HIGHLIGHTS OF OTHER VA RESEARCH PROGRAMS

PROSTHETICS

Edited by

Eugene F. Murphy, Ph. D., Chief
William M. Bernstock, A.M., Assistant Chief

Research and Development Division
Prosthetic and Sensory Aids Service
Veterans Administration
252 Seventh Avenue
New York, N.Y. 10001

John O. Esslinger M.D.
Birmingham, Mich.

This project on animal experiments toward skeletal attachments of prostheses and semi-buried implants has terminated. Originated by a grant from the Orthopaedic Research and Education Foundation and in recent years supported by a small contract from the Veterans Administration, it has studied attachment to the bone, plugging of the medullary canal, improvement of capacity for end weight bearing, and passage of perforated materials through the skin as relatively independent problems as well as making a few attempts at a total prosthesis directly attached to the skeleton.

A summary report is presented elsewhere in this issue.

Gilmatic, Northridge, Calif.
Gilbert M. Motis

The contract for this project on powered prosthesis and associated equipment has terminated and the contractor is now in the process of preparing a final report which may appear in a future issue of the Bulletin.

This contractor has been issued a patent by the United States Government on an elbow-locking device. For more information see the section in this issue entitled "Recent Patents."

Committee on Prosthetics Research and Development
National Academy of Sciences-National Research Council
Washington, D.C.
Colin A. McLaurin, D. Sc.

For progress covering this report period, see "Report on Committee on Prosthetics Research and Development" appearing elsewhere in this issue.

Committee on Prosthetic-Orthotic Education
National Academy of Sciences-National Research Council
Washington, D.C.
Herbert E. Pedersen, M.D.

Completion of a number of extensive survey studies and the emergence of new and more urgent educational needs in the fields of prosthetics and orthotics have given rise to a period of transition in the activities of the Committee on Prosthetic-Orthotic Education.

The need for dissemination of prosthetic and orthotic information, however, remains constant, calling for continuous aggressive activity. One innovation that will more effectively disperse information to amputee clinic chiefs is the publication of a bi-monthly newsletter. The first issue was distributed December, 1969. Dr. Herbert E. Pedersen, Chairman, CPOE, outlined the purpose of *Newsletter . . . Amputee Clinics* as follows:

1. Express, freely and informally, opinions relative to the conduct of amputee clinics and the care and management of the amputee patient.
2. Make suggestions or recommendations on clinical practices of value to amputee clinic chiefs and their colleagues.
3. Submit questions on clinical matters in the hope that answers or solutions might be provided.
4. Respond to CPOE's requests for feedback on procedures and practices used in clinical situations.
5. Assist the overall effort in dissemination of information.
6. Keep informed on matters of interest in the field of prosthetics.

The idea of a newsletter stemmed from an unusually interested response that the Committee experienced in communicating with physicians who represent over 430 identified amputee clinics in the United States and Canada.

Plans are proceeding to survey graduates of prosthetics and orthotics degree programs, and a survey form is being developed. The information being sought relates to placement, job descriptions, salaries, adequacy of educational programs, etc. Critical shortages of prosthetists and orthotists were projected in the Manpower Survey report. Since

an adequate supply of these personnel is essential to the welfare of the amputee and the orthopedically disabled, the Committee is necessarily concerned, not only with the status of educational programs responsible for preparation of qualified practitioners, but with the utilization of the graduates.

Final reports have been completed and either published or submitted for publication on three extensive survey studies, viz., the Manpower Survey, the Orthotics Survey, and the Facility Records Study. All data for the longterm Prosthetics Clinical Study have been submitted and the coding process is underway.

Final review of the geriatric amputee manual was accomplished in December by chairmen of panel groups who attended a workshop on the subject June 9 and 10, 1969. Publication is planned for late spring, 1970.

Journal Publications:

1. Perry, J. Warren and Barbara R. Friz, Manpower Survey, Orthotics and Prosthetics, 23:4, December 1969.
2. Review of Visual Aids for Prosthetics and Orthotics, Orthotics and Prosthetics, 23:4, December 1969.
3. Davies, E., B. Friz and F. Clippinger, Children with Amputations, Inter-Clinic Information Bulletin, 9:2, December 1969.
4. Friz, B., The Amputee Clinic Roster, a Report, Inter-Clinic Information Bulletin, 9:15, July 1969.
5. Friz, B. and F. Clippinger, Facility Case Record Study, A Preliminary Report, Orthotics and Prosthetics, 23:8, March, 1969.

The following CPOE meetings were held during the reporting period:

1. Subcommittee on Special Educational Projects in Prosthetics and Orthotics, Miami Beach, October 14, 1969.
2. Ad Hoc Committee on Publications, Miami Beach, October 13, 1969.
3. Steering Committee, Miami Beach, December 15, 1969.
4. Panel Chairmen, Geriatric Amputee Workshop, Miami Beach, December 14–16, 1969.

New York University, New York
F.A. Appoldt and Renato Contini

Studies on the forces developed between the stump and socket were continued in the period July 1 to December 31, 1969. Designs had been prepared for a transducer which would measure forces along the surface at the interface between the stump and socket. Heretofore studies had been concerned primarily with forces normal to the inter-

face, and no other group had considered parallel or tangential pressures.

In this period of time a limited number of subjects were tested. Data were gathered and interpreted insofar as the number of subjects would permit. On the basis of these tests and in view of the approach of the termination of the contract, a paper was prepared and appears in this issue of the Bulletin under the title "Tangential Pressure Measurements in Above-Knee Suction Sockets."

A summary report of the activities of the project from the initiation of the contract, July 1, 1958, to its termination has been started. Material is being compiled based on a review of monthly and quarterly reports, interim reports, and final reports which have been issued during this period.

Northwestern University, Chicago, Ill.
Robert G. Thompson, M.D.

Below-Elbow Polysar[a] *Sockets*—Two below-elbow amputees were fitted with temporary prostheses, the first, a 17-year-old male with an acquired wrist-disarticulation amputation, was fitted in the conventional manner including 5XA hook. The wrist unit was attached by pulling the warm Polysar into the tie-off groove with nylon cord. After two months of use the wrist unit was still secure. The second, a 20-year-old male with an acquired mid-length amputation, was fitted with a self-contained Munster-type myoelectric prosthesis using the 3-state control system. The socket was modified to allow a wider range of elbow flexion and still maintain suspension.

Prior to the temporary prostheses, both patients had been fitted with immediate postsurgical myoelectric prostheses.

Above-Elbow Polysar Sockets—Four above-elbow Polysar sockets were fitted for the purpose of evaluating externally powered elbows. A complete prosthesis can be constructed in approximately 3 hours using this type of socket. A report on the fabrication technique will be submitted to *Artificial Limbs.*

Self-Suspended Upper-Extremity Prosthesis—Two types of self-suspended prostheses are being evaluated which offer advantages to both body-powered and externally powered myoelectrically controlled systems. A self-contained myoelectric prosthesis allows the amputee more freedom. For body-powered systems, only the control strap is needed.

A modified Munster-type socket is made for below-elbow cases. The anterior wall is lowered and modified slightly to allow a wider range of flexion and yet maintain good suspension. The only disadvantage on

[a] Registered trademark of the Polymer Corp., Ltd., Sarnia, Ontario, Canada.

long stumps is loss of a certain amount of supination and pronation.

For above-elbow stumps anterior and posterior flares over the deltoid muscle maintain good suspension without suction, though suction should be added as an auxiliary aid. An evaluation has not been made at this time to determine what length stumps can be fitted successfully with this technique. The shortest stump fitted at present is 7½ in.

Immediate Postsurgical Myoelectric Fittings—Two myoelectric units were fitted immediately after surgery during this report period. Five such procedures have now been performed.

One patient is being followed from surgery to definitive prosthesis with the same myoelectric system and same control method. Following the second cast change the patient was fitted with a Polysar temporary prosthesis. After the stump has stabilized, the components are merely transferred to the permanent prosthesis. The goals are to permit the patient to have an arm available at all times and to have him use the same control methods and terminal device from the day of surgery until the permanent prosthesis is fitted.

Self-Contained Hand—Following a visit with Professor Scott in New Brunswick, Ca., the cordwood technique was used in the construction of the electronic systems. The reduced size has allowed the design of a myoelectric hand which contains the batteries and electronics within the inner glove. Quiescent current was cut to 1.4 ma. to make possible the use of a 100 mah. (12v.) battery.

The self-contained hand is designed for the wrist-disarticulation amputee whose stump length forces the components to be within the hand if his prosthesis is to be self-contained.

CPRD Control Study—Three above-elbow amputees, making a total of 90 visits to the laboratory, participated in a study to evaluate control of electrically powered limbs. In the Northwestern study the subjects each wore a hybrid system: a VAPC electric elbow and a conventional body-powered hook. During the first half of the study the subjects used myoelectricity from the biceps and/or triceps for control of the elbow. During the second part a switch attached to the harness was used for control. The results of the study were presented at the Eighth Workshop Panel on Upper-Extremity Prosthetics (CPRD).

Powered Wrist Rotator—The above-elbow amputee who was to evaluate the rotator expired before the prosthesis could be fitted. Noise is still a problem but has been further reduced by isolating the rotator unit from the laminated forearm with plastisol which absorbs much of the noise-producing vibrations. A second design has been initiated of a unit which will allow through-center operation of a terminal device.

Powered Hand Splint—No new patients have been fitted with this unit during this report period. One unit was returned for repair of a broken wire at the control switch after use for 32 months. A suitable

motor, with better performance characteristics and relatively inexpensive, has been purchased and will be used in two units now being fabricated.

Electric Power Assist—After 42 months of use by a forequarter amputee, the unit was disassembled and examined. The ball screw was burnished but showed no galling or peening. All parts were in excellent condition. No further work is expected on this early mechanism to provide external power now that powered elbows and other components are becoming available and a less expensive powered hand splint, as noted above, has been developed.

Self-Pressuring Pneumatic Above-Knee Socket—A third patient has been fitted with this system, a flexible polyester liner covering the inflatable area instead of the silicone rubber previously used.

Polyester-Cushion Below-Knee Socket—Several sockets are being fabricated using various materials and lamination procedures to determine the best combination. One amputee has been successfully fitted with a flexible polyester-lined-vinyl foam cushion socket. A PTB prosthesis with a flexible polyester-vinyl foam insert is being fabricated.

Modified P.F.F.D. Prosthesis—An amputee with a right proximal femoral focal deficiency (P.F.F.D.) and Van Nes procedure performed on the foot was fitted with a modified P.F.F.D. prosthesis. A plastic upper socket incorporated some principles of the conventional quadrilateral above-knee socket. A pelvic belt and hip joint to stabilize the extremity improved the gait considerably. A pelvic belt and hip joint will help prevent derotation of the foot.

Alignment and Transferring Adaptors for Greissinger Foot—The adaptors have been completed. A report is being prepared on the fabrication and use of the adaptors for submission to "Orthotics and Prosthetics."

Fracture Bracing—Three fracture braces have been fitted successfully during this past reporting period. Split quadrilateral sockets were used on all three with single pivot, drop lock joints on one and Otto Bock polycentric joints on the other two.

Mauch Laboratories, Inc., Dayton, Ohio
Hans A. Mauch

A limited production run of the new shortened strapless Swing Control (Type S) System was completed in November 1969, and the unit is available commercially.

The production run of the Type S-N-S System for the Veterans Administration was completed in July 1969. Distribution both to veterans and through commercial channels was started shortly thereafter and continued without difficulties.

A great deal was learned during this production run and, as a result, a number of changes have been incorporated in both the Type S-N-S and Type S Systems.

A manual covering the Type S-N-S as well as the Type S System was completed. It also includes a chapter on training. Copies of this manual were shipped to VAPC at the beginning of July for distribution with the S-N-S Systems.

System #501, which was the first stance-control system to be converted to the S-N-S configuration and which had been worn in New York for almost a year, was returned to Mauch Laboratories inspection in August 1969. The system showed no significant symptoms of wear. It will be reassembled and returned to VA, New York, as soon as time permits.

Work on the Hydraulic Ankle Control Unit has been resumed fully and is proceeding with high priority. As reported in the last yearly Summary Report dated June 30, 1969, rather than going ahead with all the eight production prototype units, one of them will be completed first in order to test the design changes made during the past contract year.

As reported at that time, final details of the lever arrangement for the restoring springs still had to be worked out. In carrying out this work it was found that the new lever arrangement permitted other beneficial design changes. Most important was the increased space available for the restoring springs, thus reducing the stress and lengthening the fatigue life of the springs considerably. A number of other improvements resulting in reduced manufacturing costs were also introduced. All these changes can be applied to the existing castings. However, future castings will be ordered only after modification of the existing brass patterns, core dummy, and core box. Special manufacturing methods are being worked out to make it possible to achieve the tight tolerances necessary for proper hydraulic function in spite of the unavoidably liberal tolerances associated with the use of aluminum castings.

The production of the remaining parts for this first prototype unit has been resumed and is 90 percent complete. When the unit is ready for testing in the middle of January 1970, it will be worn by a local amputee to learn more about the wear pattern and functional reliability. While waiting for the test results, solutions will be developed for the remaining problems associated with the foot and shank design as well as the cosmetic treatment of the foot/shank transition.

Work on a Voluntarily Actuated Swing and Stance Control Unit was delayed by higher priority work. At the end of September 1969, theoretical studies were resumed of a valve arrangement for the control of swing as well as stance resistances. It seems possible, by the use of a single solenoid, to produce all the necessary gradual changes of these

resistances without resorting to servo-effects or fluidics, and without exceeding reasonable limits regarding power requirements.

University of California at Los Angeles
Biotechnology Laboratory
John Lyman, Ph. D.

Research efforts of the Biotechnology Laboratory have for some time focused on the development of a patient-prosthesis system which can assist and reduce the decision load upon the patient. These efforts led to the design, realization, and experimental evaluation of a concept for an adaptive aiding system. The concept utilizes machine learning and decision-making capabilities to form a man-machine control loop.

The system consisted of a human operator, a control system, a trainable autonomous control subsystem (ACS) which operated in parallel with the operator, and an arm-like output device. There were two main control loops: an external visual-motor loop (including the operator's vision and motor system), and an internal loop, involving only the autonomous control subsystem. The arm could respond to either the operator or the autonomous subsystem. Initially, during its "training," the autonomous control system (ACS) acted as a passive observer trying to "understand" how the patient controlled the arm and to develop an "awareness" of the environment of the operation. Upon the acquisition in computer memory of some "experience," the internal loop participated in the control of the arm. It observed the output device states and other pertinent feedback and generated instructions for a future state of the arm. In this next phase the operator acted mainly as an action initiator, letting the internal loop control the arm (very roughly analogous to an autopilot controlling an airplane). Finally, the function of the operator was reduced to that of action initiator, monitor, and inhibitor. Under such a configuration the decision load associated with controlling the device was substantially reduced, to the extent desired by the subject for the particular task, unlike the extremes of full attention or a preprogramed task.

The ACS was designed to be able to "forget" what it had learned, and to "learn" new tasks in place of forgotten ones. This feature provided the adaptive capability to change behavior in response to changes in the operator's control policies and in the environment. The theories underlying this approach originated from attempts to explain the mechanisms underlying natural visual-motor skills. The system transfers control from the external visual-motor loop including the operator, to the internal loop which closes through the ACS. The ACS provided the control system for the artificial arm with a mechanism analogous to the internal feedback and reflex loops associated with normal arm control.

A learning model based on maximum likelihood decision principles was the mathematical basis for the Autonomous Control Subsystem.

The ACS was programed on an IBM 1800 process control computer and was interfaced to a three-degree-of-freedom arm-like manipulative device through a small analog computer. The operator positioned the device by means of a joystick control. In addition, a prehension device at the end of the arm was available which could be operated by a foot pedal in this laboratory model.

Experiments with the completed system indicated that it fulfilled its intended role. Subjects were able to concentrate on fine manipulative tasks while the automaton took over the major part of the decision load. Overall performance was also improved; i.e., tasks were performed in shorter time and with fewer errors. The arm-like device used with the ACS was driven directly by electric motors using pulsed (digital) controls. Though the forces and speeds were not as great as desirable, the equipment was adequate to demonstrate the concept.

The electro-pneumatic-elbow actuator described in the previous issue, and now completed as a bench model with stock parts, has mechanical feedback which both inherently adjusts to maintain piston position under varying external loads (as if "locked") and promptly responds to control by digital logic activating a small stepping motor. The high forces and rapid motions under precise control should ultimately allow much higher performance than has been feasible with pneumatic cylinders or electric motors used in present externally powered prostheses. Eventually special parts suited to the weight and space available in a prosthesis must be designed.

Movement patterns were investigated by a goniometer at the elbow of a human arm, correlated with studies of electromyographic activities of biceps and triceps measured from surface electrodes. The immediate goal is greater understanding and a mathematical model of neurological control of visual-motor skills like moving the forearm rapidly but precisely to a specified position. The human operator appears to initiate the task, follow a ballistic path for much of the distance, but only apply fine control near the target. Ultimately, the study will be extended not only to greater ranges of arcs and loads but also to coordination of multiple dimensions, joints, and muscles.

University of California at San Francisco and Berkeley
Charles W. Radcliffe, Howard D. Eberhart, and James M. Morris, M.D.

The Veterans Administration's clinical application study of the UC-BL pneumatic swing-control unit continued to show good acceptance and very little mechanical difficulty with the unit; however, a number of problems have been experienced with the setup. The Hosmer Cor-

poration, meanwhile, introduced a commercial production-engineered version with identical functional characteristics, using some UC-BL parts and others similar to the Dupaco hydraulic unit. UC-BL considered their development successfully completed.

Work continued on improved prostheses for amputations at or near the knee. A workshop was planned under CPRD auspices for June 1970.

Engineering design and development were conducted on a SACH foot with single compromise axis for rotation of the forefoot. By suitable medial inclination from the vertical, the axis allows substantial transverse rotation about a vertical axis (comparable to the transverse rotation about the longitudinal axis of the shank long studied at UC-BL) plus smaller dorsiflexion-like rotation about a horizontal axis. The rubber sole of the foot provides elastic return at toe-off.

A new sidebar for the UC-BL dual-axis ankle brace was designed and built to provide greater durability and to increase the toe-lift capability.

Analysis of locomotion data continued, with emphasis on the effects of changes in speed on the various motion patterns.

Graduate students, some with training grants from other agencies but using facilities supported by VA sponsorship, participated in a number of design projects.

VA Hospital, Seattle, Wash.
Ernest M. Burgess, M.D., and Joseph H. Zettl

The first phase was completed of a basic research program involving instrumentation of the immediate postsurgical pylon prosthesis to record objectively pressures at the interface between the stump and the socket immediately following closed amputation and during the initial 14 postoperative days. Also, electrical activity of stump muscles and temperatures were recorded and studied. For details see "A Preliminary Report of Basic Studies from Prosthetics Research Study" BPR 10–10 Fall 1968) . A final report on these studies is being prepared and as soon as the necessary equipment can be secured again further studies are planned.

Clinical research primarily involved continued refinement of surgical muscle stabilization techniques for below-knee and above-knee levels. Included also were improvements to the immediate postsurgical pylon prosthesis, which resulted in a simplified technique of applying an exteriorized pylon-thigh section for the short above-knee stump. Furthermore, this system provides an articulating friction knee with manual lock for the hip-disarticulation postsurgical pylon prosthesis.

Thirty-three new cases were managed by use of the immediate postsurgical prosthetic fitting procedures. They included one Syme, 20 below-knee, one knee-disarticulation, and 11 above-knee amputations.

A more extensive and detailed manual regarding the latest techniques in immediate postsurgical prosthetic fitting is now available through the Superintendent of Documents under the title, "The Management of Lower-Extremity Amputations—Surgery, Immediate Postsurgical Prosthetics Fitting, Patient Care," TR 10–6, by Burgess, Romano, and Zettl.

STATISTICS

July 1, 1969—December 31, 1969

1. TOTAL NUMBER OF PRS PATIENTS:		33
Males	30	
Females	3	
	33	
2. AGE GROUP IN YEARS:		
Under 10		0
10–19		1
20–29		10
30–39		0
40–49		5
50–59		5
60–69		7
70–79		3
80–90		1
Over 90		1
		33
3. LEVEL OF AMPUTATION:		
Above Knee		[a] 11
Knee Disarticulation		1
Below Knee		[b] 20
Syme		1
4. NUMBER OF DAYS TO PRIMARY HEALING:		
0–30 days		24
31–40 days		5
41–50 days		2
51–60 days		0
Over 60 days		1
		32
Expired: 5th P.O. day		1
		33

[a] Five of the above-knee amputees were revisions of previous *non-PRS* above-knee amputations.

[b] Four of the below-knee amputees were revisions of previous *non-PRS* below-knee amputations.

VA Hospital, San Francisco, Calif.
Wesley L. Moore, M.D., and Albert D. Hall, M.D.

San Francisco Veterans Administration Hospital continued its clinical evaluation of immediate postoperative fitting in patients requiring lower-extremity amputation for ischemic disease. A total of 48 lower-extremity amputations have been performed with immediate fitting. Of these, 41 were at the below-knee level. The primary healing rate and rehabilitation rate of this group are in excess of 90 percent. Immediate fitting was attempted on two patients requiring knee disarticulation. One was a healing success; however, 1 month following operation the patient had a myocardial infarction and died. The second patient failed to heal, going on to an above-knee amputation. Five above-knee amputations with immediate fittings were performed. Generally this technique seems to be somewhat cumbersome owing to a less than optimum suspension device. The prosthetist, Mr. Leigh Wilson, is working on a new above-knee suspension device as well as modification of the immediate fitting technique at the above-knee level. One patient who had an early prototype of this technique proceeded to an ischial-weight-bearing plastic prosthesis in 10 days following amputation and was discharged on a temporary pylon. It is planned to discuss this technique in greater detail in a later publication.

The project is continuing evaluation of blood flow in the skin at the level proposed for amputation in order to attempt to predict level of satisfactory healing. These studies are being carried out using intradermal injections of Xenon 133 in order to measure nutritional flow rate. With flow measurements performed on the last 11 patients undergoing lower-extremity amputation, nine had primary healing and two had failures which required above-knee amputation. It is of interest to note that in those patients going on to a primary healing, their skin blood flow at the level of amputation ranged from 0.9 cc/100 gm. of tissue per minute to a high of 3.5 cc/100 gm. of tissue per minute, with a mean flow for the group of 2.0 cc/100 gm. of tissue per minute. Of the two patients who failed to heal at the level of initial amputation, the skin blood flow in one was 0.56 cc/100 gm. of tissue per minute and in the second 0.59, considerably less than in the group with healing success. It would seem from these early data that skin blood flow measurements utilizing Xenon 133 may become an effective means of evaluating the minimum blood flow needed for successful healing.

Harvard Medical School
Boston, Mass.
Richard Warren, M.D., and Ronald B. Kihn, M.D.

Dr. Leon Sheplan of Miami, Florida, assumed the responsibility for

the "A" forms and was able to bring up to date all but 62 of the 427 1A forms.

The annual meeting of the study group was held in San Francisco on October 6, 1969, with 19 of the 22 principal investigators or their representatives present. Much was accomplished at this meeting in terms of dissemination of information and answering of questions about updating the followup forms. Suggestions were made for a future prospective random study of the immediate postoperative fit technique as compared with conventional techniques.

At the end of the year it appeared that between 10 and 20 percent of the forms were delinquent. It is expected that this will be reduced to below 5 percent before the final analysis.

The Johns Hopkins University
Silver Spring, Md. 20910
Woodrow Seamone

For progress covering this report period, see "Development and Evaluation of Externally Powered Upper-Limb Prosthesis, Summary of Research Project Activities, July 1, 1969-December 31, 1969" appearing elsewhere in this issue.