

Prosthetics and Orthotics Clinic

Vol. 2, No. 1

Issued Quarterly

Externally Powered Upper-Limb Prostheses

The earliest reference to externally powered upper-limb prostheses seems to be in connection with experiments that took place in Germany about 1918 in which electromagnets were used to close the fingers of an artificial hand (16). The next reported effort apparently is the research and development program proposed and carried out by Alderson (1) on electrically powered arm systems during 1946-1952

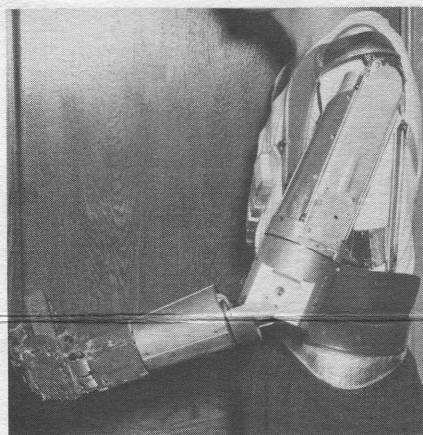


Fig. 1. An early model of the Alderson-IBM Electric Arm.

with support from International Business Machines, Inc. and the Veterans Administration.

Initial results of the Alderson-IBM project (Fig. 1) were quite impressive with respect to operation, but an extensive evaluation at UCLA in 1951 revealed that a disproportionate amount of mental effort by the wearer was required for use of the various systems (6).

As a result of the findings of the UCLA study, and because only a limited amount of money was available for work in artificial limbs, the Advisory Committee on Artificial Limbs (later the Committee on Prosthetics Research and Development) of the National Academy of Sciences recommended that development of actuators be delayed until sufficient research could be carried out concerning the control problem so as to provide means for control of the prosthesis without conscious thought by the wearer.

A project was initiated at UCLA about 1953 to explore various control methods. Among the various studies conducted at UCLA was an evaluation of the so-called Vaduz hand (Fig. 2) (6), a design that originated in Lichtenstein which used bulging of the residual muscles in

a forearm stump to provide control of an electrically actuated artificial hand. Some rather positive findings were overshadowed by the poor quality of the one unit that was available at the time, and perhaps by the introduction by Russia in 1958 of a "thought control" electric arm (12). The Russian device actually consisted of an electric hand controlled by myoelectric signals from the residual forearm agonists and antagonists of a below-elbow amputee.

The "Thalidomide tragedy" (9) in 1958-1962 prompted England and Canada to secure manufacturing rights to the Russian design, but fabrication and distribution was not successful in either country. The "Thalidomide tragedy" also encouraged work at the University of Heidelberg in the development of

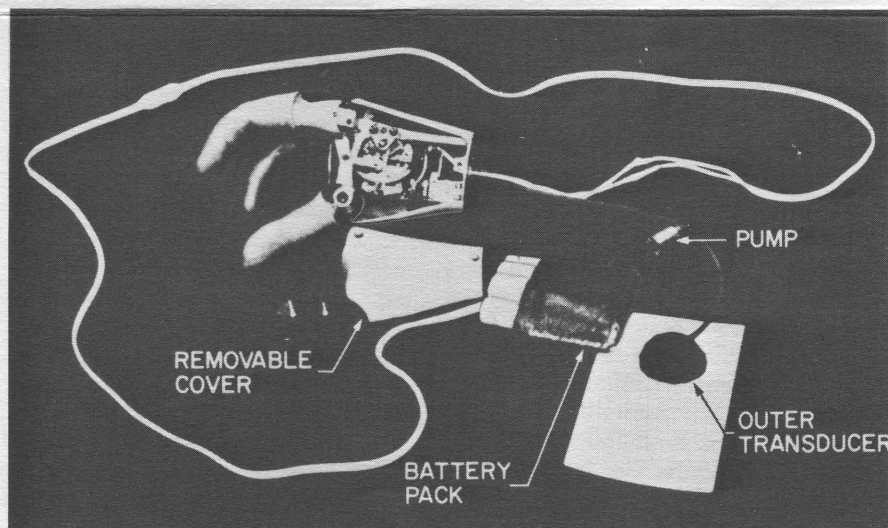


Fig. 2. The "Valdaz" hand and control system.

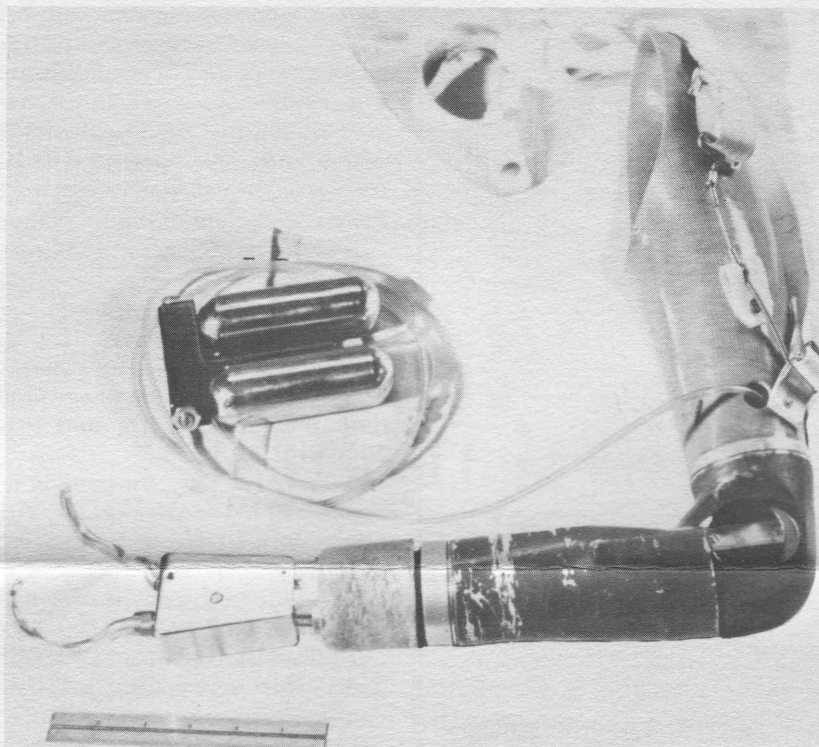


Fig. 3. On the pneumatic above-elbow systems developed by Kiessting at the American Institute for Prosthetic Research.

pneumatically powered artificial arm systems (13), and an agreement was obtained by Kessler and Kiessling (11) for continuation of this work in the U.S. (Fig. 3). This project was carried out between 1960 and 1969. Again the problem of control was the primary reason for discontinuing the work.

Because of the Thalidomide tragedy, Sweden (10) also launched a modest program in development of externally powered upper-limb prostheses about 1960. Work in this area has been carried out continuously since, but with no commercially available devices resulting, as far as is known at this time.

The Russian design caused an Austrian group, Viennatone, and the Otto Bock Company in Germany to develop and market about 1962 similar devices. A few years later Hannes Schmidl began fitting externally powered artificial arms on a relatively large scale at the INAIL Center, Budrio, Italy and continues to do so to the present time (18). Pneumatic models were used initially, but all designs used now are electric.

Simpson (20), at the Princess Margaret Rose Hospital, Edinburgh, Scotland uses routinely pneumatic prostheses for a group of "Thalido-

mid" children, but his design is not widely available elsewhere.

In 1960 while on Sabbatical study at the University of Southern California Tomovic from the Institute Pupin, Belgrade, suggested the use of electromechanical pressure sensitive systems to aid in solution to the control problem by introducing closed-loop feedback systems (14, 21). A number of prototypes (Fig.

4) were designed and fabricated upon the return of Tomovic to Yugoslavia. Results of evaluation were also overshadowed by poor workmanship and engineering, and work on this was abandoned about 1968.

McLaurin, while at Northwestern University, designed the so-called Michigan feeding arm about 1960 which used a linkage to coordinate motions about the elbow and the wrist to make it possible for young bilateral children amputees to feed themselves (7). This device met with considerable success in the clinical setting, but never became a commercial success.

McLaurin continued work in electrical arms for children at the Ontario Crippled Childrens Centre, Toronto, between 1963 and 1975. Although he was able to persuade the Variety Club to develop a facility for manufacturing, at cost, some of the products of research as a philanthropic endeavor, to date only an electric elbow has been made available, but because of the low volume the cost is extremely high in spite of subsidization.

In the late sixties a number of efforts in the U.S. were directed toward the development of electric elbows. By 1969 three designs were considered ready for clinical evaluation, the "Boston" elbow developed by M.I.T. and Liberty Mutual Insurance Co., the AMBRL elbow, developed by the Army Medical Biomedical Research Laboratory,

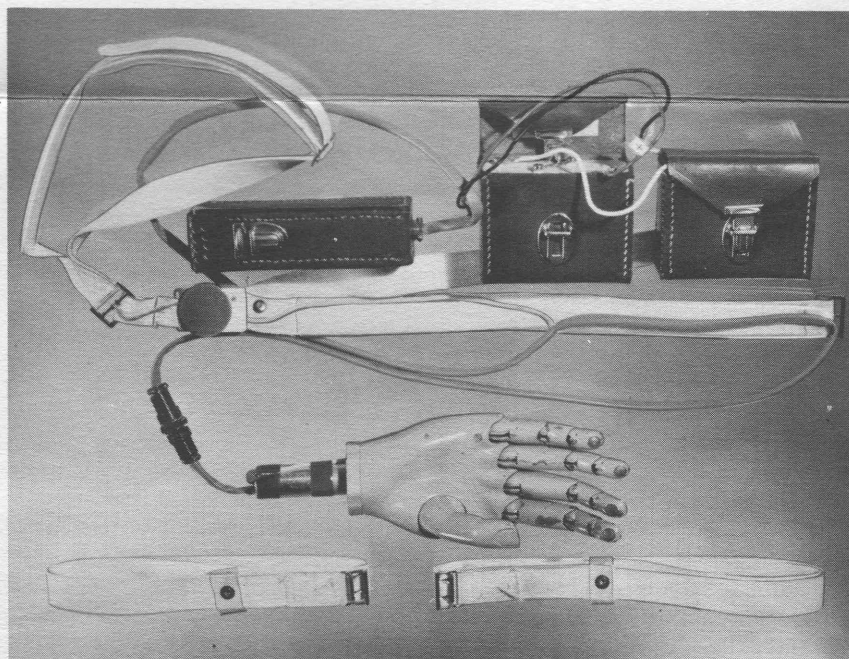


Fig. 4. The "Belgrade" hand and control system.

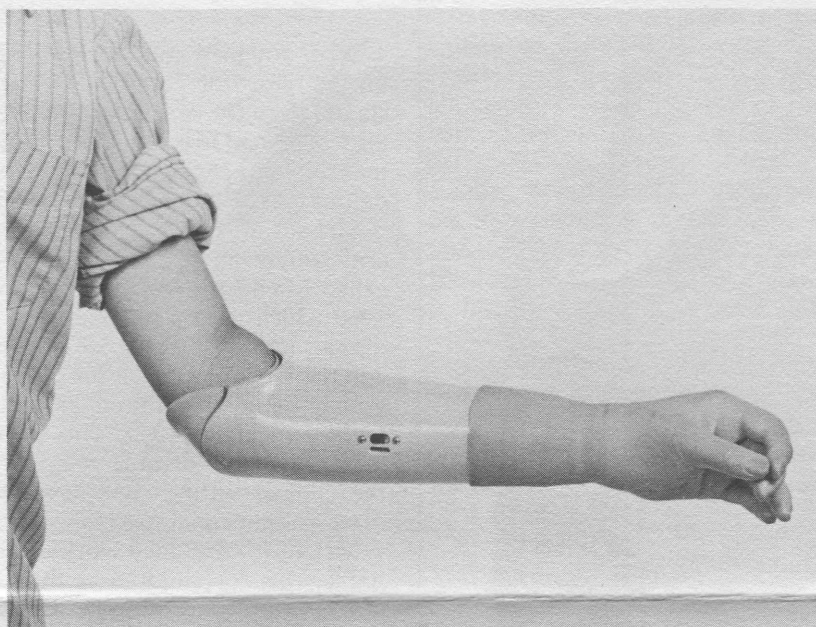


Fig. 5. The self-contained and self-suspended below-elbow system using myoelectric controls developed at Northwestern University.

and a design by Rancho Los Amigos Hospital. The clinical evaluation program was organized and coordinated by CPRD in 1969-70 (5).

Of 20 subjects in the study only 3 elected to retain the electric device. Two of these subjects had physical problems that made operation of the body powered prosthesis more difficult than would have been the case otherwise. Out of this experience came a revised set of design criteria and objectives.

In addition to all of these efforts, research and development programs in externally powered artificial arms have been carried out in the U.S. at Temple University - Moss Rehabilitation Hospital (22), Northwestern University (Fig. 5) (4), Veterans Administration Prosthetic

Center, Duke University, Rancho Los Amigos Hospital, University of California at Los Angeles, the University of Colorado, and Johns Hopkins University (8, 17).

Sweden, Great Britain, Italy, Germany, Russia, and others have continued to support research and development in this field.

Yet today it is very difficult to obtain an electric or pneumatic arm in the United States, other than the electrically operated hands that are suitable for below-elbow patients. We will be pleased to hear the opinions of readers of the NEWSLETTER concerning the reasons for this.

A. Bennett Wilson, Jr.
March 16, 1978

REFERENCES

1. Alderson, Samuel W., *The electric arm*, (Chapter 13 in Klopsteg and Wilson's "Human Limbs and Their Substitutes," McGraw-Hill, 1954, reprinted by Hafner Press, 1969).

2. Battye, C.K., A. Nightingale, and J. Whillis, "The use of myoelectric currents in the operation of prostheses," *J. Bone Joint Surg.*, 37-B, 506, Aug. 1955.

3. Berger, N., and C.R. Huppert, *The use of electrical and mechanical muscular forces for the control of*

an electrical prosthesis, *Amer. J. Occup. Ther.*, 6:110-14, 1952.

4. Childress, D.S., et al., *Myoelectric immediate postsurgical procedure: A concept for fitting the upper-extremity amputee*, *Artif. Limbs*, Vol. 13, No. 2, Autumn, 1969.

5. Committee on Prosthetics Research and Development, *Externally powered prosthetic elbows — a clinical evaluation*, Report E-4 National Academy of Sciences, 1970.

6. Committee on Prosthetics Re-

search and Development, *The application of external power in prosthetics and orthotics*, National Academy of Sciences, Publication 874, 1961.

7. Committee on Prosthetics Research and Development, *The control of external power in upper-extremity rehabilitation*, National Academy of Sciences, Publication 1352, 1966.

8. Dankmeyer, Charles H., Sr., Charles H. Dankmeyer, Jr., and Martin P. Massey, *An externally powered modular system for upper-limb prosthesis*, *Orth. and Pros.*, 26:3, Sept. 1972.

9. Frantz, C.H., *An evolution in the care of the child amputee*, *Artif. Limbs*, Vol. 10, No. 1, Spring 1966.

10. Kadefors, R., et al., *Stryning av armprotes med myosignaler*, *Elektronik*, 3:42-49, 1967.

11. Kessler, H.H., and Kiessling, E.A., *Pneumatic arm prosthesis*, *Am. J. Nursing*, 65:6: June 1965.

12. Kobrinski, A.E., Bolkhovitin, S.V., Voskoboinikova, L.M., Ioffe, D.M., Polyan, E.P., Popov, B.P., Slavutski, Y.L., Sysin, A.Y., and Yakobson, Y.S.: *Problems of bioelectric control in automatic and remote control. Proceedings of the First International Congress of the International Federation of Automatic Control*, Moscow, 1960, London, Butterworth & Co. (Publishers) Ltd., 1961, Vol. 2, p. 619.

13. Marquardt, E., *Heidelberg pneumatic arm prosthesis*, *J. Bone and Joint Surgery*, 47-B:3:425-434, August 1965.

14. Rakic, M., *Practical design of a hand prosthesis with sensory elements*, *Proceedings of the International Symposium of the Application of Automatic Control in Prosthetics Design*, 103-119, August 27-31, 1962, Belgrade, Yugoslavia.

15. Reiter, R., *Eine neue elektro-kuntshand*, *Grenzgeb. Med.*, 4, 133, 1948.

16. Schlesinger, G., *Der Mechanische aufbau der kunstchanische aufbau der kunstlichen glieder*, in *Ersatzglieder und Arbeitshilfen*, Borchardt, M., et al., Eds., J. Springer, Berlin, 1919.

17. Schmeisser, Gerhard, Woodrow Seamone, and C. Howard Hoshall, *Early clinical experience with the Johns Hopkins externally powered modular system for upper-limb prostheses*, *Orth. and Pros.*, 26:3, Sept. 1972.

18. Schmidl, Hannes, *The I.N.A.I.L. experience fitting upper-limb dysmelia patients with myoelectric control*, Bull Pros. Res. 10-27, Spring 1977.

19. Scott, R.N., *Myo-electric control*, Science J., 2-7, March 1966.

20. Simpson, D.C., *An experi-*

mental design for a powered prosthesis for children, Health, Scottish Home and Health Department Bulletin, 22:4:75-78, October 1964.

21. Tomovic, R., and G. Boni, *An adaptive artificial hand*, IRE Transactions on Automatic Control, 3-10, April 1962.

22. Wirta, R.W., Taylor, D.R., and Finley, F.R., *Engineering principles in the control of external power by myoelectric signals*, Archives of Physical Medicine, 49:294-296, 1968.

READERS COMMENTS ON:

"Should Functional Ambulation Be a Goal for Paraplegic Persons."¹

¹By Michael Quigley, Orthotics and Prosthetics Newsletter, Autumn 1977

The above article, which appeared in the last issue of the Newsletter elicited a great number of responses from physicians, orthotists-prosthetists, therapists, and counselors. More than 90 percent of our respondents agreed with Michael Quigley's position that the majority of paraplegic patients should be fitted with lower-limb orthoses despite the fact that use of such orthoses is extremely inefficient. The major reason for providing these orthoses to patients is to either have the patient prove to himself that he will not be able to walk in a normal manner again, or to make sure that every patient has a chance to walk, inasmuch as few patients are able to use orthoses even for transfer purposes or upright mobility.

The following comments represent a consensus from our respondents:

INDICATIONS FOR FITTING PARAPLEGICS WITH ORTHOSES:

Most respondents agreed that the T₁₀ lesion level seemed to be on the border between a functional ambulator and a non-ambulator. One orthotist-prosthetist responded that in his area the L₁ level is used, as this is the most proximal innervation of the major hip flexors and hip hikers.

Margaret Henry, R.P.T., of the Mt. Wilson Center in Maryland stated that the patient must first have abdominal muscles present and have a desire to walk. He is then fitted with trial braces and must be

able to complete 200 latissimus dorsi push-ups before he is fitted with his own braces. This exercise is used to determine if the patient would have the strength and endurance to ambulate functionally.

Another therapist stated, "I enjoyed the article and comply with author. However the reasoning behind Cerney's conclusions or Hussey's conclusions are faulty. Their conclusions are valid only on the type of braces their patients had and type of training. Study should be qualified!"

A rather interesting letter was sent in by Howard V. Mooney, C.P. of Burlington, Massachusetts. Mr. Mooney stated that he had no experience with paraplegics but mentioned similar experiences with bilateral above knee amputations. Mr. Mooney stated "I learned early in the profession that to some there is no such word as 'fail.'" He states that it is his policy to describe the facts and the pitfalls of walking on two above-knee prostheses but if the patient still wants to continue he gives them all the help and encouragement possible.

WHAT ORTHOTIC DESIGNS DO YOU RECOMMEND FOR PARAPLEGIC PATIENTS?

The most commonly mentioned design of orthosis is the Scott-Craig KAFO. The respondents preferred this because of the simplicity of design, the lack of a pelvic band, ease of donning, and control of ankle

motion. Those readers that did not use the Scott-Craig system preferred plastic molded knee-ankle-foot orthoses or light-weight designs. No one recommended the use of a pelvic band.

All respondents were quick to point out the indications for orthoses for children and polio patients differed from that for adult traumatic paraplegic patients.

John Glancy, C.O., University of Indiana, Indianapolis feels that rehabilitation practitioners are making a mistake when they assume that present designs of orthoses begin to provide the mechanical aid paraplegics require. Mr. Glancy feels that patient's motivation towards walking is generally poor because they have to work with such inadequate orthotic systems. Mr. Glancy is presently working on a system that uses elastic material as a source of external power and sees this as a possible solution to the problem.

IS IT PRACTICAL TO EXPECT AMBULATION WITH LSHKAFO's (BILATERAL LONG LEG BRACES WITH NIGHT SPINAL ATTACHMENTS)?

A resounding "no!" was given by all to this question. One respondent stated that this type of orthosis is too cumbersome and hard to don and that if the patient is so severely involved that he needs this measure of stabilization he undoubtedly lacks adequate muscular and respiratory reserve to ambulate any