CANADIAN EXPERIENCE WITH THE U.S.S.R. MYOELECTRIC PROSTHESIS

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Historical Aspects

The Rehabilitation Institute of Montreal was selected as one of three institutions to carry out a program for the care and treatment of Thalidomide-affected babies in Canada. In view of the importance of the development of proper prosthetic appliances, especially for children with severe congenital malformations of the extremities, the Institute followed closely the literature and reports on myoelectric control.

As a great amount of publicity and emphasis had been given in the medical and lay press concerning an active arm prosthesis with myoelectric control developed in the U.S.S.R., in July 1964, a four-member team, traveled to Moscow and visited the Central Institute of Prosthetics and Prosthetic Development.

In October 1964, through a special assistance grant from the Government of the Province of Quebec, the manufacturing rights and ten prototypes were purchased from Licensintorg, and a pilot project was instituted with the objective of gaining practical and clinical experience with the Soviet device in order to assess its potentialities and the application of myoelectric control for congenital and child amputees.

The Soviet Myoelectric Prosthesis

The externally powered active component of this device is the hand which houses the drive motor in the metacarpal area and produces a simple movement of pinch or grasp with an over-all force of four pounds available at the finger tips. A 13,000 r.p.m., 1.5-watt motor drives a gear reducer and rotary-to-linear converter. The fingers and thumb are rigid, slightly flexed and hinged at the metacarpophalangeal joints, and linked to the drive. Upon closure of the hand, the tip of the thumb falls between that of the middle and index fingers, and the grasp occurs approximately in the center line of the forearm. The hand opens and closes in 0.8 seconds.

An elastic cosmetic glove encloses the hand and generates sufficient friction to hold objects varying in diameter from 6.35 mm to 95 mm. The grasp is firm enough to hold a knife and cut meat, and delicate enough to hold a match.

The system is powered by a battery of 13.75 volts weighing 320 grams, sufficient for the activities of at least one long day, rechargeable overnight.

Movement of the fingers and 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 rotary-to-linear converter, which in turn is activated by a high-speed electric motor through a gear reducer. The entire drive occupies approximately 25 by 50 by 65 mm, weighs 115 grams, and is located in the metacaroal area of the hand.

Power is directed to the motor by two small relays, controlling operation in opposite directions. Each of the relays is energized by a control channel consisting of a set of electrodes, a myoelectric preamplifier, and 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 D.C. voltage approximately proportional to the activity in the control muscles. When this voltage is sufficiently high, the power amplifier operates the relay and the hand closes in the corresponding direction. The other channel is electrically interconnected to prevent simultaneous operation. When both relays are de-energized, the motor stops abruptly.

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 when visual observation is not possible. An average below-elbow prosthesis with this drive weighs approximately one (1 kg) kilogram exclusive of the battery.

The control amplifier and the functional unit have been tested by the Institute under cold temperature conditions, showing little change in performance from approximately 38 degrees C. to -18 degrees C. At lower temperatures, the amplifier requires a higher output to operate, and the viscous loading represented by the cosmetic glove greatly increases the operating current and the running time, but the hand will operate after a fashion even at —50 degrees C.

Canadian Modifications of the U.S.S.R. Prosthesis

The investigation, application, and maintenance of the Soviet prosthesis were commenced in December 1964. The original amplifier and battery had several weaknesses principally due to the marginal rating of component parts. The utilization of Canadian and American hardware as replacements substantially reduced the number of failures. The battery charger had to be redesigned to eliminate the danger of electric shock and two completely new amplifiers were built.

It was also found desirable to simplify the prosthesis. Originally, the amplifier and battery worn in pouches attached to a belt coupled with considerable external wiring made the system cumbersome.

The prosthesis was redesigned to minimize wiring runs, and provide and adjustable passive wrist unit (modified Hosmer). The amplifier was integrated in the socket and all wiring made internal, leaving only the power supply wire running from the prosthesis to the battery.

The original rechargeable batteries proved to be unreliable and short-lived. A new vitrathene battery pack was developed; this package may be carried in the pocket, worn as an arm band, or suspended from a harness or belt.

The original twin electrodes have been replaced by a triple stainless-steel unit, thus eliminating the need for a separate reference electrode. A jelly used in ultrasonic therapy was found to have excellent electrical characteristics; it establishes good surface contact for up to 15 hours, provided that the socket is not removed.

Very early in the development of practical prosthetic devices controlled by myoelectric signals, it became obvious that electronic circuitry of very small dimensions and with high adaptability to shapes and spaces was essential to facilitate installation and operation. Miniature electronics developed for use in space projects represented a great improvement but integrated circuit devices produced a further significant reduction of size.

In simple terms, integrated circuit technology creates a single semiconductor crystal with electrical connections. The transfer function (input-output characteristic) of this device is equivalent to one or more stages of amplification usually achieved by up to 11 transistors with associated resistors and capacitors. Switching and signal-processing devices are also available, in a very small package, produced by the same technique.

Using microelectronics, it is possible to locate the preamplifier stages directly over the electrodes of a myoelectric control site, reducing the amount of wiring required and improving the conditions for excluding extraneous signals and noise. A convenient electronic package may be made up of integrated circuit devices, which will fit into a standard prosthetic socket, eliminating the unsightly protrusions necessary with larger amplifiers.

One operational device is now in service on a below-elbow Canadian patient, controlling an otherwise standard U.S.S.R. prosthesis. Several other designs are under testing in the laboratory of the Institute. Some stability and power-line interference problems have been encountered, but with well-conditioned electrodes these effects can be neglected. With a transformer-input replacing a differential amplifier step, the circuit becomes more independent of electrode conditions and power frequency noise. Another advantage of the transformer stage is that it permits the use of simple, single-ended operational amplifiers.

In view tremendous technological developments taking place in the integrated-circuit field, it is reasonable to assume that a great variety of very inexpensive devices, suitable for myoelectric signal amplification and processing, will soon appear on the commercial market.

They will practically eliminate the necessity of circuit design, inevitable with distinct components. Hopefully, all-semiconductor packages, capable of driving small motors in a proportional mode, will also be developed.

Clinical Evaluation

As of the end of July 1966, 15 amputees were selected from a total of 17 candidates. Ten adults, consisting of nine males and one female, have now been equipped and trained. Five male adults are under evaluation and training, including two above-elbow cases and one bilateral above-elbow case of congenital origin.

The above group of 15 cases ranges from 17 to 65 years of age with amputation histories of three months to 28 years. Five of them are bilateral amputees, one of whom desired to be equipped on one side only. One unilateral case is totally blind, another bilateral and one above-elbow case have lost one eye each.

This small sample of patients indicated that a person with quick intelligence to grasp new concepts, and with good self-discipline to accept instructions and to adapt to situations, will invariably produce good results regardless of chronological or amputation age.

It appears that a well-motivated and intelligent subject will adapt to simple myoelectric control within a matter of minutes. One bilateral amputee was operating both arms independently and simultaneously an hour after being fitted with the appliance.

A full report on patient use of the myoelectric prosthesis will be published within the next 24 months. This will include the psychosocial aspects.

Training Methods and Control Site Development

In order to enable an amputee to operate the hand, the muscle control sites must be found and developed. The first objective is to establish the highest possible degree of independent operation of the control muscles, in this case two in number. The »natural« muscles, i.e., the flexors and extensors, are used to close and open the hand, respectively.

The control sites yielding a maximum of signal are located by a small myoelectric activity detector, a simple transistor amplifier with an indicator. The multichannel trainer is then used to determine the amount of interference or cross-talk existing between the proposed muscle sites, the relative signal strength and ease of control. With visual display, a significant improvement can be achieved by the amputee in a short time, greatly increasing the degree of independence of the control points. To display myoelectric activity, an indicating meter appears to be a better choice and more meaningful to the patient than the oscilloscopic trace of electromyographic signals.

A blind subjects was successfully trained to operate the hand by substituting audio signals for the visual display. Raw myoelectric signals detected by the usual electrodes were amplified and introduced into a pair of earphones. One earpiece was activated by the extensor, the other by the flexor channel. After some 12 minutes of instructions, the blind amputee was able to produce the required control signal consistently without the usual mustakes of sighted subjects. The acoustic method seems to have definite advantages as a training display for sightless subjects.

The phantom picture of the missing segment, as reported by the amputee, has been used to good advantage in training. The homologous function on the sound side is a good indicator of activity in unilateral cases. It appears that a bilateral amputee should be equipped actively and simultaneously on both sides.

In general, the initial training and control site development should be done in a short period of time; three or four sessions of one hour each spaced within a week or ten days produce the best results in most cases. Patients show a very significant improvement in attitude, cooperation and performance when they are connected to operate a prosthetic demonstrator for the first time, as against the preliminary evaluation by instrument displays.

Maintenance

The modified U.S.S.R. equipment operates with good reliability. Some of the drive units have been in continuous use for sixteen months without breakdown. Small defects occurred during the initial installation and training period. Approximately half of the amputees have had one or more stoppages following their discharge from the Institute, due to broken wires and component problems, but these minor problems were quickly attended to.

Strong radio-frequency interference may cause the hand to operate involuntarily. Specific locations are known by the users of the myoelectric prosthesis as sources of such interference, presumably in areas containing extensive communication systems. The possibility of radio transmissions in commercial air craft creating similar problems is being investigated.

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