.



2. Blind amputee patient using acoustic signals to train controlling muscles for independent operation.

Power is directed to the motor by two small relays, which control operation in opposite directions. Each of the relays is energized by a control channel consisting of a set of electrodes, myoelectric preamplifier, an integrator and a power amplifier; the latter directly connected to the relay coils. Muscle potentials are detected by the electrodes, amplified, and smoothed to produce a DC voltage approximately proportional to the activity in the control muscles. The control amplifier is designed to differentiate between the muscle signals and extraneous (electronic) noise, effectively rejecting the latter. Even with the present surface electrodes, little trouble is experienced in establishing a satisfactory signal pick-up. Most of the Institute's patients find they can operate the device without skin preparation, although using a small amount of conductive jelly helps to eliminate a short warming-up period in the morning. The control unit containing the two channels, including the relays, originally encased in a plastic box, weighs 170 grams.



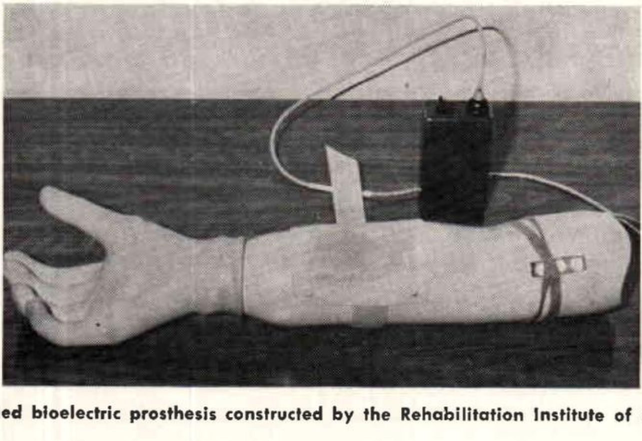
3. Prototype of bioelectric prosthesis.

The average pinch force available at the fingertips is 1.5 kilogram, which may be increased to a maximum of 2 kg., by repeating the closing command. The mechanical noise generated by the operation of the drive is audible but hardly objectionable; in fact, it provides the amputee with an indication of activity of the hand even when visual observation is not possible. An average below-elbow prosthesis with this drive weighs 0.9 Kg., exclusive of the battery.

When a set of possible sites have been identified, a multichannel device is used to determine the amount of interference or cross-talk between the muscles. The most promising pair, not necessarily anatomic antagonists, are finally selected and electrode locations established in the socket. With visual display, a significant improvement can be achieved by the amputee, greatly increasing the degree of independence of the control points.

To display myoelectric activity, an indicating meter appears to be a better choice than the oscilloscopic display or electromyographic signals.

A sightless subject was successfully trained to operate the hand by using audio-signals.



4. Modified bioelectric prosthesis constructed by the Rehabilitation Institute of Montreal.

Clinical Aspects

Patients are evaluated without the prosthesis in the activities of daily living. When the myoelectric arm has been completed the patient is trained and instructed to apply it without assistance and initiate operation. Training then consists of basic operation of the hand in different arm positions, prehension and release of small and large objects, activities demanding dexterity, speed, and co-ordination between eyes and hand. Functional activities, grooming, feeding, etc., are carried out before discharge.

No comparison between the prosthetic hooks and artificial hand is intended when the relative merits of the U.S.S.R. prosthesis are listed, however, the absence of harness and muscular effort to operate the prosthesis is a definite advantage. The cosmetic appearance is acceptable, and grip is satisfactory.

Canadian Modifications of the Soviet Prosthesis

The study of the Soviet prosthesis was commenced in December 1964. The original amplifier and battery had several weaknesses, principally due to the quality of component parts. The substitution of these with Canadian and American hardware has considerably reduced the number of failures. Component parts were obtained for a new battery pack, and newer methods for the installation of the battery on the patient were developed.

The original configuration of the prosthesis was redesigned to minimize wiring and to provide an adjustable wrist unit. The amplifier has been integrated into the socket, and all wiring made internal, leaving only the power supply wire visible. The twin electrodes on the prototype have been replaced by a triple unit eliminating the need for a separate reference electrode.

Current experimentation with micro-miniature electronics will produce a very convenient control package which will fit readily into any standard unit without the unsightly protrusions necessary with the present large amplifiers.

Conclusions and Current Work

Even the short experience with the modified Soviet prosthesis, and the heterogenous group of patients, indicates that many benefits may be derived from the use of myoelectric control.

Technically, the device requires still further development to produce an efficient and universally acceptable prosthesis at a reasonable cost. The hand at present is only available in the male adult size. Hands and interchangeable terminal devices are required in smaller sizes, to accommodate female and young patients.

Future designs will provide the means of controlling motor-function prosthesis either with electric power or in combination with other forms of external energy. Hybrid combinations of myoelectrics with pneumatic, and conventional prosthetic devices, are possible and may be beneficial for some patients.

Current work at the Institute includes the design and development of a full electric arm for every young amputees, with special reference to the thalidomide children.

Research activities into the capabilities of the human operator and human information processing techniques are very important at the present time. With the complex prostheses of the future, good understanding of the human motor system, and sophisticated controls will be necessary to establish the bridges of communication between man and machine.