Autumn 1970

Artificial Limbs

A Review of Current Developments

COMMITTEE ON PROSTHETICS
RESEARCH AND DEVELOPMENT

COMMITTEE ON PROSTHETIC-
ORTHOTIC EDUCATION

National Academy of Sciences
National Research Council

Artificial Limbs

VOLUME 14 AUTUMN 1970 NUMBER 2

CONTENTS

COMMITTEE ON PROSTHETICS RESEARCH AND DEVELOPMENT
DIVISION OF ENGINEERING
and
COMMITTEE ON PROSTHETIC-ORTHOTIC EDUCATION
DIVISION OF MEDICAL SCIENCES
of the
NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY OF SCIENCES

2101 Constitution Avenue Washington, D. C. 20418

Artificial Limbs **is a publication of the Committee on Prosthetics Research and Development and the Committee on Prosthetic-Orthotic Education, National Research Council, issued in the spring and autumn of each year in partial fulfillment of Veterans Administration Contract V1005M-1914, Social and Rehabilitation Service Contract SRS-71-7, and Maternal and Child Health Service Contract SRS-70-52.** **Library of Congress Catalog Card No. *55-77*\ 0.**

Projects, Programs, and Perspectives

EUGENE F. MURPHY, PH.D.[1]

For a quarter of a century, the National Research Council has played a major role in the coordination of research in limb prosthetics in the United States. Originally conceived as a short-term effort likely to terminate at the end of the fiscal year, the program is now mature—solidly based on major accomplishments, yet fully aware of many problems as yet unsolved in artificial limbs, bracing, aids to the blind, hearing aids, and other areas of bioengineering related to rehabilitation.

The NCR's Committee on Prosthetics Research and Development and Committee on Prosthetic-Orthotic Education, which are the descendants of variously named groups with slowly rotating memberships, carry the responsibilities for stimulating and coordinating research, advising sponsors, and speeding the diffusion of knowledge among the many disciplines concerned with rehabilitating patients.

The work of the committees has expanded over the years, not only in sponsorship but in projects, programs, and priorities. In this anniversary year, a review of the history and present status of the program may provide some perspective for a wise, vigorous, and zealous attack on the many remaining problems.

Late in World War II, the Surgeon General of the Army, faced with conflicting claims for the efficacy of various artificial limbs and with criticisms of those supplied in military amputation centers, asked the National Research Council to arrange a meeting to recommend the "best" limbs from which the army could select for standardization. The three-day meeting produced numerous claims and little evidence, but a general recognition of the fact that the "best" were not good enough and that intensive research was needed. The army therefore arranged to have the wartime Office of Scientific Research and Development (which was already supporting the Committee on Sensory Devices investigating mobility and reading aids for the blind) sponsor a contract with the National Academy of Sciences to "conduct with the utmost dispatch... studies and experimental investigations in connection with prosthetic devices." The academy, through its National Research Council, set up the Committee on Prosthetic Devices, composed

[1] Chief, Research and Development Division, Prosthetic and Sensory Aids Service, Veterans Administration, 252 Seventh Ave., New York, N.Y. 10001.

of distinguished surgeons and engineers, and proceeded to develop nonprofit subcontracts with a variety of organizations. Some of these in turn made second-tier subcontracts with smaller specialized companies. In addition to a subcontract on hip-disarticulation prostheses with the tiny laboratory then operated by the Artificial Limb Manufacturers Association, there were subcontracts with some of the best-known industries. The latter were busy with war work, but they were willing, for humanitarian and patriotic reasons, in addition to the personal enthusiasms of key officials, to undertake nonprofit work toward inventions which generally were expected to be made available royalty-free to civilians as well as veterans. Northrop Aircraft, Goodyear, International Business Machines, and United States Plywood were among the firms expecting that modern technology could quickly improve the simple and seemingly crude artificial arms and legs and resolve the major complaints of amputees, surgeons, and others. Indeed, some dramatic improvements were quickly made in laboratories, though sometimes years were to intervene before they were widely used, and many ideas never reached the stage of clinical usefulness. Concurrently, major universities—the University of California at Berkeley and at Los Angeles, Northwestern University, and New York University—undertook a variety of tasks.

In August 1945, the surgeons on the committee developed a "bill of complaints" and presented it to the engineering members. It may be instructive to trace the frontal attacks on one of the items prominent on the surgeons' list—an artificial knee which would not buckle. Some discussion of a number of devices followed, including knee friction for control of swing phase, but the primary concern was for a lock which would prevent buckling in stance phase. The demand for knee locks was further underscored by a study undertaken later by New York University on the opinions of surgeons, limb fitters, and amputees (both veterans and nonveterans). In that survey, only the amputee nonveterans gave any significant emphasis to the need for improved fitting and alignment, but even they felt that a locking mechanism for the knee was the more important need. Crash programs on knee locks were launched at a number of laboratories, with the emphasis understandably on mechanisms rather than on man-machine combinations.

These various efforts to develop knee locks led to a great variety of test models of mechanical locks, band brakes, disk brakes, and hydraulic devices with many types of control systems from numerous laboratories, which were tested first on local amputees and later independently at New York University. For a number of years after, there followed complaints about breakage, clicks, hydraulic swishing and squealing noises, hydraulic leaks, and deficiencies of control systems during patients' activities other than level walking. In the mid-1950s, much of the emphasis shifted to swing-phase control by variable mechanical friction or by hydraulic or pneumatic devices, which simplified some of the design problems and led to the commercial availability and widespread use of several devices which permitted amputees to walk easily and gracefully at a wider range of speeds. Finally, the Mauch S-N-S hydraulic stance-and-swing-phase unit, the principal survivor of a multitude of stance-phase controls, has reached acceptance for routine avail-

ability in the past year or so, several hundred being in use, with the demand growing rapidly.

This long delay in the availability of a versatile and reliable stance-phase control, and its relatively minor use even today, is more acceptable if one recognizes the substantial improvements in alignment and freedom from buckling of conventional above-knee artificial legs with simple, single-axis knee joints. These were developed largely as the result of studies of improved fitting of the socket to the stump and of the alignment between the socket, knee, shank, and foot. Such studies, and the subsequent codification of biomechanical principles, arose largely from the attempt to reintroduce a venerable invention, the suction socket.

The concept of holding an artificial limb on the body by atmospheric pressure was originally patented by Parmelee in 1863. Relatively simple changes from older conventional alignment greatly increased knee stability during stance, yet allowed controlled bending of the knee late in stance to prepare for swing phase. Correspondingly, proper mediolateral alignment not only allowed stability on the suction-socket prosthesis without sidesway or limping, but also, when applied to conventional prostheses (which continued to be used by large numbers of amputees, particularly the elderly) greatly reduced the stresses in the hip joints and pelvic bands.

Thus a relatively small program (conducted primarily by engineers) on biomechanics and fitting, working in parallel with the development of a growing number of engineering designs of knee locks, achieved substantial progress toward safety against knee buckling long before a truly satisfactory hydraulic stance-control device became available.

The foregoing is but one example of successful flanking attacks on complex problems in prosthetics. CPRD and CPOE have helped to create the climate for other similar successes in their roles of coordinators in the research and education activities of the program.

In fulfillment of that role, the Committee on Prosthetics Research and Development, with the help of its subcommittees and their panels, serves very effectively as an architect for an entire coordinated program and as advisor to the several sponsors. Organization of frequent workshops and conferences, review of proposals, and conduct of occasional site visits are typical duties. Occasionally, formal recommendations are made through official channels, but participation of liaison representatives and circulation of minutes and reports on a routine basis usually are sufficient to keep sponsors informed. Frequently, the climate of substantially unanimous opinion developing out of informal discussions, staff work, and conferences on workshops leads to actions by sponsors and laboratories without formal recommendations to sponsors, instructions from scientific officers to contractors, or detailed amendments of the broad subject-work clause typically used in contracts. The dedicated, distinguished people who have worked in this program over the past quarter century have been anxious to aid the patient as rapidly as possible without awaiting formal orders. No one wants to work in a fruitless field or to duplicate unwittingly work done elsewhere (though systematic replication or checking may prove necessary). Typically, delicate

balances have been achieved between direction and independence, between organization and spontaneity, and between caution and speed.

The Committee on Prosthetic-Orthotic Education has worked for some years to introduce prosthetics information (not separate courses) into medical and paramedical education, to stimulate interest at local medical societies, to interest the professional societies in paramedical disciplines, and to provide abstracts and bibliographies. While considerable parallel work has been done in orthotics, obviously much more remains. There are nearly untapped opportunities for both committees to make comparable efforts on research and education on orthotic aids like wheelchairs, crutches, canes, elastic hose, orthopedic shoes, and other aids to the disabled.

Clearly, a quarter of a century of work has not resolved all the problems. However, a foundation has been laid, a technique has been proven effective in carrying effective research results through to clinical practice, and an efficient, dynamic, and durable organization under the National Research Council has been created. Much more can be done by this mature organization in the whole field of bioengineering.

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-

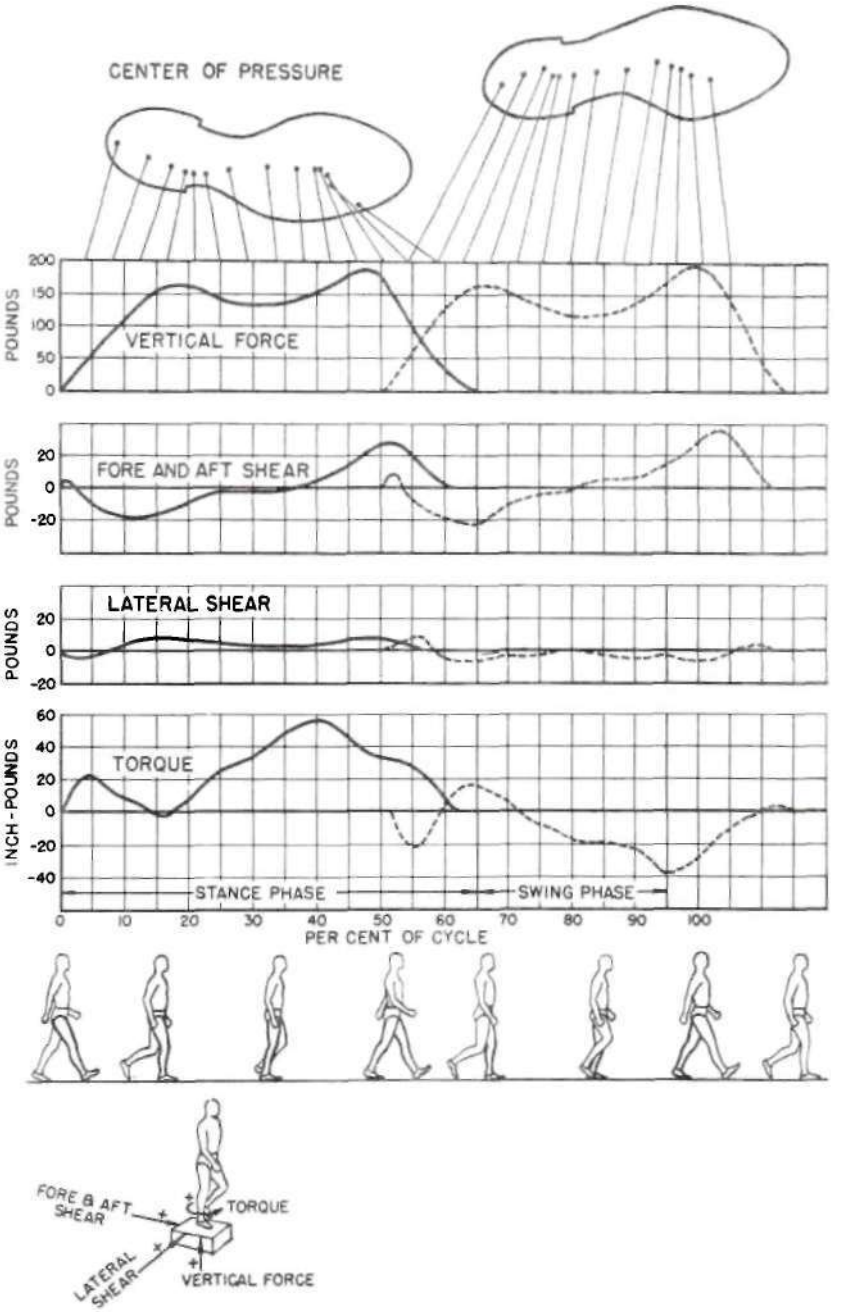


Fig. 1. Typical force-plate results for a normal subject during level walking, illustrative of the information obtained in fundamental studies. *(From Klopsteg, Wilson, et at., "Human Limbs and Their Substitutes," p. 453.)*

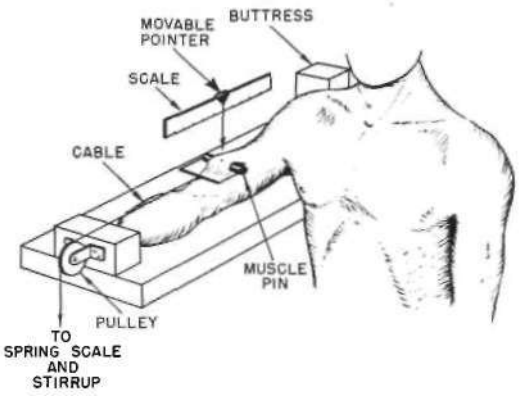


Fig. 2. Force-length measurement of a biceps tunnel. *(From "Human Limbs and Their Substitutes," p. 328.)*

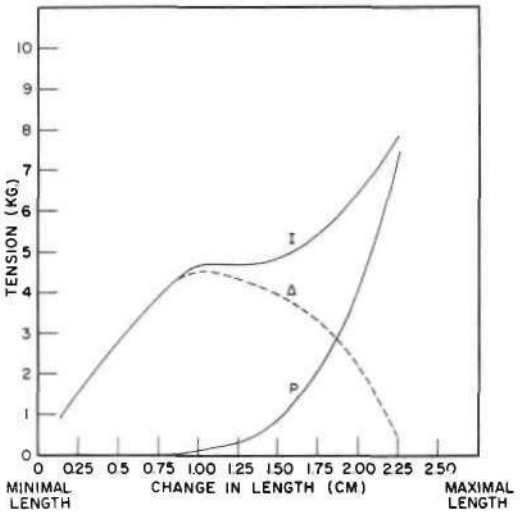


Fig. 3. Total-tension I, passive P, and developed-tension A curves for flexor muscles of the human forearm. *(From "Human Limbs and Their Substitutes," p. 306.)*

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.

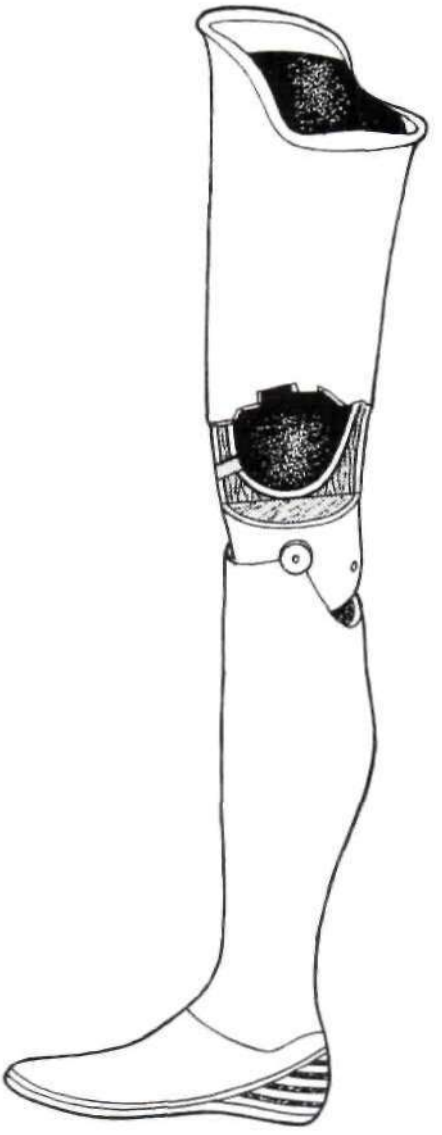


Fig. 4. A quadrilateral, total-contact socket developed for above-knee amputees under the program at University of California, Los Angeles.

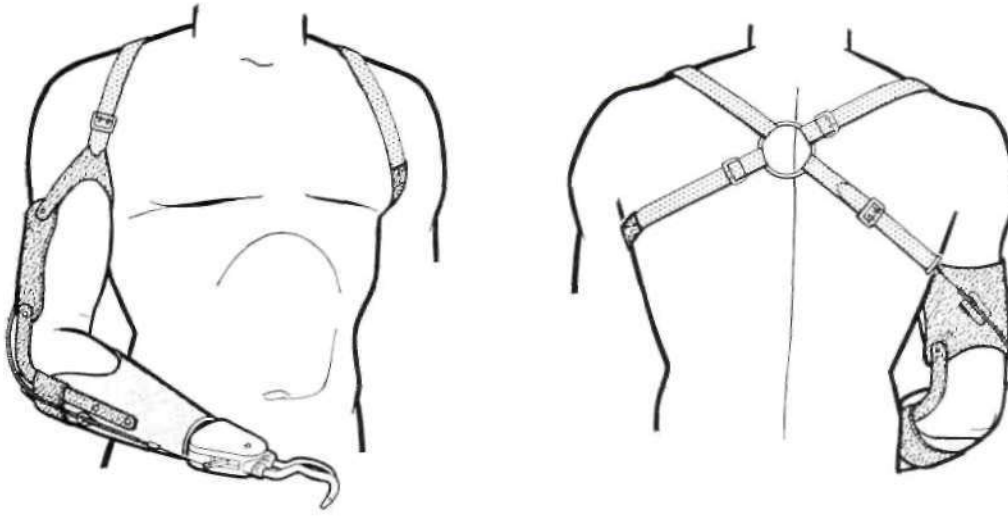


Fig. 5. The figure-eight, ring-type harness for below-elbow amputees developed at Northwestern University

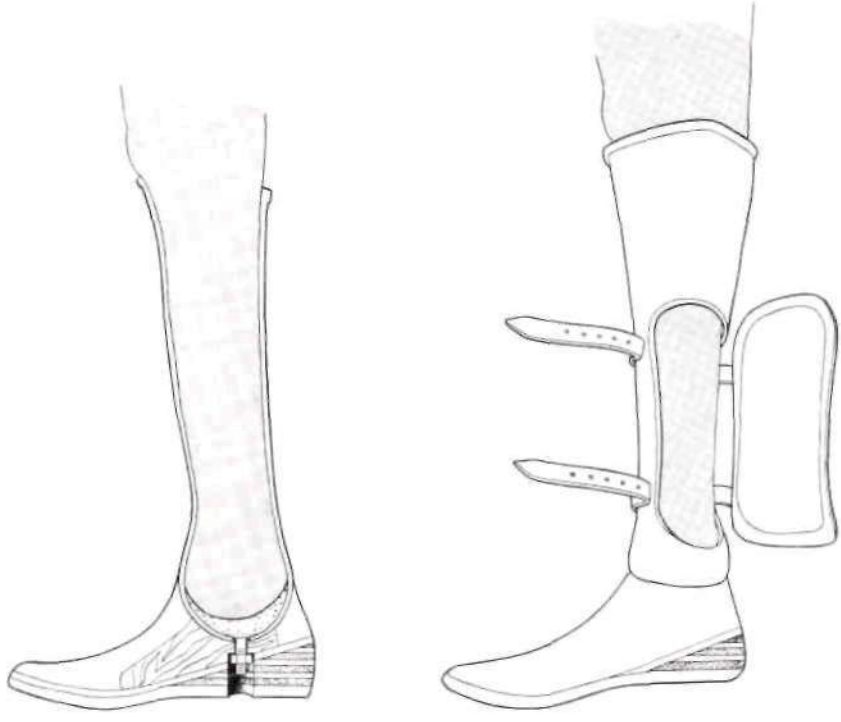


Fig. 6. The prosthesis for a Syme's amputation developed by the Veterans Administration Prosthetics Center.

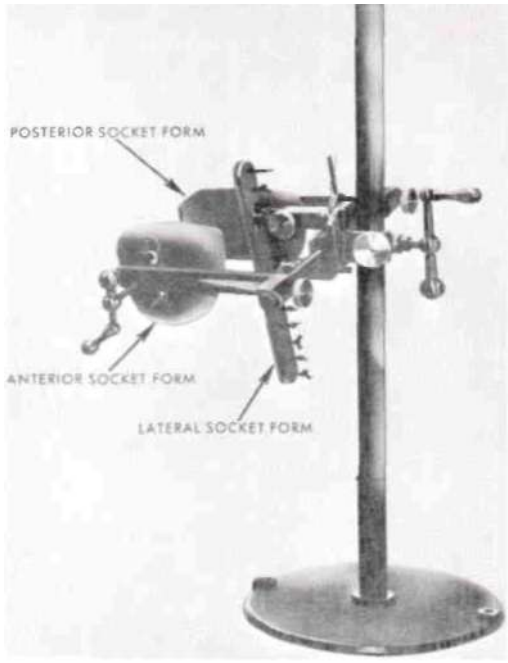


Fig 7 The casting jig for above-knee stumps developed by the Veterans Administration Prosthetics Center.

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

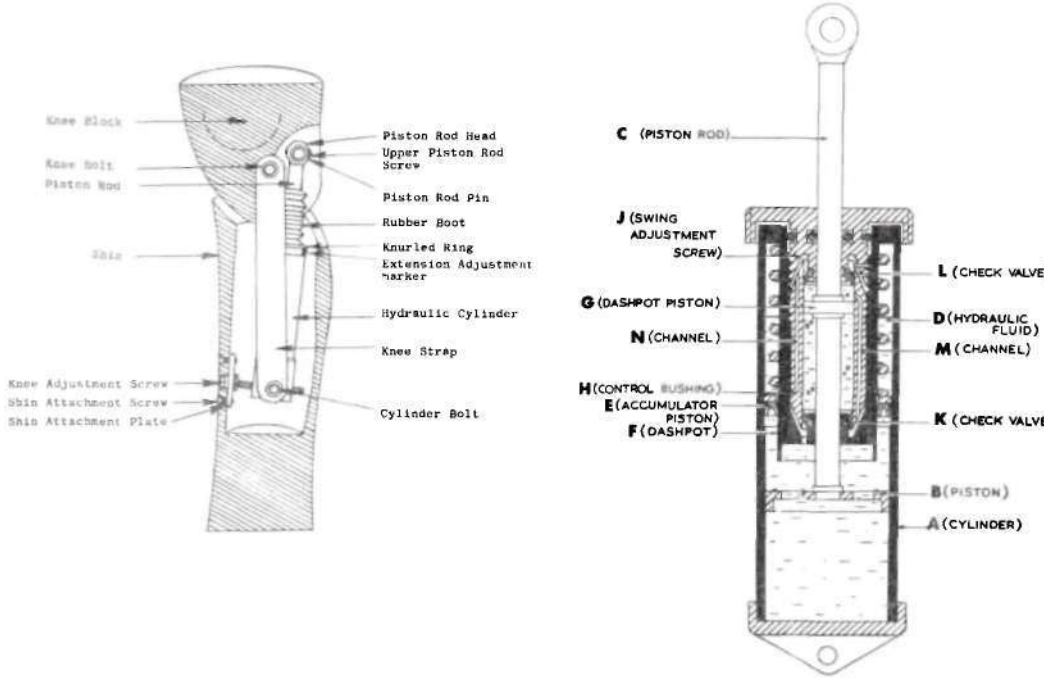


Fig 8. The Henschke-Mauch "Hydraulik" knee unit.

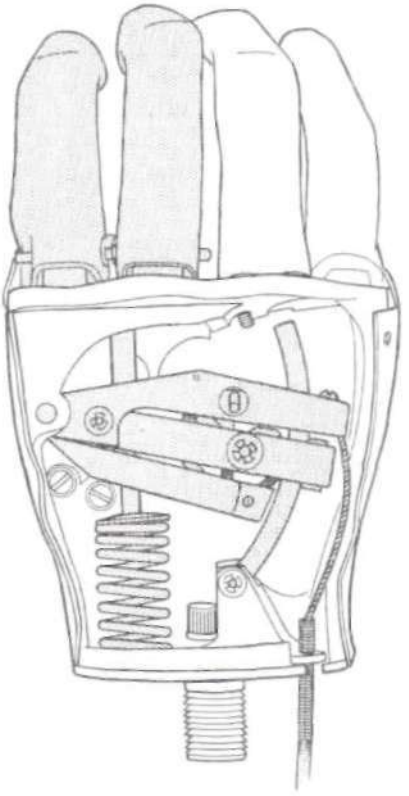


Fig. 9. The APRL-Sierra Model 44C artificial hand (without glove).

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-

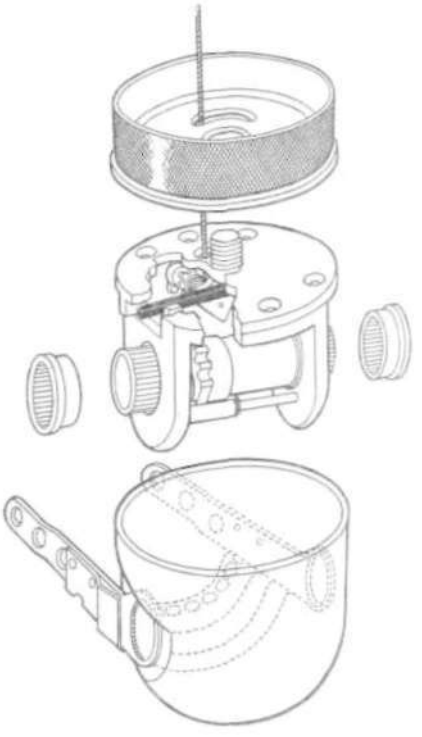


Fig. 10. The Northrop Model C elbow unit.

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

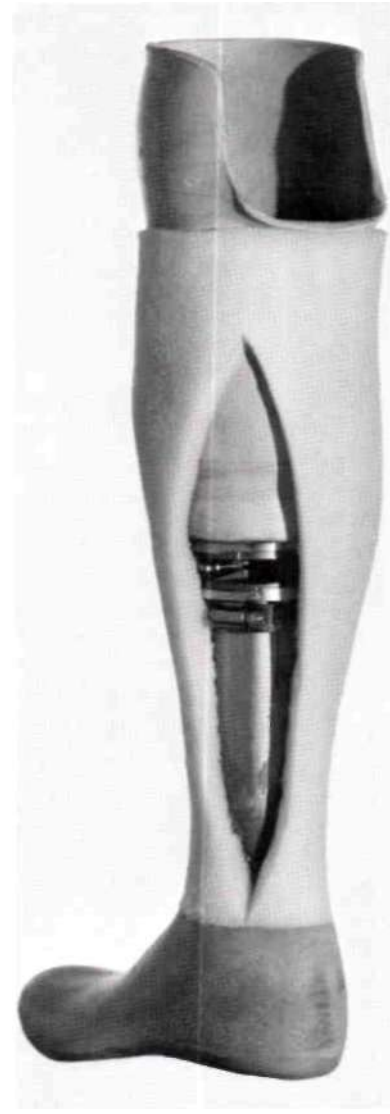


Fig. 12. A below-knee prosthesis fabricated of synthetic balata, with a cosmetic cover, developed by the Veterans Administration Prosthetics Center.

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-

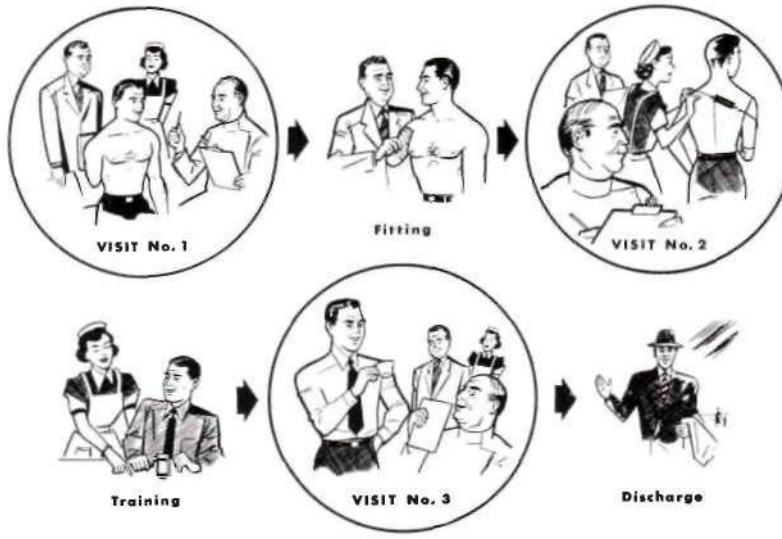


Fig. 13. Steps in the clinic-team procedure.

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).

REFERENCES

1. Burgess, Ernest M., Robert L. Romano, and Joseph H. Zettl, *The management of lower-extremity amputations,* TR 10-6, Prosthetic and Sensory Aids Service, Veterans Administration, August 1969.
2. Committee on Artificial Limbs, National Research Council, *Terminal research reports on artificial limbs covering the period from 1 April 1945 through 30 June 1947* (to the Office of the Surgeon General of the Army and the U.S. Veterans Administration),
3. Committee on Prosthetics Research and Development, Selected bibliography on limb prosthetics, *Artif. Limbs,* 12:2:42-48, Autumn 1968.
4. Klopsteg, Paul E., Philip D. Wilson, et al., *Human limbs and their substitutes,* McGraw-Hill, New York, 1954. (Reprint edition, Hafner, 1968)
5. Talley, William H., Prosthetics research—a cost reduction program, an editorial, *Bull. Pros. Res.* 10-10, Fall 1968.
6. University of California (Berkeley), Prosthetic Devices Research Project, *Fundamental studies of human locomotion and other information relating to design of artificial limbs,* Report to the Committee on Artificial Limbs, National Research Council, 1947, two volumes.

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

Artificial Limbs, Vol 14, No 2, pp 19-48, Autumn 1970

Amputees and Their Prostheses[1]

ELIZABETH J DAVIES. M.A.,[2]
BARBARA R. FRIZ, M.S.. AND[3]
FRANK W. CLIPPINGER, M.D.[4]

INFORMATION on 8,698 amputations was collected during a period of approximately two years, ending June 30, 1967. This information was extracted from case-record forms provided by 44 prosthetics facilities in 30 states. The case-record form used was initially developed and standardized by the Conference of Prosthetists of the American Orthotic and Prosthetic Association. Its purpose was to encourage prosthetists in the accurate recording of pertinent information relating to the amputee and his prosthesis. Duplicate copies of the case-record forms were submitted to the Committee on Prosthetic-Orthotic Education (CPOE)[5], National Research Council, in order that significant data could be identified and reported.

"The Facility Case Record Study: A Preliminary Report" (3) and "Children with Amputations" (2), both reporting findings emerging from this study, have been published previously.

Data analyzed in the study included those related to age, sex, level and cause of amputations, reamputations, stump length and contractures, work status of amputees, referrals, months to delivery of prosthesis, age of replaced prosthesis and reason for replacement, components most frequently prescribed for upper- and lower-extremity prostheses, and source of payment for prostheses.

METHODS

Each of the 44 facilities submitted case record forms on amputees as they were seen. Three forms were utilized, one for the amputee's medical history, one for the lower-extremity prosthesis, and one for the upper-extremity prosthesis. In cases where the meaning of the data was uncertain, follow-up forms were sent to the prosthetics facilities to clarify or add to the information provided.

A coding system was devised, and information was transferred from the case-record forms to coding sheets and then to IBM cards and magnetic tape. Selection of pertinent data for retrieval was determined by an ad hoc group and the staff of CPOE.

In order to make comparisons between different areas of the country, the states represented in the study were arbitrarily grouped into five geographical regions (Fig. 1).

SUBJECTS

The study included 8,323 amputees with a total of 8,698 amputations. Statistics in this study refer only to patients fitted with a prosthesis; amputees not fitted are not included. Table 1 indicates the types of cases included in the study.

Amputees or amputations being fitted for the first time were considered "new" cases. Amputees or amputations being

[1] Final report of the Facility Case Record Study.

[2] Formerly Professional Assistant, Committee on Prosthetic-Orthotic Education.

[3] Executive Secretary, Committee on Prosthetic-Orthotic Education, Division of Medical Sciences, National Academy of Sciences—National Research Council, Washington, D. C.

[4] Professor of Orthopaedic Surgery, Duke University; Chairman, Subcommittee on Prosthetics Clinical Studies, CPOE.

[5] The Committee on Prosthetic-Orthotic Education is supported by the Social and Rehabilitation Service, Department of Health, Education, and Welfare, and by the Prosthetic and Sensory Aids Service of the Veterans Administration.

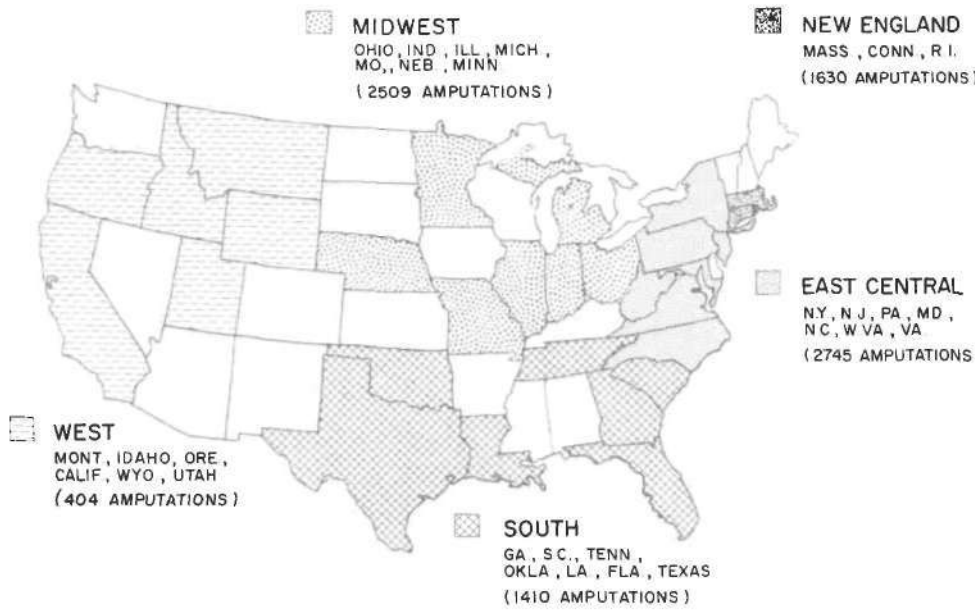


Fig. 1

TABLE 1. NUMBER OF EXTREMITIES FITTED
(N = 8,323)

Unilateral	7,954
Bilateral	356
Double	8
Triple	4
Quadruple	1

TABLE 2. "NEW" AND "OLD" AMPUTATIONS, BY SEX
(N = 8,698)

	Males	Females	Total
"New"	2,969	1,065	4,034
"Old"	3,879	785	4,664
	6,848	1,850	8,698

fitted with replacement prostheses were considered to be "old" cases. There was a total of 4,034 "new" amputations and 4,664 "old" amputations (Table 2). Amputations in males accounted for 6,848 amputations, and amputations in females, 1,850—a ratio of 3.7:1.

FINDINGS

AGE OF AMPUTEES

Table 3 shows the age of amputees fitted in prosthetics facilities during the two years covered by this study. The incidence of amputations for males peaked in the fifth decade; for females, the peak was reached in the seventh decade. Forty-eight per cent of the amputees were 51 years of age or older, 30 per cent were over 61 years, and 12 per cent were over 71 years. The fact that 23 per cent of the amputees were fitted with either a new or a replacement prosthesis after 65 years of age has Medicare implications. (It should be noted that Medicare was in effect during only the second year of data collection.)

LEVEL OF AMPUTATIONS

Amputations of the lower extremity accounted for 86 per cent of the total number of amputations (Table 4). Of these, 53

per cent were at the below-knee level. In the upper extremity, 57 per cent of the amputations were at the below-elbow level.

There was no significant difference in the incidence of left- and right- side amputation in either the upper or lower extremities. A total of 4,386 left-limb and 4,312 right-limb amputations was reported. The right upper extremity was involved slightly more than the left, 605 to 573, and the left lower extremity fractionally more than the right, 3,813 to 3,707.

CAUSE OF AMPUTATION

Causes of amputation were considered in four categories: congenital, tumor, trauma, and disease. Cases of infection, gangrene, or osteomyelitis resulting from trauma were classified under "trauma." Cases of trauma associated with vascular disease were classified under "disease."

Causes of amputation were analyzed by age group and level. Of the 8,698 amputations reported in this study, the cause was known for 8,487 cases; both cause and age were known for 8,394 cases. Fifty per cent of all amputations were caused by trauma, 37.3 per cent by disease, 8.4 per cent were of congenital origin, and 4.3 per cent were due to tumor. Table 5 shows the relative incidence of amputation by cause and level.

In Figure 2 the total number of amputations by cause of amputation and age is indicated. Amputees most frequently fitted

TABLE 3. DISTRIBUTION BY AGE AND SEX, 8,593 AMPUTATIONS

Age Group	Amputations (Male)		Amputations (Female)		Total	
	No.	%	No.	%	No.	%
0-10	265	4	197	11	462	5
11-20	475	7	199	11	674	8
21-30	608	9	123	7	731	9
31-40	852	13	114	6	966	11
41-50	1,377	20	232	13	1,609	19
51-60	1,271	19	307	17	1,578	18
61-70	1,136	17	378	20	1,514	18
(61-64)					(582)	(7)
(65-70)					(932)	(11)
71-80	642	9	239	13	881	10
81-90	127	2	38	2	165	2
91+	10	--	3	--	13	--
Total	6,763		1,830		8,593	

TABLE 4. DISTRIBUTION BY LEVEL, 8,698 AMPUTATIONS

Level	Lower Extremity		Level	Upper Extremity	
	No.	%		No.	%
Hemipelvectomy	20	--	Forequarter	13	1
Hip disarticulation	89	1	Shoulder disarticulation	43	4
Above knee	3,051	41	Above elbow	276	23
Knee disarticulation	115	1	Elbow disarticulation	31	3
Below knee	4,020	53	Below elbow	676	57
Syme's	168	2	Wrist disarticulation	77	7
Partial foot	35	--	Partial hand	60	5
Congenital NOS	22	--	Congenital NOS	2	--
Total	7,520		Total	1,178	

TABLE 5. INCIDENCE OF AMPUTATION BY CAUSE AND LEVEL, 8,487 AMPUTATIONS

Lower Extremity	Congenital	Tumor	Trauma	Disease	Total
Hemipelvectomy—Hip disarticulation	5	66	18	17	106
Above knee	95	212	1,151	1,520	2,978
Knee disarticulation	27	3	58	24	112
Below knee	255	50	2,085	1,522	3,912
Syme's	47	1	81	36	165
Partial foot	8	1	22	3	34
Congenital NOS	21	--	--	--	21
Subtotal	458	333	3,415	3,122	7,328
Upper Extremity					
Forequarter—Shoulder disarticulation	12	18	22	3	55
Above elbow	17	9	230	16	272
Elbow disarticulation	12	2	15	2	31
Below elbow	181	5	461	16	663
Wrist disarticulation	20	--	57	--	77
Partial hand	10	--	49	--	59
Congenital NOS	2	--	--	--	2
Subtotal	254	34	834	37	1,159
Total—upper and lower extremity	712 (8.4%)	367 (4.3%)	4,249 (50%)	3,159 (37.3%)	8,487

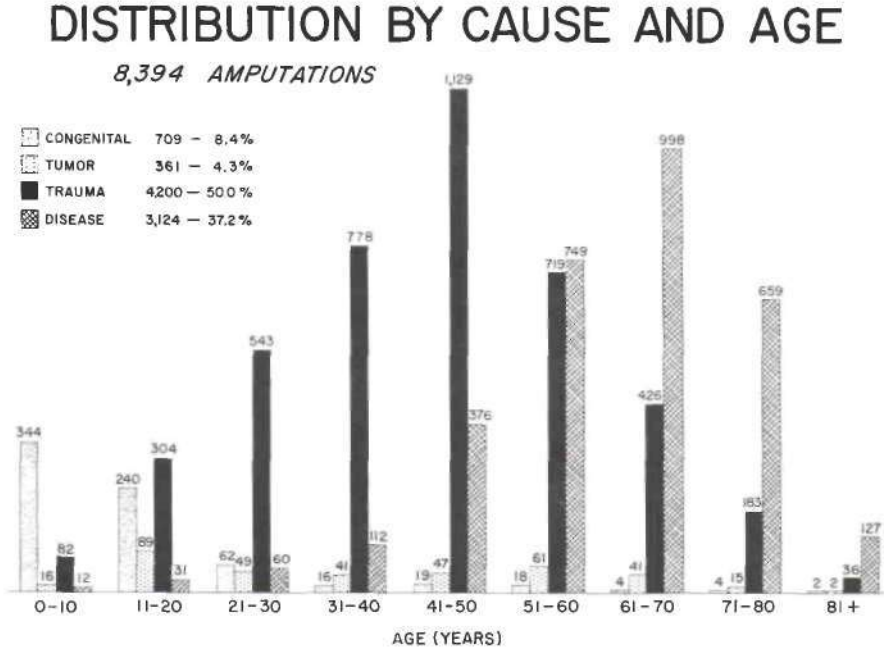


Fig. 2

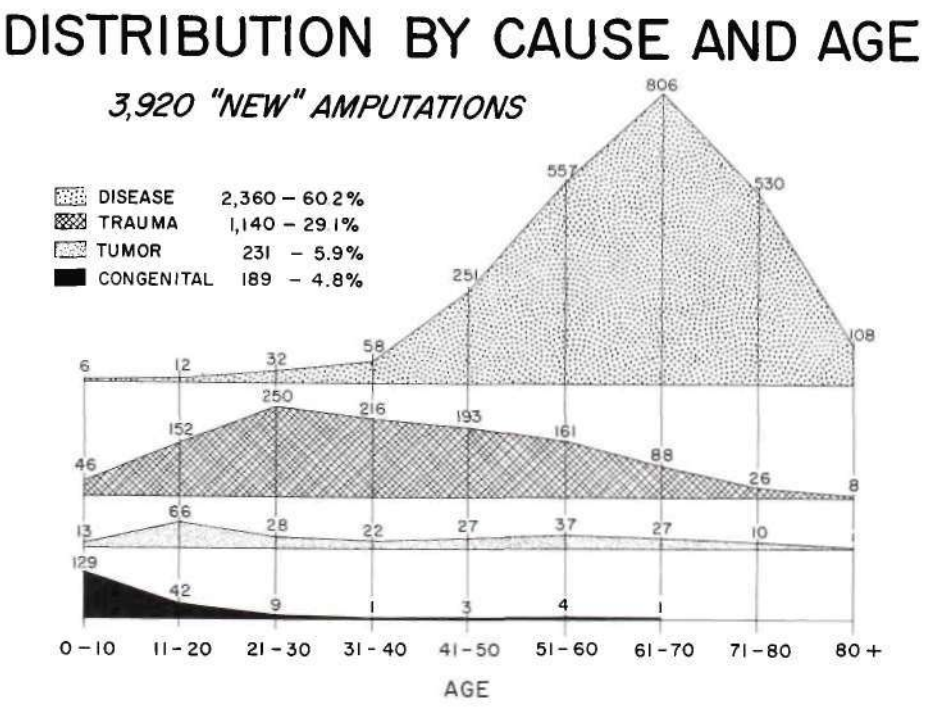


Fig. 3

or returning for replacement in the first ten years of life were those with congenital limb deficiencies. Amputations for trauma led all other categories fitted or returning for replacement between the ages of 11 through 50. In the third, fourth, and fifth decades, this group accounted for 76 per cent, 82 per cent, and 72 per cent, respectively, of all cases fitted or returning. Of those fitted in the sixth decade of life, the incidence was almost equally distributed between traumatic amputations and amputations due to disease. After age 60, the latter group led all other categories by a ratio of more than 2:1.

"New" Cases by Cause

Analysis of all amputations entered in the study gives an overview of the type of amputee being seen and fitted in prosthetics facilities, as reported above. Analysis of those being fitted for the first time, however, provides a picture of persons amputated during the two-year period of data collection and gives a better current indication of cause related to age, sex, and level of amputation.

It is probable that the statistics on age are slightly distorted, since age was reported as of the time of fitting. Age at the time of amputation, therefore, would be less, and to a variable degree.

In the group of "new" amputees, cause was reported for 3,963 cases, and both cause and age for 3,920. Figure 3 indicates the incidence of amputation by age. Of the "new" cases, 60.2 per cent of amputations were caused by disease, 29.1 per cent by trauma, 5.9 per cent by tumor, and 4.8 per cent were of congenital origin.

The predominance of trauma as the cause of amputation in the overall amputee population of the study (Fig. 2) is in striking contrast to the predominance of

TABLE 6. SEX, AGE, AND LEVEL, 191 "NEW" CONGENITAL AMPUTATIONS

Age	Upper Extremity			Lower Extremity			Total		Grand Total
	Male	Female	Total	Male	Female	Total	Male	Female	
0–10	43	34	77	24	28	52	67	62	129
11–20	11	11	22	16	4	20	27	15	42
21–30	3	3	6	1	2	3	4	5	9
31–40	--	--	--	1	--	1	1	--	1
41–50	1	1	2	1	--	1	2	1	3
51–60	--	--	--	2	2	4	2	2	4
61–70	--	--	--	1	--	1	1	--	1
71–80	--	--	--	--	--	--	--	--	--
Unknown	1	--	1	--	1	1	1	1	2
Total	59	49	108	46	37	83	105	86	191

TABLE 7. SEX, AGE, AND LEVEL, 235 "NEW" TUMOR AMPUTATIONS

Age	Upper Extremity			Lower Extremity			Total		Grand Total
	Male	Female	Total	Male	Female	Total	Male	Female	
0–10	2	2	4	6	3	9	8	5	13
11–20	3	2	5	30	31	61	33	33	66
21–30	--	--	--	15	13	28	15	13	28
31–40	4	4	8	6	8	14	10	12	22
41–50	1	2	3	13	11	24	14	13	27
51–60	3	1	4	22	11	33	25	12	37
61–70	1	2	3	14	10	24	15	12	27
71–80	1	1	2	6	2	8	7	3	10
81+	--	--	--	1	--	1	1	--	1
Unknown	--	--	--	2	2	4	2	2	4
Total	15	14	29	115	91	206	130	105	235

disease as a cause of amputation when only new patients are considered (Fig. 3). In the overall picture, the ratio of trauma to disease is 1.3:1, whereas in new patients the ratio is reversed, and disease as a cause of amputation outnumbers trauma 2:1.

Thus, the total sample data obviously includes a considerable number of traumatic amputees who lost their limbs at an earlier age and survived to require replacement prostheses. However, the noteworthy finding is that, in the period surveyed, disease-caused amputations were occurring at double the rate of those attributable to trauma.

Congenital. In the 191 reported "new" amputations of congenital origin, 105 were in males, 86 in females (Table 6). Of this number, 137 did not require amputation surgery, while 54 did. This surgery presumably involved the conversion of anomalous limbs to stumps that were more suitable for the fitting of a prosthesis. Eighty-three amputations occurred in the lower extremity, of which 44 were at the below-knee level. Of 108 upper-extremity amputations, 78 were at the below-elbow level. Thirty-two per cent of congenital amputations were not fitted until after 11 years of age.

Tumor. Of 235 "new" amputations caused by tumor, 206 (88 per cent) were of the lower extremity (Table 7). There were 120 amputations at the above-knee level, accounting for 58 per cent of the lower-extremity amputations. An additional 27 per cent were at a level higher

than above-knee, i.e., hip-disarticulation or hemipelvectomy. Males outnumbered females 130 to 105.

The highest incidence of tumor (66 cases or 29 per cent) occurred in the second decade of life. Within this decade, no particular pattern of incidence is discernible (Table 8). These data are somewhat at variance with those reported by Taft and Fishman (7) from a study conducted by the staff of New York University Child Prosthetic Studies. This study, which involved a larger sampling (278 children whose amputations were caused by tumor), showed a gradual increase in incidence beginning about the 6-8 year period and peaking in the 14-16 year group. Unfortunately, the age groupings are slightly different from those of our study, so an exact comparison cannot be made. However, both studies agree that tumor occurs most frequently in the second decade by a wide margin.

TABLE 8. INCIDENCE OF TUMOR-CAUSED AMPUTATIONS IN SECOND DECADE
(N = 66)

Age	Number
11	9
12	6
13	6
14	6
15	6
16	8
17	6
18	5
19	7
20	7

Trauma. Of the 1,156 new cases of amputations resulting from trauma, amputations in males accounted for a total of 1,050, and those in females for 106, a ratio of approximately 10:1 (Table 9). The highest incidence of trauma-related amputations occurred in the third decade (250 cases), followed closely by that in the fourth decade (216 cases). The number of amputees in these two decades accounted for 41 per cent of all new cases where age was known. The incidence of amputations in females varied only slightly in each decade between the ages of 11 and 60. The incidence of amputations in males exhibited a sharp rise through the second and third decades, and then receded gradually.

In every decade the involvement of the lower extremity exceeded that of the upper. Actually, the lower extremity was involved 1.9 times as often as the upper, 753 times as opposed to 403.

Disease. Sixty per cent (2,381 cases) of all new amputations were caused by disease (Table 10). Although males outnumbered females by more than 2:1 in this category, the relative percentages of males and females in each age group were closely parallel, e.g., 980 or 61 per cent of males

TABLE 9. SEX, AGE, AND LEVEL, 1,156 "NEW" TRAUMA AMPUTATIONS

Age	Upper Extremity			Lower Extremity			Total		Grand Total
	Male	Female	Total	Male	Female	Total	Male	Female	
0–10	15	3	18	26	2	28	41	5	46
11–20	53	6	59	79	14	93	132	20	152
21–30	94	4	98	138	14	152	232	18	250
31–40	65	4	69	136	11	147	201	15	216
41–50	68	6	74	104	15	119	172	21	193
51–60	43	6	49	101	11	112	144	17	161
61–70	23	--	23	59	6	65	82	6	88
71–80	4	--	4	21	1	22	25	1	26
81+	1	--	1	6	1	7	7	1	8
Unknown	8	--	8	6	2	8	14	2	16
Total	374	29	403	676	77	753	1,050	106	1,156

TABLE 10. SEX, AGE, AND LEVEL, 2,381 "NEW" DISEASE AMPUTATIONS

Age	Upper Extremity			Lower Extremity			Total		Grand Total
	Male	Female	Total	Male	Female	Total	Male	Female	
0–10	--	1	1	3	2	5	3	3	6
11–20	2	--	2	5	5	10	7	5	12
21–30	3	1	4	20	8	28	23	9	32
31–40	2	3	5	39	14	53	41	17	58
41–50	3	6	9	156	86	242	159	92	251
51–60	4	3	7	392	158	550	396	161	557
61–70	2	--	2	537	267	804	539	267	806
71–80	1	--	1	357	172	529	358	172	530
81+	1	--	1	82	25	107	83	25	108
Unknown	--	--	--	15	6	21	15	6	21
Total	18	14	32	1,606	743	2,349	1,624	757	2,381

were over the age of 61 years, while 464 or 62 per cent of females were also over the age of 61. After 40 years of age, a sharp rise in the incidence of amputations caused by disease was noticeable. Approximately one-third of the amputations occurred in the seventh decade. Eighty-five per cent of all new amputees in the disease category were over the age of 51 years, and 49 per cent were in the Medicare age group.

In disease-caused "new" amputations, involvement of the lower extremity greatly exceeded that of the upper, the ratio being 73:1.

COMPARISON WITH AMPUTEE CENSUS

The Glattly study *(4),* reported in 1964 and commonly referred to as the "Amputee Census," included only "new" amputees. It is of interest to compare the findings of that study with the present one. Findings of our study relating to the sex and age of new amputees and the cause, side, and level of amputations closely parallel the findings of the Glattly study. Comparative data of the two studies are depicted in Figures 4, 5, 6, and 7, and Table 11.

In our study, newly fitted amputees 51 years of age and older accounted for 60.2 per cent of the total, as compared with 58.8 per cent in the Amputee Census (Fig. 4). In both studies, the highest incidence of amputation was in the seventh decade. Because many geriatric amputees are not fitted with prostheses, the incidence of amputation in the older age groups would presumably be even higher if statistics on nonfitted amputees were included.

In both studies, male amputees exceeded female amputees by approximately three to one (Fig. 5).

The distribution of right- and left-side amputations was almost equal in both studies, and lower-extremity amputations still accounted for about 85 per cent of all new fittings (Table 11). In Figure 6 a higher incidence of below-knee amputations and a lower incidence of above-knee amputations were evident in the more recent study. Among new patients in this study, there was a total of 3,254 above- and below-knee amputations. Of these, 50.9 per cent were above-knee.

The relative incidence of truama as a cause of amputation decreased by four per cent from the Glattly to the present study, and the incidence by cause in other categories increased, but by relatively small amounts (Fig. 7).

ORIGINAL LEVEL OF AMPUTATION FOR DISEASE CORRELATED WITH GEOGRAPHICAL AREA AND AGE

The original level of amputation for disease was examined for 2,242 new cases whose amputations were at either the above- or below-knee level. Comparisons were made between below- and above-knee as the choice of amputation level in each of the five geographical areas (Table 12). Below-knee appeared to be the site

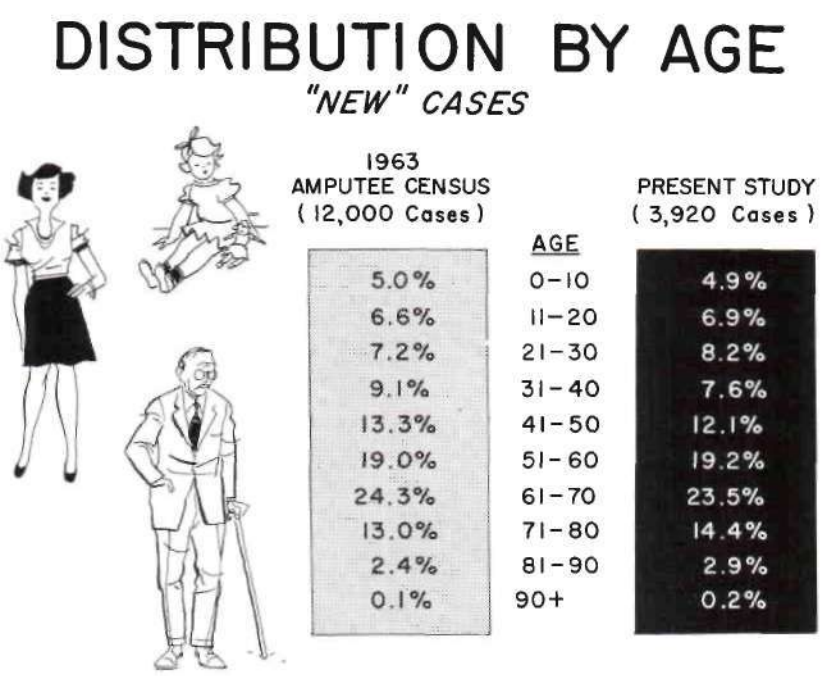

DISTRIBUTION BY AGE
"NEW" CASES
1963
AMPUTEE CENSUS
(12,000 Cases)
PRESENT STUDY
(3,920 Cases)
AGE
5.0%
6.6%
7.2%
9.1%
13.3%
19.0%
24.3%
13.0%
2.4%
0.1%
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
90+
4.9%
6.9%
8.2%
7.6%
12.1%
19.2%
23.5%
14.4%
2.9%
0.2%

Fig. 4

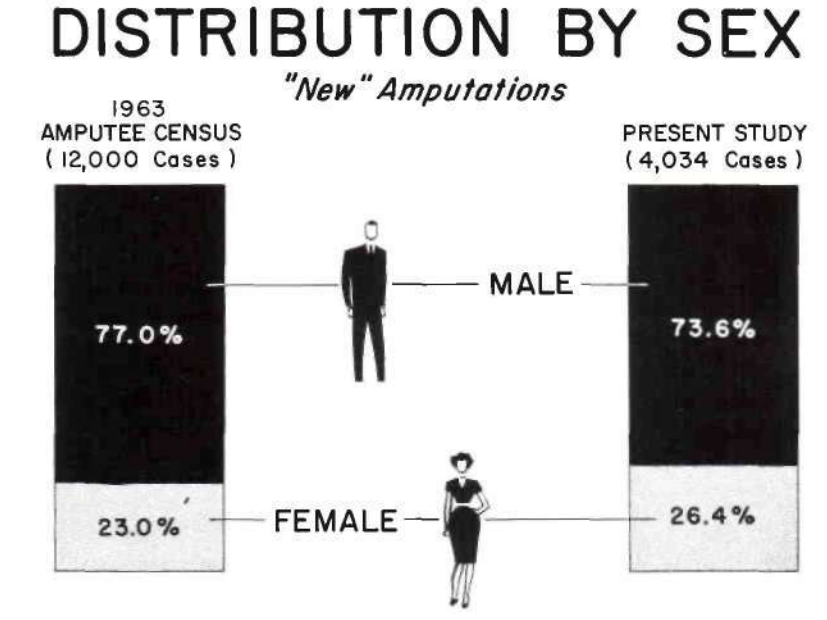

DISTRIBUTION BY SEX
"New" Amputations
1963
AMPUTEE CENSUS
(12,000 Cases)
PRESENT STUDY
(4,034 Cases)
77.0%
MALE
73.6%
23.0%
FEMALE
26.4%

Fig. 5

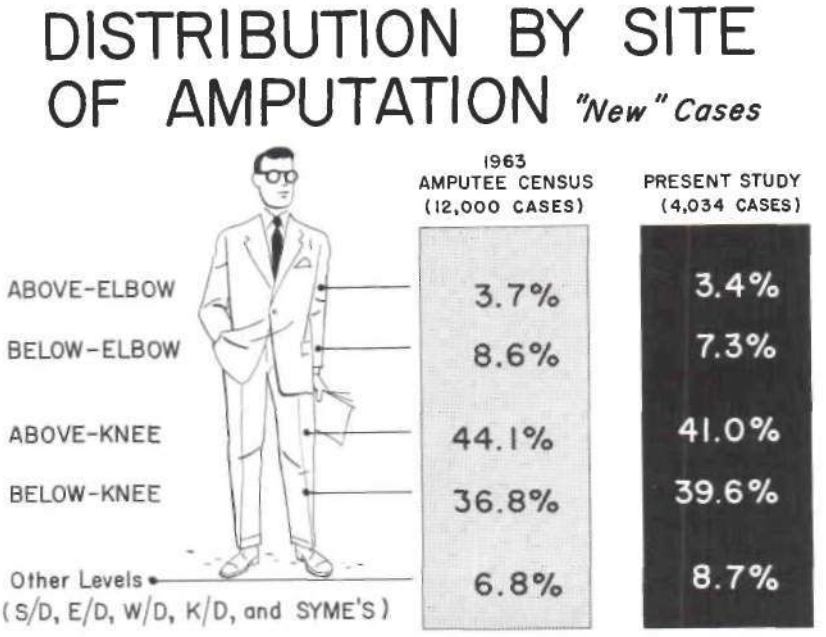

DISTRIBUTION BY SITE
OF AMPUTATION "New" Cases
1963
AMPUTEE CENSUS
(12,000 CASES)
PRESENT STUDY
(4,034 CASES)
ABOVE-ELBOW
BELOW-ELBOW
ABOVE-KNEE
BELOW-KNEE
Other Levels
(S/D, E/D, W/D, K/D, and SYME'S)
3.7%
8.6%
44.1%
36.8%
6.8%
3.4%
7.3%
41.0%
39.6%
8.7%

Fig. 6

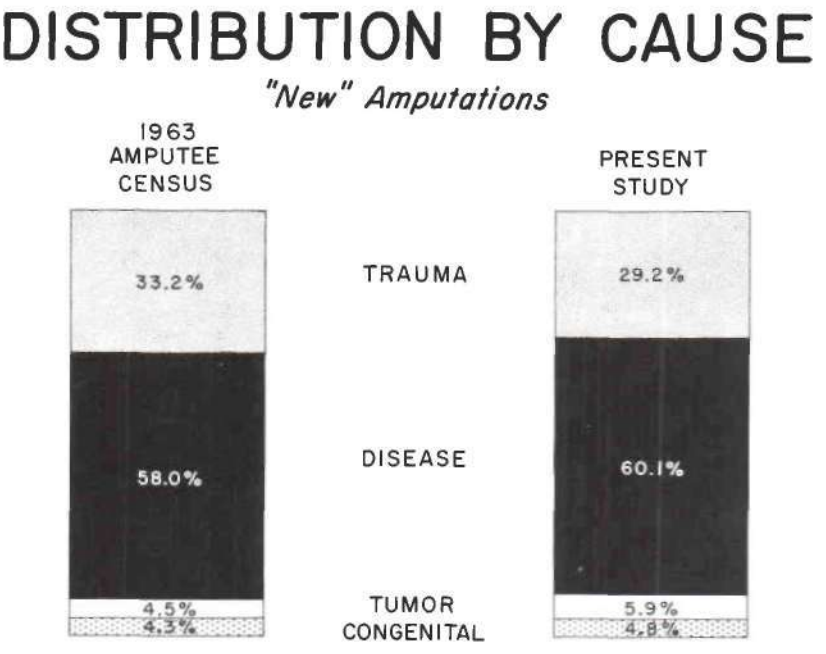

DISTRIBUTION BY CAUSE
"New" Amputations
1963
AMPUTEE
CENSUS
PRESENT
STUDY
TRAUMA
DISEASE
TUMOR
CONGENITAL
33.2%
58.0%
4.5%
4.3%
29.2%
60.1%
5.9%
4.8%

Fig. 7

of choice in less than half the total number of cases. The South led the other geographical areas in percentage of amputations at the below-knee level (54 per cent), followed in order by the Midwest (51 per cent), New England (48 per cent), East Central (46 per cent), and the West (45 per cent).

A look at the site of the original disease-related amputation for new patients 41 years of age and above revealed some interesting statistics (Table 13). In the fifth decade, below-knee was selected in preference to above-knee in 58 per cent of the cases. This percentage gradually decreased over the next two decades to a low of 43 per cent in the seventh decade. After the seventh decade, there was an increase to 47 per cent in the eighth decade and to 50 per cent after the eighth decade. For all new amputations for disease in patients 41 years of age and above, above-knee was selected in 52 per cent of the cases, below-knee in 48 per cent.

The lack of a consistent pattern in these data is intriguing. A progressive decrease in the proportion of below-knee amputations with increase in age might logically be anticipated. Surgeons, for example, might wish to be more sure of obtaining healing in older patients and elect to amputate at the above-knee level. However, other factors than age of patient obviously enter into the selection of amputation level.

TABLE 11. DISTRIBUTION BY SIDE AND EXTREMITY, "NEW" AMPUTEES

	1963 Amputee Census (12,000 Cases)	Present Study (3,920 Cases)
Left side	49.2%	51.2%
Right side	50.8%	48.8%
Upper extremity	14.9%	14.4%
Lower extremity	85.1%	85.6%

TABLE 12. ABOVE KNEE VERSUS BELOW KNEE AS SELECTED SITE OF ORIGINAL AMPUTATION, 2,242 "NEW" PATIENTS IN DISEASE CATEGORY

Geographical Area	Above Knee		Below Knee	
	No.	%	No.	%
New England	302	52	281	48
East Central	412	54	356	46
South	129	46	154	54
Midwest	269	49	279	51
West	33	55	27	45
Total	1,145	51	1,097	49

TABLE 13. ABOVE KNEE VERSUS BELOW KNEE AS SELECTED SITE OF ORIGINAL AMPUTATION CORRELATED WITH INCREASING AGE, 2,134 "NEW" PATIENTS IN DISEASE CATEGORY

Age Group	Above Knee		Below Knee	
	No.	%	No.	%
41–50	95	42	133	58
51–60	252	49	267	51
61–70	443	57	329	43
(61–64)	--	(58)	--	(42)
(65–70)	--	(57)	--	(43)
71–80	268	53	241	47
81+	52	50	53	50
Total	1,110		1,023	

SPECIFIC CAUSES OF TRAUMATIC AMPUTATIONS

Trauma was listed as the primary or precipitating cause of 4,306 amputations ("old" and "new" cases). As noted earlier, some of this number were classified in categories other than trauma, since trauma was not considered the primary cause of amputation; hence, the number 4,306 exceeds the number of cases actually coded in the trauma category. Of these 4,306 instances where trauma was mentioned, there were 392 cases where the type of trauma was unknown, so, for purposes of this analysis, reference will be to the 3,914 cases where type was known.

Figure 8 summarizes the causes of traumatic amputations. In this category, men were affected ten times as frequently as women: 3,561 to 353. In males, cars, industrial accidents, and war each accounted for approximately 20 per cent of the cases. On the other hand, automobiles were by far the outstanding cause of traumatic amputations in women (49 per cent), with no other cause approaching this in frequency. It is noteworthy that the ratio of male to

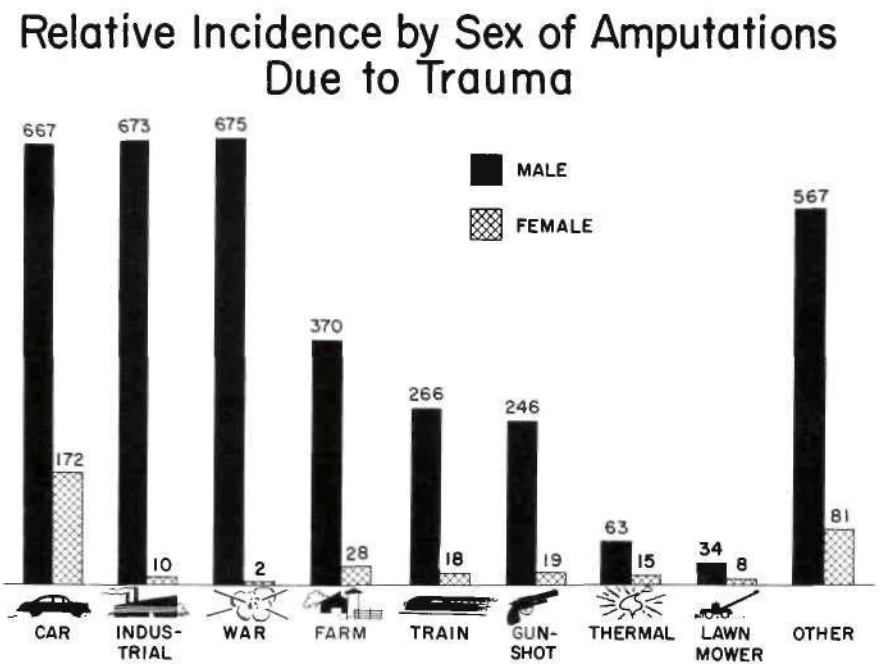


Fig. 8

TABLE 14. CAUSES OF TRAUMATIC AMPUTATIONS CORRELATED WITH SEX, SIDE, AND LEVEL, 3,914 "OLD" AND "NEW" CASES

Cause	Right Upper Extremity		Left Upper Extremity		Right Lower Extremity		Left Lower Extremity		Total		Grand Total
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	
Car	28	4	45	8	277	82	317	78	667	172	839
Industrial	148	7	105	3	227	--	193	--	673	10	683
War	28	--	30	--	296	--	321	2	675	2	677
Farm	97	3	67	4	107	14	99	7	370	28	398
Train	4	--	14	1	121	11	127	6	266	18	284
Gunshot	23	3	23	2	95	5	105	9	246	19	265
Thermal	8	1	11	2	24	4	20	8	63	15	78
Lawn mower	2	--	3	2	11	3	18	3	34	8	42
Other	49	3	38	7	231	30	249	41	567	81	648
Total	387	21	336	29	1,389	149	1,449	154	3,561	353	3,914

female automobile-caused amputations was in the order of 4:1, in contrast to the 10:1 overall ratio. Since it is not known whether these female victims were predominantly drivers or riders, the full significance of these data is not clear.

Table 14 relates cause of trauma to sex, side, and level of amputation. Involvement of the right upper extremity in males was greater than the left. This preponderance was especially evident in farm and industrial accidents and is doubtless re-

TABLE 15. SPECIFIC CAUSES OF "NEW" AND "OLD" TRAUMATIC AMPUTATIONS IN MALES

Cause	"New" Amputations			"Old" Amputations		
	No.	%	% Excluding War	No.	%	% Excluding War
Car	201	20	21	466	18	24
Industrial	287	29	29	386	15	20
War	19	2	--	656	26	--
Farm	107	11	11	263	10	14
Train	52	5	5	214	8	11
Gunshot	64	6	7	182	7	10
Thermal	24	2	2	39	2	2
Lawn mower	15	2	2	19	1	1
Other	225	23	23	342	13	18
Total	994			2,567		

lated to handedness. In car accidents, the left upper extremity was involved significantly more than the right for both males and females, 62 per cent as compared with 38 per cent. One can speculate that this incidence might be attributable to the fact that many motorists ride with the left elbow extending beyond an open window. In the small sample of train accidents, the involvement of the left upper extremity in males was also considerably greater than the right but, because of the small number, this probably was without significance.

The left lower limb was involved slightly more than the right in males, and the right and left limbs almost equally in females.

Table 15 compares causes cited for "new" traumatic amputations in males with those given for "old" traumatic amputations. Twenty-six per cent of the amputations of "old" cases were due to war injuries, whereas only 2 per cent of the new cases were due to this cause. At the time of this study, the Vietnam War had not yet exerted its full impact. The greatest increase in trauma-caused amputations was seen in the industrial-accident category. Industrial accidents caused 29 per cent of the "new" traumatic amputations, but only 15 per cent of the "old" amputations. Elimination of war cases from the total number avoids distortion of the data due to the preponderance of old war injuries, and thus presents a somewhat truer comparative picture of other traumatic causes. With war injuries eliminated, industrial accidents accounted for 29 per cent of the "new" amputations and 20 per cent of the "old" amputations, which still reflects an increased incidence of amputations caused by industrial accidents. Industrial accidents exceeded all other categories as the cause of amputation in new patients.

REAMPUTATIONS OF THE LOWER EXTREMITY

Reamputations were studied in relation to cause, original level of amputation, and present level. Level was reported for 396 reamputations of the lower extremity. Some members of this group had second reamputations, but for the purposes of this study, only the original and present level of amputation were considered. An attempt was made to exclude simple revisions that involved no shortening of bone.

In reviewing the figures presented here, it should be remembered, again, that only those patients fitted with prostheses at the time of the study are considered. Despite this limitation, analysis of the available data is thought-provoking. Of 396 reamputations reported, 189 were in the disease-related category involving a total of 3,122 cases (Table 16), and 182 were in the trauma-caused group with 3,387 total cases (Table 17). Thus, ream-

TABLE 16. REAMPUTATIONS—DISEASE; ORIGINAL COMPARED WITH FINAL LEVEL

Original Level and No. of Cases	Final Level—189 Reamputations						
	Hemipelvectomy	Hip Disarticulation	Above Knee	Knee Disarticulation	Below Knee	Syme's	Total
Hip disarticulation (10)	1	--	--	--	--	--	1
Above knee (1,432)	--	6	9	--	--	--	15
Knee disarticulation (23)	--	--	2	--	--	--	2
Below knee (1,543)	--	1	67	3	22	--	93
Syme's (44)	--	--	2	--	9	--	11
Partial foot (70)	--	--	22	--	41	4	67
Total (3,122)	1	7	102	3	72	4	189

TABLE 17. REAMPUTATIONS—TRAUMA; ORIGINAL COMPARED WITH FINAL LEVEL

Original Level and No. of Cases	Final Level—182 Reamputations				
	Above Knee	Knee Disarticulation	Below Knee	Syme's	Total
Above knee (1,094)	15	--	--	--	15
Knee disarticulation (55)	1	1	--	--	2
Below knee (2,091)	45	4	65	--	114
Syme's (103)	3	--	23	3	29
Partial foot (44)	1	--	14	7	22
Total (3,387)	65	5	102	10	182

putations in the first group ran a shade over 6 per cent, those in the second group a shade under 6 per cent. Stated in reverse, approximately 94 per cent of the cases in both groups did not require reamputation. The statistics for specific levels are also quite fascinating. In disease-related below-knee amputations, approximately 6 per cent required reamputation versus approximately 5 per cent in the like trauma group. In the above-knee group, the comparative proportions are 1 per cent versus 0.6 per cent. At the Syme's level, comparative figures are 25 per cent versus 28 per cent, and for partial feet 96 per cent versus 25 per cent. The reasons for the sharp increase in reamputations at the last two levels are worthy of further study. It would also be of interest to know whether partial foot amputations, for example, were or were not successfully performed on many patients who were never fitted with prostheses.

For the 189 (48 per cent) reamputations due to disease, Table 16 gives the final as compared to the original level. Of 93 below-knee amputations requiring reamputation, 22 (24 per cent) remained in the same segment, 67 (72 per cent) were converted to an above-knee level, 3 to a knee-disarticulation, and 1 to a hip-disarticulation level. Of the 15 original above-knee amputations, 9 were reamputated in the same segment and 6 became hip disarticulations.

Of the 11 Syme's reamputations reported, 2 were reamputated to an above-knee level and 9 to a below-knee level. Of the 67 reamputations at the partial foot level, 22 were converted to an above-knee, 41 to below-knee, and 4 to a Syme's level.

Causes of reamputation for patients in the disease category were indicated for 181 of the 189 reamputations. In some instances, two causes of reamputation were cited. In each instance where a cause was mentioned, it was counted as contributing to the reamputation. The total number of contributing causes to reamputation in the disease category therefore was 192 (Table 18). "Recurrence of the original cause of amputation" accounted for almost half (48 per cent) of the reasons cited for reamputations. This generalized response is interpreted as meaning a continuance of the original vascular problem responsible for the initial amputation. Specific causes cited were a nonhealing wound (18 per cent), gangrene (12 per cent), infection (5 per cent) stump breakdown (3 per cent), and "other" (14 per cent).

Most reamputations in the disease category occurred very shortly after the original surgery, 49 per cent occurring in less than 1 1/2 months, and 60 per cent occurring in less than 2 1/2 months. Eighty-two per cent occurred in the first year following the amputation.

In the category of traumatic amputations, levels for 182 reamputations of the lower extremity were reported. Of the 114 amputations at the below-knee level requiring reamputation, 57 per cent (65 amputations) remained at the below-knee level, a percentage considerably higher than was the case for reamputations due to disease. Forty-five amputations were converted to above-knee levels and 4 were converted to knee disarticulations. There were 29 Syme's reamputations, of which 23 were converted to below-knee, 3 to above-knee, and 3 remained at the Syme's level. Of the 22 partial foot reamputations, 14 were converted to below-knee levels, 7 to Syme's and 1 to above-knee.

Causes of reamputation were known for 157 of the trauma cases. As with reamputations in the disease category, every instance where a cause was mentioned was counted. There were 165 contributing causes to reamputations (Table 19). In 71 instances (43 per cent), "other" was coded as the cause of reamputation. Included in the "other" category were causes that could not be readily classified, such as "stump not satisfactory for prosthesis," "shorten bone and remove neuroma," "painful stump." The median number of months between amputation and reamputation was six.

TABLE 18. CAUSES OF REAMPUTATION—DISEASE CATEGORY
(N = 192)

Cause	No.	%
Recurrence of original cause	92	48
Nonhealing wound	35	18
Gangrene	23	12
Infection	10	5
Stump breakdown	6	3
Poor scar	2	1
Other	19	10
Miscellaneous combinations	5	3

TABLE 19. CAUSES OF REAMPUTATION—TRAUMA CATEGORY
(N = 165)

Cause	No.	%
Infection	28	17
Gangrene	22	13
Nonhealing wound	17	10
Stump breakdown	10	6
Bony overgrowth	7	4
Poor scar	4	3
Other[a]	71	43
Miscellaneous combinations	6	4

[a] Includes "stump not satisfactory for prosthesis," "shorten bone and remove neuroma," "painful stump," etc.

TABLE 20. REAMPUTATIONS OF THE LOWER EXTREMITY
(N = 396)

Original Level and No. of Cases	No. of Reamputations	No. and % in Same Segment	No. and % in Higher Segment
Hip disarticulation (82)	2	--	2 (100)
Above knee (2,897)	31	25 (81)	6 (19)
Knee disarticulation (112)	6	1 (17)	5 (83)
Below knee (4,046)	223	98 (44)	125 (56)
Syme's (201)	43	3 (7)	40 (93)
Partial foot (128)	91	--	91 (100)
Total (7,466)	396	127 (32)	269 (68)

There were 16 reamputations for congenital amputees and 6 for patients whose amputations were caused by tumor. Three of the latter were reamputated because of recurrence of the tumor. Reported reasons for reamputations in congenital amputees were too diverse for classification, except that 4 reamputations were because of bony overgrowth.

Table 20 summarizes the total number of reamputations for each level and includes the percentage of reamputations converted to a higher segment or remaining in the same segment.

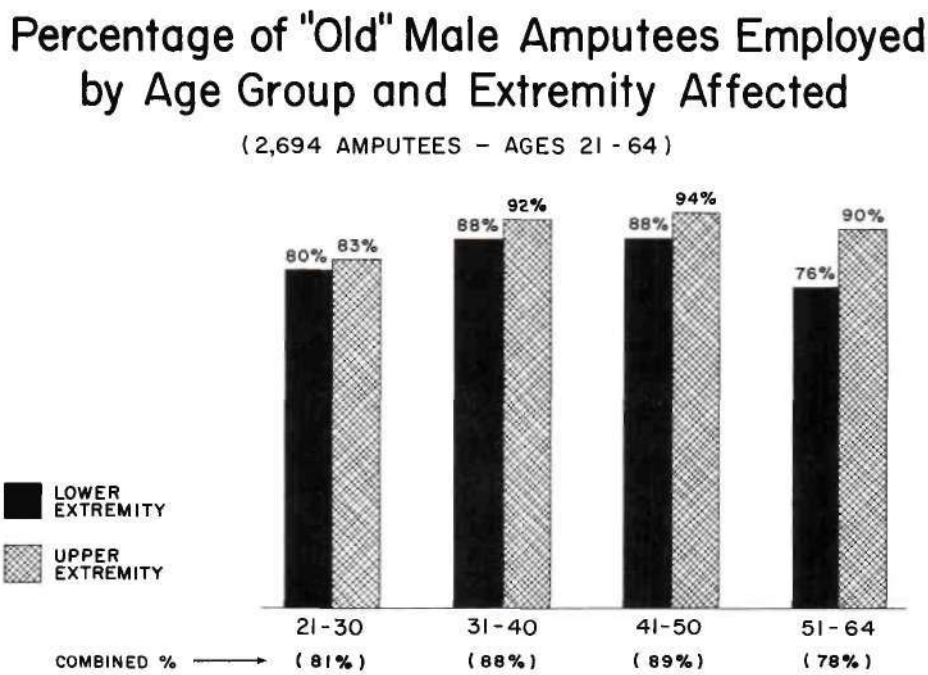
Bony overgrowth was cited eight times as a reason for reamputation: four tibial overgrowths, two fibular overgrowths, and

two not specified. All of these reamputations were performed on children, with the exception of one on a 27-year-old amputee. While not implicit in the data, it is conceivable that this 27-year-old had had bony overgrowth for a long time prior to reamputation (his first amputation occurred at age 10).

STUMP LENGTH AND CONTRACTURES

There were 2,602 above-knee amputations for which the presence or absence of contractures of the hip was reported. Of this group, 1,345 had either no flexion contracture or a contracture of less than 5 deg, and are not included in this analysis, other than the notation that they comprised over half of the group reported. Stumps with 5+ deg of contracture ranged in length from 2 - 2 1/2 inches to 14 - 15 1/2 inches. Three stumps had flexion contractures of more than 60 deg. Hip-flexion contractures were greatest in the very short stump. The average contracture at the above-knee level fell in the 5-9 deg range.

There were 3,781 below-knee amputations for which the presence or absence of knee contractures was reported. Of this number, only 12 per cent were reported as having contractures of 5 deg or more. In general, the shorter the stump, the more severe the contracture. Considering only those cases reporting contractures of 5 deg or more, stumps averaging more than 7 1/2 in. in length had average contractures of between 5 and 9 deg; for stumps between 4 and 7 1/2 in. long, contractures averaged between 10 and 14 deg; and for stumps 3 1/2 in. and less in length, contractures averaged 15 to 19 deg. The average contracture, excluding those of less than 5 deg, was 10-14 deg. Three stumps had contractures of 60 deg or more.



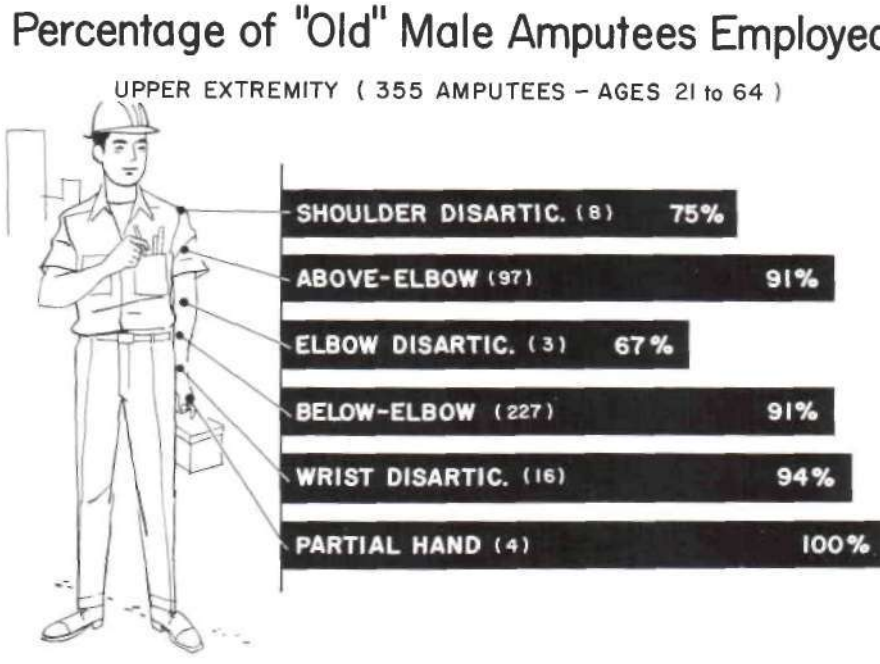


Fig. 10

WORK STATUS

The work status of "old" male amputees between the ages of 21 and 64, with 2,694 amputations, was reported. "New" amputees were not studied, since the majority of the group had not yet had time to return to employment. Eighty-four per cent of the "old" amputees in the cited age group were employed, the highest employment rate (89 per cent) occurring in the 41- to 50-year-old age group (Fig. 9). In each of the age groups studied, a higher rate of employment was reported for upper-extremity than for lower-extremity amputees. It should be noted here that only 6.4 per cent of amputees between the ages of 21 and 64 were reported as not being gainfully employed. The remainder of the group (9.3 per cent) were students, retired, or fell into some other category. This percentage of unemployment is a little higher than that reported for the national average for the years 1965, 1966, and 1967 (4.5, 3.8, and 3.8 per cent respectively).

The rate of employment in relation to each upper- and lower-extremity amputation level appears in Figures 10 and 11.

Work status was reported for 383 female amputees between the ages of 21 and 64. Of this number, 200 were housewives, 148 were gainfully employed, and only 18 were not gainfully employed. Seventeen had either retired or reported their work status in some other category.

REFERRALS

The majority (58 per cent) of cases fitted at prosthetics facilities were referred by amputee clinics; 26 per cent were referred by physicians; 16 per cent were not referred. Of the "new" cases, 5 per cent were not referred to prosthetics facilities by either a clinic or physician,

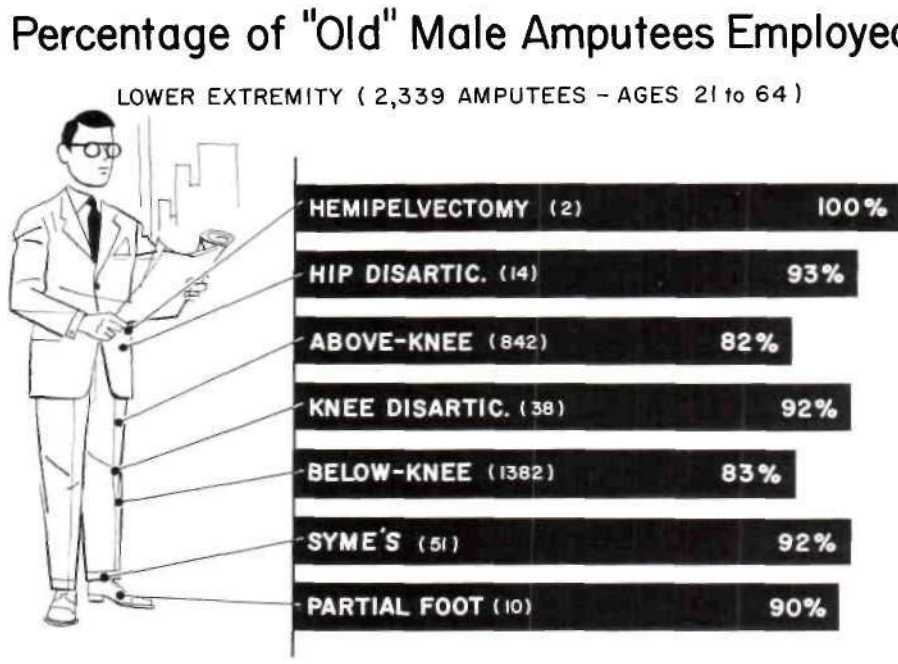


Fig. 11

as contrasted to the 26 per cent of the "old" cases not so referred.

MONTHS TO DELIVERY OF PROSTHESES

For "new" amputations, the time from amputation (or from birth for congenital amputees not requiring surgery) to date of delivery of the prosthesis was analyzed by level and cause for the five geographical regions (Table 21). The median period to delivery for all prostheses was 6 months. Comparing geographical areas, the median was 5 months for New England, the Midwest and West, 6 months for the South, and 7 months for the East Central region. Of the 3,588 prostheses with times to delivery reported, 71 were delivered in 1 month or less, 67 were not delivered for 99 months or longer. Thirty-seven of the latter were for congenital amputations not requiring surgery, i.e., 37 children were not fitted with their first prosthesis until after the age of eight years, three months. A comparison of time to delivery by levels indicated that the median time lapse was 5 months for the below-knee prosthesis and 6 months for all other levels. Time to delivery of prostheses ranged from a median of 4 months for below-knee prostheses in the New England area and the West to a median of 10 months for below-elbow prostheses in the East Central region. These data will provide a basis for later comparisons in areas where programs of immediate and early prosthetic fitting have been instituted.

Data on months to delivery were analyzed by cause of amputation and related to geographical regions (Table 22). The shortest median length of time for delivery was 3 months for congenital amputees who had had surgery. The longest time was for congenital amputations without surgery, where the median was 31 to

TABLE 21. MEDIAN NUMBER OF MONTHS TO DELIVERY OF PROSTHESIS BY LEVEL AND AREA, 3,588 "NEW" CASES

Level	New England	East Central	South	Midwest	West	Median of Total Cases
Above elbow	6	9	7	5	5	6
Below elbow	6.5	10	6.5	5	6	6
Above knee	5	7	6.5	5	5	6
Below knee	4	7	6	5	4	5
All other levels	8	8	6	5	5	6
Median no. of months, all levels	5	7	6	5	5	6

TABLE 22. MEDIAN NUMBER OF MONTHS TO DELIVERY OF PROSTHESIS RELATED TO CAUSE, 3,537 "NEW" CASES

Cause and No. of Cases	New England	East Central	South	Midwest	West	Median of Total Cases
Tumor (222)	4	5	4	4	5	4
Disease (2,119)	5	7	6	5	5	6
Trauma (1,015)	5	7	6	4	5	5
Congenital, with surgery (53)	3	6.5	3	3	--[a]	3
Congenital, without surgery (130)	31–36[b]	25–30[b]	37–48[b]	37–48[b]	--[a]	31–36[b]

[a] Too few cases for data to be valid.

[b] Median range.

36 months; however, it should be recognized here that this median also represents the median age of congenital amputees not requiring surgery who were being fitted for the first time. Median time to delivery for amputations caused by tumor was 4 months; by trauma, 5 months; and by disease, 6 months.

AGE OF REPLACED PROSTHESES AND REASONS FOR REPLACEMENT

The average age of replaced prostheses for all patients was 6.1 years. For children up to 21 years of age, it was 2.5 years, and for adults, 6.7 years.

Comparisons of the ages of replaced prostheses for above- and below-elbow and above- and below-knee amputees in relation to the age of the patient (by decade) are shown in Table 23. In almost every instance, the "life" of the prosthesis increased with the age of the patient. The average life of above-elbow prostheses for 124 amputations was 9.2 years. The range was from 2.5 years for the child through the age of 10 years to 16.7 years for amputees over the age of 61. The average age of below-elbow prostheses for 349 amputations was 6.5 years, ranging from 2.5 years for the child through age 10, to 10.3 years for amputees over age 51. The average age of above-knee prostheses for 1,269 amputations was 6.2 years, with a range from 2.2 years for the child in the first decade, to 8.1 years for amputees over age 71. The below-knee prosthesis

TABLE 23. AVERAGE AGE (YEARS) OF REPLACED PROSTHESES ($N = 3,943$)

Age of Patient	Below Elbow (349 Cases)	Above Elbow (124 Cases)	Below Knee (2,201 Cases)	Above Knee (1,269 Cases)
0–10	2.5	2.5	1.7	2.2
11–20	2.8	4.2	2.5	3.1
21–30	4.0	6.0	4.1	4.7
31–40	7.9	8.6	4.9	6.0
41–50	7.7	10.0	5.8	6.5
51–60	10.3	12.1	6.8	7.1
61–70	} 10.3	} 16.7	7.8	7.0
71+			8.6	8.1
Average age of prosthesis	6.5	9.2	5.8	6.2

TABLE 24. AGE OF REPLACED PROSTHESES RELATED TO CAUSE OF AMPUTATION AND SEX ($N = 4,279$)

Cause	Males		Females		Total No. of Cases	Average Age (Years)
	No. of Cases	Average Age (Years)	No. of Cases	Average Age (Years)		
Congenital	265	3.7	206	3.2	471	3.5
Tumor	65	4.5	61	5.6	126	5.0
Disease	543	5.0	171	5.1	714	5.1
Trauma	2,608	6.7	256	7.1	2,864	6.8
Not reported	87	6.5	17	7.9	104	6.7
Total	3,568	6.2	711	5.4	4,279	6.1

had the shortest life, averaging 5.8 years for 2,201 amputations, and ranging from an average of 1.7 years for the child through age 10, to 8.6 years for amputees over 71 years of age.

In comparing ages of replaced prostheses by cause of amputation and the sex of the amputee, it is found that prostheses for congenital amputees had the shortest life, averaging 3.5 years, and prostheses for traumatic amputees had the longest life, averaging 6.8 years (Table 24). The growth rate of children in the congenital group undoubtedly accounts for the more frequent replacements of prostheses evident here. Replacement of prostheses for patients in the disease category occurred, on average, every 5 years, and there was very little difference between replacements for males and females. The life of prostheses for tumor patients also averaged 5 years; however, prostheses for males in this category needed more frequent replacement, lasting 4.5 years as compared with an average 5.6 years for females.

It is interesting to note that the age of replaced prostheses for males averaged 6.2 years, and that of females 5.4 years. The large number of males in the trauma category may account for this difference, inasmuch as the average life of prostheses in this category is longer than in others.

Table 25 indicates the reason for replacement of prostheses. The majority of prostheses were replaced because they were worn out. "Worn out" was listed as the sole or contributing cause of replacing

TABLE 25. REASONS FOR PROSTHESIS REPLACEMENT

Reason	Percentage of Times Cited, Singly or in Combination				
	Tumor	Congenital	Trauma	Disease	Total
Worn out	50	33	67	44	58
Outgrown	12	52	6	4	12
Unsatisfactory	6	5	4	4	4
Stump shrinkage	7	1	5	14	6
Weight loss	12	3	7	10	7
Weight gain	8	1	5	11	6
Change type of prosthesis	1	--	1	1	1
Provide two prostheses	1	1	1	--	1
Other	3	4	4	12	5

a prosthesis in 58 per cent of the cases. It was the leading reason for replacing prostheses of persons whose amputations were caused by tumor (50 per cent), trauma (67 per cent), and disease (44 per cent). As would be expected, the primary reason for replacing prostheses of congenital amputees was that the prosthesis was "outgrown." In 52 per cent of replacements for congenital amputees, the prosthesis was outgrown; in 33 per cent of the cases it was worn out.

"Unsatisfactory" was cited as the reason for replacement in four per cent of the cases. However, it should be noted that although the "unsatisfactory" category was meant to include only those cases in which problems arose relating to fabrication or patient tolerance, it was often cited for other reasons which rendered the prosthesis unsatisfactory. Had this item

TABLE 26. AVERAGE AGE OF "WORN OUT" PROSTHESES RELATED TO AMPUTATION LEVEL, 2,898 CASES

Level and No. of Cases	Average Age of Prosthesis (Years)
Above elbow (103)	10.0
Below elbow (236)	8.1
Above knee (893)	7.6
Below knee (1,489)	7.3
All other (177)	7.4
Total (2,898)	7.6

been interpreted correctly, the percentage undoubtedly would have been lower.

The average age of all "worn out" prostheses that were replaced was 7.6 years (Table 26). This exceeds the average age of prostheses replaced for any reason (6.1 years) by a year and a half. This higher age undoubtedly reflects the longer life of the prostheses of traumatic amputees reported above, since "worn out" was the sole or contributing factor for 67 per cent of the replacements in the trauma category. Additionally, the lower average age of all the replaced prostheses was affected by the inclusion of children's prostheses, which had shorter lives.

COMPONENTS FOR UPPER-EXTREMITY PROSTHESES

The components most frequently used for upper-extremity prostheses at the above- and below-elbow levels are depicted in Figure 12. The voluntary-opening hook was used with 87 per cent (201 instances) of the above-elbow prostheses and 90 per cent (517 instances) of below-elbow prostheses. The preference for this type of hook was reflected in all areas except the West, which showed a preference for the voluntary-closing hook with below-elbow prostheses. New England was the only area that did not prescribe the voluntary-closing hook at all.

The hand-type terminal device was utilized to a limited extent, being prescribed 309 times as opposed to the hook-type device which was prescribed 806 times. Many amputees for whom hooks were prescribed were also equipped with hands. Where hand-type devices were reported, the voluntary opening hand was prescribed for above-elbow prostheses 40 per cent of the time (36 cases) and for below-elbow prostheses 36 per cent of the time (79 cases). Both the East Central and Midwest areas preferred voluntary-closing hands for use with above-elbow prostheses. The East Central and Western areas preferred voluntary-closing hands for below-elbow prostheses. New England showed a preference for the passive hand with the below-elbow prosthesis.

The simple friction wrist unit was overwhelmingly preferred to quick-change types in all geographical areas, being used with 83 per cent of above-elbow and 85 per cent of below-elbow prostheses.

Although the triceps pad was used with 56 per cent of the below-elbow prostheses, its use ranged from 35 per cent in the South to 94 per cent in the New England area. The South preferred the half cuff. Plastic laminate was the cuff material of choice in 61 per cent of the total cases, although the East Central and Western areas preferred leather to the extent of 54 per cent and 55 per cent respectively.

The double-wall socket was used in 89 per cent of the above-elbow and 77 per cent of the below-elbow prostheses. Preflexed sockets, some of which also had double walls, were used in 11 per cent of the below-elbow prostheses. Sixty-one per cent of the preflexed sockets were utilized by children.

In 98 per cent of the upper-extremity prostheses, the sockets were made of plastic.

The elbow unit with internal lock was the item of choice for above-elbow prostheses in all geographical areas, being used in 78 per cent of all fittings. Seventeen per cent of all elbow units had spring-flexion assists. Sixty-four per cent of the elbow hinges used in below-elbow prostheses were flexible, the range being from 44 per cent in the West to 92 per cent in New England. The Midwest showed almost equal preference for the single-pivot (47 per cent) and the flexible hinge (50 per cent).

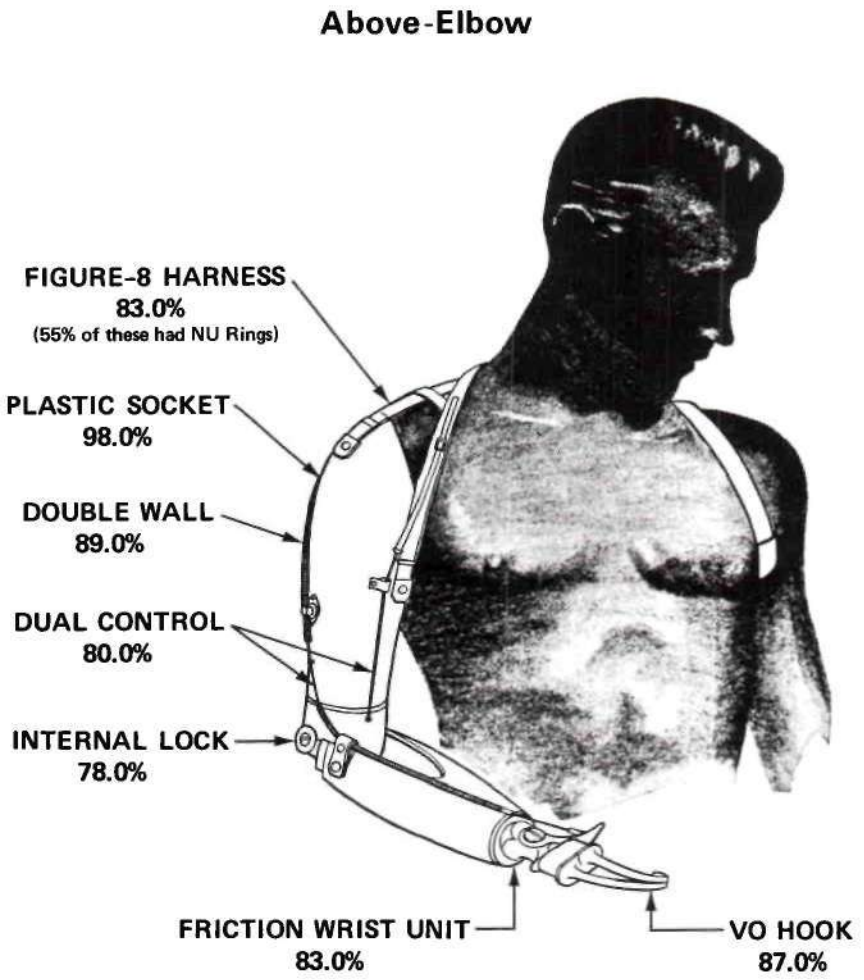


Fig. 12a. Most frequently used components for above-elbow prostheses.

Dual-control systems were used in 80 per cent of above-elbow and single control in 96 per cent of the below-elbow prostheses.

Eighty-three per cent of the harnesses for above-elbow prostheses were of the figure-eight type, the majority of this group (55 per cent) being equipped with the Northwestern University harness ring. The East Central area and the West showed a preference for the figure-eight harness without the ring. Of the 14 cases with reported type of harness in the West, none used the ring with the figure-eight. The South used the ring to the greatest extent for above-elbow prostheses. Ninety-two per cent of the below-elbow harness were of the figure-eight type, 59 per cent of these being equipped with rings. The East Central, South, and Midwest areas showed greatest preference for the ring figure-eight harness; the New England and Western areas used the figure-eight harness without the ring almost as often as with it.

COMPONENTS FOR LOWER-EXTREMITY PROSTHESES

Components most frequently used for above- and below-knee prostheses appear in Figure 13. The various geographical areas showed more consistency in pre-

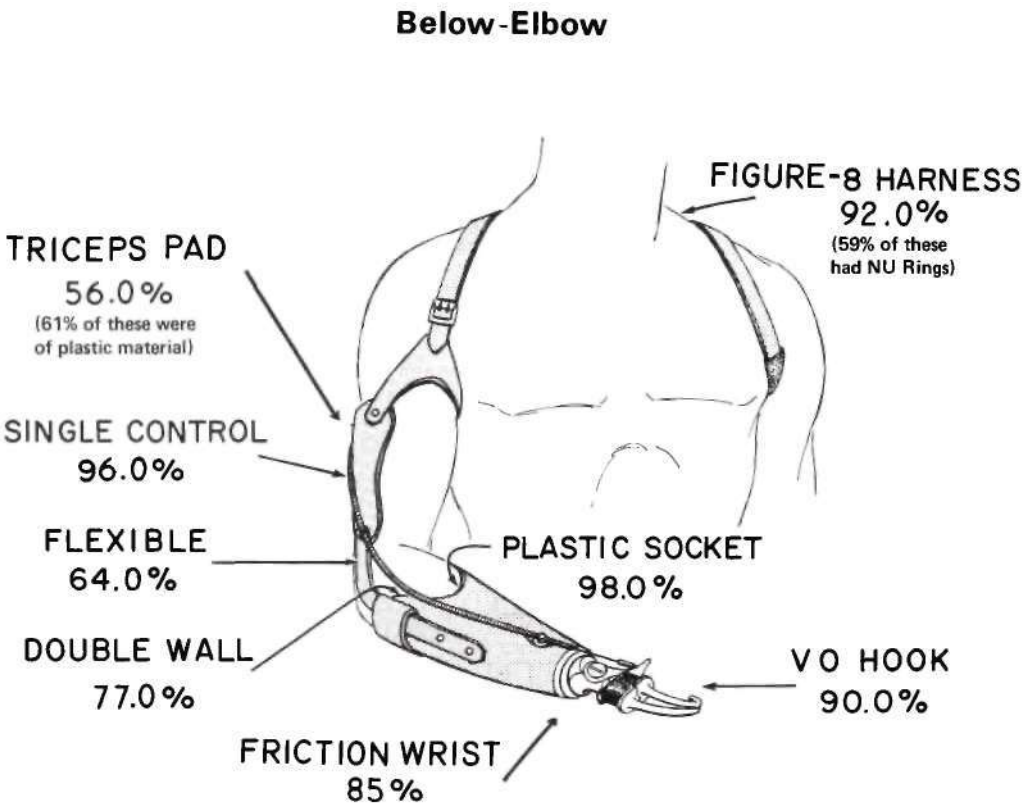


Fig. 12b. Most frequently used components for below-elbow prostheses.

scription of lower-extremity than upper-extremity components. In most instances, only the percentage varied, not the type of component.

The SACH foot was prescribed for 55 per cent of the above-knee and 73 per cent of the below-knee prostheses. In area comparisons, the South showed the greatest usage of the SACH foot, and the Midwest the lowest. For the above-knee prosthesis, prescription of the SACH foot rose from 76 per cent in the first to 83 per cent in the second decade, and then gradually declined with advancing amputee age. In the below-knee group, the SACH foot was prescribed 96 per cent of the time for children under 10 years of age; the percentage declined steadily to a low of 56 per cent in the eighth decade, then rose to 63 per cent for the group of amputees 81 years of age and over.

Wood was used as the shank material in 95 per cent of the above-knee and in 90 per cent of the below-knee prostheses.

The most frequently used knee component for above-knee prostheses was the single axis, with friction being used in 74 per cent of the fittings. Twelve per cent of the knees were single axis with manual locks. Eight per cent of the knees were hydraulic, with the West showing the greatest preference (17 per cent) and the Midwest the least (4 per cent). In instances where metal joints were reported for below-knee prostheses, the lap joint was specified in 48 per cent of the cases and the clevis joint in 22 per cent. The type of joint was not specified in 30 per cent of the cases.

For above-knee amputees, the quadrilateral socket was used in 85 per cent of the prostheses. It was the overwhelming

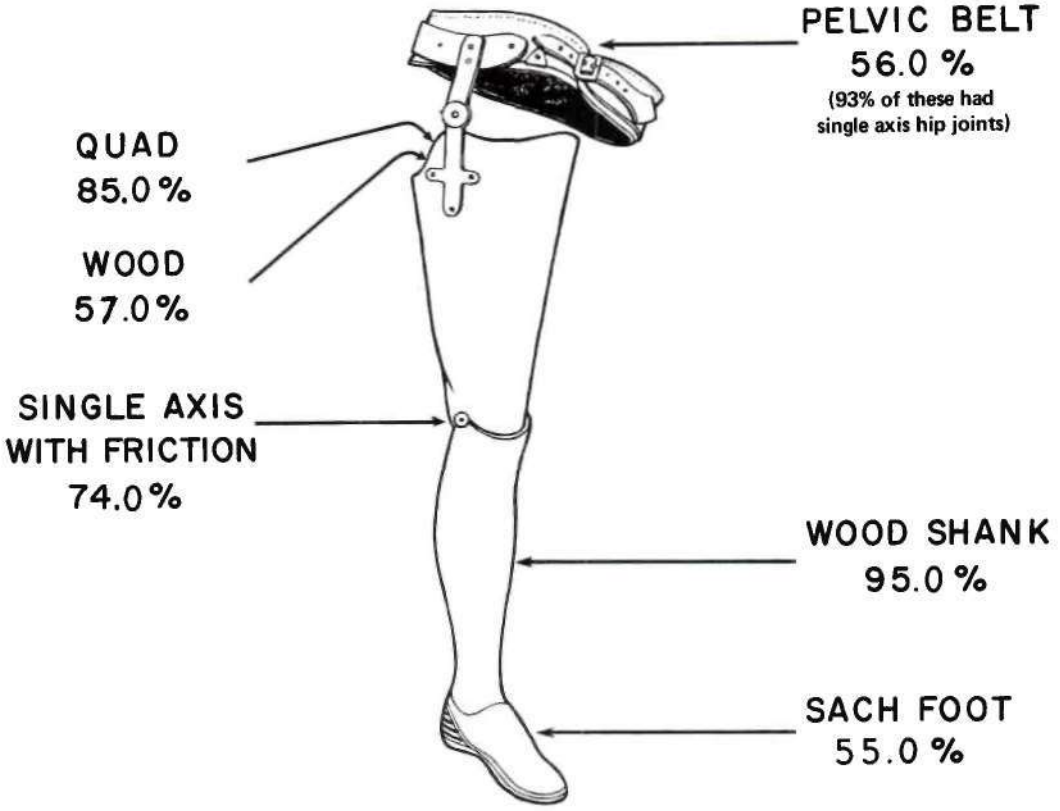


Fig. 13a. Most frequently used components for above-knee prostheses.

choice in each of the geographical areas. The socket of choice for below-knee amputations was the patellar-tendon-bearing. Preference for this socket averaged 58 per cent, the South and West showing greatest utilization, 79 per cent and 82 per cent respectively, and the New England and Midwest areas the least utilization, 44 per cent and 47 per cent respectively.

Wood was used most often for above-knee sockets, averaging 57 per cent, although the South showed a preference for plastic, using it for 55 per cent of all sockets. Below-knee sockets were most often (55 per cent) fabricated in plastic. New England showed a preference for leather sockets, and the Midwest preferred wood (41 per cent) to either plastic or leather.

The pelvic belt was the preferred method of suspension (56 per cent) for above-knee prostheses. Only in the West did the use of suction, either alone or in combination with other suspension, exceed the use of the pelvic belt. In correlating methods of suspension with age, it was noteworthy that during the second, third, and fourth decades, suction alone was preferred to all other types of suspension. In all other decades, the pelvic belt was preferred.

In considering types of suspension reported for all below-knee prostheses, the knee cuff alone was the choice of suspension in 36 per cent of the cases. It was least used in the Midwest (22 per cent). The South and West utilized the knee cuff alone most frequently (55 per cent). When type of suspension for the patellar-tendon-bearing prosthesis is analyzed by age group, it is found that, while the knee cuff alone was used for 62 per cent of all

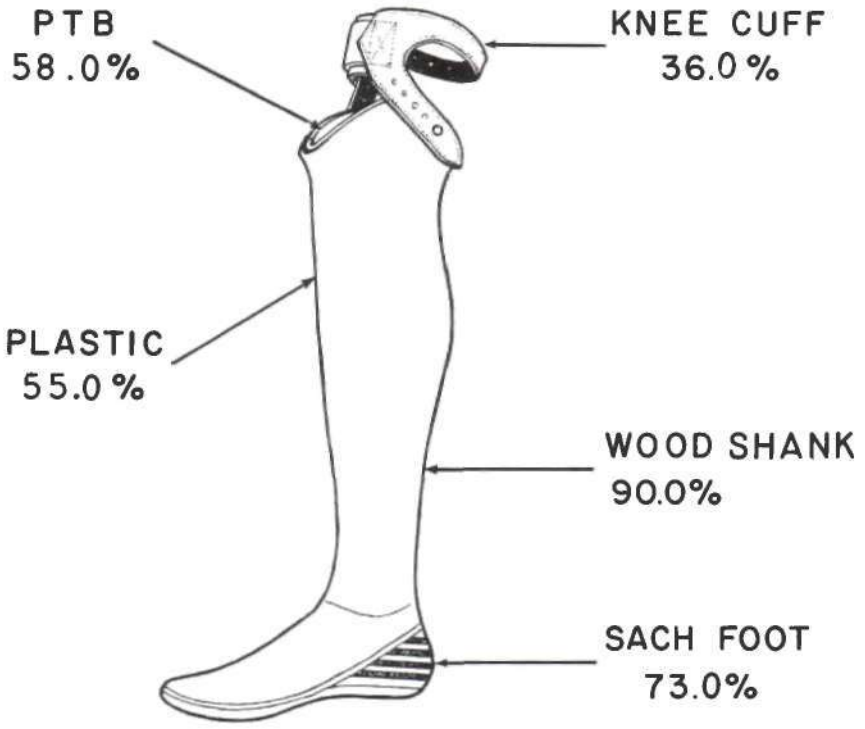


Fig. 13b. Most frequently used components for below-knee prostheses.

the prostheses, greatest usage occurred in the second decade (73 per cent) and next greatest in the third decade (71 per cent). Least use of the knee cuff alone occurred in the very young child (48 per cent), but the inclusion of cases where a waist belt was used in conjunction with the knee cuff raised this percentage to 68.

SOURCES OF PAYMENT

Tables 27, 28, and 29 indicate the sources of payment for prostheses. More than one source was sometimes listed, in which case they are reported under "combinations of the above "or" "other". Medicare had been in operation only one year prior to the conclusion of this study and presumably would rank considerably higher as a source of payment at the present time. As mentioned earlier, over 23 per cent of the amputees in this study were in the Medicare age bracket.

Source of payment was given for 8,631 prostheses (Table 27). The greatest contributors to defraying the costs of prostheses were State Bureaus of Vocational Rehabilitation (22.5 per cent) and the patient himself (22.8 per cent). Next in order were the Veterans Administration (14.3 per cent), welfare (10.8 per cent) and insurance (9.9 per cent).

The Children's Bureau paid for 46.5 per cent of the prostheses for children up to the age of 21. Through the wage-earning years, 21 to 64, State Bureaus of Vocational Rehabilitation paid for 31.9 per cent of the prostheses, the amputee for 24.3 per cent, and the Veterans Administration for 19.3 per cent. During the retirement years, 65 and over, the amputee alone paid for 29.9 per cent of the prostheses, Social Security and Medicare for 19.5 per cent, and welfare for 15.3 per cent.

A further analysis of sources of payment relating to the wage-earning years yields some interesting facts (Table 28). The Veterans Administration paid for 30 per

TABLE 27. SOURCE OF PAYMENT FOR PROSTHESES BY AGE GROUP
($N = 8,631$)

Source of Payment	Age Group: Number of Cases and Percentage of Category Total				Total
	Age Not Reported	Children	21–64 Years	65 and Older	
Self	31	28 (2.5)	1,317 (24.3)	592 (29.9)	1,968 (22.8)
Bureau of Vocational Rehabilitation	21	49 (4.3)	1,729 (31.9)	145 (7.3)	1,944 (22.5)
Veterans Administration	16	6 (0.5)	1,044 (19.3)	172 (8.7)	1,238 (14.3)
Welfare	10	200 (17.7)	416 (7.7)	302 (15.3)	928 (10.8)
Insurance	13	70 (6.2)	681 (12.6)	90 (4.5)	854 (9.9)
Children's Bureau	6	525 (46.5)	13 (0.2)	--	544 (6.3)
Social Security (Medicare)	4	--	10 (0.2)	386 (19.5)	400 (4.6)
Family	1	190 (16.8)	39 (0.7)	27 (1.4)	257 (3.0)
Combinations of above and "other"	--	62 (5.5)	170 (3.1)	266 (13.4)	498 (5.8)
Total	--	1,130	5,419	1,980	8,631

TABLE 28. SOURCE OF PAYMENT ("OLD" AND "NEW" PROSTHESES) FOR THE 21–64 WAGE-EARNING YEARS

Source	Males			Females		
	"Old" (%)	"New" (%)	Total (%)	"Old" (%)	"New" (%)	Total (%)
Bureau of Vocational Rehabilitation	32	28	31	43	34	38
Veterans Administration	30	10	23	1	1	1
Self	23	22	22	39	35	37
Insurance	8	24	14	2	7	5
Welfare	5	10	7	8	13	11
Combinations of above and "other"	2	6	3	7	10	8

TABLE 29. SOURCE OF PAYMENT RELATED TO EMPLOYMENT DURING THE 21–64, WAGE-EARNING YEARS ("OLD" CASES ONLY)
($N = 3,055$)

Source	Gainfully Employed		Not Gainfully Employed		Other	
	No.	%	No.	%	No.	%
Bureau of Vocational Rehabilitation	830	35	52	28	134	28
Veterans Administration	668	28	51	27	78	17
Self	599	25	17	9	145	31
Insurance	180	7	18	10	23	5
Welfare	68	3	45	24	60	13
Combinations of above and "other"	55	2	4	2	28	6
Total	2,400		187		468	

cent of replacement prostheses, but only 10 per cent of new prostheses. This statistic doubtless reflects the continuing supply of prostheses to veterans of World War II and the Korean War and a decreased number of fresh cases. More "new" male amputees were supported by insurance or compensation than "old" male amputees, 24 per cent as opposed to 8 per cent. This may reflect the policy of some insurance companies to pay for the first prosthesis only. On the other hand, it may indicate an increase in opportunity for insuring oneself against disability and a greater awareness of the values of health insurance. In comparing source of payment for males and females in this age group, one notices the higher level of support by the amputees themselves and the Bureaus of Vocational Rehabilitation for the female group, and also the very low percentage of females supported by insurance or compensation.

In correlating source of support with occupation, only "old" amputees were considered, since in most instances "new" amputees had not yet returned to work at the time the data forms were submitted. Amputees were studied in three categories: those gainfully employed, those not gainfully employed, and those who were students, housewives, or retired (Table 29).

Of the 3,055 "old" cases included above, only 187, or 6 per cent, were reported as not being gainfully employed. The Bureaus of Vocational Rehabilitation paid for 35 per cent of the prostheses for the gainfully employed group, the Veterans Administration for 28 per cent, and the amputee for 25 per cent. For the group of amputees not gainfully employed, the Bureaus of Vocational Rehabilitation were the source of payment for 28 per cent of the prostheses, the Veterans Administration for 27 per cent, and welfare for 24 per cent. In the 468 amputations of students, housewives, or retired amputees, 31 per cent of the prostheses were paid for by the amputee, 28 per cent by the Bureaus of Vocational Rehabilitation, and 17 per cent by the Veterans Administration.

DISCUSSION

In recent years, there has been increasing interest in defining the characteristics of the amputee population, and also in providing amputees with functional stumps and prostheses. Much progress has been made in understanding the amputee and his problems, and in the fabrication of improved prosthetic components. This study has sought to document some of the characteristics of the amputee and his prosthesis during a particular period in time—the approximately two years ending June 30, 1967.

Certain characteristics of amputees, namely sex and age, and the cause, side, and site of amputation, were well established in Glattly's study of 12,000 new amputees for whom data were collected over a two-year period, ending in 1963. In the present study of over 8,000 amputees, 4,034 of whom were new, data were likewise collected over a two-year period which ended in 1967, four years later. Unless some catastrophic event had occurred immediately before or during either of the two periods, it would be expected that in large samples such as these, the sex and age of the amputee and side and cause of the amputation would be relatively constant. Such was indeed the case, indicating that the sample in the latest study was a valid cross-section of the amputee population. As noted before, neither the Medicare Act nor the conflict in Vietnam had exerted a significant impact on this study. Although medical advances over a number of years have been largely responsible for the increasing age of the amputee, with a resulting shift from trauma to disease as a predominant cause of amputation, such changes would not be expected to exert a significant difference in as short a period as four years.

In amputations caused by disease, the site of amputation can be influenced by

medical judgment at a particular time. In the vast majority of cases where amputation is categorized as disease, the amputees had vascular insufficiency. For this condition, amputation at a level above the knee had been widely advocated for many years because it was felt that this procedure facilitated healing. It has been found, however, that amputation may be performed at a below-knee level, with primary healing occurring in the majority of cases (6). By preserving the knee joint, amputation at this level greatly enhances the rehabilitation potential of the patient.

Burgess has reported that most below-knee amputations for ischemia heal primarily, and with proper prosthetic care do not break down (7). Lim reports that 92 per cent of below-knee amputations were successful when a popliteal pulse was present, and 75 per cent were successful when pulse was absent (5). He also reports a lower mortality rate for below-knee amputees, 16 per cent as opposed to 35 per cent for above-knee amputations. Tracy cites a 90 per cent successful healing rate for below-knee amputations for ischemic gangrene *(8).*

Although the increase in the percentage of below-knee amputations in our study, as compared with the Glattly study, is relatively small in view of the *potential* increase, it is nevertheless an encouraging trend, and it is to be hoped that a dramatic increase will be reflected in future surveys as the results of ongoing educational programs take effect.

Although the incidence of amputations due to trauma appears to have declined, as far as percentage of the total amputee population is concerned, this does not necessarily imply a decrease in the overall incidence of traumatic amputations. Actually, the increasing age of amputees, with its corollary of increasing incidence of amputations due to disease, is certainly partly responsible for the decline in percentage of trauma cases. In the younger age groups, trauma continues as the major cause of amputations. The Public Health Service report *(9)* published in 1964 shows that "absence of major extremity," classified as an accident "while at work," occurred almost three times as often as amputation caused by "moving motor vehicles." In the present study, the ratio was closer to 1:1 than 3:1, i.e., moving vehicles as a cause of traumatic amputations was almost equal to that of industrial accident. A higher percentage of auto accidents than industrial accidents occurred in the female group, a pattern which is typical of other reported findings. These results may indicate improved safety controls in industry, or may underscore the soaring rate of automobile accidents, or both. The large number of amputations resulting from trauma continues to have strong implication for improved accident-prevention programs and more effective human-factors engineering. The need for greater safety of design, particularly in cars and industry, continues to be great.

It is of interest to note that prosthetic prescription varied among the geographical areas, some areas having a greater tendency than others to incorporate newer prosthetic techniques. It might be expected that the latest prosthetic developments would be incorporated into prosthetic practice in those areas which were near the prosthetic—orthotic educational centers (New York, Chicago, and Los Angeles) or in areas of greatest concentration of prosthetic facilities (California, Pennsylvania, New York, and Illinois), or amputee clinics (New York, Pennsylvania, California, and Texas). With the exception of the West, where newer developments were used in a high percentage of cases, there appeared to be no relationship between the nature of prosthetic services provided and the factors cited above. Both the South and the West showed a more consistent use of newer techniques than did the other areas.

The provision of prosthetic services reported in the study indicates that much improvement is to be desired as far as length of time for delivery of the prosthesis is concerned. The time between

the date of amputation (or reamputation) and delivery of the prosthesis was inordinately long, ranging from a median of four months for patients whose amputations were caused by tumor to six months for patients with vascular disease. The provision of temporary prostheses and immediate postsurgical fitting of prostheses would help shorten this time lag.

The finding that a relatively high percentage of congenital amputees (32 per cent) were not fitted until after their eleventh birthday is distressing. Since current philosophy is to fit congenital amputees at a very early age, it would be interesting to know the reason for this reported delay. Whether the fault lies with amputee clinics, or with parents who are either reluctant to take their children to clinics or are ignorant of the prosthetic opportunities available to them, is not evident from the present analysis. The implication is that more needs to be done at the educational level. The growth and implementation of dynamic treatment programs would surely result in a much more optimistic picture.

A composite picture of amputees reported in this study would present the following profile:

1. The congenital amputee seen in prosthetic facilities was a male under 10 years of age with involvement at the below-knee level.

2. The amputee whose amputation was caused by tumor was a male between 11 and 20 years of age whose amputation was at the above-knee level.

3. The traumatic amputee was a male now between the ages of 41 and 50 years who had received his amputation between the ages of 21 and 30 years. His amputation was at the below-knee level and was most likely received as a result of a car accident, industrial accident, or war injury.

4. The amputee whose amputation was caused by disease was also a male, between the ages of 61 and 70 years, who was amputated during these same years. His amputation was as likely to be at the above-knee level as at the below-knee level.

SUMMARY

1. This study, which extended over a two-year period ending in June 1967, presents data on 8,323 amputees with 8,698 amputations, all of whom were fitted with prostheses.

2. Of the "new" amputations seen in prosthetic facilities, 60 per cent were caused by disease, 29 per cent by trauma, 6 per cent by tumor, and 5 per cent were of congenital origin.

3. Of all amputations, "new" and "old," being fitted in prosthetic facilities, 50 per cent were caused by trauma, 37.3 per cent were caused by disease, 8.4 per cent were of congenital origin, and 4.3 per cent were caused by tumor.

4. The greatest incidence of disease-caused amputations occurred in the seventh decade, those of trauma in the third decade, and those of tumor in the second decade.

5. Males outnumbered females in every category, the ratio for "new" amputations of males to females being approximately 2:1 for disease, 10:1 for trauma, and 1.2:1 for both congenital causes and tumor.

6. Eighty-six per cent of the total number of amputations were of the lower extremity, with 53 per cent of this group being at the below-knee level.

7. Although automobile accidents were cited as the single greatest cause of all traumatic amputations, war injuries, industrial accidents, and automobile accidents were cited almost equally for male amputees.

8. Forty-eight per cent of all reamputations were in the disease category, 60 per cent of these occurring within two and one-half months of the original amputation. The reamputation rate for below-knee amputations caused by disease was not significantly higher than that for trauma-caused amputations—approximately 6 per cent in both instances.

9. Degree of contracture reported at both hip and knee varied inversely with

the length of the stump. Excluding contractures of less than 5 deg, the average hip flexion contracture for above-knee amputations was in the 5-9 deg range; the average knee flexion contracture for below-knee amputations fell in the 10-14 deg range. Fifty-two per cent of those cases reporting presence or absence of contractures had either no contracture or one of less than 5 deg.

10. Unemployment rate for "old" male amputees between the ages of 21 and 64 was 6.4 per cent, slightly higher than the national average for the years covered by the report.

11. Fifty-eight per cent of patients were referred to prosthetic facilities by amputee clinics, 26 per cent by physicians, and 16 per cent were not referred.

12. The median time from amputation to delivery of a prosthesis was six months, the below-knee prosthesis being delivered in the shortest length of time. Congenital amputees who required surgery received prostheses in a median time of three months postsurgery. Patients in the disease category waited the longest time—six months.

13. Prostheses had an average life of 6.1 years, with the life of the prosthesis increasing with the age of the patient. Below-knee prostheses generally and prostheses for congenital amputees had the shortest life. Prostheses for males lasted longer than those for females. "Worn out" was the primary reason given for replacing a prosthesis.

14. Prosthetic prescription varied in the geographical areas, some regions demonstrating a greater tendency than others to incorporate newer prosthetic techniques. Generally, as the age of the amputee advanced, there was a tendency to use the older types of components, e.g., pelvic hands, articulated ankles.

15. The Children's Bureau was the largest single source of financial support for the purchase of prostheses for children, and the State Bureaus of Vocational Rehabilitation provided the greatest financial support for amputees during the wage-earning years. The Veterans Administration paid for a high percentage of prostheses for males who were in the "old" category. In all, the federal government paid entirely for 48 per cent of all prostheses and provided partial support for another 3 per cent.

ACKNOWLEDGMENTS

Grateful appreciation is extended to the 44 facility owners and their staffs who provided the data on which this study is based.

REFERENCES

1. Burgess, Ernest M., The below-knee amputation, *Bull. Pros. Res.*, 10-9:19-25, Spring 1968.
2. Davies, E. J., B. R. Friz, and F. W. Clippinger, Jr., Children with amputations, *Inter-Clinic Inform. Bull.*, 9:3:6-19, December 1969.
3. Friz, Barbara R., and Frank W. Clippinger, Jr., The facility case record study: a preliminary report, *Orth. and Pros.*, 23:1:8-17, March 1969.
4. Glattly, H. W., A statistical study of 12,000 new amputees, *Southern Med. J.*, 57:1373-1378, November 1964,
5. Lim, R. C, Jr., et al.. Below-knee amputation for ischemic gangrene, *Surg. Gynec. Obstet.*, **125:** 493-501, September 1967.
6. Sarmiento, A., and W. D. Warren, A re-evaluation of lower extremity amputations, *Surg. Gynec. Obstet.*, 129:799-802, October 1969.
7. Taft, C. B., and S. Fishman, Survival and prosthetic fitting of children amputated for malignancy, *Inter-Clinic Inform. Bull.*, 5:5:9-28, February 1966.
8. Tracy, G. D., Below-knee amputation for ischemic gangrene, *Pacif. Med. Surg.*, 74:251-253, September-October 1966.
9. U. S. Department of Health, Education, and Welfare, Public Health Service, *Impairments due to injury by class and type of accident, United States, July 1959—June 1961*, Washington, D.C., 1964.

Artificial Limbs, Vol. 14. No. 2. pp 49-57. Autumn 1970

The Use of External Support in the Treatment of Low Back Pain

JACQUELIN PERRY. M.D.[1]

1 HE origin of therapeutic procedures can generally be traced to local efforts directed toward resolving continuing disability of the patient. In the treatment of low back pain, this approach often included designing special supports by individual physicians and orthotists. Such independent activity in numerous locales resulted in a long list of brace designs, many of which carry impressive eponyms that tend to stress differences rather than elements of commonality.

To compile the available information concerning bracing, the American Academy of Orthopaedic Surgeons published the *Orthopaedic Appliances Atlas (1)* in 1953. Of the 30 types of spinal support described in that volume, 17 were specifically designed for the sacroiliac or lumbosacral areas. Ten years later, in 1962, a survey of orthopedic services in the United States by Nattress and Litt (2) identified 30 braces, of which 22 corresponded to the design customarily considered effective at the lumbosacral region. These two reports, along with the present study, described a total of 40 different devices designed for low back problems.

Details of designs are readily available, but objective criteria to weigh the relative merits of the different devices are almost nonexistent. As a consequence, physicians generally make their selection either by adopting the customs observed during their training, or by accepting the preference of the local orthotist. Undoubtedly, some braces have withstood the test of time, while others have become items only of historical interest. Superimposed on this background, the more recent introduction of prefabricated parts for brace construction has probably influenced the frequency with which certain types of braces are prescribed.

The extent to which these influences have altered the availability and prescription of brace designs today has not been reported. Also unknown is the nature of the relationship between the etiology of the low back pain and the type of support that clinicians have found to be effective. Identification of this type of information is pertinent because the subject of orthotics is now being presented in formally organized courses on a nationwide basis.

This paper records the results of a three-phase study conducted in 1968-69 by the Subcommittee on Orthotics, Committee on Prosthetic-Orthotic Education (CPOE) of the National Research Council. Approval of the Executive Committee of the American Academy of Orthopaedic Surgeons was obtained. The purpose of the survey was to identify the current practices of orthopedic surgeons with respect to external supports for the management of low back pain.

METHOD

PILOT STUDY

An unstructured pilot questionnaire was sent to 150 orthopedic surgeons selected because of their considerable experience in the management of low back pain. They were asked to list the types of support they prescribed, and to indicate the clinical conditions for which each support

' Chief, Kinesiology Service, Rancho Los Amigos Hospital, Downey, Calif.; Associate Clinical Professor of Orthopaedic Surgery, University of Southern California School of Medicine, Los Angeles.

was chosen. The results of this pilot study formed the basis for the next phase of the investigation.

The 90 physicians (60%) who responded were explicit in their choice of a device and the clinical indication for its use. Eighty-three reported frequent prescription of external support as part of their therapeutic program. (Two said they never used external supports, and five indicated they rarely prescribed such aids.)

Within each class of support (brace, corset, cast), a similar pattern of practice was evident. Numerous designs were listed, but most were mentioned only occasionally. The majority of the respondents preferred one or two types of support. Within a total of 12 different braces reported, three-fourths of the physicians listed the Chairback (Knight) and Williams braces (Figs. 1, 2, and 3). Six other designs were mentioned only once. Identification of corset preference was a bit clouded by the indiscriminate use of both generic and trade names. The generic term "lumbosacral" was specified by half of those responding. An additional one-fourth of the pilot-study participants used trade names such as Camp, Spencer, and Winchester. The next most frequently mentioned device was the sacroiliac belt (8%). Of the six casts identified, the flexion jacket was preferred by more than half of the pilot-study orthopedists; the second choice was the body jacket (19%).

In designating the clinical conditions warranting external support, two response patterns developed in the pilot survey. Seven types of disability were mentioned frequently and in explicit terms, viz., postoperative fusion, spondylolisthesis, chronic backache, acute strain, disc syndrome, degenerative joint disease, and the postoperative disc. Several other conditions, identified by a wide variety of terminology, were mentioned with moderate to rare frequency.

NATIONAL SURVEY OF AAOS

The findings of the pilot survey were used to construct a questionnaire applicable for a comprehensive national study. This questionnaire was sent to the membership of the American Academy of Orthopaedic Surgeons (AAOS). The form (presented at the end of this article) was a check sheet on which physicians were asked to match the types of support they prescribed with the clinical conditions they treated in this manner.

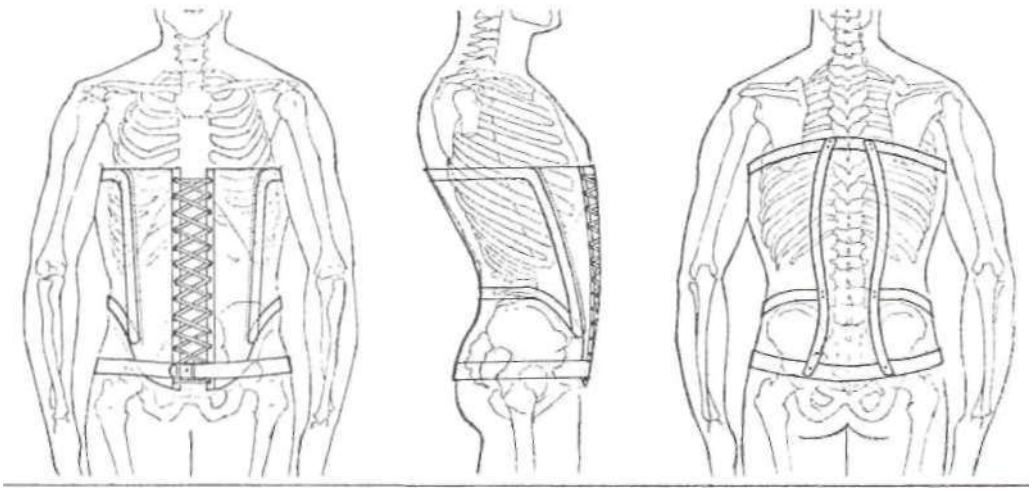


Fig. 1. The Knight dorsolumbar brace.

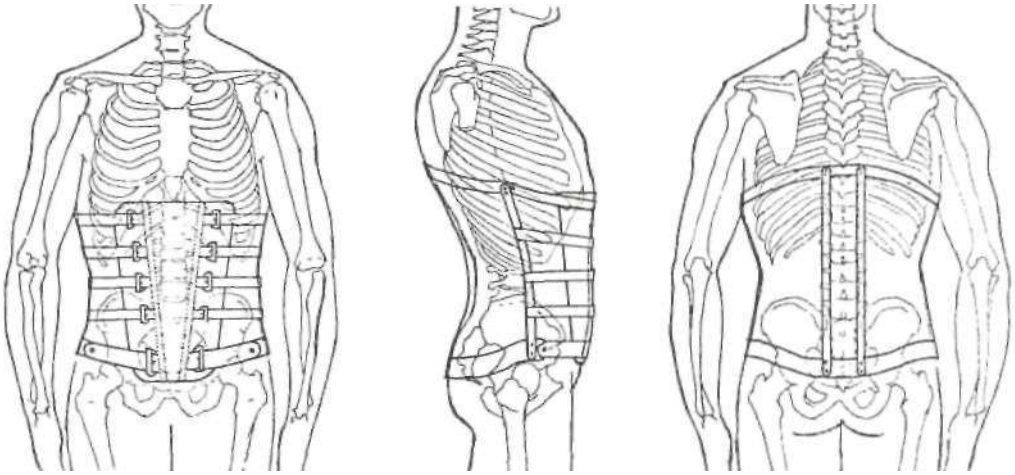


Fig. 2. A typical modification of the Knight brace.

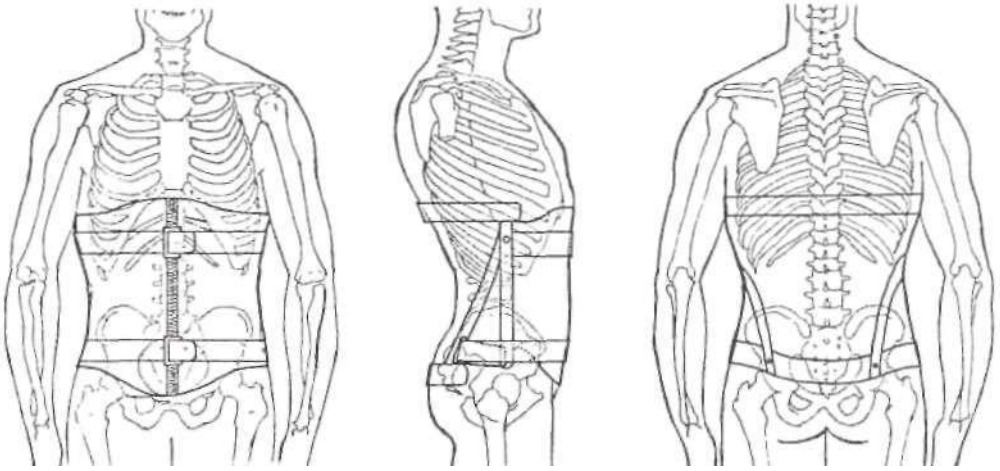


Fig. 3. The Williams lumbosacral brace. (Illustrations from *Orthotics for Physicians and Therapists,* Prosthetic-Orthotic Education, Northwestern University Medical School, Chicago, HI.)

The following supports, all of which were more than rarely mentioned in the pilot study, were included. (The restriction on corset choice was the result of a decision to use generic rather than trade names in order to avoid repeating the confusion produced in the pilot study.)

Braces

1. Chairback (Knight)
2. Williams
3. Norton-Brown
4. Goldthwaite
5. Bennett

Corsets

1. Lumbosacral
2. Sacroiliac

Casts

1. Flexion
2. Body jacket
3. Cast with one leg

Eleven clinical conditions were selected for the national inquiry, based upon the

returns of the pilot study and upon the clinical experience of the NRC committee. Provision was made throughout for physicians to indicate devices or clinical problems other than those listed on the form. The questionnaire was also designed to indicate the relative frequency ("usually" or "rarely") of the prescriptions.

SURVEY OF THE FUNCTIONS OF SUPPORT

Late in 1968, a second national survey was conducted among the AAOS membership to determine prevailing opinions about the functions of the various types of support. The purpose of this phase of the study was to attempt to relate the anticipated function of the external support to the different preferences in prescription.

Profiting from the findings of part one of the national survey, the list of supports was again shortened. This time, the orthopedists were queried about two braces (Williams and Chairback [Knight]); "corset" was listed as a single category, as were the flexion casts. A miscellaneous category was added for other comments. (The questionnaire appears on page 57.)

Six probable functions were selected for study. These included: immobilization of the spine, restriction of lumbosacral motion, unloading of the intervertebral disc, support of the abdomen, correction of posture, and psychological effect. As always, there was a provision for other choices.

RESULTS

On the first national survey, 5,215 questionnaires were mailed. With the aid of one follow-up, 3,140 (60%) were returned completed. An additional 1% of the returns were incomplete because the physicians had retired or their practices did not include patients with low-back problems.

In the second phase of the study, the same number of forms were sent out, with 2,192 (42%) being filled in and returned. No follow-up mailing was conducted,

Annotated responses or explanatory letters accompanied 1,034 (33%) of the questionnaires. These consisted of: (*a*) identification of the type of device they preferred if it was not specifically mentioned on the form; *(b)* comments regarding precise fitting or construction characteristics considered to be important; (*c*) reasons for not prescribing external support; and (*d*) other modes of treatment which should accompany use of a support.

USE OF SUPPORTS FOR LOW-BACK PROBLEMS

Most of the orthopedic surgeons indicated use of a judicious selection of braces, casts, and corsets; the average physician reported that he used three different devices in his practice. A small group stated that they used only one type of device: a brace (4%), a corset (4%), or a cast (1%). Only 14 respondents stated that they "never used support" for the patient with a low-back problem.

Among the clinical indications, the inclusion of the term "fracture" caused considerable confusion in the information collected. Either all types of braces are used for fractures in the "low back," or the orthopedist's attention was directed to fractures of the spine in general. The latter seemed highly probable, as most indicated that a brace other than those listed was used. Typically, these were the Jewett, Taylor, and Baker types, commonly used for lesions in the thoracic and thoracolumbar areas. As the extent of this confusion could not be identified, all data referring to "fracture" were omitted from the analysis.

Certain characteristics in the prescription of external support became evident. A majority of the profession used the same groups of devices. The nature of the disability dictated the frequency of prescription as well as the type of support preferred.

SUPPORT PREFERENCE

The lumbosacral corset is the most popularly used low-back support, followed by the Chairback (Knight) spinal brace. Utilization of the other types of

support fell far behind these two leaders (Table 1).

The degree of dominance by the lumbosacral corset varied with the method of comparison; 28.5% of the physicians indicated use of the lumbosacral corset for at least one condition. When all clinical indications were considered, preference for the lumbosacral corset was 44.2%. The Chairback brace was used by 21% of the physicians for 22% of the clinical conditions listed. All other types of support were used less than 9% of the time. The Williams brace was third in popularity. A variety of casts preceded any other choice of brace or corset (Table 1).

As "lumbosacral corset" is a generic term that overlooks design differences between the Camp, Winchester, Spencer, and other specific corset styles, a comparison was made with the designated preferences for the total group of "low-back braces." The relative preference between the corset and the low-back brace again depended on the method of comparison. The use of a brace at some time was indicated by 40.2% of the physicians, in comparison to 32.4% for corsets. However, when all the clinical indications were totaled, the preference reversed, with the corsets dominating (46.7% in contrast to 39.0% for braces).

Some geographic patterns for brace preference were found, especially for those used less frequently (Table 2). The middle and southeastern sections of the United States were the only areas where the Williams brace was used widely; it was fourth in preference on the West coast. With the exception of New York, no mention of it was made in the eastern or New England states. The Bennett brace was second in popularity in Maryland and third in Ohio. Predominance of the Norton-Brown *(3)* brace was restricted to Massachusetts and Maine, a note consistent with the fact that the originators are from Boston.

TABLE 1. SUPPORT PREFERENCE

Support	By Individual Physician (% Response)	For All Clinical Indications (%)
Lumbosacral corset	28.5	44.2
Chairback (Knight) brace	21.1	22.4
Williams brace	9.9	8.3
Body cast	9.2	6.3
Flexion cast	8.4	5.0
Body cast + 1 leg	6.0	2.6
"Other" braces	5.6	3.7
Goldthwaite brace	2.4	1.4
"Other" corsets	2.3	1.3
Bennett brace	2.1	1.9
Norton-Brown brace	1.5	1.3
Sacroiliac corset	1.6	1.2
"Other" casts	1.2	0.5

TABLE 2. SUPPORT PREFERENCE BY STATES

Support	Number of States with this Level of Preference		
	First	Second	Third
Lumbosacral corset	43.5[a]	5.5[a]	1
Chairback (Knight)	6.5[a]	35.5[a]	3
Williams	0	3.5[b]	19.5[b]
Body cast	0	1	10
Flexion cast	0	2	7
Bennett	0	1	1
Norton-Brown	0	0	2
"Other" braces	0	1	2

[a] Three states showed equal preference for the lumbosacral corset and Chairback brace, thus this value was divided between both columns.

[b] One state showed equal preference for the Chairback and Williams braces as second choice.

CLINICAL INDICATIONS

The survey form asked the physician to check whether he rarely or usually used some type of support for each of ten clinical conditions listed (Table 3). Three patterns of use were apparent. The responding physicians seldom used external support in the treatment of an acute strain (17%), for an obese person with pain (19%), or during the postoperative period following disc surgery (28%). When support was used for these conditions, it was generally a corset.

At the other extreme, most physicians used support following spine fusion (84%), for treatment of spondylolisthesis (70%), and for pseudoarthrosis (66%). In these in-

TABLE 3. EXTERNAL SUPPORT PREFERENCE BY CLINICAL ENTITY

Clinical Entity	Total Listing	Frequency of Use		Support Preference		
		Rarely (%)	Usually (%)	Brace (%)	Corset (%)	Cast (%)
Postoperative fusion	3590	16	84	51	20	29
Spondylolisthesis	3472	30	70	59	33	28
Pseudoarthrosis	2784	34	66	57	28	15
Preoperative trial	2523	46	54	37	25	38
Disc syndrome	3164	49	51	34	51	15
Chronic backache	2635	52	48	29	67	4
Degenerative joint disease	2818	52	48	32	64	4
Postoperative disc	1677	72	28	31	65	4
Obesity and pain	1453	81	19	13	84	2
Acute strain	1552	83	17	14	77	9

TABLE 4. BRACE PREFERENCE BY CLINICAL ENTITY, ANALYSIS OF 7,142 RESPONSES

Clinical Entity	Number and Percentage of Listings													
	Chairback		Williams		Norton-Brown		Goldthwaite		Bennett		Other		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Postoperative fusion	845	11.9	153	2.2	65	0.9	45	0.6	51	0.7	157	2.0	1,316	18.3
Spondylolisthesis	856	12.0	396	5.6	46	0.6	56	0.8	72	1.0	84	1.0	1,510	21.0
Pseudoarthrosis	769	10.8	150	2.1	49	0.7	38	0.5	49	0.7	98	1.4	1,153	16.2
Preoperative trial	403	5.7	141	2.0	25	0.4	20	0.3	37	0.5	51	0.7	677	9.6
Disc syndrome	338	4.8	305	4.3	29	0.4	28	0.4	30	0.4	52	0.7	782	11.0
Degenerative joint disease	378	5.3	120	1.7	15	0.2	32	0.5	36	0.5	76	1.0	657	9.3
Chronic backache	215	3.0	120	1.7	13	0.2	23	0.3	19	0.3	43	0.6	433	6.1
Postoperative disc	187	2.6	63	0.9	20	0.3	9	0.1	15	0.2	39	0.4	333	4.5
Obesity and pain	45	0.6	47	0.7	5	0.1	10	0.1	6	0.1	21	0.3	134	1.9
Acute strain	62	0.9	30	0.4	8	0.1	6	0.1	8	0.1	33	0.5	147	2.1
Total	4,098	57.6	1,525	21.6	275	3.9	267	3.7	323	4.5	654	8.7	7,142	100.0

stances, the most common type of support was a brace.

The orthopedists were evenly divided as to the advisability of prescribing any type of support in treating the degenerative back, the disc syndrome of chronic backache, or as a preoperative trial. A similar lack of agreement was indicated concerning the type of support preferred. As a preoperative trial, there was equal preference for a brace or cast. For the other disabilities, the preferred support was the lumbosacral corset.

Comparison between the specific brace design and the clinical condition (Table 4) showed that the Chairback was the most frequently used brace in each situation, and the Williams brace ranked second in preference. Spondylolisthesis and the disc syndrome were the most common indications for the Williams brace. Spondylolisthesis was also the primary reason for using the Bennett brace. Otherwise, preference for the Norton-Brown, Goldthwaite, and Bennett braces paralleled the use of back support in general.

FUNCTION OF EXTERNAL SUPPORTS

Three approaches to the data collected on functions of supports seemed pertinent: the general expectation for external supports, the types of support chosen for

each of these functions, and the functions expected of each of the support designs.

The function most commonly ascribed for external support was restriction of lumbosacral motion (30%); abdominal support was second (19%), followed by postural correction (15%) and immobilization of the spine (12%).

To restrict lumbosacral motion, the Chairback (Knight) brace or a corset were equally preferred. The Williams brace was the third specific device indicated for this purpose, although a larger number of physicians indicated that they used some type of cast to restrict motion.

Abdominal support was most often assigned to the corset. This dominated its next competitor, the Chairback (Knight) brace, by a ratio of two to one. Again, the Williams brace ranked third for the function of supporting abdominal muscles.

Postural correction was almost equally divided between the corset and a Williams brace, although the use of casts was not uncommon.

An interesting situation developed in the category of spinal immobilization. It was the only function identified for the flexion cast, yet this device was fourth in preference. The support most often indicated for spinal immobilization was the Chairback (Knight) brace, a finding which probably reflects its national popularity.

While external supports are seldom used for psychological reasons, when the practice is followed the corset is the most popular device, followed by the Chairback brace.

The concept of unloading the disc has obviously not been accepted by the majority of orthopedic surgeons, since only 8% indicated this as a function of external support. However, those who did think in these terms showed a strong preference for the Williams brace, with a cast as an alternate.

Focus on the individual types of support showed that the prime functions of the corset were considered to be abdominal support and restriction of lumbosacral motion. The Chairback (Knight) brace was assigned the same functions, but with greater emphasis on restriction of motion. This function was also considered the main purpose of the Williams brace, with correction of posture as its second indication. Casts were generally used to restrict lumbosacral motion, although a surprisingly larger number were also assigned the function of correcting posture. Consistent with the belief that immobilization, as opposed to restriction of lumbosacral motion, is seldom accomplished with external support, even casts were assigned this as a third function.

In addition to completing the survey form, a third of the respondents (1,034) added notes to further explain their preferences. These varied from a single listing of a specific brace to lengthy letters explaining their philosophies of low-back management. A majority of these replies were focused on either the fitting or construction characteristics of their support preferences.

Sixty respondents emphasized the advantages of using exercise early in the treatment of low back pain. Two purposes were expressed: to avoid external support and to overcome the muscle weakening and contracture development that accompanies prolonged immobilization. One respondent summarized this philosophy very succinctly by stating he "never prescribed support without a plan to eliminate it." A smaller group (30) felt that the disadvantages were sufficient to preclude any prescription of external support. All who said they "never" or "rarely" used support emphasized instead their reliance on an organized program of exercise. Specific application of this philosophy was frequently mentioned in relationship to postoperative management of spine fusions. Many respondents also brought out the fact that the treatment of low back pain must be individualized to fit the particular patient's need. This fact must never be forgotten, of course, and the purpose of the survey was not to contradict the concept of individualized patient care, but merely to identify the

spectrum of external support which physicians have found adequate to meet their multiple goals.

DISCUSSION

The potential list of 40 external-support designs for low back pain has been severely pruned by the influences of prolonged clinical experience, greater intermingling of orthopedists through professional meetings, and the use of prefabricated parts. Notes by some of the respondents indicated that cost, emphasis on exercise, and early surgery are other important influences.

The clinical indications for use or nonuse of external support were rather sharply defined, but there is no comparable distinction between the accepted styles of support. The latter was indicated by the overlap between clinical entity and support design, as well as by the identification of the functions of the different devices. The mechanical characteristics and the limitations of these various designs which lead to such ambiguity have yet to be objectively identified.

Investigators (3) have found that, unless the support is carefully designed, motion at the lumbosacral joint could be increased with the support rather than restricted. Personal experience indicates that this might also lead to increasing the patient's pain.

A problem still not studied is identification of the characteristics of the patients which govern the choice of support.

SUMMARY

The lumbosacral corset is the most commonly prescribed external support for low back pain. The Chairback (Knight) and Williams braces are next in preference, with a cast being used least frequently. There is a definite relationship between the etiology of the low back pain and the type of support chosen. The major indication for support prescription is to restrict lumbosacral motion.

REFERENCES

1. American Academy of Orthopaedic Surgeons, *Orthopaedic appliances atlas, vol. 1, braces, splints, shoe alterations,* J. W. Edwards, Ann Arbor, Mich., 1952.
2. Nattress, LeRoy Wm., Jr., and Bertram D. Litt, *Orthotic services USA 1962, report 2, survey to determine the state of services available to amputees and orthopedically disabled persons,* American Orthotic and Prosthetic Assoc, Washington, D.C., 1962.
3. Norton, Paul L., and Thornton Brown, The immobilizing efficiency of back braces: their effect on the posture and motion of the lumbosacral spine, *J. Bone Joint Surg.,* 39A:111-139, January 1957.

NATIONAL SURVEY PHASE-ONE QUESTIONNAIRE

CHECK THERAPEUTIC SUPPORTS GENERALLY PRESCRIBED FOR EACH DIAGNOSIS

	BRACES								CORSETS			CASTS			
CAUSES OF LOW BACK PAIN	Rarely Use Supports	Usually Use Supports	Chairback (Knight)	Williams	Norton Brown	Goldthwaite	Bennett	Other	Lumbo-sacral (Camp, Spencer, etc.)	Sacro-iliac	Other	Plexion	Body cast	Body cast with leg	Other
Acute Strain															
Disc Syndrome															
Spondylolisthesis															
Degenerative															
Fracture															
Obesity and Pain															
Chronic															
Preoperative Trial															
Postoperative Fusion															
Postoperative Disc															
Pseudoarthrosis															
Other															

NATIONAL SURVEY PHASE-TWO QUESTIONNAIRE

CHECK RESULTS YOU EXPECT FROM THE SUPPORTS YOU PRESCRIBE FOR LOW BACK PAIN

Type of Support	Immobilizes spine	Restricts lumbosacral motion	Decreases load on disc	Supports abdomen	Corrects posture	Psychological	Other
BRACE: Williams							
Knight (Chairback)							
Other Braces (Specify)							
CORSET							
CAST, flexion							
CAST, other (Specify)							
Other types of support (Specify)							

Evaluation of Synthetic Balata for Fabricating Sockets for Below-Knee Amputation Stumps

A. BENNETT WILSON, JR.[1]

At the present time, most sockets for artificial limbs are made of a plastic laminate (usually polyester resin and Dacron) which has been molded over a modified replica of the stump. A replica of the stump is required because human tissues cannot withstand the temperatures generated by the exothermic reaction of the plastic as it cures. The replica is modified, using general rules established by research groups, in order to achieve a relationship between the stump and socket that is physiologically satisfactory, yet permits weight-bearing and provides stability. In addition, reliefs must be provided to accommodate bony prominences and any tender spots. A simple plaster-of-paris wrap will usually be too loose for normal use. Therefore, fabrication of plastic-laminate sockets with presently available materials involves at least the following steps (Fig. 1): (a) development of a female mold of the stump by wrapping the stump with plaster-of-paris bandages, (ft) casting a male model of the stump by filling the female mold with plaster of paris, (c) modification of the male model by trimming away plaster in selected areas and building it up in other areas when necessary, and *(d)* lay-up and cure of the plastic laminate. The average time required to make a hard socket below-knee plastic prosthesis is eight man-hours.

It has been the goal of a number of research workers to find a simpler and less time-consuming method for fabricating satisfactory sockets for all levels of amputation. After many experiments involving a number of casting methods and a variety of materials, the Veterans Administration Prosthetics Center[2] by 1961 had developed a technique for molding a socket of synthetic balata directly over a below-knee stump. The first successful results were achieved by using an air-pressure sleeve over a tube of synthetic balata,[3] which had been softened by immersion in hot water (160 deg F) and then pulled over the stump *(1,2)* (Fig. 2).

Upon the recommendations of the CPRD Subcommittee on Design and Development, the Subcommittee on Evaluation undertook responsibility for the evaluation of the new technique.

The claims of the development laboratory were: (a) a substantial decrease in elapsed time between measurement of the stump and production of a wearable limb, thereby speeding the rehabilitation process, (ft) a substantial reduction in man-hours involved, (c) a capability for easy adjustment of the prosthesis at any time, and *(d)* a decrease in the amount of skill and training required to produce an adequate socket.

Executive Director, Committee on Prosthetics Research and Development, National Academy of Sciences—National Research Council.

[2] 252 Seventh Ave., New York, N.Y. 10001.

[3] From Polysar X-414 resin produced by the Polymer Corporation Limited, Sarnia, Ontario, Canada.

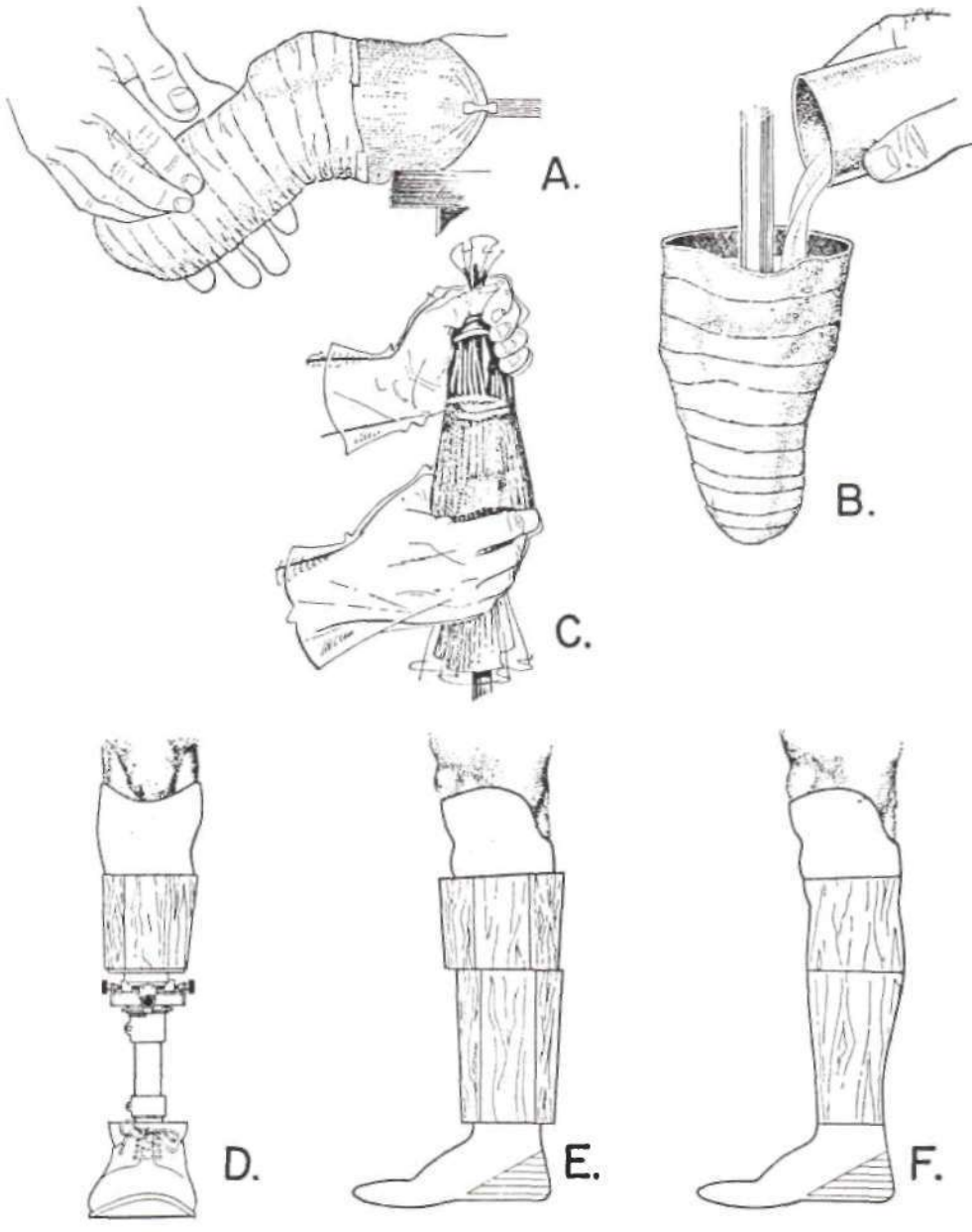


Fig. 1. Steps in the fabrication of a plastic prosthesis for a below-knee amputation. *A,* taking the plaster cast of the stump; *B,* pouring plaster in the cast to obtain model of the stump; *C,* introducing plastic resin into fabric pulled over the model to form the plastic-laminate socket; *D,* the plastic-laminate socket mounted on an adjustable shank for walking trials; *E,* a wooden shank block inserted in place of the adjustable shank after proper alignment has been obtained; *F,* the prosthesis after the shank has been shaped. To reduce weight to a minimum, the shank is hollowed out and the exterior covered with a plastic laminate.

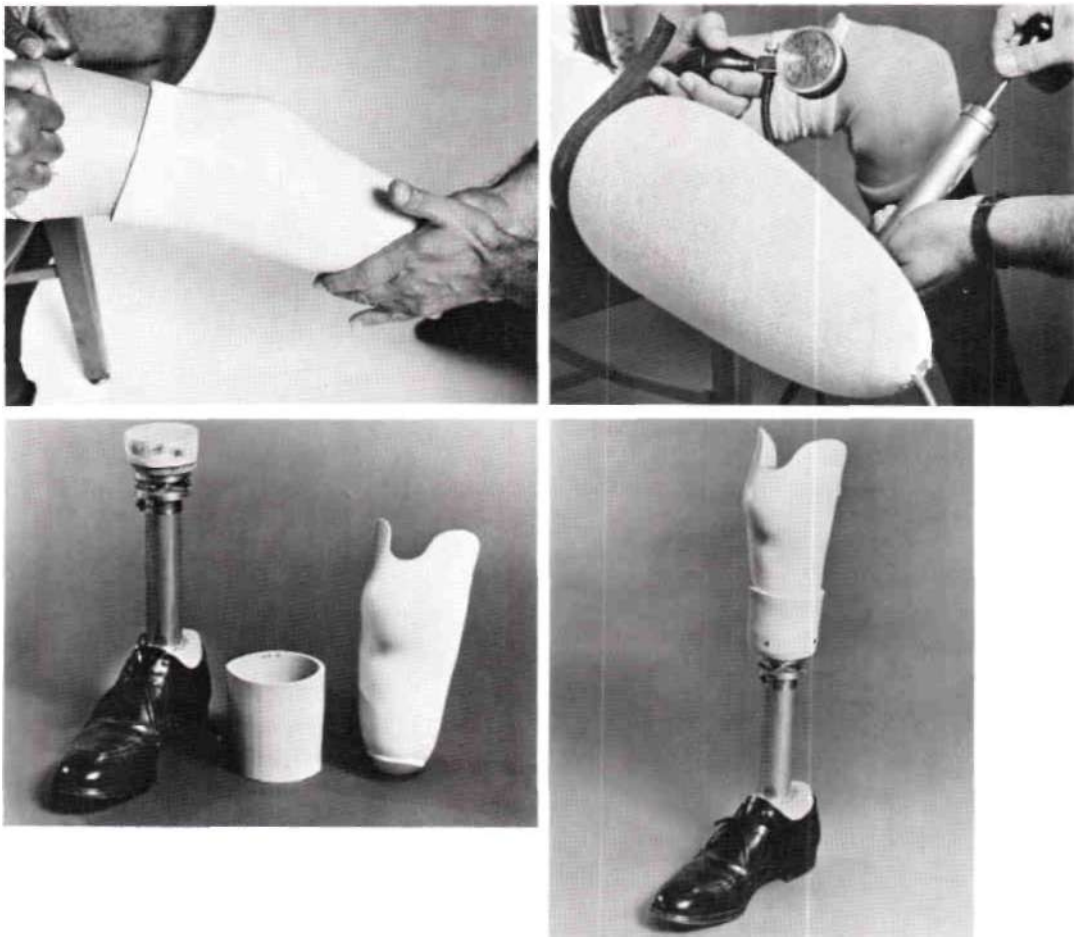


Fig. 2. The air-pressure method of forming synthetic balata sockets for PTB prostheses: application of the tube to the lubricated sleeve of the stump; application of pressure to the sock-covered pressure sleeve; and the socket and bonded tubing attached with screws to the pylon.

PROCEDURE

A protocol (given at the end of this article) was developed and five clinics[4] were asked to participate in the evaluation. The prosthetists from the clinics were trained as a group at the Veterans Administration Prosthetics Center on November 6-8, 1968. Each clinic was requested to fit five new amputees and five amputees who had worn PTB prostheses before, and provided with sufficient material and equipment to carry out the fittings.

[4] Rancho Los Amigos Hospital, Duke University, the University of Miami, the Veterans Administration Hospital/Los Angeles, and the Veterans Administration Hospital/Buffalo.

RESULTS

Follow-up in the spring of 1969 revealed that all the prosthetists were encountering difficulty in obtaining adequate fits in nearly all cases except those with long tapered stumps, most of the sockets being too loose proximally. To overcome this problem, the VAPC devised a method whereby the air bag was eliminated, and molding pressure was

brought about by wrapping the softened balata tube with one-inch-wide elastic webbing and controlling the shape of the socket with the hands and fingers as it cooled.

All of the participating prosthetists were instructed in the revised method, and other prosthetists were instructed in the new procedure at the same time. Shortly afterwards, plastic pressure-sen-

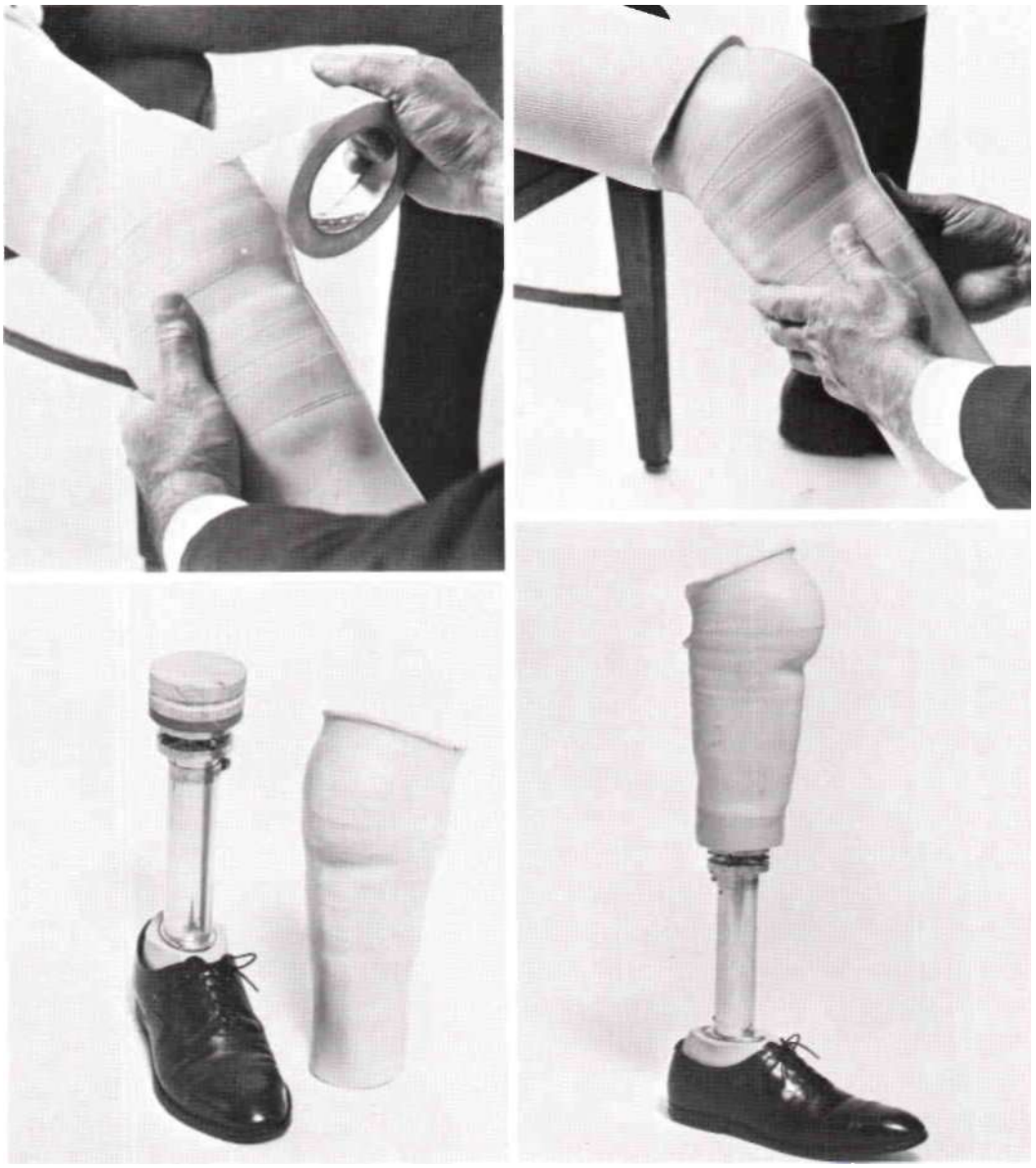


Fig. 3 The tape-wrap method of forming synthetic balata sockets: application of pressure with elastic, pressure-sensitive tape; molding by hand to define the medial tibial flare and tibial crest; and the heated socket bottom joined to the pylon by an elastic tape wrap. *(Courtesy Veterans Administration Prosthetics Center. New York, N Y)*

sitive tape was substituted for the elastic webbing (Fig. 3) (3).

The results with the revised procedure were considerably better. The average synthetic balata prosthesis, with pylon but without cosmetic treatment, weighed 3 1/2 lb, and could be made in 2 1/2 hr. All of the claims of the developer were substantiated with the exception of the relative amount of skill required, a factor that would be very difficult to measure at this stage of development. At any rate, it is safe to say that no more skill is required for the new technique than for older methods.

All prosthetists who used the technique, with one exception, felt that synthetic balata is quite useful for temporary prostheses. Some have adopted the method as standard procedures where procurement practices permit use of temporary prostheses of this type.

CONCLUSIONS

When this technique is used, a considerable saving in time can be effected, and the patient can be provided with a prosthesis within a few hours. Furthermore, the use of synthetic balata permits easier adjustment of the socket later, and the adjustable pylon permits adjustment in alignment at any time.

It is therefore recommended that use by federal and state agencies of the VAPC technique for fabricating below-knee temporary prostheses be encouraged, and that the technique be included in the curricula of all below-knee prosthetics courses.

REFERENCES

1. Fleer, Bryson, and A. Bennett Wilson, Jr., Construction of the patellar-tendon-bearing below-knee prosthesis, *Artif. Limbs,* 6:2:25-73, June 1962.
2. The Staff, Veterans Administration Prosthetics Center, Direct forming of below-knee patellar-tendon-bearing sockets with a thermoplastic material, *Orth. and Pros.,* 23:1:36-61, March 1969.
3. Staros, Anthony, and Henry F. Gardner, Direct forming of below-knee PTB sockets with a thermoplastic material, *Bull. Pros. Res.,* 10-12:34-47, Fall 1969.

PROTOCOL FOR BK POLYSAR SOCKET EVALUATION PROJECT

The purposes of the study are:

1. To determine the usefulness of Polysar as a material for sockets;

2. To determine the usefulness of the Gardner technique of socket fabrication using the pneumatic bag;

3. To gather information on the use of pylon prostheses, including cosmetic treatment, for use by designers and manufacturers.

Each prosthetist is requested to fit five new patients and five patients who have worn PTB prostheses before. Instructions given in the VAPC manual should be followed as closely as possible.

A data-collection sheet including the Medical History Form A- and Lower-Extremity Prosthetic Information Form B-l must be completed for each patient and held on file until requested by the CPRD staff. (It is not necessary to complete items 3, 4, and 7 on the Medical History Form.)

INSTRUCTIONS: FORM A

1. *Site of Amputation*
Indicate side and level of amputation(s) being fitted. Use appropriate standard abbreviations—R for right—L for left. (E.g., right below-knee = RBK)

FQ = Forequarter
SD = Shoulder Disarticulation
AE = Above Elbow
ED = Elbow Disarticulation
BE = Below Elbow
WD = Wrist Disarticulation
PH = Partial Hand
HP = Hemipelvectomy
HD = Hip Disarticulation
AK = Above Knee
KB = Knee Bearing (all cases using outside joints)
BK = Below Knee
SY = Syme
PF = Partial Foot

2. *Type of Case*
New = Stump never previously fitted.
Old = Replacement prosthesis. (Fill out item 14 regarding cause of replacement.)

3. *Source of Patient*
a. List official name of amputee clinic and physician clinic chief for all clinic cases.
b. List name of physician who refers a non-clinic case.
c. Check "Case Not Referred" in all instances where prosthetist writes the limb prescription.

4. *Source of Payment*
The more common sources of payment for a limb are:
State Bureau of Vocational Rehab.
Veterans Administration
State Crippled Children's Comm.
Workmen's Compensation
Insurance Company
Public Welfare Agency
Amputee or Family

5. *Medical Complications*
Consult clinic physician or doctor who referred case for proper item(s) to be checked.

6. *Condition of Other Extremities*
Include loss of toes, fingers or partial foot or partial hand amputations, if present.

7. *Post-Prosthetic Training*
If answer is "No," specify. The remark, "Previous prosthetic wearer," will apply in most cases where training is not prescribed.

8. *Amputation History*
Many diabetic and arteriosclerotic cases have had one or more previous amputations involving one or both of their lower extremities. This form provides space for three such amputations. *Do not record a "partial foot"* as a separate amputation on this form. Record as a separate amputation a reamputation at a higher level. A high percentage of such reamputations occur within six weeks of the original amputation and are due to a failure of the wound to heal properly. Record the cause of such reamputations as "Failure of amputation of _____ (date) _____ to heal." These stumps are never fitted, so the items "Date Prosthesis Provided" and "Prosthetic Result" would be left blank. Multiple amputations that occasionally occur in injury cases should be recorded as a single amputation, listing the two or more levels (left above elbow and right below elbow as LAE-RBE). In old amputations, if exact dates are unknown, record an estimate.

9. *Level and Side of Amputation*
Use standard abbreviations as listed above.

10. *Cause of Amputation*
For a correct diagnosis, consult with the clinic chief or physician who refers the case. One of the following listed causes will apply in nearly all cases:

Injury (specify type)	Thrombosis
Arteriosclerosis	Embolism
Diabetes	Buerger's Disease
Malignant Tumor	Infection

11. *Date Prosthesis Provided*
Record the date of the initial check-out of the completed prosthesis. Leave this item and the following item "Prosthetic Result" blank in all new cases since the tear-off Form A will have been forwarded to the National Academy of Sciences before this information is known. At periodic intervals, you will receive a list of the new cases you have sent and, at that time, by referring to your facility copy of Form A, you will be able to furnish this information.

12. *Prosthetic Result*
Consider the age and physical condition of the amputee as well as the purpose for which the device was provided in recording this item. In an elderly person, limited ambulation about his home might be considered as "Satisfactory."

13. *Protective Surgery*
An increasing number of vascular cases are today receiving protective surgery to prevent or delay amputation. Consult the clinic chief or referring physician for type of procedure used. These include: sympathectomy, thrombendarterectomy, arterial graft, and venous graft.

14. *Old Cases*
Indicate reason for replacing present prosthesis.

15. *Remarks*
This space can be used to note any item of importance not covered previously or to add additional information on any of the above data items.

MEDICAL HISTORY

(Name of Facility)

Name of Patient _____ Date _____

Male ☐ Female ☐ Date of Birth _____ Height _____ Weight _____

1 Site of Amputation _____ 2 Type of Case: New _____ Old _____

3 Source of Patient (prosthetic prescription)

☐ Amputee Clinic _____ Clinic Chief _____

☐ Name of Physician _____ ☐ Case Not Referred

4 Source of Payment _____ Occupation _____

5 Medical Complications (check conditions that can affect type of prescription or use of prosthesis)

☐ Heart Disease ☐ Arthritis ☐ Serious Visual Impairment

☐ Mental Disease ☐ Obesity ☐ Other (specify) _____

6 Condition of Other Extremities ☐ Amputated Level _____

☐ Normal ☐ Vascular Disease ☐ Paralysis

☐ Other (specify) _____

Amputee Received Pre-Prosthetic Training: Yes ☐ No ☐ (specify) _____

7 Post Prosthetic Training Prescribed: Yes ☐ No ☐ (specify) _____

8 Amputation History

Date of First Amputation _____ 9 Level and Side of Amputation _____

Cause of Amputation (if congenital, describe) _____

Prosthetic Result: ☐ Satisfactory Date Prosthesis Provided _____

☐ Unsatisfactory (specify) _____

Date of Second Amputation _____ Level and Side of Amputation _____

10 Cause of Amputation _____

12 Prosthetic Result: ☐ Satisfactory 11 Date Prothesis Provided _____

☐ Unsatisfactory (specify) _____

Date of Third Amputation _____ Level and Side of Amputation _____

Cause of Amputation _____

Prosthetic Result: ☐ Satisfactory Date Prosthesis Provided _____

☐ Unsatisfactory (specify) _____

13 Protective Surgery

Date	Procedure	Extremity

14 Old Cases

Replacement of Present Prosthesis: (Type and Age) _____

☐ Worn Out ☐ Outgrown ☐ Weight Gain ☐ Weight Loss

☐ Present Prosthesis Unsatisfactory (Cause)

15 Remarks: _____

Form A-

INSTRUCTIONS: FORMS B-1 AND B-2

1. Forms B-1 and B-2 provide certain information that has already been entered on Form A. These items are repeated for the convenience of the shop worker.
2. Draw in approximate length and shape of stump to show a Syme, knee disarticulation, or hip disarticulation amputation level. Indicate location of stump abnormalities with an "X" and identify each "X" with appropriate code letters (e.g., Bs for bone spur, etc.). Use space under "Remarks" for additional information on any item.
3. Rx for Prosthesis: Record physician's prescription. For example, "One PTB below-knee prosthesis."
4. Give model name and/or number as provided by supplier of item.
5. In measurement diagrams:


= circumference
= distance between two points
= diameter

LOWER-EXTREMITY PROSTHETIC INFORMATION

Name of Patient _____

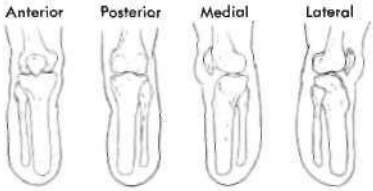
Site of Amputation _____ Right _____ Left _____

Clinic _____ Physician _____

(Show Location of Stump Details, Identify with Code Letters)

BELOW KNEE

Anterior Posterior Medial Lateral

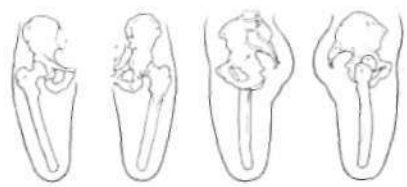


Stump Length: _____ inches

A = abrasion
B = boil or skin infection
Bu = bursa
Bs = bone spur
D = discoloration
E = edema
I = irritation
M = muscle bunching
P = pressure point
R = redundant tissue
S = scar
T = trigger point

ABOVE KNEE

Anterior Posterior Medial Lateral



Stump Length: _____ inches

BELOW-KNEE STUMP CHARACTERISTICS

Stump Shape: _____ Distal Padding: _____

Subcutaneous Tissue: Heavy ☐ Light ☐

Distal Pressure Tolerance: None ☐ Slight ☐ Good ☐

Condition of Thigh Musculature: Atrophy ☐ Normal ☐

Condition of Stump Musculature: Atrophy ☐ Normal ☐

Knee Stability: _____

Range of Knee Motion: _____

Degrees of Knee Contracture: _____ °

Condition of Cut Bones: Tibia _____ Fibula _____

Remarks: _____

ABOVE-KNEE STUMP CHARACTERISTICS

Stump Musculature	Soft	Average	Hard
General			
Hamstring Group			
Gluteal Group			
Rectus Femorus			
Adductor Longus			

Subcutaneous Tissue: Heavy ☐ Light ☐

Ischium: Toughened ☐ Pressure Sensitive ☐
Muscle Padding Prominent

Position of Trochanter: Anterior ☐ Midline ☐ Posterior ☐

Previous Ischial Bearing: Yes ☐ No ☐

Stump Lateral Contour: Convex Out ☐ Flat ☐ Concave In ☐

Degree of Contracture: Hip Flexion °
Stump Adduction ☐ ° Abduction °

Remarks:

3 Rx for Prosthesis:

4 Foot Comp. Model	**4** Knee Comp. Model	Socket Materials	Type of Symes	**4** Hip-Joint Model Type
4 Ankle Comp. Model	Type of Socket	Shank Materials	Hip Disartic. Type	Type of Suspension

B-1

(Consult instructions on back for all items marked with numbers)

LOWER-EXTREMITY PROSTHETIC MEASUREMENTS

Name of Patient _____ Phone _____ Date _____

Address _____ City _____ State _____

Male ☐ Female ☐ Date of Birth _____ Height _____ Weight _____

Type Prosthesis _____ Right ___ ___ Left _____

Shoe Furnished: One ☐ Both ☐ None ☐

Shoe Lace Opening: Top ___ In. Bottom ___ In.

Extra Light-Weight Limb: ☐

Extra Strong Limb: ☐

KB or BK Knee Joints: Size _____ Style _____

Ankle Joint: Size _____ Style _____

KB or BK Thigh Lacing: Eyelets ☐ Hooks ☐

Other: _____

Thigh Lacer Height: _____

Shoulder Loop Size: _____

Waist Belt Size: _____

Finish of Limb: Plastic Laminate ☐

Rawhide Enamel ☐

Color: Caucasian ☐ Negroid ☐

Light Brown ☐ Medium ☐ Dark Brown ☐

Check Strap: Lace ☐ Leather Strap ☐

Measured by: _____

Shop Alterations

Lengthen Thigh ___ In. Shorten Thigh ___ In.

Lengthen Shin ___ In. Shorten Shin ___ In.

KB or BK Lace Opening: Top ___ In. Bottom ___ In.

Set BK Lacer on Joints:

Higher ___ In. Lower: ___ In.

Lateral BK Joint Head:

Set In ___ In. Set Out ___ In.

Medial BK Joint Head:

Set In ___ In. Set Out ___ In.

Fit Foot In Shoe: Tight ☐ Loose ☐ Medium ☐

Make Heel Cushion: Soft ☐ Medium ☐ Firm ☐

Special Changes: _____

Fitted By: _____

Finished BK Limb, Knee Center to Floor: ___ In.

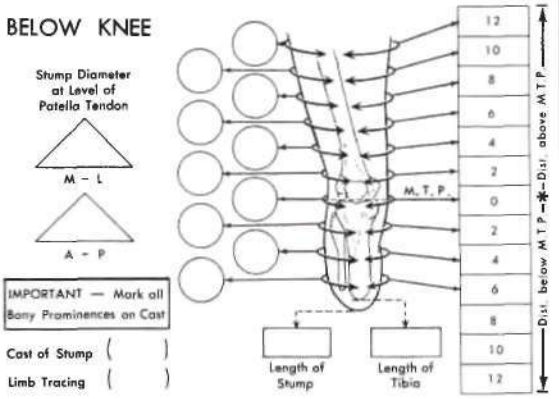
Finished AK Limb, Ischium to Floor: ___ In.

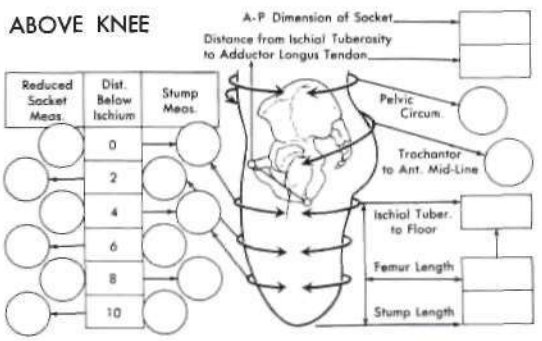
Weight of Finished Limb: ___ lbs. ___ oz.

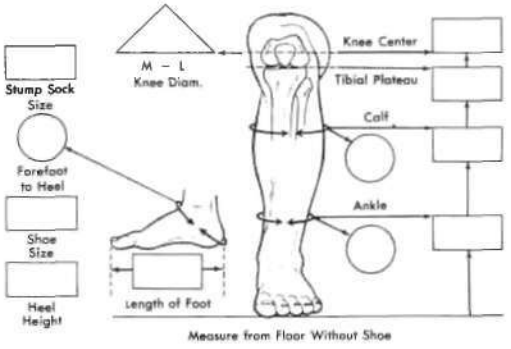
Special Features: _____

Date Completed: _____

B-2







Artificial Limbs, Vol. 14. No. 2, pp 68-80. Autumn 1970

A New Approach to Patient Analysis for Orthotic Prescription— Part I: The Lower Extremity

NEWTON C. MCCOLLOUGH III. M.D.[1]
CHARLES M. FRYER. MA..[2] AND
JOHN GLANCY, CO.[3]

There is liittle question that the field of orthotics has taken a back seat to prosthetics in modern times, and perhaps for good reason. The needs of the amputee are more immediate and obvious, and the wars of the past thirty years have yielded untold numbers of young men in their prime whose productivity depended upon satisfactory functional restoration of their missing limbs. Medicine, engineering, and the prosthetic profession have responded to the needs of the amputee through extensive research and development, widespread educational programs, improved fabrication and fitting techniques, and better delivery of services. The field of orthotics remains in comparative disarray with more limited, though no less sophisticated, research activities, few educational endeavors, and little improvement upon local fabrication and delivery services over the past fifty years.

Much of the blame for this rather distressing state of affairs must be laid to the physician, whose approach to orthotic prescription has been somewhat less than scientific. More often than not, little thought is given to analyzing specific biomechanical defects present in an extremity with the aim of translating them into an appropriate mechanical substitute. Even when this is done, all too often the device that is prescribed impairs to some degree the normal biomechanical functions which coexist in the same extremity. For example, a long leg brace prescribed for genu recurvatum may also limit normal functioning of the subtalar joint. Much of the physician's casual approach to orthotic prescription stems from a relatively sparse education in orthotic principles, but an even greater deficiency is the failure to relate well-known biomechanical principles to the mechanical substitute, or orthosis. Therein lies the trap, for without this awareness, prescriptions will continue to reach the orthotist calling for simply a "short leg brace" or a "long leg brace," and thus there is no stimulation for new or improved design criteria for orthotic components and systems.

There is little doubt that the great advances which have been made in prosthetics in recent years have resulted primarily from a systematic appraisal of normal human posture and locomotion, with resultant attempts to duplicate not only the missing anatomy but also the biomechanical functions of the extremity. The problem in orthotics is somewhat different: specific functional losses must be substituted for in the presence of intact anatomy, and the variety of functional losses which may be present in a given extremity necessitates correspondingly var-

[1] Assistant Professor of Orthopaedics, Associate Director of Rehabilitation, University of Miami School of Medicine, Miami, Fla. 33152.

[2] Director, Prosthetic-Orthotic Center, Northwestern University Medical Center, Chicago, Ill. 60611.

[3] Orthotic Division, Indiana University Medical Center, Indianapolis, Ind. 46207.

ied design criteria. It is apparent, therefore, that an initial step in developing a rational approach to orthotic design and prescription would be some means of systematically analyzing the biomechanical losses in an impaired extremity. Once properly identified, these losses could then be matched against specific components or component systems to substitute for the functions lost. In addition, such an analysis might point up certain areas or functions for which truly satisfactory components are not available, and thus it might serve as a stimulus for future design and development.

Recognizing the need for a more organized and systematic approach to orthotic prescription as a part of current efforts to revise volume 1 of the *Orthopaedic Appliances Atlas,* the Committee on Orthotics and Prosthetics of the American Academy of Orthopaedic Surgeons appointed an ad hoc committee for the development of a lower-extremity analysis form. In essence, this article represents a report of that committee, whose work commenced two years ago. During the development of the form, workshops were held periodically with the parent committee, together with representatives of the American Orthotic and Prosthetic Association, the Veterans Administration Prosthetics Center, and the Committee on Prosthetics Research and Development of the National Research Council. The form underwent periodic revision as it was applied to patients with a variety of disabilities, utilizing several clinics. The most recent and final application of the lower-extremity analysis form was in conjunction with the Workshop Panel on Lower-Extremity Orthotics held at Rancho Los Amigos Hospital in Downey, California, in March 1970. Its applicability to the evaluation of lower-extremity disability is now felt to be such as to warrant description for more widespread usage.

LOWER-EXTREMITY ANALYSIS FORM

The form consists of four pages of appropriate size for insertion into the patient's hospital chart. The first page (Fig. 1) contains spaces for patient data, including the diagnosis and a summary of major impairments existing in one or both extremities. At the bottom of the first page there is a legend for symbols to be used on the extremity diagrams. The second and third pages (Figs. 2 and 3) contain skeletal outlines of the right and left lower extremities, respectively, in the sagittal, coronal, and transverse planes. Overlying the major joints are shaded areas, representing the normal ranges of joint motion within a circle divided into thirty-degree segments. Similar smaller circles overlie the mid-shafts of the long bones for diagraming angular, rotational, or translational deformities of the femur and tibia. The fourth page (Fig. 4) includes spaces for summarizing the functional disability, and for orthotic recommendations based upon this summary.

INSTRUCTIONS FOR USE

Most of the "Major Impairments" portion of the form is self-explanatory. "Abnormal bone and joint" conditions may include such entities as osteoporosis, Paget's disease, and coxa vara. "Muscle" may be normal, flaccid, or spastic, but a space is provided for description of rarer disorders such as muscular dystrophy and fibrosis of muscle. Under the heading of "ligament," check boxes are provided to indicate abnormal laxity of the major ligaments of the knee and ankle. The sections on "sensation," "skin," and "vascular" impairments cover considerations which may influence orthotic design, and are self-explanatory.

"Balance" is either normal or impaired, and if impaired, the following definitions are applicable: "mild" impairment is compatible with independent ambulation; "moderate" impairment is compatible with ambulation utilizing external support; and "severe" impairment indicates the need for maximal support or personal assistance in ambulation.

"Extremity shortening" is recorded as follows: ischial tuberosity to sole of heel,

DIAGNOSIS _____ NAME _____

_____ NO _____ SEX _____

_____ AGE _____ HEIGHT _____ WEIGHT _____

DATE _____

MAJOR IMPAIRMENTS:

A. Musculoskeletal:

1. Bone & Joint: Normal ☐ Abnormal _____
2. Muscle: Normal ☐ Flaccid ☐ Spastic ☐
   Other _____
3. Ligament: Normal ☐ Abnormal ☐: Knee: AC ☐ PC ☐ MC ☐ LC ☐
   Ankle: MC ☐ LC ☐
   Other _____

B. Sensation: Normal ☐ Abnormal ☐

1. Anaesthesia ☐ Location _____
   Protective Sensation: Lost ☐ Retained ☐
2. Proprioceptive Loss ☐
   Location _____ Degree: Mild ☐ Moderate ☐ Severe ☐
3. Pain ☐ Location _____

C. Skin: Normal ☐ Abnormal _____

D. Vascular: Normal ☐ Abnormal ☐ RT ☐ LT ☐

1. Arterial ☐ 2. Venous ☐ 3. Coagulation Defect ☐

E. Balance: Normal ☐ Impaired: Mild ☐ Moderate ☐ Severe ☐

F. Extremity Shortening: None ☐ LT ☐ RT ☐
   Amount of Discrepancy:
   I.T. – Heel _____
   I.T. – M.T.P. _____
   M.T.P. – Heel _____
   X-ray _____

LEGEND

= Direction of Translatory Motion

= Abnormal Degree of Rotary Motion (60°)

= Fixed Position (30°, 1 CM)

= Fracture

Volitional Force

G = Good
F = Fair
P = Poor
T = Trace
Z = Zero

Spastic Muscle (SP)

SP_M = Mild
SP_{MO} = Moderate
SP_S = Severe

= Pseudarthrosis

= Absence of Segment

E = Edema

D = Local Distension or Enlargement

Fig. 1. Front sheet of patient analysis form, including summary of major impairments and legend.

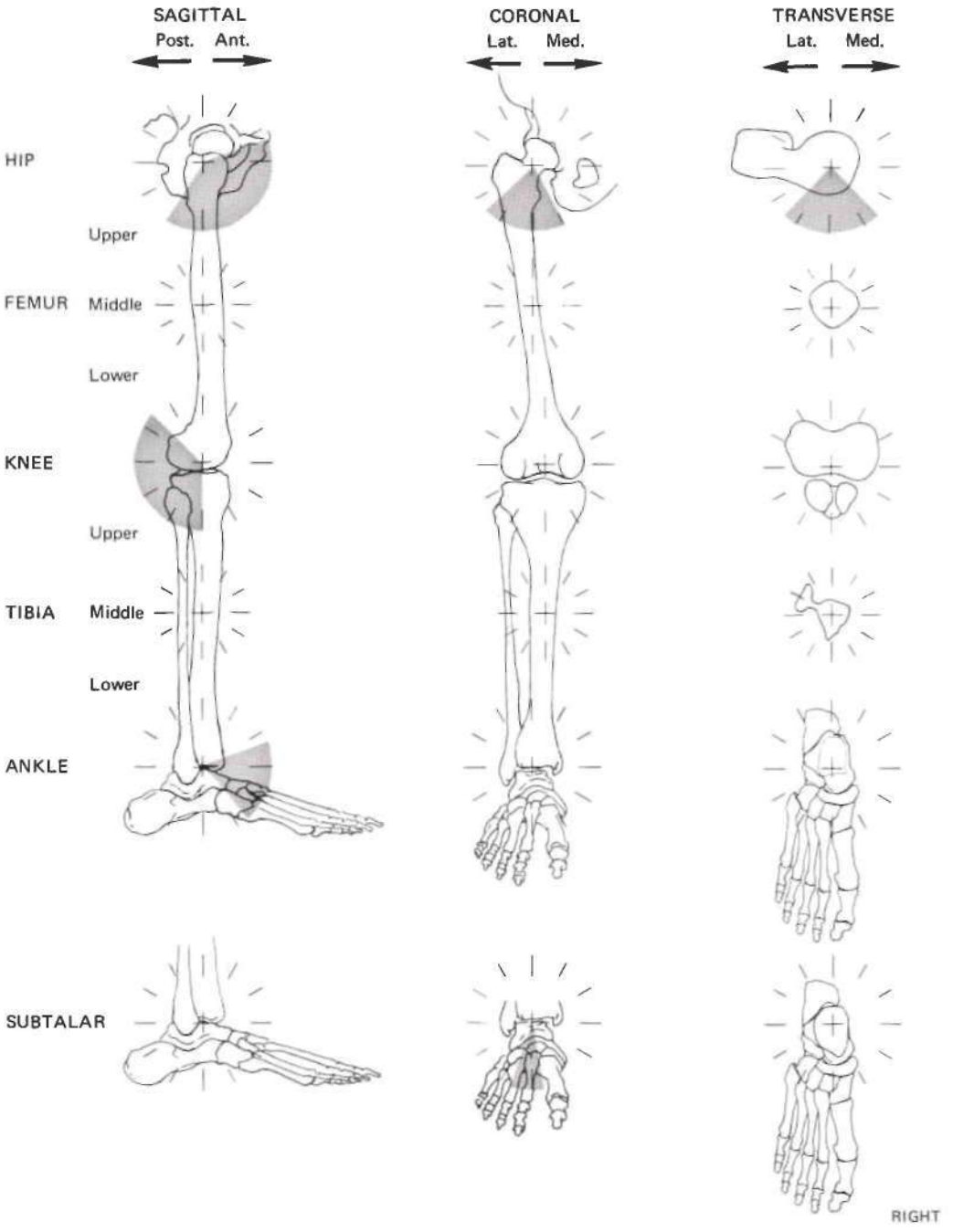


Fig. 2. Second page of patient analysis form, with diagram of right lower extremity.

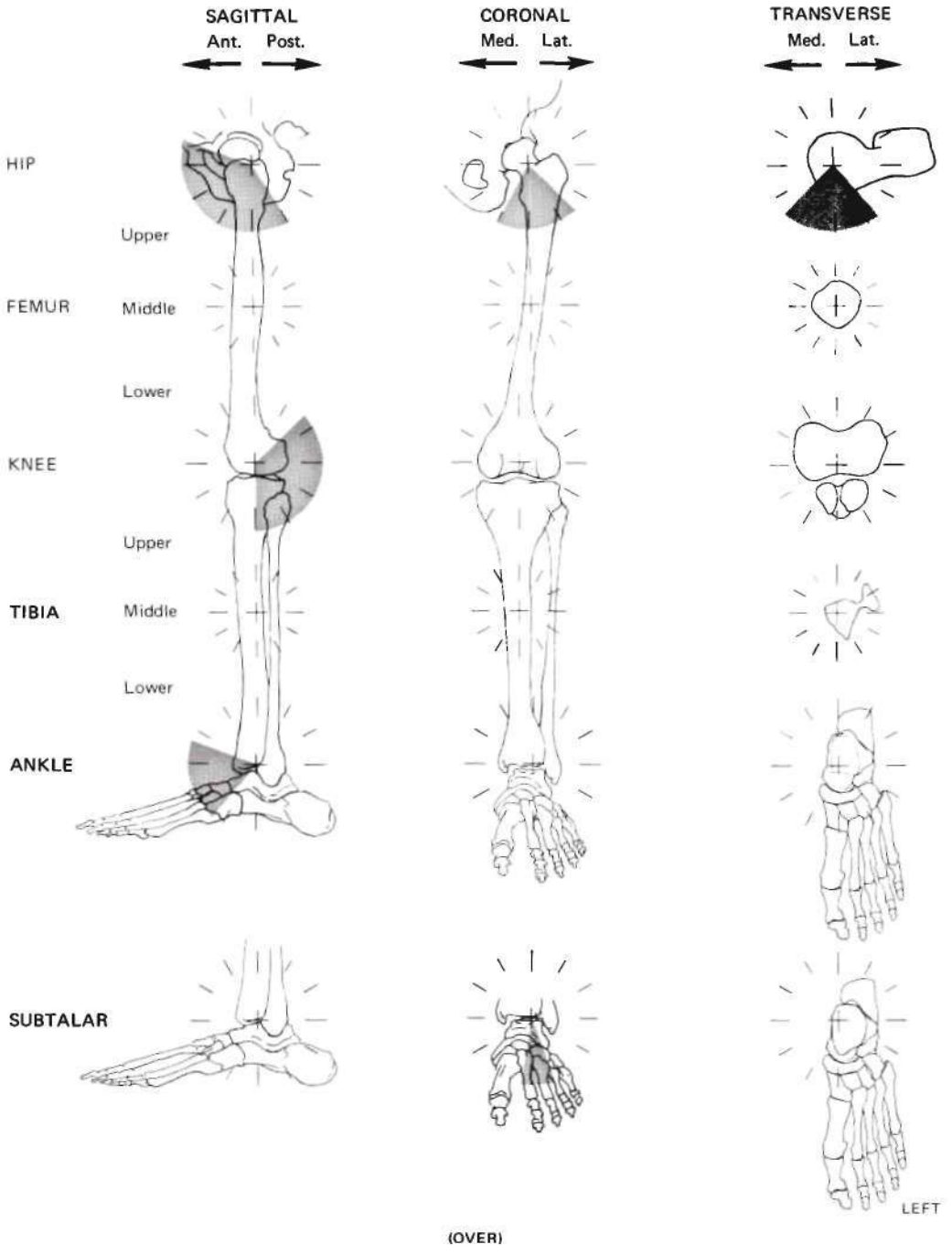


Fig. 3. Third page of patient analysis form, with diagram of left lower extremity.

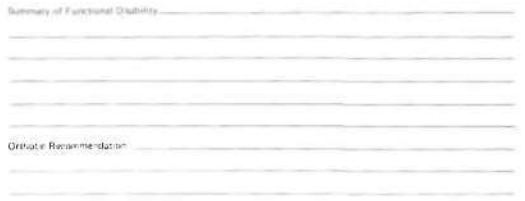


Fig. 4. Fourth page of patient analysis form provides space for summary of patient's functional disability and for the orthotic recommendation.

ischial tuberosity to medial tibial plateau, and medial tibial plateau to sole of heel.

In leg-length discrepancies exceeding one-half inch, X-ray studies of leg length may be indicated, and an appropriate space is provided for this measurement.

Legend and Extremity Diagrams

Two terms must first be defined:

1. "Translatory motion" is motion in which all points of the distal segment move in the same direction, with the paths of all points being exactly alike in shape and distance traversed (Fig. 5).
2. "Rotary motion" is motion of a distal segment in which one point in the distal segment or in its (imaginary) extension always remains fixed (Fig. 6).

The symbols described in the legend are used in conjunction with the right- and left-extremity diagrams according to the following rules:

1. Recording motion

   The degrees of rotary motion or centimeters of translatory motion are to be obtained from passive manipulation, and are to reflect passive (not active) motion at the site being examined. In the lower extremity, joints are to be observed during weight-bearing, and if the degree of joint excursion is greater under conditions of loading than under passive manipulation, this figure is diagramed rather than the smaller figure (e.g., recurvatum of the knee).

   a) Translatory motion

   Linear arrows horizontally placed below the circle indicate the presence of (abnormal) translatory motion at one or more of the six designated levels of the lower extremity listed on the left side of the form. The head of the arrow always points in the direction of displacement of the distal segment relative to the proximal segment. Linear arrows vertically placed on the right side of the circle indicate

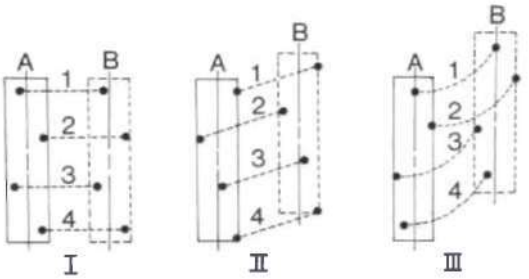


Fig. 5. "Translatory motion": motion in which all points of the distal segment move in the same direction, with the paths of all points being exactly alike in shape and in distance traversed. In all three examples, the pathways between original position "A" and final position "B" of four arbitrarily selected points in each figure are each exactly alike in direction, form, and distance traversed. Note that the long axes of the figures also remain parallel throughout the "translation" from A to B.

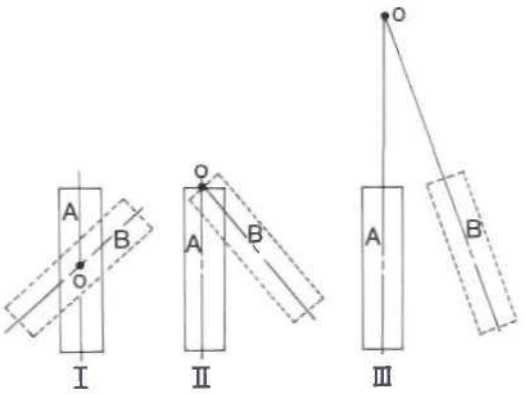


Fig. 6. "Rotary motion": motion of a distal segment in which one point in the segment, or in its (imaginary) extension, always remains fixed. The axis "O," in each of the three examples, represents a point in the figure (or as in "III" in its imaginary extension) that always remains fixed in position when the body "rotates" from position "A" to position "B."

(abnormal) translatory motion along the vertical axis at the site indicated.

b) Rotary motion

Normal ranges of rotary motion about joints are preshaded on the diagram. Abnormal rotary motion, either as limited or excess motion, is indicated by double-headed arrows placed outside and concentric to the circle, to indicate the extent of available motion present in the affected joint. In certain instances, it may be more meaningful to use two double-headed arrows in order to describe the range of motion to either side of the neutral joint axis, rather than a single arrow which describes the total range of motion present. If one head of an arrow fails to reach the preshaded margin, limitation of joint motion is denoted. Conversely, if one head of an arrow projects beyond the preshaded margin, excess motion is designated. Numbers in degrees are placed adjacent to the arrows to indicate the arc described. In addition, radial lines drawn from the center of the circle and passing through its perimeter at the tips of the double-headed arrow are to be used for more graphic representation of the arc of available motion. At sites where rotary motion does not occur (e.g., fracture site, or knee joint in the coronal plane), the presence of abnormal rotary motion is similarly designated by a double-headed arrow with adjacent numerical value in degrees.

c) Fixed position

Double radial arrows indicate a fixed joint position, and describe in degrees the deviation from the neutral joint position. Horizontal or vertical double arrows indicate a fixed joint position in a translatory sense, and the extent of abnormal translation is indicated in centimeters adjacent to the arrow (e.g., subluxation of the tibia in a hemophiliac knee).

2. Muscle dysfunction

a) Flaccid muscle

Flaccid muscle is designated as such under the section on major impairments. Muscle-group strength, not individual muscle strength, is determined by conventional means on the examining table, and the letter grade corresponding to volitional force is recorded adjacent to the skeletal outline at the proper location for each muscle group. The letter grades correspond to the standard muscle-grading system used in poliomyelitis. No symbol is used if muscle strength is normal.

b) Spastic muscle

Spastic muscle is designated as such under the section on major impairments. It is further identified in the legend as "SP." The letter grade (e.g., SP_{MO}) for muscle-group tone, not individual muscles, is to be placed adjacent to the skeletal outline at the proper location for each muscle group. Spastic-muscle estimates are to be made with the patient in the functional position for the lower extremity, i.e., observation during standing and walking. The subletter grades for spastic muscle are as follows:

"M" indicates a mild degree of spasticity;

"MO" indicates a moderate degree of spasticity sufficient for useful holding quality;

"S" indicates severe spasticity, obstructive in terms of function.

In certain instances, muscle groups in a patient with spastic paralysis may be more appropriately graded according to volitional force, e.g., dorsiflexion of the foot in a hemiplegic.

3. Recording fracture or bone deformity

All translatory or rotary motions at the fracture on the shaft of a long bone are diagramed on the circle located

DIAGNOSIS Left Hemiplegia

NAME E. L.

NO 819644 SEX M

AGE 63 HEIGHT 5'11" WEIGHT 162

DATE 5/20/69

MAJOR IMPAIRMENTS:

A. Musculoskeletal:

1. Bone & Joint: Normal ☑ Abnormal ☐
2. Muscle: Normal ☐ Flaccid ☐ Spastic ☑
   Other Anterior tibial inverts foot in swing phase
3. Ligament: Normal ☑ Abnormal ☐: Knee: AC ☐ PC ☐ MC ☐ LC ☐
   Ankle: MC ☐ LC ☐
   Other

B. Sensation: Normal ☐ Abnormal ☑

1. Anaesthesia ☐ Location
   Protective Sensation: Lost ☐ Retained ☐
2. Proprioceptive Loss ☑
   Location (L) Foot Degree: Mild ☐ Moderate ☑ Severe ☐
3. Pain ☐ Location

C. Skin: Normal ☑ Abnormal

D. Vascular: Normal ☐ Abnormal ☑ RT ☐ LT ☐

1. Arterial ☐ 2. Venous ☑ 3. Coagulation Defect ☐

E. Balance: Normal ☐ Impaired: Mild ☑ Moderate ☐ Severe ☐

F. Extremity Shortening: None ☑ LT ☐ RT ☐

Amount of Discrepancy:

I.T. – Heel

I.T. – M.T.P.

M.T.P. – Heel

X-ray

LEGEND

= Direction of Translatory Motion

= Abnormal Degree of Rotary Motion (60°)

= Fixed Position (30°, 1 CM)

= Fracture

Volitional Force

G = Good
F = Fair
P = Poor
T = Trace
Z = Zero

Spastic Muscle (SP)

SP_M = Mild
SP_{MO} = Moderate
SP_S = Severe

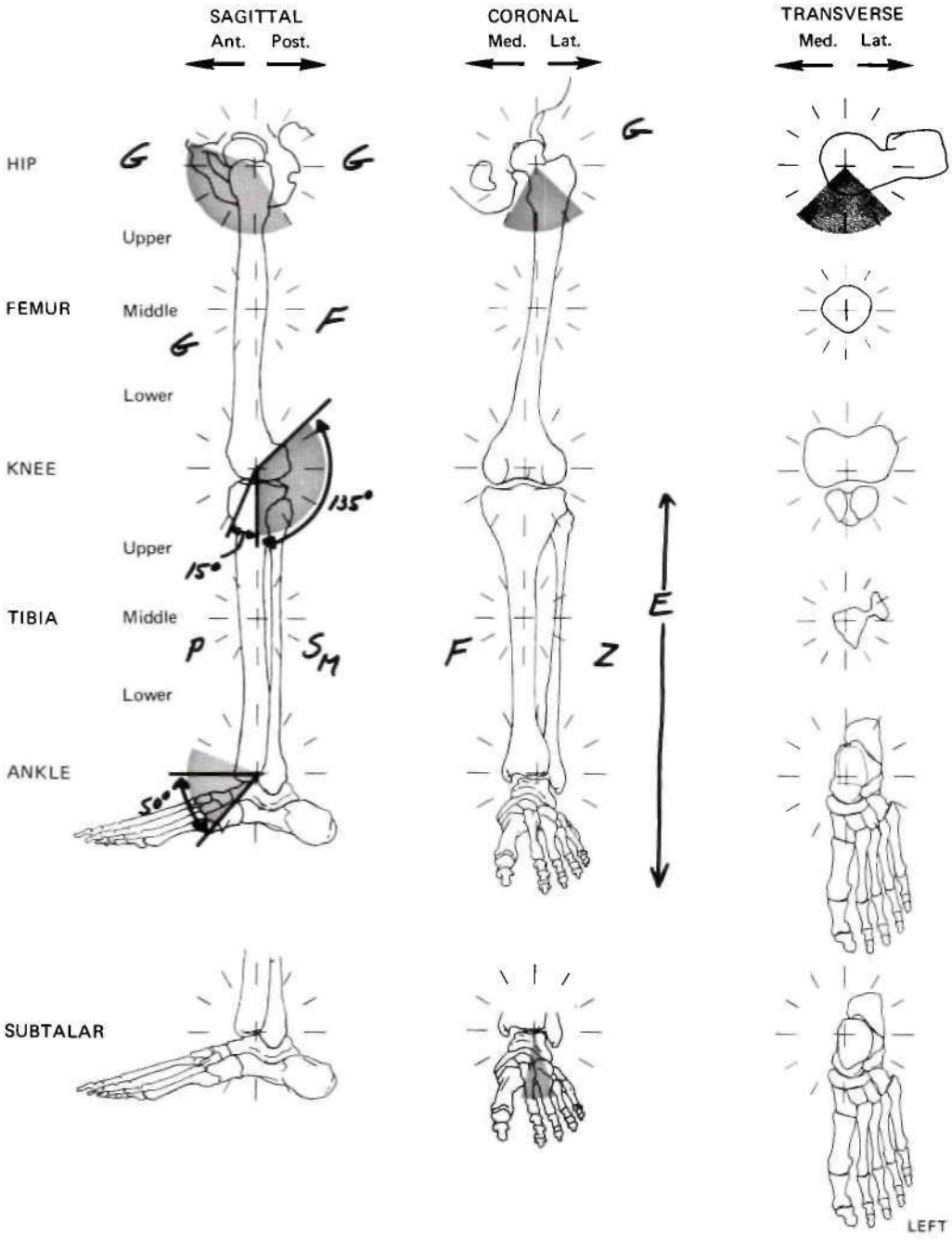
= Pseudarthrosis

= Absence of Segment

E = Edema

D = Local Distension or Enlargement

Fig. 7. Record for patient with left hemiplegia. Information given on front sheet includes spastic muscle picture with inversion deformity of foot, mild loss of proprioception, venous stasis in left leg, and mild impairment of balance.



(OVER)

Fig. 8. Diagram of patient E.L.'s left lower extremity. Muscles which are not normal are designated by letter grade. Muscles which are not spastic clinically and which possess volitional control are designated by conventional letter grading. The diagram illustrates presence of good hip flexors, extensors, and abductors, good knee extensors, fair knee flexors and foot invertors, poor foot dorsi flexors, zero foot evertors, and mild calf spasticity. There is 15° of hyperextension at the knee, and the heel cord is tight, limiting dorsiflexion of the foot to neutral. The presence of edema from the knee to the foot is also noted.

Summary of Functional Disability Dorsiflexion of foot inadequate in swing phase; inversion of foot in swing phase; tight heel cord with slight spasticity, probably contributing to recurvatum at knee.

Orthotic Recommendation Double upright below-knee brace with adjustable anterior and posterior stop ankle joint, lateral T strap; steel shank entire length of shoe.

Fig. 9. Summary of the patient's functional limb disability, and the orthotic recommendation based upon that summary.

at the mid-shaft of each bone. The actual fracture site is indicated by the fracture symbol. All bony deformities such as valgus angulation of the shaft are likewise diagramed on the circle located at the center of the shaft, regardless of the position of the angular deformity. The location of the angular deformity is designated by circling the appropriate level on the left side of the chart.

The technique of completing the analysis forms for specific lower-extremity disabilities is shown in Figures 7 through 12.

DISCUSSION

The stated purpose of developing a patient analysis form of this type is to organize a systematic approach to orthotic prescription. In addition, through stimulation of a careful appraisal of biomechanical faults in a given extremity, it may also serve as a basis for identifying certain areas in need of new or further design and development. It is also viewed as a valuable teaching tool for students of orthotics at both the technician and physician levels. Most importantly, it may serve as a common ground upon which both the orthotist and the physician can meet to work out satisfactory solutions to bracing problems. (Sample copies of the form are available from the CPRD office).

As a further step in making such an analysis form more meaningful to orthotists and physicians, a list of available lower-extremity orthotic components is currently being compiled in such a way as to categorize these components by their biomechanical function. Ideally then, one might diagramatically plot the biomechanical losses present in a limb and then select a mechanical device from the appropriate category to substitute for the lost function. In this way, the orthotic prescription can evolve as a carefully thought-out combination of specific components to create a suitable orthotic system for the deficient limb.

A revitalized approach to orthotics is urgently needed. According to a recent estimate, there are 3,370,000 orthotic patients in the United States as opposed to 311,000 amputees, or ten times as many patients who need orthoses as need prostheses *(1).* Little that is new has been done for many of these patients until very recently. Several research centers in the United States and Canada are engaged in sophisticated and promising orthotic research. Unfortunately, by and large, the products of this research have not yet reached the masses of handicapped people. Stimulation of new approaches to mechanical design at the local level must be achieved through close and meaningful collaboration between physician and or-

DIAGNOSIS Poliomyelitis
(L) Lower extremity residual

NAME W. S.
NO. 608213 SEX M
AGE 22 HEIGHT 6'0" WEIGHT 195
DATE 3/9/70

MAJOR IMPAIRMENTS:

A. Musculoskeletal:
1. Bone & Joint: Normal ☐ Abnormal Old triple arthrodesis (L) foot; Old, healed supracondylar Fx (L) femur
2. Muscle: Normal ☐ Flaccid ☑ Spastic ☐
Other Severe atrophy thigh & calf, left
3. Ligament: Normal ☐ Abnormal ☑ Knee: AC ☐ PC ☐ MC ☑ LC ☐
Ankle: MC ☐ LC ☐
Other

B. Sensation: Normal ☑ Abnormal ☐
1. Anaesthesia ☐ Location
Protective Sensation: Lost ☐ Retained ☐
2. Proprioceptive Loss ☐
Location Degree: Mild ☐ Moderate ☐ Severe ☐
3. Pain ☐ Location

C. Skin: Normal ☑ Abnormal

D. Vascular: Normal ☑ Abnormal ☐ RT ☐ LT ☐
1. Arterial ☐ 2. Venous ☐ 3. Coagulation Defect ☐

E. Balance: Normal ☑ Impaired: Mild ☐ Moderate ☐ Severe ☐

F. Extremity Shortening: None ☐ LT ☑ RT ☐
Amount of Discrepancy:
I.T. – Heel 1 3/4"
I.T. – M.T.P. 3/4"
M.T.P. – Heel 1"

X-ray

LEGEND

= Direction of Translatory Motion

= Abnormal Degree of Rotary Motion (60°)

= Fixed Position (30°, 1 CM)

= Fracture

Volitional Force
G = Good
F = Fair
P = Poor
T = Trace
Z = Zero

Spastic Muscle (SP)
SP_M = Mild
SP_{MO} = Moderate
SP_S = Severe

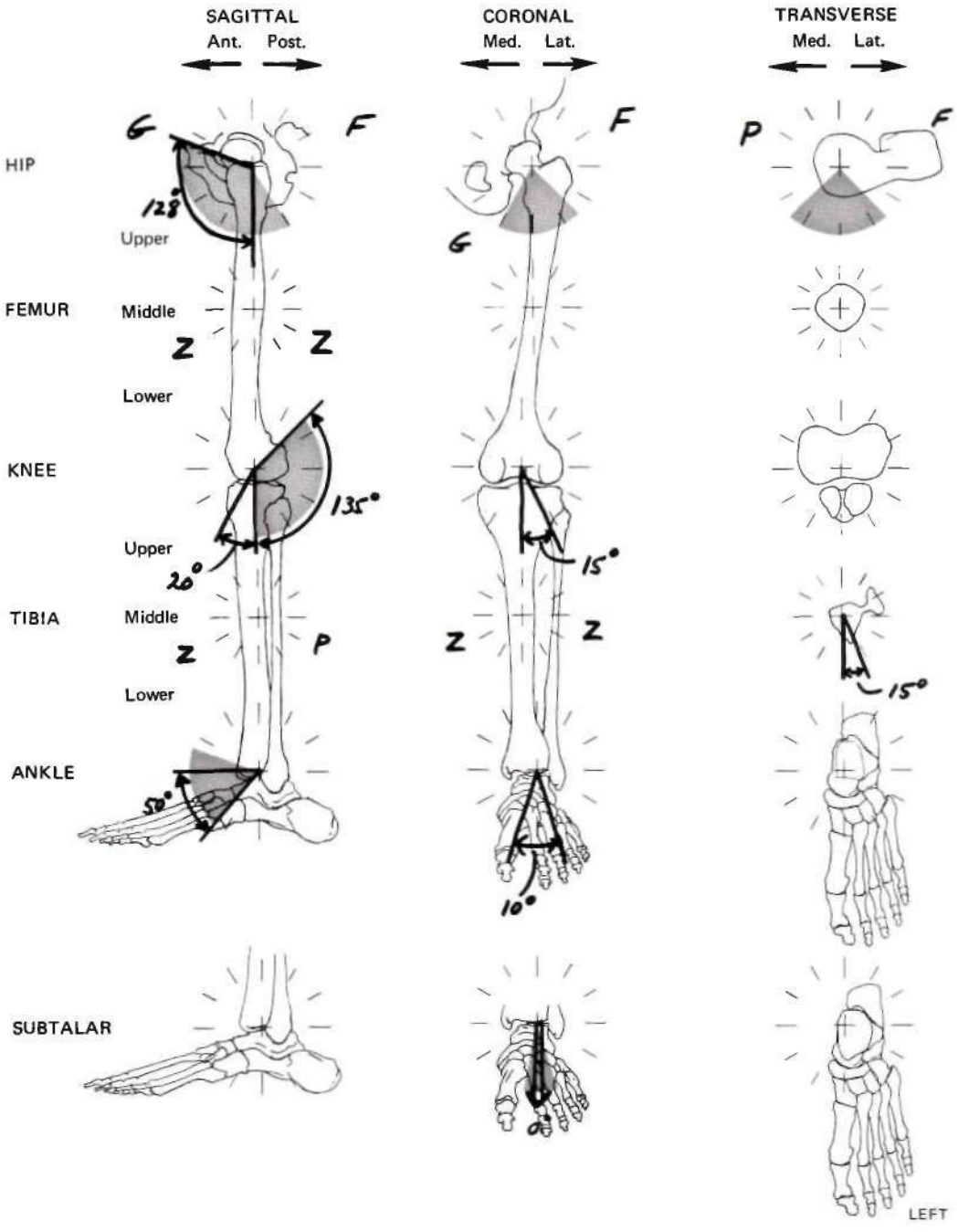
= Pseudarthrosis

= Absence of Segment

E = Edema

D = Local Distension or Enlargement

Fig. 10. Record for patient with residual poliomyelitis affecting his left lower extremity. Information given indicates flaccid paralysis with severe atrophy, laxity of the medial collateral ligament of the knee, and 1 3/4 in. shortening of the left lower extremity. In addition, the patient had an old supracondylar fracture of the femur and a previous triple arthrodesis.



(OVER)

Fig. 11. Diagram of patient W.S.'s left lower extremity. In addition to showing the letter grades for muscle-group strength, the diagram also shows 20° of hyperextension at the knee, 15° of valgus instability of the knee, 15° of external tibial torsion, limitation of dorsiflexion at the ankle, abnormal inversion and eversion at the ankle, and a fixed position of the subtalar joint.

Summary of Functional Disability Flail knee and ankle; recurvatum (20°) and valgus (15°) of knee on weight-bearing; hip extensors inadequate for knee stability; abnormal ankle inversion and eversion 2° to triple arthrodesis; external tibial torsion 15°

Orthotic Recommendation Single lateral upright (double bar) long leg brace with heavy-duty drop-lock knee joint; posterior thigh cuff; Silesion bandage; proximal pretibial cuff with posterior straps; 90° plantar stop at ankle; accommodate external tibial torsion.

Fig. 12. Summary of patient W.S.'s functional limb disability, and the orthotic recommendation based upon that summary.

thotist. It is hoped that the material presented in this article will be an initial step toward that goal.

Work is currently being done on a similar approach to the upper extremity and the spine. These areas will be the subjects of future reports.

ACKNOWLEDGMENTS

The authors wish to express special appreciation to Dr. George T. Aitken, former chairman of the American Academy of Orthopaedic Surgeons Committee on Prosthetics and Orthotics; Dr. Robert Keagy; Mr. A. Bennett Wilson, Jr.; Mr. Anthony Staros; and Dr. Edward Peizer for their specific contributions to this work.

REFERENCES

1. Committee on Prosthetics Research and Development, *Report of the Seventh Workshop Panel on Lower-Extremity Orthotics of the Subcom.ittee on. Design and Development,* National Research Council—National Academy of Sciences, March 1970.

Technical Notes

Wrist-Driven Prostheses for a Bilateral Partial-Hand Amputee

The patient discussed in this article is a 70-year-old man who lost all his fingers on both hands due to frostbite and resultant gangrene (Figs. 1 and 2). The usual prescription for this type of amputation is a cable-driven hook or partial hand. However, when the amputee was presented at the prosthetic clinic,[1] we decided to use the wrist-driven flexor-hinge splint with prosthetic fingers to utilize available wrist motion and to eliminate the usual shoulder harness.

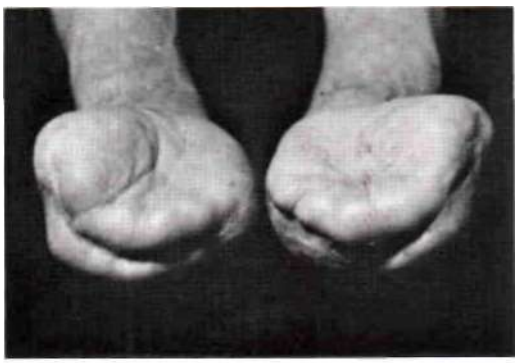


Fig. 1

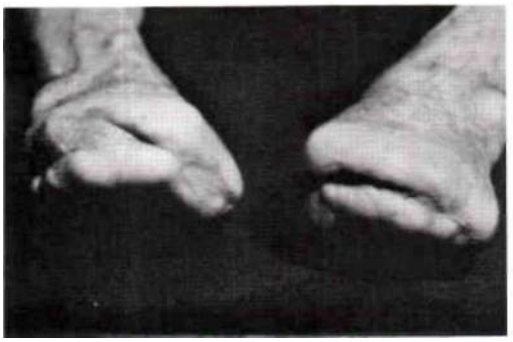


Fig. 2

All fingers had been amputated just proximal to the metacarpophalangeal joints, with split-thickness skin grafts to both stumps from the left thigh.

[1] University of North Dakota Medical Center Rehabilitation Unit, Grand Forks, N.D.; Donald Barcome, M.D., Clinic Chief.

Following surgery, the patient's measurements showed full ranges of shoulder, elbow, and forearm motion, with somewhat limited wrist motion of 0-40 deg flexion and 0-35 deg extension on the left side and 0-30 deg flexion and 0-35 deg extension on the right side. Hypersensitivity was noted on the ends of both stumps and palms.

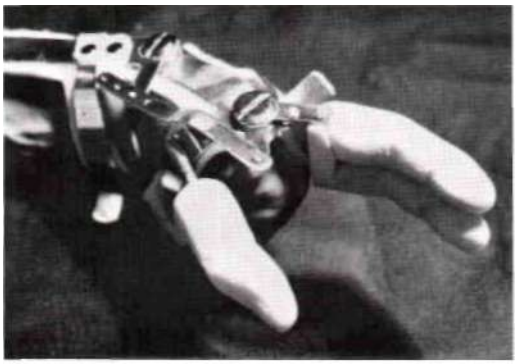


Fig. 3

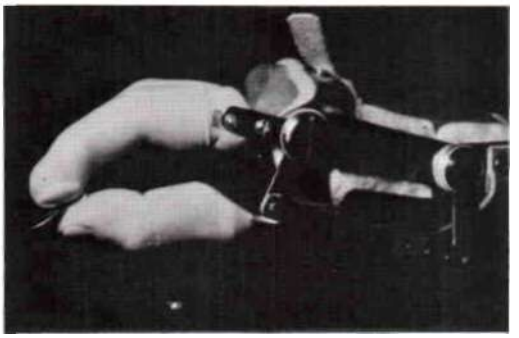


Fig. 4

The patient was well motivated, and a program of therapy was initiated to (1) improve upper-extremity strength with special emphasis on wrist musculature, (2) evaluate ADL status and provide necessary adaptive equipment, and (3) assess prosthetic needs, including initial check-out, patient training, and final check out of the prostheses. This treatment program included weighted overhead pulleys, weighted wristlets, and manual stretch and resistance exercises to the wrists daily.

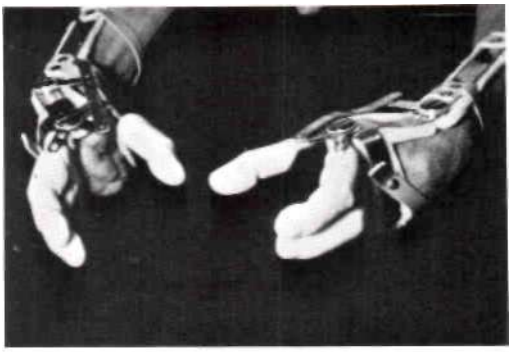


Fig. 5

Fig. 6

Following the therapy program, the prosthetic goals were to utilize available wrist motion, to eliminate contact with tender ends of the stumps, and to provide ease of application, simplicity of operation, and light weight.

The completed prostheses are shown in Figures 3, 4, and 5. Wrist flexion provides finger opening, and wrist extension provides finger closing for three-point prehension.

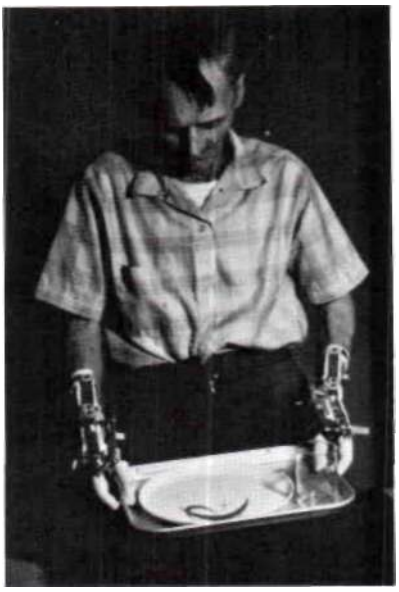


Fig. 7

The splint portions were made from commercially available kits,[2] and the fingers were made of acrylic plastic with brass reinforcing rods. The molds for the acrylic fingers were alginate impressions of my own fingers.

Three weeks after prosthetic fitting, the patient was performing normal tasks and was independent in activities of daily living (Figs. 6 and 7).

The prostheses achieved the goals stated above, resulting in self-contained, cosmetic units which do not require a shoulder harness or adaptive equipment. In addition, there is good sensory feedback, which is so helpful in the grasping of objects.

—Leslie Dent
Director, Brace and Limb Dept.
The Crippled Children's School
Jamestown, N. D.

[2] Orthopedic Supplies Inc., 9126 Firestone Blvd., Downey, Calif. 90241.

News and Notes

Prosthetics-Orthotics Education

University of California, Los Angeles

On July 1, 1970, Harlan C. Amstutz, M.D., assumed the positions of Chief of the Division of Orthopedic Surgery and Director of the Prosthetics-Orthotics Program at University of California, Los Angeles, School of Medicine, succeeding Charles 0. Bechtol, M.D.

Dr. Amstutz received his college and medical training at UCLA and the Los Angeles County General Hospital in 1953-57, served a surgical residency at the UCLA Medical Center, and an orthopedic residency at the Hospital for Special Surgery, New York.

Following duty with the 862nd SAC division of the United States Air Force from 1961 to 1963, Dr. Amstutz continued his postgraduate studies at the National Orthopaedic Hospital and the Institute of Orthopaedics, London, England, in 1963-64.

Prior to his appointment to the post at UCLA, Dr. Amstutz had held numerous teaching and hospital affiliations in New York, including: Assistant Professor of Surgery (Orthopedics) at Cornell Medical College; Assistant Attending, Associate Scientist, Director of Bioengineering, and Chief of Prosthetics and Orthotics at the Hospital for Special Surgery; lecturer in Bioengineering at the Polytechnic Institute of Brooklyn; and Assistant Attending at the New York Hospital.

Dr. Amstutz is a member of the American Academy of Orthopaedic Surgeons' Committee on Bioengineering and Committee on Nomenclature, and is co-chairman of the Subcommittee on Ceramics of the American Society for Testing and Materials, Committee F4 on Surgical Implants.

His honors include chairmanship of the Gordon Research Conference on the Science and Technology of Biomaterials for 1970.

* * * *

Harlan C. Amstutz, M.D.

The schedule of courses of the UCLA prosthetics and orthotics education program for the 1970-71 academic year is:

Physicians and Therapists

Prosthetics-Orthotics for Physicians X-482
Prosthetics-Orthotics for Therapists X-481
Oct. 19-30, Dec. 7-18, 1970; Feb. 8-19, Apr. 12 23, June 7-18,1971

Rehabilitation Personnel

Prosthetic-Orthotic Rehabilitation M-840
Nov. 9-11, 1970; Mar. 22-24, May 26-28, 1971

Prosthetists, Orthotists, and Certificate Students

Prosthetic Orientation for Certificate Students X-422*
Aug. 31-Sept. 11, 1970
Upper-Extremity Prosthetics X-468
Sept. 14-Oct. 16, 1970
Special Problems in Upper Extremities X-468.1
Oct. 19-30, 1970
Below-Knee Prosthetics X-480
Nov. 2-25, 1970
Advanced Below-Knee Prosthetics for Prosthetists X-467**

* Certificate students only.
** Limited to enrollees who have completed X-480.

Nov. 30-Dec. 4, 1970
Special Problems in Below-Knee Prosthetics X-480.1*
Dec. 7-23, 1970
Above-Knee Prosthetics X-463
Jan. 4-Feb. 5, 1971
Special Problems in Above-Knee Prosthetics
Feb. 8-26, 1971
Hip Disarticulation and Syme's X-486
Mar. 1-19, 1971
Special Problems in Hip and Syme's X-486.1*
Mar. 22-Apr. 2, 1971
Advanced Below-Knee Prosthetics for Prosthetists X-467**
Mar. 29-Apr. 2, 1971
Orthotic Orientation for Certificate Students X-422.1
Apr. 19-23, 1971
Lower-Extremity Orthotics X-485
Apr. 26-May 21, 1971
Special Problems in Lower-Extremity Orthotics X-485.1
May 24-28, 1971
Upper-Extremity Orthotics X-476
May 31-June 4, 1971
Child Amputee Prosthetics X-469
June 7-11, 1971

Further information and applications can be obtained from Mr. John Bray, UCLA Prosthetics-Orthotics Education Program, 1000 Veteran Ave., Room 22-46, Los Angeles, Calif. 90024.

New York University

At the invitation of the director, Dr. Victor M. Santana Carlos, a course in "Upper-Extremity Prosthetics for Prosthetists" was conducted at the Centro de Medicina de Reabilitacao, Alcoitfio-Estoril, Portugal, from July 27 to August 28, 1970, by Dr. Sidney Fishman, Norman Berger, Ivan Dillee, and George Hartmann of the New York University Post-Graduate Medical School Prosthetics and Orthotics program.

The purpose of the course, which was presented in English with simultaneous Portuguese translation, and for which a prosthetics manual in Portuguese had been especially prepared, was to train Portuguese prosthetists in modern methods of fabricating, fitting, and harnessing prostheses for use with upper-limb amputations of various levels, from wrist disarticulation through shoulder disarticulation. Lectures were also presented on anatomy, prosthetic components, and checkout and training procedures.

As an outgrowth of the prosthetics education program conducted by New York University Prosthetics and Orthotics staff in Portugal since 1968, they have been asked to assist in the formation of a national prosthetic association in that country.

* * * *

The schedule of courses of the NYU Post-Graduate Medical School prosthetics and orthotics education program for the 1970-71 academic year is:

Physicians and Surgeons
Lower Extremity Prosthetics
741A Oct. 19-24, 1970
741B Nov. 16-21, 1970
741C Feb. 1-6, 1971
741D May 17-22, 1971
Upper Extremity Prosthetics and Orthotics
744A Dec. 7-11, 1970
744B Apr. 5-9, 1971
Lower Extremity Orthotics
751A Oct. 5-9, 1970
751B Mar. 22-26, 1971
751C Apr. 19-23, 1971
Spinal Orthotics
755A Dec. 2-4, 1970
755B Mar. 31-Apr. 2, 1971
755C Apr. 28-30, 1971
Immediate and Early Postsurgical Prosthetics
741 IB Mar. 22-24, 1971

Therapists
Lower Extremity Prosthetics
742A Sept. 14-25, 1970
742B Nov. 2-13, 1970
742C Feb. 22-Mar. 5, 1971
742D May 3-14, 1971
Upper Extremity Prosthetics and Orthotics
745A Nov. 30-Dec. 11, 1970
745B Mar. 29-Apr. 9, 1971
Lower Extremity Orthotics
752A Oct. 5-9, 1970
752B Mar. 22-26, 1971
752C Apr. 19-23, 1971

Prosthetists
Below-Knee Prosthetics
740A Aug. 24-Sept. 11, 1970
Advanced Below-Knee Prosthetics
7402A Sept. 14-19, 1970
7402B Jan. 25-30, 1971
7402C June 28-July 3, 1971
Immediate and Early Postsurgical Prosthetics
7401B Mar. 22-27, 1971
Above-Knee Prosthetics
743A June 7-25, 1971

Upper Extremity Prosthetics
746A July 12-23, 1971

Orthotists
Spinal Orthotics
756A Jan. 11-22, 1971
Lower Extremity Orthotics
753B May 17-28, 1971
Advanced Lower Extremity Orthotics
7531A Jan. 4-8, 1971
7531B June 1-5,1971

Rehabilitation Counselors
Prosthetics and Orthotics
750 B Nov. 2-6, 1970
750D May 3-7, 1971

Further information and applications can be obtained from Dr. Sidney Fishman, Prosthetics and Orthotics, New York University Post-Graduate Medical School, 550 First Avenue, New York, N.Y. 10016.

Northwestern University

The schedule of courses of the Northwestern University Medical School Prosthetic-Orthotic Center education program for the 1970-71 academic year is:

Prosthetists

Above-Knee Prosthetics 601
Section A (Date to be announced)
Below-Knee Prosthetics 611
Section A (Date to be announced)
Advanced Below-Knee Prosthetics 621
(Dates to be announced)
Management of the Juvenile Amputee 631
Section A Nov. 9-12, 1970
B May 17-20, 1971
Review Course in Prosthetics 641
Section A June 7-10, 1971
Review of Fluid Control Mechanisms 671
Section A (Date to be announced)
Immediate Postsurgical Fitting Procedures 681
Section A Nov. 30-Dec. 1,1970
B June 3-4,1971

Orthotists

Spinal Orthotics 701
Section A (Date to be announced)
Lower-Extremity Orthotics 711
Section A (Date to be announced)
Upper-Extremity Orthotics 721
Section A (Date to be announced)
Review Course in Orthotics 731
Section A June 7-9, 1971

Rehabilitation Counselors

Orientation in Prosthetics and Orthotics 640
Section A Nov. 16-19, 1970
B Dec. 14-17, 1970
C Jan. 25-28, 1971
D Mar. 29-Apr. 1, 1971

Therapists

Lower-Extremity Prosthetics 622
Section A Sept. 14-18, 1970
B Oct. 5-9, 1970
C Oct. 26-30, 1970
D Nov. 2-6, 1970
E Jan. 18-22, 1971
F Feb. 8-12, 1971
G Mar. 22-26, 1971
H Apr. 5-9, 1971
I May 3-7, 1971
Management of the Juvenile Amputee 632
Section A Nov. 9-12, 1970
B May 17-20, 1971
Upper-Extremity Prosthetics 662
Section A Nov. 16-19, 1970
B Dec. 14-17, 1970
C Jan. 25-28, 1971
D Apr. 12-15, 1971
E May 10-13, 1971
Orthotics 702
Section A Oct. 19-23, 1970
B Dec. 7-11, 1970
C Feb. 15-19, 1971
D Apr. 19-23, 1971

Physicians and Surgeons

Lower-Extremity Prosthetics 623
Section A Sept. 14-18, 1970
B Oct. 5-9, 1970
C Oct. 26-30, 1970
D Nov 2-6, 1970
E Jan. 18-22, 1971
F Feb. 8-12, 1971
G Mar 22-26, 1971
H Apr. 5-9, 1971
I May 3-7, 1971
Management of the Juvenile Amputee 633
Section A Nov. 9-12, 1970
B May 17-20, 1971
Upper-Extremity Prosthetics 663
Section A Nov. 16-19, 1970
B Dec. 14-17, 1970
C Jan. 25-28, 1971
D Apr. 12-15, 1971
E May 10-13, 1971
Immediate Postsurgical Fitting Procedures 683
Section A Nov. 30-Dec. 1, 1970
B June 3-4, 1971
Orthotics 703
Section A Oct. 19-23, 1970
B Dec. 7-11, 1970
C Feb. 15-19, 1971
D Apr. 19-23, 1971

Nurses

Management of the Amputee 644

Section A Nov. 30-Dec. 2, 1970
B Apr. 26-28, 1971

Further information and applications can be obtained from Charles H. Fryer, M.A., Director, Prosthetic-Orthotic Center, 401 East Ohio Street, Chicago, 111. 60611.

Committee on Prosthetic-Orthotic Education

Subcommittee on Orthotics Meeting

A meeting of the CPOE Subcommittee on Orthotics was held on March 10, 1970, in Los Angeles, California. Members present at the meeting were: Jacquelin Perry, M.D., chairman; Norman Berger, Hans R. Lehneis, Charles W. Rosenquist, and Roy Snelson. Guests representing various educational programs included: Kenneth Schwartz, Dr. Elwyn C. Saferite, Art Guilford, and Ralph Storrs.

Most of the meeting was devoted to an open discussion on the committee's possible future activities. Suggestions for projects included a survey related to the types of collars for cervical support, a survey related to a type of lower-extremity brace for stroke patients, and the development of a brochure on bracing for the general medical profession.

The members decided to proceed with a project advocated by Mr. Snelson in which all technical manuals on orthotics would be assembled and made available in packet form. Sale of the packets by the American Orthotic and Prosthetic Association was considered a possibility.

Annual Meeting of CPOE

The annual meeting of the Committee on Prosthetic-Orthotic Education (CPOE) was held at the Prosthetic and Orthotic School, New York University, or. March 27, 1970. The morning session was a joint meeting with the Council on Orthotic-Prosthetic Education (COPE), arranged for the purpose of saving time by eliminating duplication of reports at separate meetings.

Attending the morning session were: Herbert E. Pedersen, M.D., chairman; William M. Bernstock; Margaret Bryce; Clinton L. Compere, M.D.; Alvin L. Muilenburg; J. Warren Perry, Ph.D.; Lena M. Plaisted; Charles W. Rosenquist; and Augusto Sarmiento, M.D.

Guests attending were: Col. George I. Baker, M.C., U.S. Army; John Bray; Sidney Fishman, Ph.D.; Charles Fryer; Charles R. Goldstine; Florence Knowles; Edward J. Ryan; Elwyn C. Saferite; N. Elane Wilcox, Ph.D.; Comdr. Leo V. Willet, Jr., M.C., U.S. Navy; and A. Bennett Wilson, Jr.

Barbara R. Friz, the executive secretary of CPOE, represented the Division of Medical Sciences, National Research Council.

Mr. Bernstock, representing the Prosthetics and Sensory Aids Service of the Veterans Administration, called attention to the recent publication of the manual, *The Management of Lower-Extremity Amputees,* by Burgess, Romano, and Zettl, which is being sold by the Superintendent of Documents for $1.50. He announced the various VA educational programs for the coming year and discussed plans for a qualifications program in which VA contracts will require prosthetists to meet certain specified standards, effective January 1, 1972. These include certification by the American Board for Certification and satisfactory completion of selected short-term courses.

Mrs. Knowles, speaking for the Social and Rehabilitation Service, Department of Health, Education, and Welfare, noted many administrative changes within the agency, as well as changes in priority, with emphasis on training programs at a lower level. Despite a substantial cut in budget last year and again this year, the Division of Training will try to keep commitments for continuing grants.

Speaking for the Council on Orthotic-Prosthetic Education, Mrs. Knowles noted that "University" has been dropped from the title of the organization because of the

expanded membership, which now includes all prosthetic and orthotic educational programs.

Reports from the various prosthetic and orthotic educational programs reflected common financial problems during the past year. Various ways in which the schools had accommodated to their situation were discussed.

Dr. Fishman, of New York University, noted that, despite curtailments, enrollment of prosthetists had not been affected, and enrollment of physicians and therapists affected only slightly. Thirty students have been graduated from the baccalaureate program. Inquiries and applications have increased, while at the same time the quality of applicants continued to improve.

Several volumes of written materials compiled at New York University from various sources were displayed at the meeting.

Dr. Compere stated that financial problems had resulted in cancellation of the Associate in Arts degree program in orthotics at Northwestern University. The A.A. program in prosthetics was possible because of financial support from Chicago City College.

Mr. Fryer listed the following new courses at Northwestern University: a three-day course for nurses, advanced below-knee prosthetics courses, and review courses for prosthetists and orthotists. He expressed the opinion that three laboratories would be ideal in a prosthetic-orthotic educational setting—one for A.A. orthotics, one for A.A. prosthetics, and one for short-term prosthetics and orthotics.

Mr. Bray stated that Dr. Harlan C. Amstutz had been named chief of orthopedic surgery, replacing Dr. Charles Bechtol, who recently resigned from the University of California at Los Angeles. In speaking of financial problems, he noted that three of the ten students enrolled in their certificate program had paid the full tuition of $2,000 each. The short-term course program at UCLA included four new advanced below-knee prosthetic courses this year.

Mr. Ryan, of Delgado Junior College, announced that a full-time prosthetist-orthotist, Mr. Charles Goldstine, is now with the school.

Mrs. Knowles announced that Mr. Basil Peters, a certified prosthetist-orthotist, is with the program at Intra-American University in Puerto Rico on a full-time basis, an arrangement which is much better than one in which the faculty is rotated. Plans are being made for an A.A. program at that university.

Written reports on the activities of CPOE and its subcommittees, which had been distributed prior to the meeting, were discussed. According to Dr. Pedersen, two matters that deserve priority status were identified during the past year. The first is the problem of reaching general surgeons, who are doing most of the amputation surgery in this country. Very few surgeons attend prosthetic courses or seminars on prosthetics, and relatively few attend amputee clinics. He stated that if the geriatric amputee is to achieve optimal rehabilitation, a program must be launched whereby general surgeons are not only alerted but are educated to more acceptable approaches in the overall management of the amputee. He noted that widespread distribution of the geriatric-amputee manual, to be published within the next few months, would be one way to reach many surgeons, but he called on the members for other suggestions. The other priority item relates to a request by the American Orthotic and Prosthetic Association—American Board for Certification for CPOE to assume a leading role in a cooperative effort to establish standards and guidelines for prosthetic and orthotic educational programs. This tied in with Dr. Perry's report on the Subcommittee on Special Educational Projects in Prosthetics and Orthotics, as the subject had been discussed at the last subcommittee meeting. In speaking of the urgency to

move ahead in establishing standards, Dr. Perry noted that many educational institutions are starting programs without knowing the requirements of the field and without any consultation or relationship with the national group concerned. This development is particularly true in community colleges where it is not necessary to go to the federal government for funds. Another pertinent consideration is the tremendous move to start certifying programs at the state level.

In the absence of Dr. Frank Clippinger, chairman of the Subcommittee on Prosthetics Clinical Studies, Mrs. Friz reported that final results of two large studies, the "Facility Case Record Study" and the "Prosthetics Clinical Follow-up Study," are expected to be published within the next year. The subcommittee has recommended that the "Amputee Census," a survey conducted during 1962-64, be repeated during 1972-74 for the purpose of making comparisons after a 10-year period.

The Subcommittee on Publications and Educational Materials has incorporated the Ad Hoc Committee on Publications, and Augusto Sarmiento, M.D., has been named the chairman. The former ad hoc committee, of which Mr. Bernstock was chairman, instigated the idea of a newsletter, which was published for the first time in December 1969. Also published during the past year were: (1) *Amputees, Amputations, and Artificial Limbs,* which contains 1,235 annotated articles on prosthetics; (2) *Braces, Splints, and Assistive Devices,* containing 495 annotated articles on orthotics; and (3) *Review of Visual Aids in Prosthetics and Orthotics,* which reviews 58 films and, in addition, lists available slides and audiotapes. The subcommittee is currently interested in a system for data retrieval in prosthetics and orthotics, plans to exhibit publications at national conferences, and will continue to review educational teaching materials.

At the executive session of the Committee on Prosthetic-Orthotic Education, the following proposed recommendations and activities were approved for the coming year:

1. The Subcommittee on Prosthetics Clinical Studies will explore the possibility of developing a standard form to record clinical data on amputees. This is in response to requests from amputee clinic chiefs.
2. *Newsletter ... Amputee Clinics* will be given wider circulation, and distribution will not be limited to amputee clinics.
3. An ad hoc committee will be appointed to consider and plan an educational program in which modern approaches to the care and management of the geriatric amputee may be brought to the attention of the general surgeon.
4. Technical reports from research and development activities in the field of orthotics will be assembled in packet form for use in educational programs.
5. The Subcommittee on Publications and Education Materials will explore the possibility of acquiring or developing modern teaching aids for the fields of prosthetics and orthotics.
6. CPOE will support and conduct a workshop on educational programs for orthotists and prosthetists and will work with appropriate groups in a cooperative effort to establish standards for prosthetic and orthotic educational programs.

Subcommittee on Prosthetics Clinical Studies Meeting

The Subcommittee on Prosthetics Clinical Studies met at Duke University, Durham, North Carolina, on June 4, 1970, for the purpose of developing a standard form for the collection of clinical data on amputees. By the end of the day, two separate forms had been drafted: (1) a simple record-keeping form for clinical use, and (2) a McBee punch-card form for collection of data. When the forms are finished, they will be distributed to selected amputee clinic chiefs for trial use.

Attending the meeting were: Frank Clippinger, M.D., chairman; Eugene Record, M.D.; Edward Haslam, M.D.; Alvin Muilenburg; James Rae, M.D.; and Barbara Friz, executive secretary of CPOE.

Workshop on Educational Programs for Prosthetists and Orthotists

A three-day workshop on educational programs for prosthetists and orthotists was sponsored by the Committee on Prosthetic-Orthotic Education on June 15-17, 1970, at Ponte Vedra Beach, Florida. Dr. Herbert Pedersen, chairman of CPOE, presided at the general sessions, and Dr. J. Warren Perry, chairman of the Subcommittee on Educational Projects in Prosthetics and Orthotics, served as consultant. In discussing the purpose of the workshop at the first session, Dr. Perry stated: "With the expansion of educational programs at all levels, it becomes imperative that a profession spell out its own standards and objectives. It must claim the right to offer direction to its own development. It can be assumed that outside sources will assume this role if the field neglects its own responsibility." He spoke of the necessity of a cooperative effort of all involved groups, but noted, also, that our primary task is to spell out in writing that the organization of prosthetists and orthotists has, indeed, accepted responsibility for its own educational destiny. "If this fails," he said, "then it has no right to call itself a profession, either today or in the future."

Herbert Warburton, executive director of the American Orthotic and Prosthetic Association—American Board for Certification, reminded the group of the need to bring people into the profession, and emphasized AOPA-ABC's responsibility in ensuring proper educational channels to meet future requirements.

Four panels convened during the workshop, as follows:

1. Panel on Job Descriptions. Chairmen: William Bernstock and Roy Snelson. Recorder: John Eschen
2. Panel on Interrelationships of B.S. and A.A. Programs and Apprenticeship Instruction. Chairmen: Paul Meyer, M.D., and Ralph R. Snell. Recorder: Audrey Calomino
3. Panel on Essentials Format for A.A. Instruction. Chairmen: Charles Fryer and Raymond J. Pellicore, M.D. Recorder: Elwyn Saferite, Ed.D.
4. Panel on Essentials Format for B.S. Instruction. Chairmen: Sidney Fishman, Ph.D., and Samuel Hamontree. Recorder: Herbert Warburton

A general discussion on accreditation and methods of achieving a recognized accreditation system was the subject of one general session. The last session was devoted to discussion of panel recommendations as reported by the chairman. It was the consensus of the participants that the workshop provided the impetus needed to move ahead in this endeavor as well as a foundation on which to base future action.

Participants at the workshop included: William M. Bernstock; John Billock; Audrey Calomino; Kermit Clayton; John H. Eschen; Sidney Fishman, Ph.D.; Barbara R. Friz; Charles Fryer; Samuel E. Hamontree, C.P.; Paul R. Meyer, Jr., M.D.; Herbert E. Pedersen, M.D.; Raymond J. Pellicore, M.D.; Jacquelin Perry, M.D.; J. Warren Perry, Ph.D.; Elwyn C. Saferite, Ed.D.; Bernard Simons, C.P.; Ralph R. Snell, C.P.; Roy Snelson, C.P.O.; and Herbert B. Warburton.

Committee on Prosthetics Research and Development

Subcommittee on Sensory Aids

The third meeting of the CPRD Subcommittee on Sensory Aids was held on March 5-7, 1970, in San Francisco, Menlo Park, and Santa Monica, California. At the previous meeting of the subcommittee, the major research projects in sensory aids supported by the Veterans Administration were reviewed. The purpose of this meeting was to review the status of research projects located on the West Coast. The schedule included: demonstrations at the Institute of Medical Sciences, San

Francisco; Stanford University and Stanford Research Institute, Menlo Park; the Veterans Administration Hospital, Menlo Park; and the Rand Corporation, Santa Monica; and by representatives of the West Coast Laboratories of Bolt, Beranek, and Newman of Van Nuys.

In addition to all members of the subcommittee, Eugene F. Murphy, Howard Freiberger, Hector Kay, and A. Bennett Wilson, Jr., participated in the site visits. Joseph Traub also participated in the visit to the Rand Corporation and the demonstration of the Bolt, Beranek, and Newman work. At an executive session, the subcommittee reviewed five research proposals for the Sensory Study Section of the Social and Rehabilitation Service.

At the Institute for Medical Sciences, the group was met by Drs. Carter Collins and Benjamin White, Dr. Bach-y-Rita being on sabbatical leave in Italy. No formal presentation was made, but one blind subject demonstrated use of the tactile image projection device. The responsible investigators stated that their objective is to develop an array of electrical stimulators that can be mounted in a vest across the back, so that the "image" can be used as a mobility aid. The television camera will be placed on the head.

At the Stanford Research Institute, the group was met by Drs. James Bliss and William K. Linvill. A thorough briefing was given on the history, present status, and future plans for the development of the Optacon, a tactile facsimile reading aid for the blind.

At the Menlo Park branch of the Veterans Administration Hospital, the group met with Mr. L. E. Apple and other staff members. A complete briefing on the evaluation project for the Bionic C-4 (laser) cane was given. Reasons for the methods used were presented, and a demonstration of the cane in a normal outdoors environment was given.

At the Rand Corporation, the group was met by Mr. S. M. Genensky and his associates. The Telesight closed-circuit television system for enlargement of printed material or of the partially sighted person's own handwriting was demonstrated, and used by members of the subcommittee.

At a meeting in Santa Monica, a representative of the Bolt, Beranek, and Newman West Coast Laboratories presented stereo-tape-recorded demonstrations of binaural lateralization of pulses presented through earphones. In this system, if the signal to the left ear arrives slightly earlier, the combined effect is perceived as to the left of the center within the observer's head. Multiple "spots" can be perceived. Intensity can be used to give a second dimension, allowing pen-like "tracing" of a pattern. He suggested that further psychological research with the aid of the PDP-8 computer and other equipment might indicate possible applications to aid the blind by scale-like outputs of laboratory or workshop instruments and ultimately two-dimensional displays.

Summaries of the subcommittee members' observations will be included in a report to be prepared for the Veterans Administration and the Social and Rehabilitation Service on the general status of research and development in aids to the blind.

The members of the Subcommittee on Sensory Aids are: Richard E. Hoover, M.D., chairman; Samuel Ashcroft, Ph.D.; Newman Guttman, Ph.D.; John Lyman, Ph.D.; Colin A. McLaurin; and Patrick W. Nye.

Panel on Lower-Extremity Orthotics

The Panel on Lower-Extremity Orthotics of the Subcommittee on Design and Development, CPRD, met at Rancho Los Amigos Hospital, Downey, California, on March 9-12, 1970. It was a "do and show" meeting, during which 14 orthotists fitted patients with 19 new leg braces.

Following explanations of the braces and demonstrations on patients, recommendations were made for further design and development, evaluation, and incorporation into educational programs. A complete report of this meeting, with

photographs and descriptions of each brace, has been published by CPRD ("Seventh Workshop Panel on Lower-Extremity Orthotics of the Subcommittee on Design and Development").

Panel on Upper-Extremity Prosthetics

The eighth workshop panel on upper-extremity prosthetics of the Subcommittee on Design and Development, CPRD, met at the Tahitian Village Inn in Downey, California, on March 31-April 2, 1970. Thirty-six conferees participated in the workship, which was the last in a series of three conferences on the current state of development in the field of externally powered prosthetics components.

The first workshop was convened in March 1968 to study a number of externally powered elbows. The second was held in July 1969 to consider externally powered terminal devices. At both of these meetings, it had been strongly recommended that steps be taken to obtain information on various methods and systems currently available for *controlling* externally powered components. Two prime systems were identified: those involving myoelectric signals and those involving pull-type electrical switches. To obtain information on the effectiveness of these two types of controls, five experiments were planned and conducted by cooperating laboratories which had participated in the planning. These studies and the associated centers were:

1. Control of externally powered hand for below-elbow amputee by means of myoelectric signals and electrical pull switches. Lawrence E. Carlson, University of California, Biomechanics Laboratory, Berkeley, Calif.
2. Control of externally powered hand and conventional elbow by means of EMG and pull switches. John W. Hodge, Jr., and William R. Bartells, USAMBRL, Walter Reed Army Medical Center, Washington, D.C.
3. Myoelectric and pull-switch control of electric elbow and conventional hook. Dr. Dudley Childress, Prosthetic Research Center, Northwestern University, Chicago, Ill.
4. Myoelectric and pull-switch control of externally powered elbow and externally powered hand. James Allen and Herbert Hartman, Medical Engineering Laboratory, Rancho Los Amigos Hospital, Downey, Calif.
5. Myoelectric and pull-switch control of conventional elbow. Roy W. Wirta, Biokinetics Research Laboratory, Moss Rehabilitation Hospital, Philadelphia, Pa.

At the eighth workshop panel on upper-extremity prosthetics, Dr. Dudley Childress of Northwestern University demonstrates a technique for control of the hand.

At the panel meeting, reports were received from each laboratory on the experiment which had been conducted under its auspices. Discussion of the results obtained led to the formulation of a number of conclusions and recommendations. Principal among these were:

1. *UCBL study*
   a) Choice of hand or hook for below-elbow amputee should be based on amputee use and preference.
   b) If a hook is prescribed, it will be

bodily powered because there are no externally powered hooks available at this time.

c) If a hand is prescribed, the choice of a bodily or externally powered hand must be carefully weighed with advantages and disadvantages.

d) If an externally powered hand is prescribed, EMG control is superior in function to pull-switch control, but is more costly and less reliable.

2. *AMBRL study*

a) The prescription of an externally powered terminal device and a bodily powered elbow is not recommended, because elbow-control motion interferes with TD (terminal device) operation and because the greater weight of the externally powered TD must be lifted by the bodily powered elbow.

3. *NU study*

a) If a bodily powered TD and externally powered elbow are prescribed, pull-switch control is preferable, in the light of present technology, although EMG control is judged superior in principle.

4. *Rancho study*

a) If an externally powered hand and elbow are prescribed, EMG control is preferable for both components *if* adequate technical back-up is available. *However,* an externally powered elbow and bodily powered TD are preferred to having both components externally powered.

5. *Moss study*

a) If an externally powered hand is prescribed with a pull-switch-controlled, externally powered elbow, EMG control is preferred functionally over pull-switch control of the hand.

Discussion of the above results recognized the need for further studies and development of externally powered components for upper-extremity prosthetics. The report of the meeting will enumerate recommendations made for future work.

Twenty-first Meeting of CPRD

The twenty-first meeting of the Committee on Prosthetics Research and Development was held in Cleveland, Ohio, on April 21-22, 1970. Dr. Knud Jansen, an orthopaedic surgeon from the Orthopaedic Hospital in Copenhagen, Denmark, and chairman of the International Committee on Prosthetics and Orthotics of the International Society for Rehabilitation of the Disabled, was a special guest.

The primary purpose of the meeting was to continue development of program planning for the immediate and long-range future. For this purpose, committee members and invited participants were divided into three groups to consider requirements in the areas of Fundamental Research, Design and Development, and Evaluation. The reports prepared at the twenty-first meeting will be transmitted to the respective subcommittee, where they will be developed further. These reports, supplemented by other reports on the objectives and operation of the program, will be presented at the Twenty-fifth Anniversary meeting in Washington, D.C., October 12-16, 1970.

Kessler Institute Seminar

On April 24-25, 1970, the Kessler Institute for Rehabilitation presented a clinical seminar on the adult lower-extremity amputee and the limb-deficient child. Co-chairmen of the event were Dr. Henry H. Kessler, director of professional education at the institute, and Dr. Knud Jansen, chairman of the International Committee on Prosthetics and Orthotics, Copenhagen, Denmark. The seminar was sponsored by the Committee on Prosthetics Research and Development, the Kessler Institute for Rehabilitation, the New York University Orthotics and Prosthetics Research Division, and the Veterans Administration. Approximately 300 physicians, therapists,

At the Kessler Institute seminar on the adult lower-extremity amputee and the limb-deficient child, *left to right:* Dr. Knud Jansen, Chairman of the International Committee on Prosthetics and Orthotics, Copenhagen, Denmark; Dr. Henry Kessler, Director of Professional Education at the institute; and Dr. Newton C. McCollough III, Assistant Professor of Orthopaedics, University of Miami School of Medicine.

Participating in the panel discussion on lower-extremity amputations in elderly adult patients, *left to right:* Dr. Henry Kessler, Dr. Knud Jansen, Dr. Saul Firtel, Dr. Newton McCollough, Dr. George Murdoch, Anthony Staros, Earl Lewis, and Dr. Richard Sullivan.

nurses, prosthetists, and others from an eight-state area attended.

The first day's program was devoted to considerations of the elderly adult patient with lower-extremity amputations, including: "Surgical Techniques of Lower-Extremity Amputations"—Dr. Newton C. McCollough III; "Surgical Management of Lower-Extremity Amputations"—Dr. George Murdoch; "Prosthesis for Above-Knee and Below-Knee Amputations"—Anthony Staros; and "Recent Advances in Prosthetic Knee Mechanisms"—Earl Lewis.

A panel discussion with audience participation was moderated by Dr. Jansen, and included the above speakers and Drs. Richard Sullivan and Saul Firtel, medical director and associate medical director, respectively, of the Kessler Institute.

The second day's program was devoted to the limb-deficient child. Papers presented and their authors were: "Modern Philosophy of Treatment"—Dr. Jansen; "Classification of Anomalies"—Dr. Leon Kruger; "Experimental Devices for Children with Upper-Extremity Disabilities"—Dr. Sidney Fishman and Norman Berger; and "Surgical and Prosthetic Management of Lower-Extremity Juvenile Amputations"—Dr. Kruger.

Conference on Electrical Stimulation of Paralyzed Muscle

On May 4, 1970, the Committee on Prosthetics Research and Development sponsored a conference to ascertain the status of research involving the stimulation of paralyzed muscle to provide or enhance function, with the goal of developing recommendations for future action by sponsoring agencies and research groups. All research projects active in this field in North America and one in Yugoslavia were represented. The conference was held at the Texas Institute for Rehabilitation and Research (TIRR) in Houston, with William A. Spencer, M.D., serving as chairman.

Research activities at the Rancho Los Amigos Hospital, Case Western Reserve University, National Research Council of Canada, University of California, and the University of Ljubljana were reported, and stroke patients who had been fitted at TIRR with the surface-electrode system for toe pickup developed at Ljubljana were presented, in person and with videotape recordings.

The conference concluded with the following observations and recommendations: 1. Functional electrical stimulation is a

promising development that should be pursued vigorously and thoroughly.
2. The surface-electrode system for toe pickup developed at Ljubljana appeared to be nearly ready for an organized clinical evaluation in the United States.
3. A steering committee should be appointed by CPRD to determine when the evaluation program should begin and to assist in development of the protocol. In addition, the chairman of CPRD, subsequent to the meeting, has asked that the Subcommittee on Design and Development give special consideration to the design and development aspects of this research area.

Subcommittee on Evaluation

A meeting of the CPRD Subcommittee on Evaluation was held at the National Academy of Sciences on May 12-13, 1970. The purposes were to review the progress of the clinical evaluation of externally powered elbows and to introduce several leg braces into the CPRD evaluation program.

The six clinics involved with the trial fittings of the AMBRL, Boston, and Rancho externally powered elbows reported on the amputee wear and acceptance to date. The clinical evaluation of these elbows will be continued, and the subcommittee will meet again later in the year to discuss the final results and recommendations.

It was recommended that four leg braces—the NYU insert brace, the UC-BL shoe insert, the UC-BL dual-axis ankle brace, and the VAPC single-bar long leg brace—be clinically evaluated for routine use on patients and for incorporation into educational programs. It was also recommended that a comparative study be undertaken on seven, different, short leg braces.

Prosthetics-Orthotics Conference

On May 20-22, 1970, a highly successful conference was held at the University of New Brunswick in Fredericton, Canada. Prof. Robert N. Scott coordinated the meeting on behalf of the host institution. The occasion was the joint convention assembly of the Canadian Association of Prosthetists and Orthotists, the conference of Canadian prosthetics-orthotics research groups, and the annual meeting of the Canadian Amputee Clinic Chiefs. This was the first joint meeting of the three groups.

The registered attendance included 22 representatives of the Canadian prosthetics research groups, 48 members of the Canadian Association of Prosthetists and Orthotists, and 12 amputee clinics chiefs or designates. Guests attending the sessions included: Hector W. Kay, assistant executive director of CPRD, Barbara R. Friz, executive secretary of CPOE, and Warren Springer, senior research scientist at New York University Post-Graduate Medical School. Highlights of the meeting included a number of excellent technical papers by both the research groups and by participating prosthetists. Two stimulating panel discussions were also conducted, one on education of prosthetists and orthotists and the other on research priorities. Also of great interest were a number of technical exhibits on prosthetics-orthotics components and materials.

One decision of major significance reached by the research groups was to attempt to arrange a national conference on prosthetics, orthotics and technical aids for 1971, to bring all aspects of these topics into perspective and to focus national attention upon the urgent need for a coordinated long-range program. Also, it was clear throughout the conference that the research groups are becoming increasingly convinced of the necessity of using the economic cost/benefit ratio to determine priorities for various research projects.

A final highlight of the meeting was the closing banquet at which the participants were the guests of the city of Edmonton and the province of New Brunswick.

Child Amputee Clinic Chiefs Meeting

The Ontario Crippled Children's Centre (OCCC), Toronto, Canada, was host to

At the prosthetics-orthotics conference at the University of New Brunswick, a meeting of a panel on education of prosthetists and orthotists included, *left to right, standing:* Colin A. McLaurin, Warren Springer, James Foort, and Peter Kraft; *seated,* William Henderson and John Hall.

the 1970 meeting of Child Amputee Clinic Chiefs on June 9-11, 1970. The more than 100 physicians, engineers, prosthetists, orthotists, therapists, and others attending enjoyed an outstanding program. Highlights were a symposium on "The Child with an Acquired Amputation," a presentation of lower-extremity braces which had evolved out of CPRD's Subcommittee on Design and Development, presentations of braces and mobility devices developed at OCCC for children with spina bifida, cerebral palsy, and Legg-Perthes disease, and a visit to the Variety Village electrical component factory. Representatives of 28 clinics affiliated with the program attended the meeting, as well as representatives of 24 clinics not yet affiliated.

Dr. 0. Hoffman, Department of National Health and Welfare, and Dr. K. C. Charron, Deputy Minister of Health, Province of Ontario, presented the welcome on behalf of the Canadian provincial and federal governments, and Mr. Ray Auld, Administrator, welcomed the group on behalf of the Ontario Crippled Children's Centre.

The symposium on "The Child with an Acquired Amputation," moderated by John E. Hall, M.D., Charles H. Epps, Jr., M.D., and Leon M. Kruger, M.D., included presentations on "Etiology"—Claude N. Lambert, M.D.: "Psychologi-

cal and Social Factors"—Sidney Fishman, Ph.D.; "Principles of Amputation Surgery"—Dr. Hall; "Immediate Postsurgical Fitting of Prostheses"—Robert L. Romano, M.D.; "The Amputee with Extensive Scarring (Burns, etc.)"—Dr. Hall; "Limb Replantation"—Gael Frank, M.D.; "Stump Lengthening"—James Hunter, M.D.; and "Limb Loss through Malignancy"—Dr. Lambert. Concerning "Prosthetics Principles," papers were presented on "Upper Limb, Conventional"—Robert E. Tooms, M.D., and Ralph R. Snell, C.P.; "Upper Limb, Powered"—Maurice Mongeau, M.D., Camille Corriveau, C.P.O., and R. N. Scott; "Lower Limb"—Frank W. Clippinger, M.D., and Bert Titus, C.P.O. "Training Considerations" included papers on "Upper Limb, Conventional"—Maurice Mongeau, M.D., Miss Jeannette Hutchison, and Miss Elaine Treffler; "Upper Limb, Powered"—Colin A. McLaurin, Miss Barbara O'Shea, Dr. Mongeau, and Miss Hutchison; "Lower Limb"—Charles H. Epps, Jr., M.D., and Miss Helen Vaughn; "School Factors"—Yoshio Setoguchi, M.D.; and "Rehabilitation Considerations"—Robert C. Hamilton, M.D.

The session concerning the cooperative research program was moderated by Dr. Lambert, with presentations on "Status of Clinics"—Hector W. Kay; "Bracing Items from Subcommittee on Design and Development"—Dr. Fishman and Norman Berger; "Evaluation Projects"—Dr. Fishman and staff; "Inter-Clinic Information Bulletin"—Mr. Kay; "Proposed Expansion of Program to Include Bracing" and "Data Handling Systems"—Mr. McLaurin.

The session on children's orthotics was moderated by Dr. Fishman and included "Demonstration of Braces Used at OCCC"—Mr. McLaurin and Clendon P. Wooldridge; "Items from Subcommittee on Design and Development"— Mr. Berger; and "Brace Designs from Ohio State University"—Charles Rosenquist.

Conference on Bioengineering Centers

At the request of the Social and Rehabilitation Service of the Department of Health, Education, and Welfare, CPRD conducted a conference on June 19-20, 1970, for preliminary discussions on methods for initiating bioengineering (or rehabilitation engineering) centers for conducting research in problems of the neuromusculoskeletal system. The meeting was prompted by the submission by Rancho Los Amigos Hospital of a proposal to the Social and Rehabilitation Service for a pilot study to demonstrate, using one example, how an organization might effectively develop a product from the idea stage to patient application on a wide basis, and is considered to be a part of the development of future plans being undertaken currently by CPRD.

The following points and recommendations were made:

1. It is highly desirable that a number of centers be established and operated in this country where the engineering and medical disciplines can work together effectively in developing better procedures for rehabilitation of individuals with disorders of the neuromusculoskeletal system. Support of comprehensive centers will not supplant the present grant and contract systems of the federal government for support of individual projects—the large centers being needed to bring together, as well as to develop, new knowledge in care of patients.

2. The objective of the rehabilitation engineering program is to seek ways to enhance the quality of life of the physically handicapped by the combined application of medicine, engineering, and related sciences.

3. It was recommended that October 12-13, 1970, be devoted to presentation by CPRD of a preliminary report on a recommended program for the next five-to-ten-year period. Recommendations for establishment of biomedical centers will form a part of that report. The meeting

will be open to all those with a bona fide interest in research in rehabilitation.

4. It was recommended that Rancho Los Amigos Hospital, Temple University, Case Western Reserve University, the University of California, and Baylor University develop proposals during the summer, and convene early in September for the purpose of preparing a report for presentation at the October 12-13 meeting.

Workshop on Knee-Disarticulation Prosthetics

A Workshop on Knee-Disarticulation Prosthetics was held in San Francisco on June 22-23, 1970, for the purpose of reviewing the surgical procedures and the prostheses for amputations about and through the knee.

At the first session, five knee-disarticulation units were demonstrated on amputees, and two other units were discussed. Recommendations for future work on the units were made.

Various levels and types of amputation surgery about and through the knee were discussed at the second session. The participants agreed that a reasonably satisfactory knee-disarticulation prosthesis exists for each level and type of amputation. It was recommended that more information be gathered on the results of clinical experience on the various amputations so that more definite recommendations could be made to surgeons on which level and type of amputation to perform.

A report of the meeting has been published by CPRD.

ISRD Announces Copenhagen Symposium

Dr. Knud Jansen, chairman of the International Committee on Prosthetics and Orthotics of the International Society for Rehabilitation of the Disabled, has announced that a seminar on "Trends in Prosthetics and Orthotics" will be held in Denmark on November 6-15, 1970.

Topics to be covered in the symposium are:

1. The Engineer in the Clinic Team
2. Amputation Techniques and Levels
3. Modular Prosthetics
4. Management of Congenital Deficiencies of the Lower Extremity
5. Rehabilitation of Spinal Cord Injuries
6. Education/Training of Specialists in Prosthetics and Orthotics

All lecturers and participants (the number will be limited to 100) will be housed in a new Conference Centre at Rungsted, near Copenhagen, where all meetings will be held.

The course is open to physicians, engineers, prosthetists/orthotists, therapists, and social workers. The consolidated registration fee of Danish kr. 2000 covers accommodations, all meals, coffee, tea, the conference dinner, and copies of lectures given. The working language of the symposium will be English.

Registration forms and further information may be obtained from the secretariat: Miss Birgit Cederholm, c/o Orthopaedic Hospital, 3 Hans Knudsens Plads, 2100 Copenhagen 0, Denmark.

University of Miami Postgraduate Courses

The University of Miami School of Medicine will conduct two postgraduate courses in Miami Beach, Florida, on December 4-9, 1970.

The first, "Lower-Extremity Prosthetics and Orthotics, Recent Development," on December 4-6, will be sponsored by the National Academy of Sciences and the Veterans Administration. The second, "Lower-Extremity," on December 7-9, will be sponsored by the Committee on Injuries of the American Academy of Orthopaedic Surgeons.

Further information regarding these seminars may be obtained from Augusto Sarmiento, M.D., Department of Orthopaedics and Rehabilitation, University of Miami School of Medicine, P. O. Box 875, Biscayne Annex, Miami, Fla. 33152.

Publications

A compilation of articles on various aspects of limb prosthetics, *Selected Arti-*

cles from "Artificial Limbs," was recently published in hard-cover form by the Krieger Publishing Company, Huntington, New York.

The volume (392 pp., indexed, illustrated), consisting of twenty classic articles (most of them long out of print), should be of interest to all those concerned, directly or indirectly, with limb disabilities.

The book is available (price: $17.00) from:

Krieger Publishing Co., Inc.
P. O. Box 542
Huntington, N. Y. 11743

* * * *

Eycleshymer and Schoemaker's *A Cross-Section Anatomy,* a highly regarded reference since it was first published in 1911, was reissued in 1970 by Appleton-Century-Crofts. The detail and accuracy of the illustrations, obtained from the original plates, make for a text invaluable to students, clinicians, and researchers. The price of $35.00, while not low, is not excessive when the uniqueness of this publication is considered.

Contents—*SELECTED ARTICLES FROM ARTIFICIAL LIMBS*

NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

THE NATIONAL ACADEMY OF SCIENCES is a private, honorary organization of more than 700 scientists and engineers elected on the basis of outstanding contributions to knowledge. Established by a Congressional Act of Incorporation signed by Abraham Lincoln on March 3, 1863, and supported by private and public funds, the Academy works to further science and its use for the general welfare by bringing together the most qualified individuals to deal with scientific and technological problems of broad significance.

Under the terms of its Congressional charter, the Academy is also called upon to act as an official—yet independent—adviser to the Federal Government in any matter of science and technology. This provision accounts for the close lies that have always existed between the Academy and the Government, although the Academy is not a governmental agency and its activities are not limited to those on behalf of the Government.

THE XATIOXAL ACADEMY OF ENGINEERING was established on December 5, 1964. On that date the Council of the National Academy of Sciences, under the authority of its Act of Incorporation, adopted Articles of Organization bringing the National Academy of Engineering into being, independent and autonomous in its organization and the election of its members, and closely coordinated with the National Academy of Sciences in its advisory activities. The two Academies join in the furtherance of science and engineering and share the responsibility of advising the Federal Government, upon request, on any subject of science or technology.

THE NATIONAL RESEARCH COUNCIL was organized as an agency of the National Academy of Sciences in 1916, at the request of President Wilson, to enable the broad community of U. S. scientists and engineers to associate their efforts with the limited membership of the Academy in service to science and the nation. Its members, who receive their appointments from the President of the National Academy of Sciences, are drawn from academic, industrial, and government organizations throughout the country. The National Research Council serves both Academies in the discharge of their responsibilities.

Supported by private and public contributions, grants, and contracts, and voluntary contributions of time and effort by several thousand of the nation's leading scientists and engineers, the Academies and their Research Council thus work to serve the national interest, to foster the sound development of science and engineering, and to promote their effective application for the benefit of society.

COMMITTEE ON PROSTHETICS RESEARCH AND DEVEIOPMENT
COMMITTEE ON PROSTHETIC-ORTHOTIC EDUCATION

The *Committee on Prosthetics Research and Development* and the *Committee on Prosthetic-Orthotic Education,* units of the Division of Engineering and the Division of Medical Sciences, respectively, undertake activities serving research and education in the fields of prosthetics and orthotics, when such activities are accepted by the Academy as a part of its functions. Activities of the Committees are presently supported by the Department of Health, Education, and Welfare and the Veterans Administration. Information or reports developed by activities of the Committees are officially transmitted and published through the National Academy of Sciences.