A Myoelectrically Controlled Powered Elbow[1]

Herbert H. Hartman, M.S.,[2]
David C. Hobart, B.S.E.E.,[3]
Worden Waring, Ph.D.,[4] and
Vernon L. Nickel, M.D.[5]

Since the appearance of the "Russian hand" about ten years ago (3), an increasing number of externally powered prostheses controlled by electrical signals from muscles have been developed. Most of these are built as entire systems, including electrodes, circuitry, motor, and battery. A basic requirement of such systems has been that the user must have two essentially normal muscles in order to operate the motor bidirectionally and so control prehension and release, or elbow flexion and extension.

Because of our concern in fitting patients having greatly reduced muscular function, we have developed circuitry using as control signals the minute electrical activity generated in severely paralyzed muscles. In addition, because of the disabilities of our patients, we have not only circuitry for control from two muscles, but also circuitry which permits bidirectional control from a single muscle site, as does that of Dorcas and Scott (2). In the latter case, when the muscle is relaxed, the motor controlling the orthotic device holds its position. With a small effort, the motor is turned on and the device moves in one direction; a moderate effort operates the motor in the reverse direction. Until recently, all our fittings had been for patients with orthotic devices. The present report describes our first fitting using a prosthesis.

Mrs. S. S. had a traumatic complete avulsion of her right forearm from the elbow. We first saw her nine months post injury, when she was using a prosthesis with two cables, for control of the elbow and the terminal device. The prosthesis was not entirely comfortable, and it required enough force in operation to be rather fatiguing. We decided to fit her with power at one joint; the elbow was selected because it was believed that the sensory feedback of cable control would be more valuable in operating the terminal device than the elbow. Because there was some remaining musculature in the upper arm, it was hoped that electrical signals from the biceps and triceps muscles could be used to control the powered elbow.

On examination, voluntarily controlled electrical signals were obtained from the biceps and triceps areas, but the signals were small and the muscles were not controlled independently. In collaboration with an occupational therapist, muscle strengthening and isolation of control were undertaken. Improvement was noted two weeks later, when the patient was able to operate a test hand splint with a myoelectric control circuit, using her triceps.

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[2] Research Physiologist, Rancho Los Amigos Hospital, 7601 East Imperial Highway, Downey, Calif. 90242.

[3] Research Electronics Engineer.

[4] Principal Investigator. Present address: School of Medicine, University of California, Davis, Calif.

[5] Medical Director.

But even after further training exercises, signals from the biceps area were too weak and too highly correlated with triceps signals to be used for control in a two-muscle system. In view of our observations, of the nature of the accident, and of a discussion with the physician who had attended her, it seemed best to use the triceps alone as a control muscle, with the single-muscle, bidirectional control described above.

The powered elbow used is essentially the "Rancho Los Amigos" unit designed by Karchak and Allen (Fig. 1) *(1).* Some modifications were suggested and made by

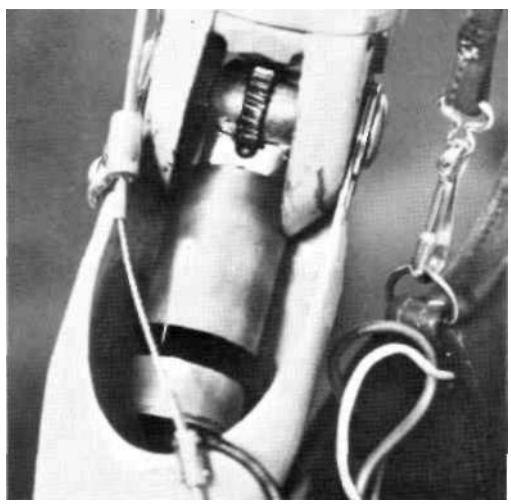

Fig. 1. View of electric elbow designed by Karchak and Allen with motor installed in forearm. Harness snap and strap suspend the battery pack.

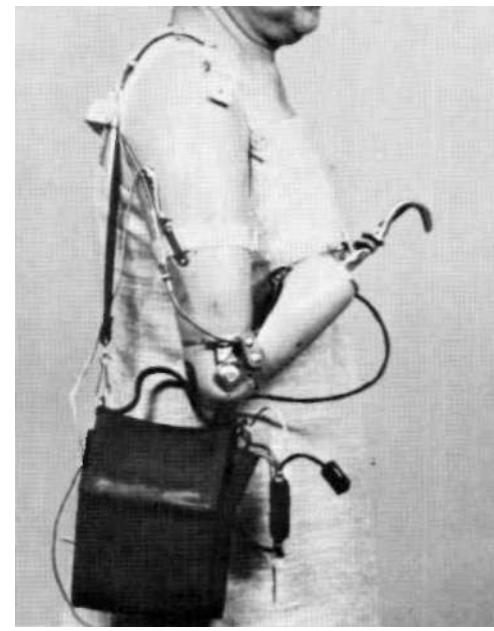

Fig. 3. Patient with the electric elbow controlled by myoelectric signals from the triceps. Note the method of holding the electrode in place.

Kenneth Foshay, of our group. Because of the long length of the stump of the patient, there was no space for parts within the upper arm shell.

The circuit used is shown in Figure 2. It is similar to that described earlier (4), except that an integrated circuit device was substituted for the separate semiconductor components in the front end, and a voltage regulator was added to the power

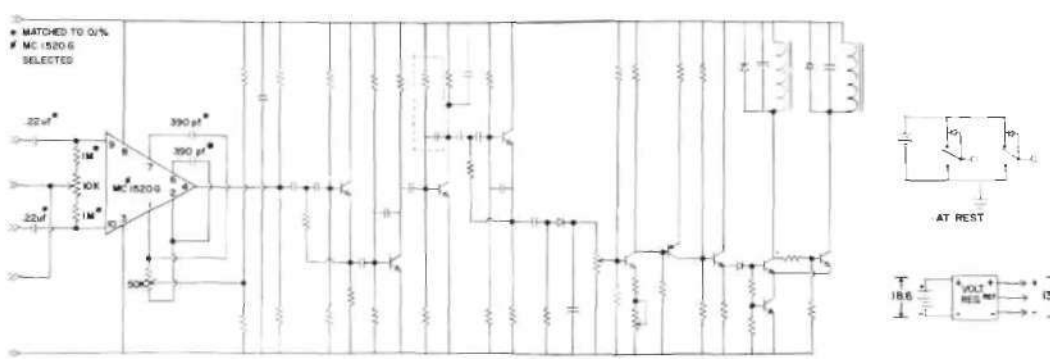

Fig. 2. Circuit used in electric elbow.

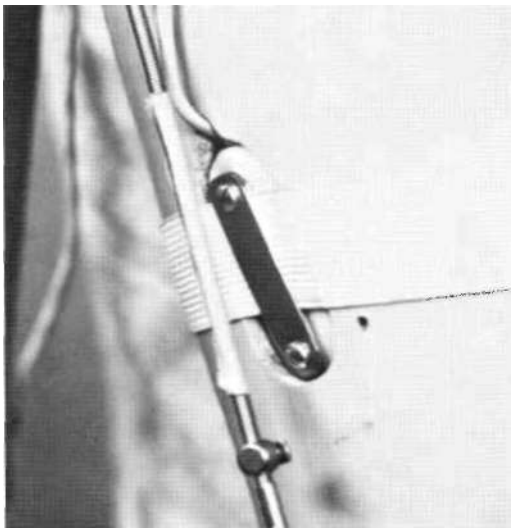

Fig. 4. Close-up view of method of holding the electrode in place.

supply to reduce sensitivity of the circuit to the somewhat varying battery voltage. As indicated in Figure 2, values of three pairs of components should be close to the nominal values shown, and the pairs must be carefully matched so as to minimize common mode interference.

Power for the system is obtained from small, rechargeable, nickel-cadmium batteries. These, together with the electronic circuitry, are carried in a shoulder bag (Fig. 3). An on-off switch is included so that the motor can be disconnected when she puts on or takes off the prosthesis or wishes to lock the elbow for some period of time.

Signals from the triceps area are picked up by surface electrodes fitted into a hole cut into the prosthesis socket and held in place by an elastic band (Figs. 3 and 4). The electrode assembly consists of three domes of textured stainless steel mounted in medical-grade Silastic (5).

The system is insensitive to rather severe challenge by 60 Hz current intentionally brought near to it in the laboratory. In use, there seems to be no significant interference from her car, from an electric sewing machine or iron, or other electrical signal generators. The patient has been using it at home for her various household activities some five to ten hours daily for seven months at the time of writing. Evidence of use is shown by the need to install a new gear after about three months, and recently the elbow joint needed tightening because of increased play from the wear.

ACKNOWLEDGMENTS

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