

Myoelectric elbow and hand prosthesis controlled by signals from 2 muscles only, in a 9 year old girl

L. PHILIPSON and R. SÖRBYE

Department of Clinical Neurophysiology, Regional Hospital, Örebro, Sweden

Abstract

A nine year old girl with a congenital above-elbow amputation was supplied with a myoelectrically controlled arm prosthesis at the Regional Hospital, Örebro, Sweden, in May 1978. The prosthesis was equipped with an artificial hand as well as an elbow joint. The latter was designed at New York University, for switch control but adapted to myoelectric control in the Department of Clinical Neurophysiology at the Regional Hospital, Örebro. The electric signals from the biceps and triceps muscles were used for the control of hand closing and opening as well as elbow flexion and extension. Two different control methods have been applied and clinically tested.

The first is a three-level method in which slight contraction of biceps/triceps gives closing/opening motions of the hand and a higher contraction level in these muscles gives flexion/extension of the elbow.

The second is a contraction-rate detection method in which slow contraction of biceps/triceps gives closing/opening of the hand and faster contraction of these muscles gives flexion/extension of the elbow.

Both methods have been tested on the patient in a laboratory set-up and in a clinical trial which is still going on. Small electronic control circuits have been designed and placed inside the socket of the prosthesis, which is completely self-contained.

From the different tests performed, the second control method seems to be the most suitable for the actual patient. She is using her prosthesis every day, continuously improving her controlling ability.

Introduction

Since 1971, young children with congenital below-elbow amputations have been successfully supplied and trained with myoelectrically controlled hand prostheses at the Regional Hospital, Örebro, Sweden, (Sörbye et al 1972; Sörbye, 1977 and 1980). When in early 1978 a 9 year old girl with a congenital above-elbow amputation was referred to the hospital, it was decided to use the same type of prosthetic hand. At about the same time an offer to test an electric elbow, developed by Fishman and Lembeck at the New York University, Post-Graduate Medical School, Prosthetics and Orthotics was received. For several reasons it was then decided to supply the girl with a myoelectrically controlled prosthesis where the hand as well as the elbow were externally powered.

Method

A 6.75 in (17 cm) prosthetic hand of Otto Bock type was chosen, equipped with passive rotation and a quick disconnect. The electric elbow from New York University was designed to be controlled by switches, but it was adapted to myoelectric control by means of some minor electrical modifications. To keep electrodes and wires inside the prosthesis it was decided to use only the two muscles biceps and triceps for control of both the hand and the elbow.

In order to control four movements from two muscles some type of multistate control system had to be used. A multi-state control technique was first presented by Dorcas and Scott (1968). Based upon their idea, Dillner and Hägg (1971) described three different methods to control two movements with one muscle only:

1. A sequence method. Each movement is performed every second time the muscle is activated.

All correspondence to be addressed to: Dr. R. Sörbye, Head, Department of Clinical Neurophysiology, Regional Hospital, S-701 85 Örebro, Sweden.

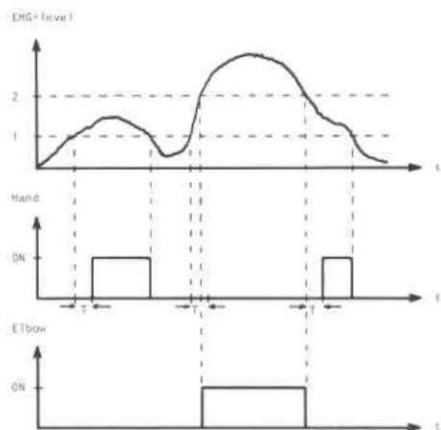


Fig. 1. Function of an EMG-level detector for three-state control (method 2)

2. A method that classifies the instantaneous EMG-level from the muscle as belonging to one of three level groups. The term "EMG-level" throughout this paper should be understood as the actual amplitude of the amplified rectified and integrated surface EMG-signal.

3. A method that classifies the initial EMG-level rate into one of three different categories.

Of these three methods the authors used the two latter ones.

Figure 1 illustrates the function of the EMG-level detector according to method 2. In the upper graph the EMG-level is plotted against time. Assuming that the EMG-level originates from biceps, the result will be that as long as the EMG-level is below the lowest threshold, level 1, there is no output from the control system. An EMG-level that resides in the interval 1–2 during at least a period of time T will start a hand closure. As soon as the EMG-level is found to be outside the interval 1–2 the hand activity is discontinued. An EMG-level exceeding the highest threshold, level 2, will immediately initiate an elbow flexion, which again stops when the EMG-level drops below threshold 2. By introducing the delay-time T it has become possible to operate the hand or the elbow exclusively. The activity from the triceps muscle will operate hand opening and elbow extension in the same way.

The function of the rate detection method (method 3) is illustrated in Figure 2. If again the EMG-level plotted is the one concerning biceps

the result will be that as long as the EMG-level is below threshold 1 there will be no output from the control system. As soon as the EMG-level exceeds threshold 1 a clock is started. After a delay-time T the EMG-level is checked. If the EMG-level is found to be within the interval 1–2 a hand closing motion will be initiated. Should the EMG-level be above level 2 an elbow flexion motion will result. Whatever movement was initiated will continue until the EMG-level drops below threshold 1.

With this method the rate of increase in EMG-level in the initial phase of a muscle contraction determines the output. It should be noted that the EMG-level, after a decision is made, is free to vary to a great extent without affecting the status of the output. The above discussion also applies for triceps and hand opening/elbow extension.

When two control sites are used, for instance over the muscles biceps and triceps respectively, each operating a three-state controller, the result is a five-state controller (generating four

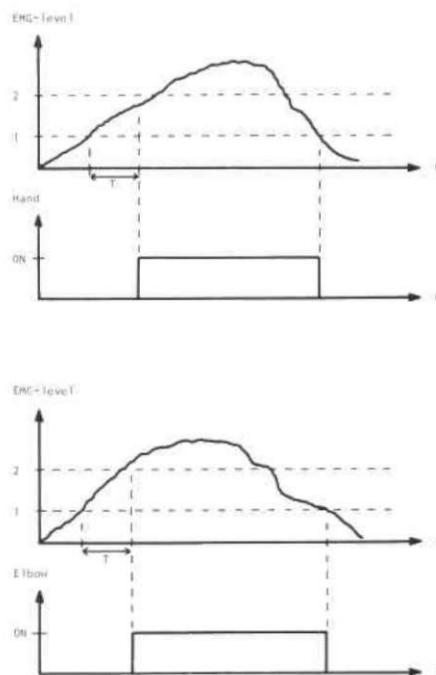


Fig. 2. Function of rate detection in the initial part of the increasing EMG-level for three-state control (method 3).

movements and a resting state). Similar techniques have been described by Childress et al (1971), Schmidl (1977) and the team directed by Scott at the University of New Brunswick (1978).

Application and clinical experience

To find out whether it was possible for the patient to operate a two-site/five-state control system, a test set-up was designed with the necessary electronics mounted on a prototype board to facilitate changes and adjustments. The hand and the elbow were placed on a stand in front of the patient (Fig. 3, top).

Two electrodes, serving the biceps and triceps muscles respectively, were mounted in a prosthetic socket fitted to the patient. In this project the electrode system developed at the Chalmers University of Technology and the Sahlgren Hospital, Göteborg, Sweden was used. The electrode includes amplifier, rectifier and integrator, and the output from the device is a DC voltage-level closely related to the EMG-activity in the muscle, as described by Almström (1977).

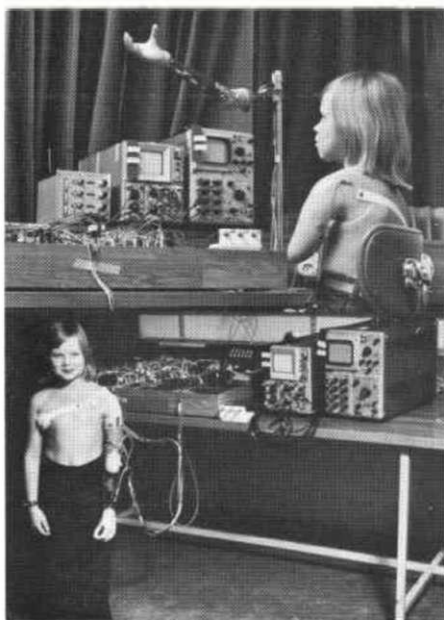


Fig. 3. Top, test set-up as described in the text. Bottom, at a later stage in training the hand and elbow are attached to the socket.

Initially control method 2 was tested (Fig. 1). With the devices arranged as described the girl was able to perform the four different movements of the prosthetic arm after some 15 minutes of practice. Later in the process of training the hand and elbow was attached to the prosthetic socket, thus achieving a test situation very similar to the use of a self-contained prosthesis. This test set up and the assembled prosthesis can be seen in Figure 3, bottom. After the necessary testing and training a miniaturized version of the control system was built and fitted inside the prosthetic socket.

Finally the patient went home with the self-contained arm prosthesis fully mounted.

Control method 2 (Fig. 1) gave the user good control over the four arm movements. There are, however, two drawbacks with this system.

Quite a high EMG-level is required for operating the elbow of the prosthesis. If elbow movements are frequently needed, the repetitive strong contractions of the control muscle will cause muscle fatigue.

Furthermore, while the hand is being used the patient will sometimes find it difficult to keep the EMG-level constantly within the actual interval.

Neither of these two drawbacks is present in the rate-detection method (Fig. 2). For that reason, after about 6 months of experience with the patient using control method 2, it was then changed to control method 3. The electronics

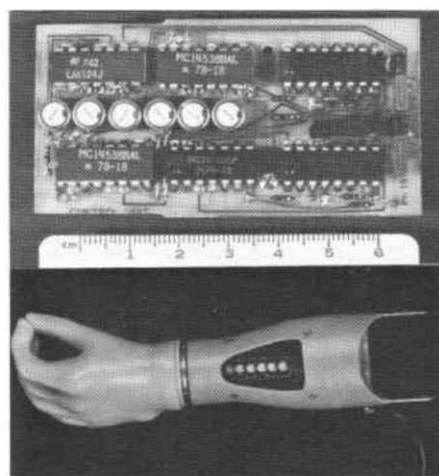


Fig. 4. Top, final version of the miniaturized control circuitry. Bottom, the control circuitry mounted in the forearm of the prosthesis.

were redesigned to function according to this method and the procedure of testing, training and constructing was repeated.

The anticipated improvements with this method turned out to be true. The system worked well and has now been in daily use by the patient for the last 2 years.

The miniaturized control circuitry for method 3 is shown in Figure 4 (top). The bottom picture shows the electronics mounted inside the forearm of the prosthesis. The assembled prosthesis showing the holders for the rechargeable batteries is illustrated in Figure 5 (left). Figure 5 (right) shows the patient wearing the complete prosthesis.

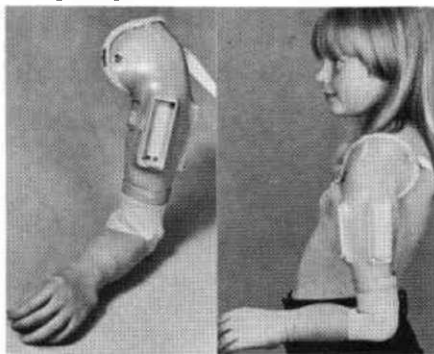


Fig. 5. Left, assembled prosthesis showing the holders for the rechargeable batteries. Right, the patient wearing the complete prosthesis.

The control system has been completed by a circuit that makes it impossible to perform more than one movement at a time; this is helpful to avoid unwanted movements.

When the two control systems were compared after each had been used for 6 months, test results and the opinion of the patient indicated that method 3 was the best. This method, was therefore adopted, the observation time of which now exceeds 2 years.

Improvements concerning the socket design have been made, the batteries have been moved to the forearm socket and some modifications regarding the electrode design have been worked out.

A new and more advanced control system for the hand/elbow prosthesis is now being prepared, according to a principle described by Philipson et al. (1981).

Conclusion

A myoelectric arm prosthesis containing externally powered hand and elbow has been controlled by two muscles only. Two different control methods have been tested, both in a laboratory setup and in clinical use by a 9 year old girl. The device has been functioning very well, with only a couple of minor breakdowns. It has been well accepted by the user. The control method that classifies the instantaneous EMG-level into three groups was useful, but in our opinion the method which is sensitive to the initial EMG-level rate is even better. The latter method therefore has been used in the actual patient during the greater part of the observation time which now exceeds 2½ years.

REFERENCES

- ALMSTRÖM, C (1977). An electronic control system for a prosthetic hand with six degrees of freedom. *Research Laboratory of Medical Electronics. Report 1:77*. Chalmers University of Technology, Göteborg, Sweden.
- CHILDRESS, D. S., HOLMES, D. W. AND BILLOCK, J. N. (1971). Ideas on myoelectric prosthetic systems for upper-extremity amputees. In: *The Control of Upper-extremity Prostheses and Orthoses*, 86–106, Charles C. Thomas publisher, Springfield, Illinois.
- DILLNER, S. AND HÄGG, G. (1971). Three methods of controlling an externally powered prosthesis with one myoelectric signal only. *Research Laboratory of Medical Electronics. Report 4:71*. Chalmers University of Technology, Göteborg, Sweden.
- DORCAS, D.S. AND SCOTT, R. N. (1968). A three-state myoelectric control. *Med. & Bio. Eng.*, **4**, 367–370.
- PHILIPSON, L., CHILDRESS, D. S. AND STRYSIK, J. S. (1981). Digital logic and microcomputer approaches to proportional myoelectric system design: Three-state single-site and multi-state multi-site control of prostheses. *Bull. Pros. Res.* (in press).
- SCHMIDL, H. (1977). The I.N.A.I.L. experience fitting upper-limb dysmelia patients with myoelectric control. *Bull. Pros. Res.* **10-27**, 17–42.
- SÖRBYE, R., BARTELS, W. AND ROLANDER, S. (1972). Experiences from myoelectric controlled prosthesis in a three year old child. The Third International Conference on Medical Engineering, Göteborg, Sweden, Chalmers University of Technology.
- SÖRBYE, R. (1977). Myoelectric controlled hand prostheses in children. *Int. J. Rehab. Res.*, **1:15**.
- SÖRBYE, R. (1980). Myoelectric prosthetic fitting in young children. In: *Clinical Orthopaedics and Related Research*, **148** (May 1980), 34–40.
- UNIVERSITY OF NEW BRUNSWICK (1978). Progress Report No. 16, Clinical evaluation of UNB 3-state myoelectric control.