Artificial Limbs, Vol 14. No 2, pp 1-18. Autumn 1970

The Prosthetics and Orthotics Program

A BENNETT WILSON. JR.[1]

Early in 1945, at the request of the Surgeon General of the Army, the National Research Council sponsored a conference of surgeons, engineers, physicists, and prosthetists to consider the feasibility of effecting improvements in artificial limbs (2). Conclusions that emerged from the conference were that virtually no organized research of significance had been conducted in the field of limb prosthetics, and that application of technology already in existence should produce improved devices.

ORGANIZATION OF RESEARCH PROGRAM

Subsequently, at the request of the surgeon general, the NRC established the Committee on Prosthetic Devices (later the Committee on Artificial Limbs) to organize a research program (2). (The members of the Committee on Prosthetic Devices were: Paul E. Klopsteg, Ph.D., Chairman; Harold R. Conn, M.D.; Roy D. McClure, M.D.; Robert R. McMath, D.Sc; Mieth Maeser; Paul B. Magnuson, M.D.; Edmond M. Wagner; and Philip D. Wilson, M.D. Consultants: Robert S. Allen and Charles F. Kettering.) Subcontracts were entered into with sixteen universities, industrial laboratories, and foundations:

Adel Precision Products Corp., Burbank, Calif.
Armour Research Foundation, Chicago, Ill.
C. C. Bradley and Sons, Inc., Syracuse, N.Y. (Catranis, Inc.)
Goodyear Tire and Rubber Co., Akron, Ohio
A. J. Hosmer Corp., Los Angeles, Calif.
International Business Machines Corp., Endicott, N.Y.
Mellon Institute of Industrial Research, Pittsburgh, Pa.
National Research and Manufacturing Co., San Diego, Calif.
Northrop Aircraft, Inc., Hawthorne, Calif.
Northwestern University, Evanston, Ill.
Research Institute Foundation, Detroit, Mich.
Sierra Engineering Co., Sierra Madre, Calif.
United States Plywood Corp., New Rochelle, N.Y.
University of California, Berkeley and San Francisco, and Los Angeles
Vard, Inc., Pasadena, Calif.

Funds were initially supplied by the Office of Scientific Research and Development. With the impending disestablishment of OSRD shortly after World War II, the Office of the Surgeon General of the Army for a short time assumed fiscal responsibility for the program. Then, for fiscal year 1947, the Army and the Veterans Administration shared the support. The Army, the Navy, and the Veterans Administration cooperated by establishing laboratories within their own organizations.

In some laboratories, development of components and application of new materials was begun, but it soon became clear to the committee that more knowledge of the patients' requirements was needed if significant progress was to be made. This in turn required a more detailed knowledge of the biomechanics of human extremities, and thus projects in this area were started. Also, anthropometric data were obtained with the idea of selecting rationally a series of standard sizes of components.

The activities of the various groups were initially coordinated by the Committee on Artificial Limbs, and considerable progress was made during the first two years. By the spring of 1947, the commit-

[1] Executive Director, Committee on Prosthetics Research and Development, National Academy of Sciences—National Research Council

tee felt that it had completed its task of establishing an organized program and suggested that contracts between the government and the research laboratories be made directly, and that the committee be reconstituted as an advisory group to the sponsoring agency. At that time, the majority of service-connected amputees had been discharged from the armed forces, and their medical care had become the responsibility of the Veterans Administration. Therefore, new contracts were effected between the VA and those laboratories in which promising developments were identifiable (1947: Catranis, Inc.; Northrop Aircraft, Inc.; University of California, Berkeley and San Francisco, and Los Angeles; 1948: New York University.) At the request of the VA, the NRC established the Advisory Committee on Artificial Limbs to continue the coordination and the correlation of the program. The Army, the Navy, and the VA continued to operate their own laboratories.

The general feeling at the beginning of the program was that the solution to the problem of providing better prostheses lay in developing new devices, and rapid advances were made by applying new materials and fabrication methods. It was apparent, however, that fit, suspension, and control were at least as important as components were in the successful use of an artificial limb, and perhaps even more so. Letters of inquiry were sent by the committee early in its history to all known limb manufacturers, and one of the first subcontracts was made with the Research Institute Foundation, a laboratory operated by the Orthopedic Appliance and Limb Manufacturers Association.

In the spring of 1946, arrangements were made with certain prosthetists to fit experimental suction-socket above-knee limbs, with cooperation from local surgeons and assistance from the committee staff. Studies to establish the principles of socket configuration, fitting, and alignment were initiated as supplements to the existing projects. Both fitting and harnessing of artificial arms were studied at other projects.

PUBLIC LAW 729

In 1948, the Eightieth Congress, recognizing the need for continuity in a program of this kind, passed Public Law 729, which authorized the expenditure of $1,000,000 annually for research in limb prosthetics and sensory aids (amended by P.L. 85-56, Eighty-fifth Congress, to remove the $1,000,000 limitation). The Veterans Administration was designated as the appropriate agency for the administration of the funds, and the Administrator of Veterans Affairs was authorized and encouraged to make the results of the proposed program widely available, so that all disabled persons might benefit.

SUCTION-SOCKET "SCHOOLS"

By October 1948, experience in a number of experimental settings indicated that the suction socket provided significant advantages over other methods of fitting and suspension for above-knee amputations, and that the technique should be released for general use. Because of the many factors which enter into the successful application of the suction socket, however, the publication of a teaching manual was not considered sufficient to ensure success. Therefore, with the assistance of the Orthopedic Appliance and Limb Manufacturers Association (now the American Orthotic and Prosthetic Association) and a distinguished group of surgeons, the NRC organized a series of regional workshops to teach surgeons and prosthetists the proper application of the suction socket. The University of California at Berkeley was assigned the initial responsibility for this program. The regional workshops were continued under VA auspices with cooperation of OALMA through 1952, by which time it was felt that the suction-socket technique had become established. During the entire program, approximately forty workshops were held.

PROSTHETICS EDUCATION PROGRAM

Through the findings of the UCLA case study and other endeavors, a considerable body of knowledge in upper-extremity

prosthetics had been accumulated by 1952. Hence, the development was undertaken of a medium through which knowledge about the greatly improved devices and techniques that were available could be disseminated throughout the nation. Since the new developments involved the use of plastic laminates for all upper-extremity amputation levels, the time required for thorough instruction in fabrication of prostheses ruled out the use of regional teaching sessions. The Veterans Administration therefore financed the organization and operation of the Prosthetics Education Program at the University of California at Los Angeles. Following a pilot school in 1952 for teams from the Chicago area, participation in the UCLA cources was ultimately extended to surgeons, physicians, occupational and physical therapists, and prosthetists from all over the United States. Prosthetists attended for six weeks; they were joined by the therapists for the last two weeks, and by the physicians and surgeons for the final week, during which these disciplines worked together as a clinic team.

The upper-extremity courses proved to be extremely popular and very successful. During the initial, intensive phase of the program (1953-55), 12 courses were conducted. As a result of these efforts, personnel constituting 75 specialized amputee clinics, and representing 30 states and the District of Columbia, were trained. Twenty-eight of these clinics were held at Veterans Administration installations, while 47 were at other public and private institutions. Concomitant with the upper-extremity education program, the VA funded a nationwide field study, conducted by New York University, to assess the value not only of specific devices but also of the treatment program taught at the schools. This study gathered much useful information and also served to reinforce the instructional material.

This combined education-research program not only served to introduce new improved concepts in the management of upper-extremity amputees, but also was a tremendous stimulus to the formation of amputee clinics and clinic teams throughout the nation. Today, more than 400 amputee clinics staffed with trained personnel are in operation in the United States. This treatment concept has also spread to other countries throughout the world.

The education program at UCLA proved to be so successful that the VA sponsored the establishment of a similar education program at New York University in 1956 to meet the needs of clinic personnel. Subsequently, the Vocational Rehabilitation Administration funded an additional prosthetics school at Northwestern University in 1959. As new devices and techniques emerged from the research program, additional courses were developed at all three schools, so that today every aspect of amputee management is covered.

PRESENT PROGRAM ORGANIZATION

By 1953, the Advisory Committee on Artificial Limbs recognized that child amputees had special problems, and began to work with the Michigan Crippled Children Commission to determine what might be done to solve some of these problems. The Children's Bureau supported the establishment of several research centers, and in 1955 the committee created the Subcommittee on Child Prosthetics Problems.

From the beginning, the committee had felt that much of the experience gained in research in limb prosthetics was applicable to the field of orthopedic bracing, but it recognized that problems in orthotics were even more complex. Therefore, work was initially concentrated on prosthetics. About 1960, the Committee on Prosthetics Research and Development took steps to assist in the development of improved orthotic devices and techniques. At the present time, an active program in orthotics, supplementary and complementary to the prosthetics program, is under way.

In 1966, at the request of the Veterans Administration, CPRD formed the Subcommittee on Sensory Aids to advise the

VA concerning its research program in that area. The subcommittee also serves the Social and Rehabilitation Service in the same capacity.

Prior to 1954, most of the research, development, and education activities in prosthetics and orthotics in the United States were supported by the Veterans Administration. In 1954, Congress enacted the Vocational Rehabilitation Act, which for the first time authorized the Office of Vocational Rehabilitation (later the Vocational Rehabilitation Administration and now the Social and Rehabilitation Service of the Department of Health, Education, and Welfare) to support research and education in rehabilitation. The prosthetics and orthotics research and education programs of the VRA were initiated gradually, beginning in 1955—a significant milestone being the assumption of the fiscal responsibility for the three prosthetics schools.

Today the Veterans Administration, the Social and Rehabilitation Service, the Maternal and Child Health Service, and, to a limited extent, the National Institutes of Health, all support extramural research in these fields. The VA, the Army, and the Navy also operate research and development laboratories as part of their respective organizational endeavors.

The VA, SRS, and MCHS support the Committee on Prosthetics Research and Development, which is responsible for correlating the various research projects and for advising the interested governmental agencies on matters related to prosthetics and orthotics. The VA and SRS also support the Committee on Prosthetic-Orthotic Education of the Division of Medical Sciences, National Academy of Sciences—National Research Council. CPOE's activities are directed toward the stimulation of educational programs for medical and paramedical personnel.

Laboratories supported by the VA, SRS, MCHS, the Army, and the Navy, and their areas of interest, are listed at the end of this article.

ACCOMPLISHMENTS

As a result of the research program, virtually every aspect of the management of amputees has been changed and improved. A similar program has now been initiated in orthotics, with the findings of the prosthetics program already strongly influencing research and clinical practice in orthotics.

FUNDAMENTAL STUDIES

The fundamental studies supported originally by the VA, supplemented later by support from SRS and NIH mainly at the University of California at Berkeley and at Los Angeles (6), have widely increased our knowledge about human locomotion, phantom pain, the functions of the upper extremities, the properties of voluntary muscle, and energy consumption. These studies not only have provided the basis for most of the new designs that have emerged from the research program but also have proven to be a stimulus to others to investigate the basic principles underlying the neuromuscular system. It is anticipated that fundamental studies will continue to contribute to the total research effort.

FITTING, ALIGNMENT, AND HARNESSING TECHNIQUES

Prior to the research program, it was the general surgical practice to amputate at certain specified levels, referred to as "sites of election." Most lower-extremity amputations resulted either in below-knee stumps that were six inches or shorter, or, in the case of above-knee amputations, in stumps no longer than two-thirds the length of the original thigh. Similar circumstances prevailed for upper-extremity amputations. The primary reason for these surgical practices was the lack of satisfactory techniques for fitting the longer stumps, especially those involving disarticulation, despite the fact that, in most cases, the longer the stump, the more functional it is. Improved tech-

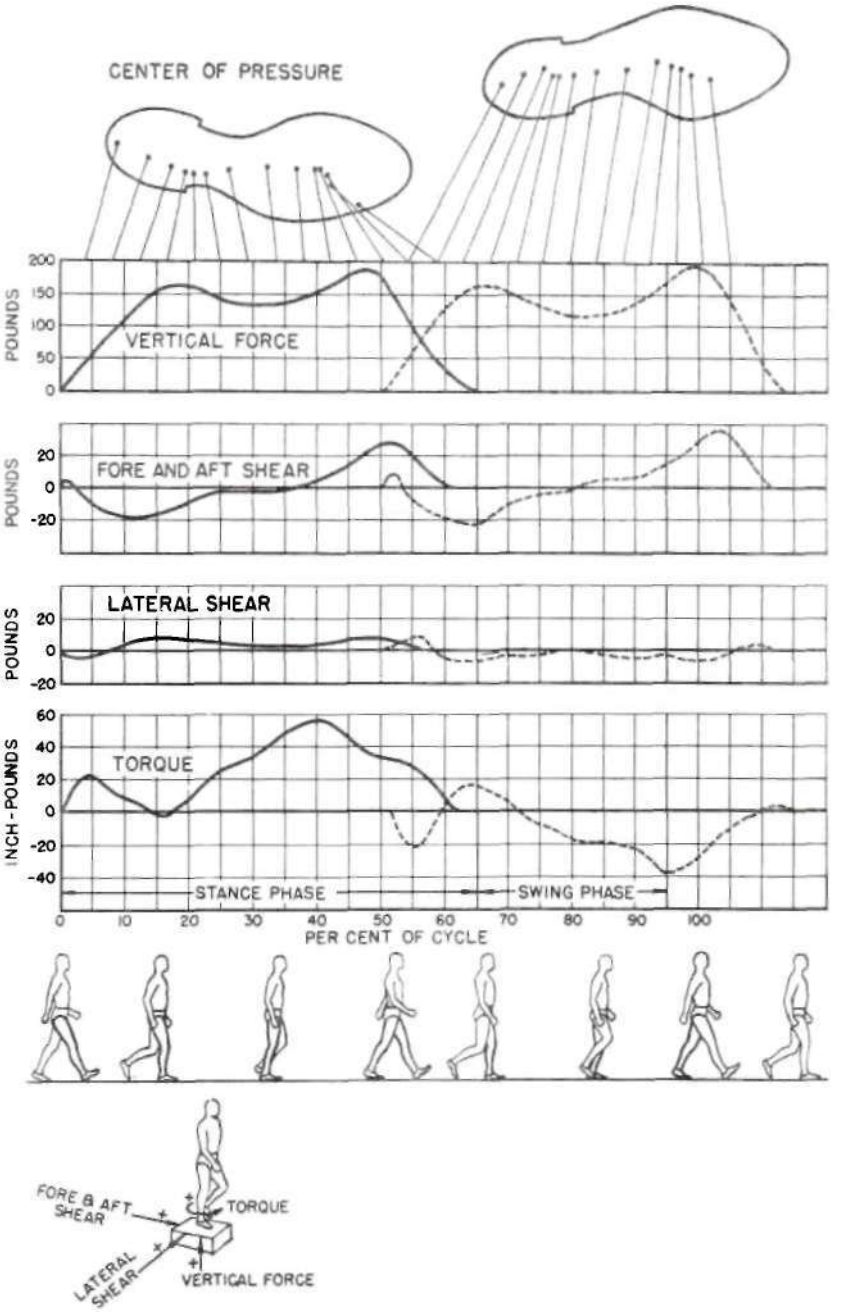

Fig. 1. Typical force-plate results for a normal subject during level walking, illustrative of the information obtained in fundamental studies. *(From Klopsteg, Wilson, et at., "Human Limbs and Their Substitutes," p. 453.)*

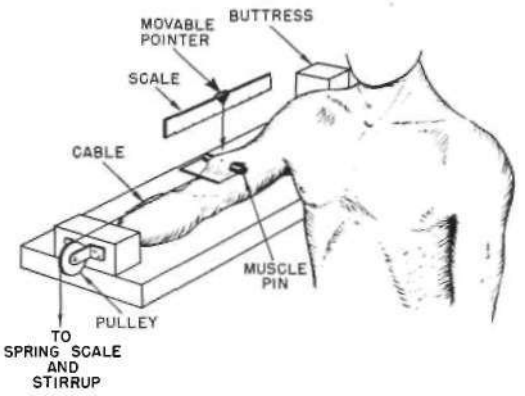

Fig. 2. Force-length measurement of a biceps tunnel. *(From "Human Limbs and Their Substitutes," p. 328.)*

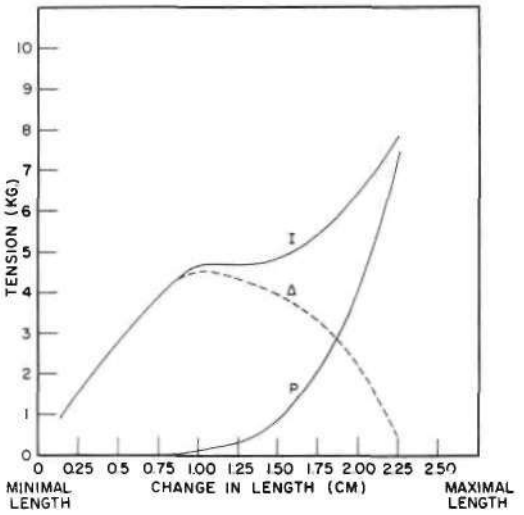

Fig. 3. Total-tension I, passive P, and developed-tension A curves for flexor muscles of the human forearm. *(From "Human Limbs and Their Substitutes," p. 306.)*

niques have now been developed for fitting stumps at all levels, and surgeons have been encouraged to save all length medically feasible.

New approaches to alignment based on biomechanics have been established for most amputation levels. New devices to aid in achieving optimum alignment have been devised and made available commercially. Descriptions of the new alignment principles, techniques, and instruments have been widely published, and their application is stressed in the Prosthetics Education Program.

As an outcome of biomechanical analyses, new lower-extremity socket designs have been developed for all levels of amputation. The new socket designs have revolutionized fitting practices not only in the United States but also throughout the world.

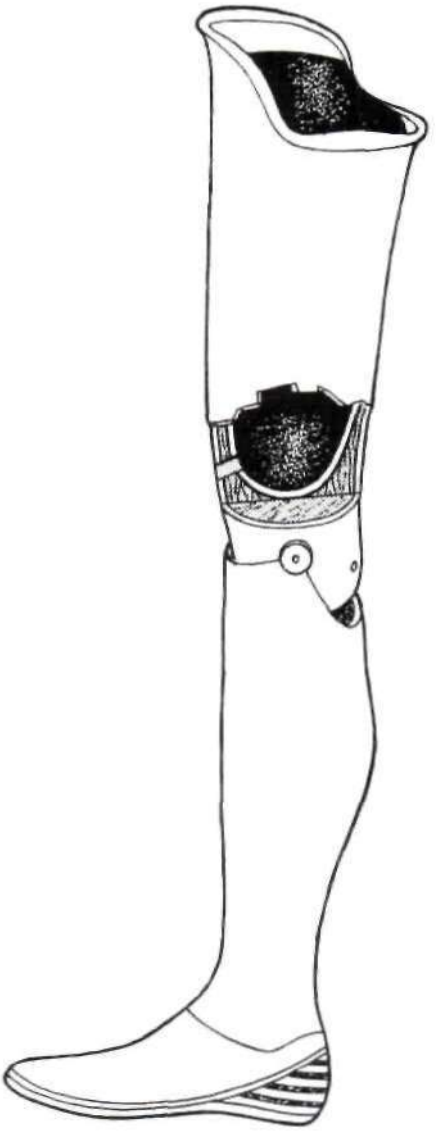

Fig. 4. A quadrilateral, total-contact socket developed for above-knee amputees under the program at University of California, Los Angeles.

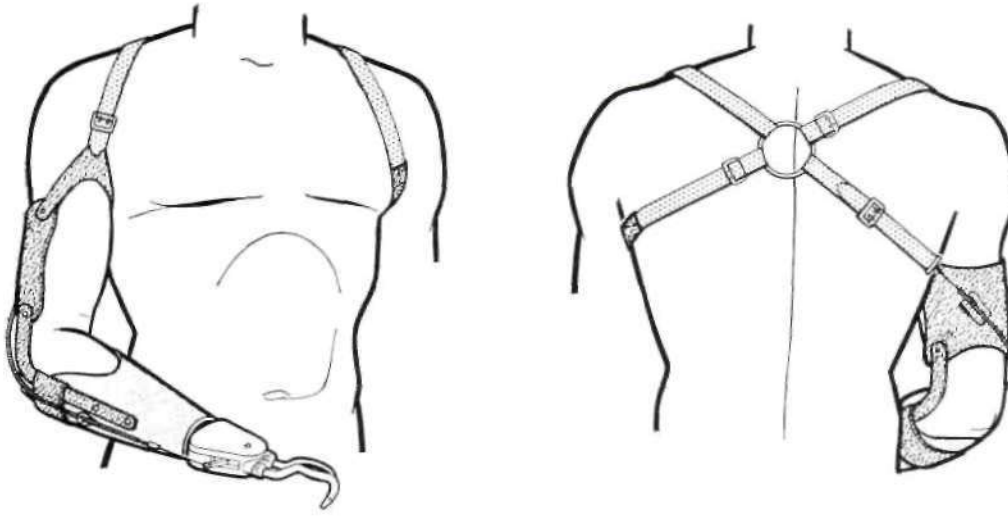

Fig. 5. The figure-eight, ring-type harness for below-elbow amputees developed at Northwestern University

Fig. 6. The prosthesis for a Syme's amputation developed by the Veterans Administration Prosthetics Center.

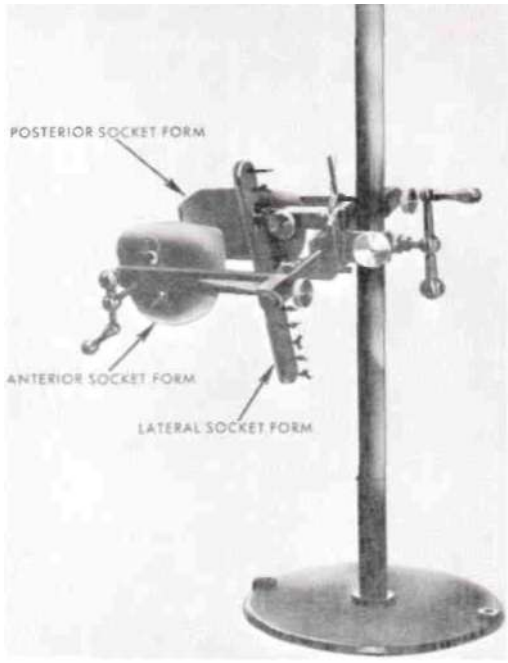

Fig 7 The casting jig for above-knee stumps developed by the Veterans Administration Prosthetics Center.

New harnessing techniques for upper-extremity prostheses, also based on biomechanical analyses, have been developed and made available for general use.

Not only have the new fitting, alignment, and harnessing techniques provided the patient with increased function and comfort, but they also are easier for the prosthetist to apply than the older methods.

Among the more significant techniques developed under the program are: the plastic Syme prosthesis, the patellar-tendon-bearing below-knee prosthesis and its variations, the quadrilateral total-contact above-knee socket (with or without suction suspension), the Canadian-type hip-disarticulation and hemipelvectomy prostheses, and various plastic-socket designs for upper-extremity amputations.

DEVICES

A large number of mechanical components have been developed to provide additional or improved functions. While

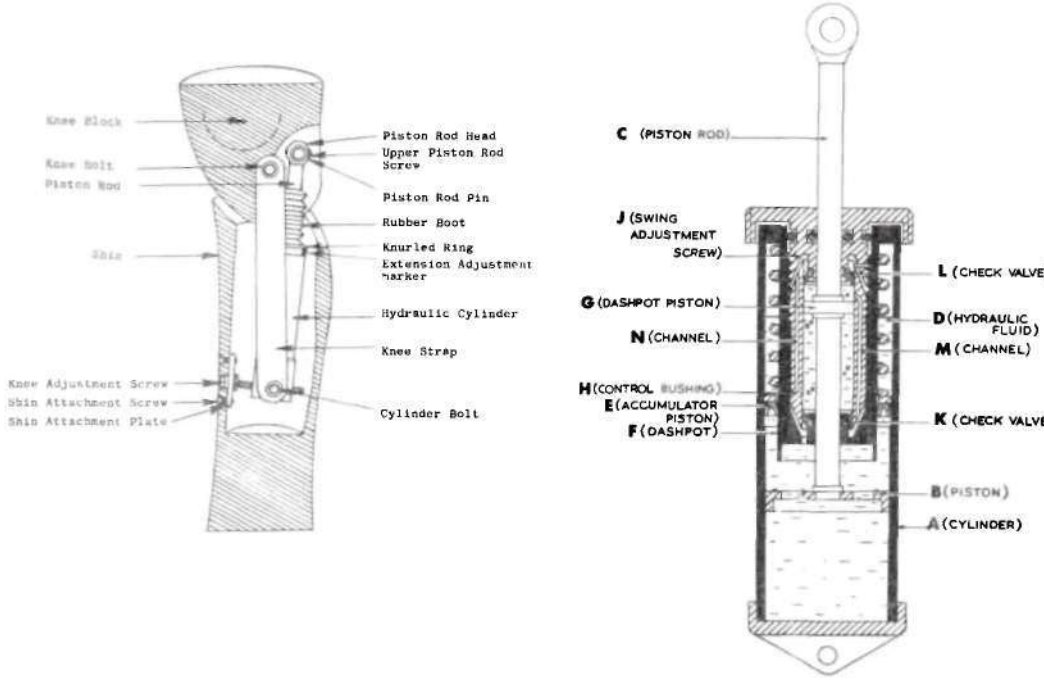

Fig 8. The Henschke-Mauch "Hydraulik" knee unit.

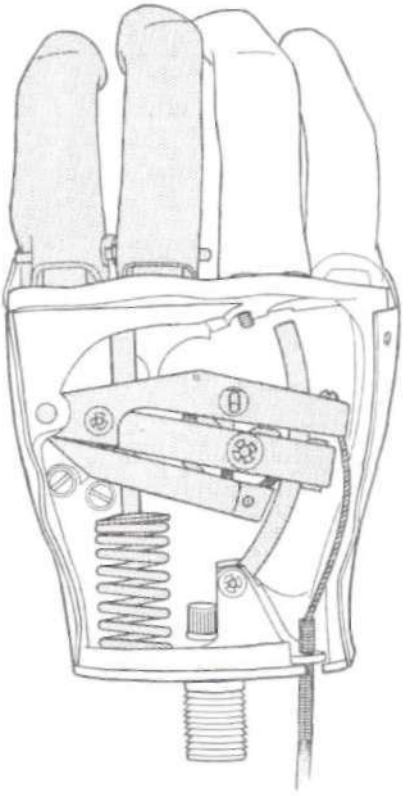

Fig. 9. The APRL-Sierra Model 44C artificial hand (without glove).

most of the designs have involved individual components, each was planned in relation to the total prosthesis. Hence, these new items can be used in various combinations to meet the needs of each individual patient. Noteworthy examples among the components developed through the research program are: the harness-operated elbow lock, the APRL voluntary-closing hand and hook, the Northrop 2-load hook, voluntary-opening hand sizes 1-5, the SACH foot, the Henschke-Mauch "Hydraulik" knee units, the Hosmer-DuPaCo "Hermes" unit, and the UCB pneumatic knee unit.

CLINIC-TEAM CONCEPT

As a planned objective of the VA research program, the clinic-team concept was introduced and encouraged as the preferred method of amputee management. The results achieved have fully established the validity of this concept in providing superior service to the amputee and in promoting more successful use of prostheses. Today, utilization of the amputee clinic team is standard practice in the VA, and many state agencies have followed the lead of the VA by insisting that their patients be treated by a clinic team. Moreover, as a result of the VA experience, the Children's Bureau has encouraged the establishment of more than twenty specialized clinics throughout the United States to serve child amputees.

SPECIFICATIONS AND CHECKOUT PROCEDURES

In the course of the research program, specifications for manufactured compo-

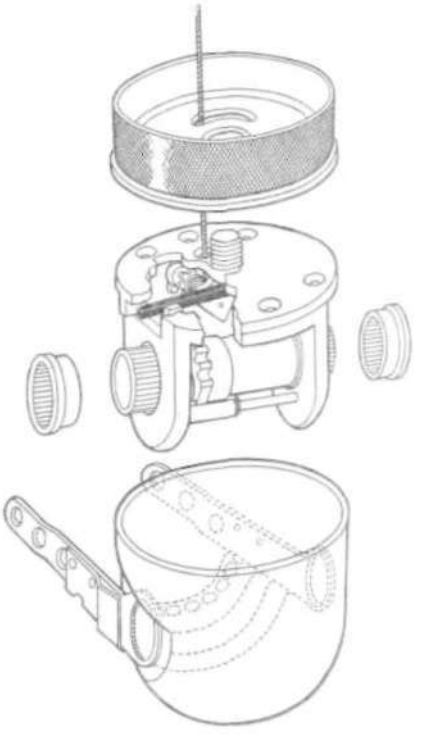

Fig. 10. The Northrop Model C elbow unit.

Fig. 11. The Multiplex above-knee pylon-type prosthesis. Various knee-control devices are interchangeable when this unit is used.

nents have been developed. The Veterans Administration Prosthetics Center in New York City regularly checks components against the specifications in order to insure

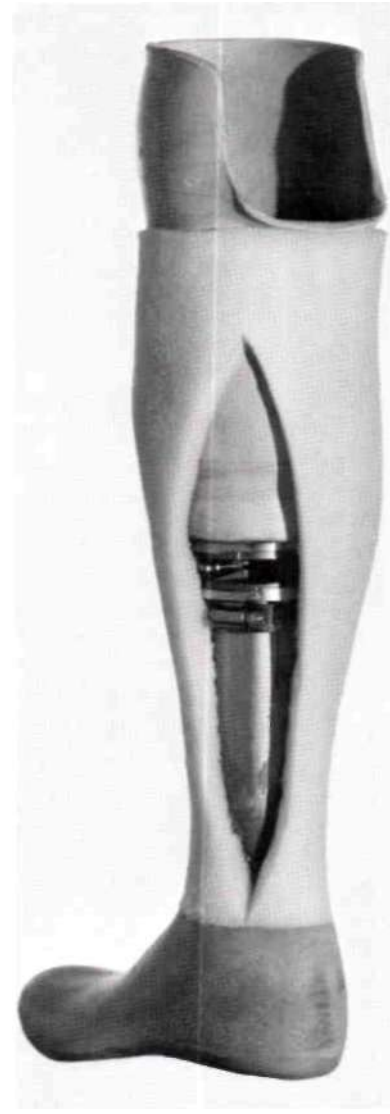

Fig. 12. A below-knee prosthesis fabricated of synthetic balata, with a cosmetic cover, developed by the Veterans Administration Prosthetics Center.

that quality is being maintained. This procedure not only insures the provision of safe, durable devices to veterans, but also helps to keep the quality of the devices used by others at a high level.

Procedures designed to assure that the total prosthesis is adequately constructed, fitted, and aligned have been developed for the use of clinic teams. These "check-out" procedures are modified as new de-

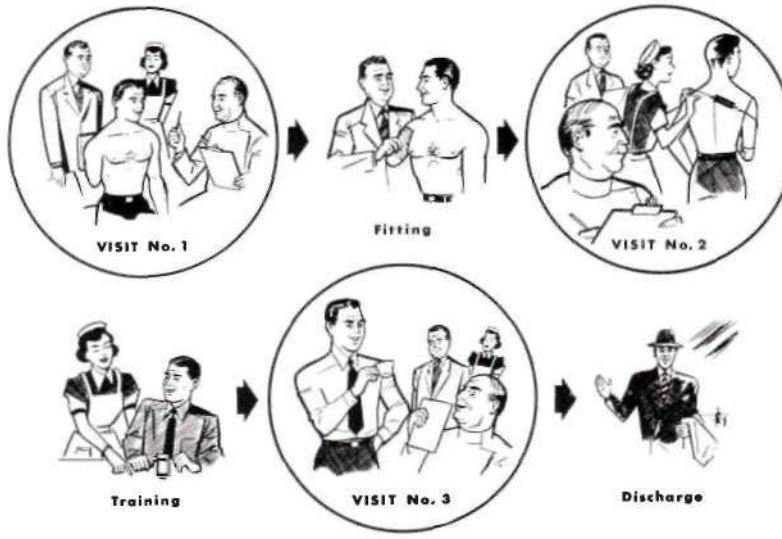

Fig. 13. Steps in the clinic-team procedure.

vices and techniques become available, and have been of great assistance in raising the quality of amputee management.

REDUCTION IN REHABILITATION TIME

As a result of the introduction of immediate postoperative fitting procedures *(1)* and early fitting procedures, a substantial reduction in the time between amputation and return to home and job has been effected. The use of a rigid dressing immediately after amputation also helps to reduce edema and pain.

At one time it was the rule in many hospitals, once the decision was made to remove part of a limb because of peripheral vascular disease, to amputate through the thigh because of the better blood supply in that region. Various studies have shown, however, that the knee joints in peripheral vascular cases can, with judicious care, be saved. As a result of these studies, rehabilitation time for many geriatric cases has been reduced even further. Indeed, the probability of rehabilitation itself can be markedly increased.

REDUCTION IN COSTS

The Veterans Administration has shown that, because of improved devices and procedures for fitting and aligning prostheses, artificial limbs were lasting twice as long in 1968 as they were in 1948. Although the average cost of artificial limbs increased 116.5% during that period, the increased "life" reduced the cost per year per eligible amputee veteran to about the same as it was in 1948 (5).

In addition to an effective reduction in the cost of the devices, repair, maintenance, and clinic visits were also reduced substantially. There has been no discernible increase in the number of prosthetists in the United States over the past 20 years, yet the number of patients being served has increased considerably during that period, owing to the increase in the general population and to an increase in the number of amputations because of peripheral vascular disease in a population surviving to greater ages.

DISSEMINATION OF INFORMATION

Prosthetics Education Program

The Prosthetics Education Programs originally established by the VA for training its clinic teams have proven to be extremely successful. The short-term courses have made possible the rapid and effective introduction to clinic teams of the new devices and techniques developed by the research program.

Fig. 14. A typical laboratory scene in prosthetics-orthotics education.

Since the Prosthetics Education Program was organized in 1953, over 15,000 students have attended the courses offered by the three participating schools—New York University, Northwestern University, and the University of California at Los Angeles.

Degree and Associate in Arts Programs

Historically, the provision of educational opportunities in a given discipline has tended to create a demand for further education. This phenomenon has also been true of prosthetists and orthotists, and has led to the establishment of longer-term courses at several institutions.

New York University undertook the most ambitious venture by establishing, in 1964, a four-year curriculum in prosthetics and orthotics leading to the Bachelor of Science degree. Two-year courses leading to the degree of Associate in Arts in prosthetics were begun at Chicago City Junior College (1965) and Cerritos College (1964).

These expanding educational endeavors, plus numerous additional offerings such as the certificate course at UCLA and the technicians course at Delgado College, have raised the standard of prosthetics—orthotics practice at all levels, and have exerted a steady upward pressure on the requirements for certification.

Publications

From the beginning of the research program, it has been the policy of the sponsoring agencies to make new information available as it is developed to those concerned with the welfare of the amputee. This program, which has involved both periodic and special reports *(3),* was financed initially by the Veterans Administration. SRS and the MCHS have since added their support.

Artificial Limbs, a semiannual journal, was created in 1953 to provide a vehicle for dissemination of timely information, primarily to clinic-team personnel. Publication and distribution of the journal is

the responsibility of the Committee on Prosthetics Research and Development, and it is mailed gratis to more than 4300 physicians, surgeons, therapists, prosthetists, and research personnel.

In 1961, the Subcommittee on Child Prosthetics Problems of the Committee on Prosthetics Research and Development inaugurated the publication of the *Inter-Clinic Information Bulletin,* a monthly bulletin which serves as a vehicle for the exchange of information between child amputee clinics. The material for each issue is provided on a regularly scheduled basis by the 29 clinics affiliated with the SCPP's cooperative research program. More than 2500 copies of the ICIB are distributed gratis each month to interested individuals and institutions in the United States and abroad.

In 1964, the Prosthetic and Sensory Aids Service of the VA began publication of its own semiannual journal, the *Bulletin of Prosthetics Research,* which is designed primarily to meet the needs of PSAS and covers a wide range of topics. It is available from the Superintendent of Documents of the U.S. Government Printing Office. Typically, some 2300 copies of each issue are sold, in addition to an official distribution of 3500 copies.

In 1954, *Human Limbs and Their Substitutes (4),* published by McGraw-Hill Book Company, was prepared principally from manuscripts developed by research personnel supported by the VA, and with the collaboration of the Office of the Surgeon General of the Army. This book was essentially a report on the results of the research program up to that time, and contains much basic information. Four thousand copies were printed, and the book had been out of print after 1960 until it was reprinted by the Hafner Publishing Company in 1968.

Reports of special conferences organized by the Committee on Prosthetics Research and Development have been prepared in order to provide information useful to others as well as to those attending the meeting (3).

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5. Talley, William H., Prosthetics research—a cost reduction program, an editorial, *Bull. Pros. Res.* 10-10, Fall 1968.
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MAJOR PROJECTS IN THE UNITED STATES COORDINATED BY THE COMMITTEE ON PROSTHETICS RESEARCH AND DEVELOPMENT

July 1, 1970

PROSTHETICS AND ORTHOTICS

Organization and Responsible Investigator	*Major Area(s) of Investigation*	*Sponsoring Agency*[1]
Army Medical Biomechanical Research Laboratory, Forest Glen, Md. Orlyn Oestereich Fred Leonard	Development of Prosthetic and Orthotic Materials and Devices	U.S. Army

[1] Abbreviations: SRS—Social and Rehabilitation Service, Dept. of Health, Education, and Welfare. VA—Veterans Administration Prosthetic and Sensory Aids Service. MCHS—Maternal and Child Health Service, Dept. of Health, Education, and Welfare.

Organization and Responsible Investigator	*Major Area(s) of Investigation*	*Sponsoring Agency*
Baylor University, Houston, Tex. Lewis Leavitt	Kinesiological and Quantitative Evaluation of Prosthetic Fit and Gait Analysis in Amputees and Vocational Implications	SRS
California, Univ. of, Los Angeles	Functional Long Leg Brace Research	SRS
Harlan Amstutz	Prosthetic and Orthotic Evaluation Procedures	SRS
John Lyman	Fundamental and Applied Research Related to the Design and Development of Upper-Extremity Externally Powered Prostheses	VA
	Fundamental Studies of Patient-Prostheses/Orthoses Externally Powered Control Interfaces	SRS
Arthur Moss Yoshio Setoguchi	Child Amputee Prosthetics Project	MCHS
California, Univ. of, San Francisco and Berkeley Charles Radcliffe Howard Eberhart James Morris	Design of Prosthetic and Orthotic Devices and Biomechanical Studies of Locomotion	VA
California, Univ. of, San Francisco	Electrical Stimulation of Afferent Fibers as a Means of Reducing Spasticity	SRS
Verne Inman	UC-BL Dual-Axis Ankle-Control System	SRS
H. J. Ralston	Dynamics of the Human Body During Locomotion	SRS
R. F. Steidel	An Engineering Analysis of the Human Spinal Column	SRS
Cambridge Hospital, Cambridge, Mass. Richard Warren	Immediate Postoperative Fitting	VA
Case Western Reserve University, Cleveland, Ohio Victor Frankel	Pathomechanics of Disorders of the Locomotor System	SRS
Donald Gann	Cybernetic Orthotic/Prosthetic Systems Development	SRS
Olgierd Lindan	Application of Medical Engineering to Automation of Selected Aspects of Patient Care and Rehabilitation	SRS
Duke University, Durham, N.C. Leonard Goldner	Pneumatic Prosthesis Research Project	SRS
Emory University, Atlanta, Ga. J. V. Basmajian	Radiographic Study of Hip Dysplasia in Cerebral Palsy	MCHS
Georgetown University, Washington, D.C. George Hyatt	Biophysical Evaluation of Healing Bone	SRS
Harvard Medical School, Boston, Mass. Richard Warren	Survey of Lower-Extremity Amputations	VA

Illinois, Univ. of, Chicago Jorge Galante	A Study of Spinal Orthotics in Idiopathic Scoliosis	SRS
Iowa, Univ. of, Iowa City Adrian Flatt	A Clinical Research Study of Congenital Hand Anomalies	MCHS
Iowa State Univ., Ames Allan Potter	Myoelectric Brace Development	SRS
Johns Hopkins University, Baltimore, Md. Gerhard Schmeisser Woodrow Seamone	Development and Evaluation of Externally Powered Upper-Limb Prosthesis	VA
Louisiana State Univ., Baton Rouge Eugene Tims	Development of Instrumentation for Insensitive Limbs	SRS
Massachusetts Institute of Technology, Cambridge Igor Paul	Performance Testing of Artificial Joints	SRS
Mauch Laboratories, Dayton, Ohio Hans Mauch	Research and Development in the Field of Artificial Limbs	VA
Miami, Univ. of, Coral Gables, Fla. Augusto Sarmiento	The Development of Functional Methods of Treatment of Tibial, Femoral, and Forearm Fractures	SRS
	Evaluation of Prosthetic-Orthotic Devices	SRS
	Study of the Development of Refined Fitting Procedures for Lower-Extremity Orthotics	VA
Michigan, Univ. of, Ann Arbor G. E. Sharples	Child Amputees: Disability Outcomes and Antecedents	MCHS
Moss Rehabilitation Hospital, Philadelphia, Pa. Richard Herman	Rehabilitation Biomedical Engineering: Orthotics Design	SRS
	Upper-Extremity Prosthetics	SRS
	Neuromotor Control Systems: A Study of Physiological and Theoretical Concepts Leading to Therapeutic Application	SRS
Navy Prosthetics Research Laboratory, Oakland, Calif. D. W. Rohren Charles Asbelle	Lower-Extremity Prosthetic and Orthotic Development	U.S. Navy
New York University, New York Sidney Fishman	Clinical Evaluation of Prosthetic and Orthotic Appliances	SRS
	Fit and Alignment Studies of Spinal Braces and Lower-Extremity Prostheses	SRS
	Child Prosthetic and Orthotic Studies	MCHS
Richard Lehneis	Bioengineering Design and Development of Lower-Extremity Orthotic Devices	SRS
Ralph Lusskin	The Control of Adventitious Bone Formation with Plastic Implants	SRS

Northwestern University, Chicago, Ill. Charles Fryer Robert Thompson	Demonstration of Prosthetic and Orthotic Devices and/or Techniques	SRS
	Prosthetic-Orthotic Research	VA
Rancho Los Amigos Hospital, Downey, Calif. Donald McNeal Vert Mooney Roy Snelson	Investigation of Electronic Systems for Neuromuscular Disabilities	SRS
	Orthotic and Prosthetic Evaluation Center	SRS
	Feasibility Study of the Use of Transparent Sockets and Modular Prostheses in Clinical Practice	SRS
Texas Institute for Rehabilitation and Research, Houston Thorkild Engen	Research Developments of Lower-Extremity Orthotic Systems as They Relate to Patients with Various Functional Deficits	SRS
U.S. Public Health Service Hospital, Carville, La. Paul Brand	Study of the Prevention of Deformity in Insensitive Limbs	SRS
Veterans Administration Prosthetics Center, New York, N.Y. Anthony Staros	Research, Development, and Testing of Prosthetic and Orthotic Devices and Techniques	VA
VA Hospital, San Francisco, Calif. Wesley Moore Albert Hall	Study of Below-Knee Amputation for Vascular Insufficiency	VA
VA Hospital, Seattle, Wash. Ernest Burgess Joseph Zettl	Immediate Postoperative Prosthesis Fitting and Ambulation	VA
Virginia, Univ. of, Charlottesville Warren Stamp David Lewis	Fitting of Lower-Extremity Prosthetics	SRS
	SENSORY AIDS	
Albert Einstein College of Medicine, New York, N.Y. Herbert G. Vaughan Herbert Schimmel	Electrocortical Prosthesis Feasibility Study	SRS
Association for Computing Machinery, New York, N.Y. T. D. Sterling	Investigation of Optimum Employment Procedures in Computing (Blind)	SRS
Bionic Instruments, Bala Cynwyd, Pa. Thomas A. Benham J. Malvern Benjamin	Development of Obstacle Detectors for the Blind	VA

Department of Children and Family Services, Springfield, Ill. Thomas J. Murphy	Postural Determinants of the Blind	SRS
Hadley School for the Blind, Winnetka, Ill. Donald W. Hathaway	Development of a Braille Medical Dictionary	SRS
	Development of Correspondence Courses for Personal Reading Aids for the Blind	VA
Haskins Laboratory, New Haven, Conn. Franklin S. Cooper Jane Gaitenby	Research on Audible Outputs of Reading Machines for the Blind	VA
Maryland, Univ. of, College Park Joseph W. Wiedel Paul A. Groves	Tactual Mapping: Design, Production, Reading, and Interpretation	SRS
G. Donald Causey Earleen Elkins	Development of Improved Techniques for the Analysis of Hearing Aid Performance	VA
Massachusetts Institute of Technology, Cambridge Robert W. Mann	Sensory Aids Development and Evaluation	SRS
Mauch Laboratories, Dayton, Ohio Hans A. Mauch Glendon C. Smith	Development of Personal Reading Machines for the Blind	VA
Michigan, Univ. of, Ann Arbor Geraldine T. Scholl	Vocational Adjustment Follow-up Study of Groups of Visually Handicapped	SRS
National Accreditation Council for Agencies Serving the Blind and Visually Handicapped, New York, N.Y. Alexander F. Handel	Strengthening Services for the Visually Handicapped through the Application of Standards	SRS
National Industries for the Blind, New York, N.Y. Robert C Goodpasture	Development of a Sheltered Workshop Laboratory to Serve Agencies for the Blind	SRS
New York Medical College, New York Stanley Taub	Development of a Removable Prosthetic Larynx	SRS
North Carolina Museum of Arts, Raleigh, N.C. Charles W. Stanford, Jr.	Development and Operation of Mary Duke Biddle Gallery for the Blind	SRS
Northwestern University, Evanston, Ill. Raymond Carhart Wayne O. Olsen	Development of Test Procedures for Evaluation of Biaural Hearing Aids	VA

Puerto Rico, Univ. of, Rio Piedras Carlos Albizu-Miranda	Psychological-Social Factors in the Vocational Rehabilitation of the Blind (Census)	SRS
San Francisco Bay Area Speech and Hearing Society, San Francisco, Calif. George Hospiel	Measurement of Acoustic Parameters for Speech Compression Transportation	SRS
VA Hospital, Hines, Ill. John D. Malamazian Harvey L. Lauer	Clinical Application of Reading and Mobility Aids for the Blind	VA

PROJECTS IN CANADA WHICH COOPERATE CLOSELY WITH THE OVERALL PROGRAM

Organization and Responsible Investigator	*Major Area(s) of Investigation*
Prosthetic Research and Training Program, Ontario Crippled Children's Centre, Toronto Colin A. McLaurin	Development of a Wide Variety of Upper-Extremity and Lower-Extremity Body-Powered and Externally Powered Prosthetic and Orthotic Devices for Children
Rehabilitation Institute of Montreal, Montreal Maurice Mongeau	Development of Externally Powered Upper-Extremity Prosthetic Devices, with Special Reference to Children
Prosthetics/Orthotics Research and Development Unit, Manitoba Rehabilitation Hospital, Winnipeg James Foort	Development of a Variety of Prosthetic Devices with Special Reference to Lower-Extremity Requirements
The University of New Brunswick Bio-Engineering Institute, Fredericton R. N. Scott	Orthotics and Prosthetics Systems Research with Special Emphasis on the Employment of Electromyographic Signals as Controls