The Objectives of the Upper-Extremity Prosthetics Program

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JL HE upper-extremity prosthetics program, under the sponsorship of the Advisory Committee on Artificial Limbs, National Research Council, has been a growing and evolving program from its inception in 1945. Its initial objectives were limited to time and motion study of amputees and to device invention and development. But from the vantage point of 1954 we may list many additional objectives that have been assumed according to the necessities of a national program dedicated to the welfare of the amputee. As new activities have been added, none of the original have been abandoned, although certain of the original ones have been reduced in relative emphasis and expenditure.

Figure 1 illustrates in schematic form the major phases of the upper-extremity program as they have waxed and waned over the years from 1946 to 1953. The scope and magnitude of these activities represent a program with few parallels in our peacetime economy. As is evident in Figure 1, not all the activities were started (or even conceived) at the outset. But, as has been pointed out by Strong,[2] no one could predict at the outset the ramifications of a program dedicated to the tangible goal of putting new and improved prostheses on amputees. The appropriateness of this program under the auspices of the National Research Council was underscored by President Bronk, who praised the ACAL program as a fitting example of the service to the public welfare for which NRC was founded.[3]

FUNDAMENTAL STUDIES

The study of normal and amputee biomechanics underlies all improvement in prosthetic replacement. A continuous program of inquiry in this field is therefore essential. Although much of such research is undertaken without immediate practical goal, free inquiry brings to light ideas which find widespread application, as has already been demonstrated time and again. The continuous observation of arm motions and of prosthetic motions provides a nourishing bed of interest and information from which the application phases draw strength and purpose.

The program of fundamental studies has featured research on normal motions, analyzed in terms of physical mechanics and in terms of industrial time and motion concepts. These investigations have built up a body of information on the patterns of motion, speeds, forces, and skills that is invaluable in conceiving, planning, and predicting the results of new developments. A special phase of this program has had to do with cineplasty, where the direct utilization of muscle force has remarkable potentialities for prosthetic replacement but where intimate knowledge of the mechanics of the muscle is required in order to obtain successful operation of the prosthesis. Knowledge of stump shrinkage, of finger forces, of external power controls, of accessory body mechanics, of mechanical stresses in the prosthesis during use—all these are fundamental to the proper

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[2] Strong, F. S., Jr., *The Artificial Limb Program: Five Years of Progress.* Advisory Committee on Artificial Limbs, NRC, Washington, November 1951.

[3] Bronk, D. W., President, National Academy of Sciences. Address to the Advisory Committee on Artificial Limbs, Annual Meeting, Washington, May 1953.

assessment of normal and of amputee biomechanics.

The objectives of the program of fundamental studies in the upper extremity may be summarized as:

1. To study the performance of manipulative activities in normal individuals and to analyze the activities in terms of biomechanics and of time and motion criteria.
2. To compare the motions of amputees with prostheses with similar motions of normals in order to define the patterns of altered and substitute motions peculiar to amputees.
3. To measure the forces and displacements of muscles and muscle groups in relation to cineplasty, harness controls, and external power controls.
4. To define the alterations in general body mechanics in amputees as a result of the asymmetrical loss of body weight.

DEVELOPMENT OF PROSTHETIC DEVICES

The "bread and butter" of the ACAL program is the development of improved prosthetic devices, and a major emphasis has always been placed upon this phase of the program. Development of each device originates in the need shown by fundamental studies or by experience with amputees. Design, experimental fabrication, amputee test, and field evaluation are the successive steps through which each device must pass. The past and present development laboratories include Northrop Aircraft, Inc., the Army Prosthetics Research Laboratory, and the University of California at Los Angeles, but other agencies, such as New York University and many cooperating industry limbshops, function in the final evaluation phases.

ACAL developments in prosthetic devices include new inventions and many adaptations of mechanisms and materials from other technical fields. Engineers have delved deep into the rich heritage of American technology to find applications of plastics, lightweight metals, and mechanisms that have immensely improved the structural and functional characteristics of upper-extremity prostheses. In short, the development objectives are:

1. To invent, adapt, and apply new materials and mechanisms so as to add new functions, or to improve old functions of prostheses, seeking in the end to provide an armamentarium of devices to meet the needs of every amputee type.
2. To design and redesign prosthetic components for simplicity and ease of manufacture, and for durability, without loss of essential function.
3. To create a system of interchangeable components which may be singly prescribed for the individual amputee case, but which can be combined into a func-

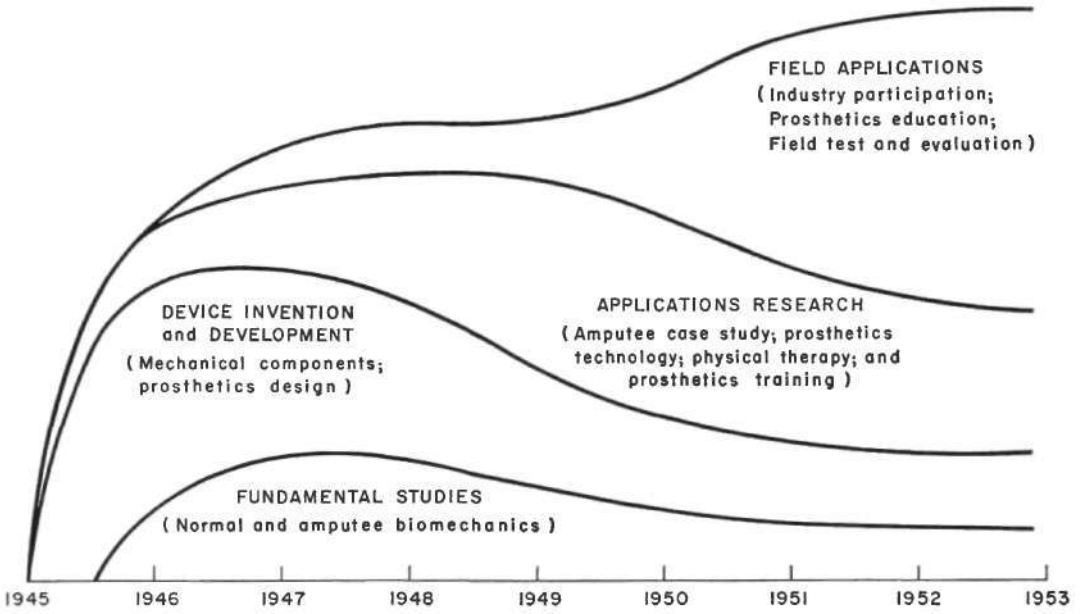

Fig. 1. Trends in the upper-extremity prosthetics program, 1945-53.

tionally integrated and an esthetically compatible prosthesis.

4. To incorporate cosmetic and anthropomorphic principles into basic design so that prostheses are not abnormally conspicuous and are pleasing from the standpoint of color, texture, and form.

INDUSTRY ADVISORY PARTICIPATION

From earliest days, ACAL has recognized the benefit that would accrue to its activities if the experienced "know-how" of the industry could be utilized in an effective way. To attain this goal, it was considered necessary to bring into the planning meetings of the ACAL group the counsel of leading prosthetists and limb manufacturers. Accordingly, three members of the limb industry were made members of the Upper-Extremity Technical Committee to serve at the national level, while in Los Angeles a local Industry Advisory Committee was set up to advise and aid the UCLA project. These cooperative ventures have proved to be of great mutual benefit, the objectives being briefly as follows:

1. To learn from the industry the needs for device development, for advancement in prosthetics technology, and for improvement of amputee services.

2. To utilize the experience and judgment of members of the limb industry in determining policy and in planning cooperative ventures involving field application studies.

CONTRIBUTIONS TO PROSTHETICS TECHNOLOGY

With the wealth of World War II technological development to draw upon, the ACAL program rapidly adopted new materials and practices, not only in the design and development of new prostheses but also in shop fitting and fabrication practices. Most outstanding of these innovations is the incorporation of plastics for prosthetic use. The principal laboratories under the program, APRL, Northrop Aircraft, Inc., and UCLA, have exemplified these uses, and their reports have been a source of information to the industry.

The objectives are:

1. To adapt new and different materials for use in fitting and fabrication.

2. To introduce into prosthetics practice methods of measurement and fabrication tending to improve quality of service and economic efficiency.

AMPUTEE CASE STUDY

In the early stages, the ACAL program emphasized research and development on devices, and amputees necessarily were fitted with experimental prostheses in order to conduct studies, trials, and tests of the equipment. It soon became apparent, however, that established practices in prescription, fitting, and training of amputees were highly variable and that, to round out consideration of all factors bearing on amputee rehabilitation, these practices themselves should become the subject of investigation. This objective was strengthened by the knowledge that no single design of prosthesis is superior for all amputees but rather that, of many types of equipment, the most suitable selection for a given amputee depends upon his individual personal, social, and occupational needs and desires. Accordingly, the Case Study Program was initiated at UCLA in 1950 and continued until 1952. The large amount of information on the 70 amputees in this study is being reduced for publication; much of it has been directly transferred into the Educational Program (see below).

The case study of cineplastic amputees at APRL has followed in its major outline the procedures at UCLA, and much valuable information is being gathered on this important class of amputee.

These programs serve an especially important role in bridging the gap between fundamental work in the laboratory and practice in the field. Prosthetics involves, in unique degree, a combination of science and technology with the practical arts. Every amputee is to some extent a special case. It has therefore been necessary to incorporate the case-study phase in order to ensure the i applicability of technical improvements.

In concise form, the objectives of the Case Study Program may be stated as follows:

1. To investigate the application of prostheses to a wide range of amputee types so that a rational procedure for prescription for the needs of the amputee can be formulated.

2. To test and develop the elements of physical and occupational therapy that apply to amputee rehabilitation and prosthetic use.

3. To discover the effect of occupation, education, recreational interest, and other personal factors of the amputee upon his prescription, fitting, and training.

4. To determine effective methods for evaluation of amputee service, not only pertaining to the quality of mechanical equipment but also to the results of training, to the end that the amputee obtains a truly functional prosthesis.

PROSTHETICS EDUCATION

It has been a cardinal principle of the ACAL group that the products of its research, investigation, and development should be speedily disseminated to all technical and professional groups interested in applying such knowledge for the welfare of the amputee. The scope of these activities has steadily increased. Early discoveries were conveyed by means of technical reports which were primarily useful to the other member laboratories and to manufacturers within the industry. Later, as case study and other application phases of the program developed, the broader responsibility was assumed of supplying educational materials dealing with many aspects of technical and professional prosthetics service. Two volumes have been prepared. *Human Limbs and Their Substitutes* (McGraw-Hill, in press) supplies an authoritative reference on prosthetics, while the *Manual of Upper-Extremity Prosthetics* (University of California at Los Angeles, 1952) has been issued to serve as a shop guide for the practicing prosthetist.

Valuable as the printed material has proved to be, it was found that the needs of the prosthetist for advanced training could not be met with sufficient rapidity and thoroughness. These craftsmen, lacking formal institutional training in their specialty, and with the highly variable backgrounds of apprentice training, displayed great need for direct instruction to bring them up to the standard required by the new technology. Two other professional groups most concerned in amputee service, physical and occupational therapists and physicians and surgeons, were no less in need of learning the newer knowledge of prosthetics.

This condition made it imperative to offer an accelerated advanced training in the theory and practical arts concerned in prosthetics. Accordingly, the Prosthetics Training Program was instituted at UCLA with the following objectives:

1. To give for selected groups of prosthetists advanced training in the skills and knowledge needed to make and fit upper-extremity prostheses using many of the most recent refinements arising from research.

2. To give for selected groups of physical therapists and occupational therapists advanced training in the skills and knowledge needed to assist amputees in adjusting themselves physically, mentally, and vocationally to the use of the newer developments in upper-extremity prostheses.

3. To enable physicians and surgeons to expand their understanding of the possibilities and limitations of the more recent developments in prostheses and of some effective procedures for taking advantage of these developments.

4. To encourage the acceptance and practice of the "team approach" to the problem of prosthetic prescription, in which the physician or surgeon, as captain of the team, is assisted by professionally qualified physical therapists, occupational therapists, and prosthetists.

FIELD RESEARCH STUDIES

To test the usefulness of the knowledge gathered during the ACAL research program, a field research project was instituted in Chicago during 1952. The intent was to determine whether the local rehabilitation people concerned with the problems of prosthetics—the physician, the therapist, and the prosthetist—would benefit from the new knowledge. Accordingly, a group of Chicago physicians, therapists, and prosthetists were invited to attend a "pilot" course in upper-extremity prosthetics at UCLA, the content of the course being based almost exclusively upon the research performed under the ACAL program.

Upon completion of the training, a clinic was established in Chicago, where a group of 50 amputees was processed in accordance with the information taught at UCLA. The status of each amputee was carefully evaluated both before and after clinic treatment. Results showed a dramatic and clear-cut improvement in the functional and psychological attributes of this group of amputees. Thus, initial field evaluation clearly demonstrated the practical usefulness of the research results when applied to amputees in the local situation.

Upon completion of the Chicago study, and

in close coordination with the educational program already described, nationwide field studies were instituted under the supervision of the Prosthetic Devices Study, New York University. The purposes of these studies, which are presently going on, are as follows:

1. To ensure the proper application of the research findings to upper-extremity amputee cases throughout the country.
2. To provide the local clinics throughout the country with administrative and technical consultation so that assistance may be provided in the resolution of difficult problems.
3. To evaluate the effectiveness of these procedures when applied to amputees, in order to determine where problem areas still exist and thus to direct future research toward the resolution of these difficulties.

It is anticipated that, upon conclusion of the present field research program, studies will have been conducted in conjunction with clinics operating in some 40 of our largest communities.

CONCLUSION

As a result of the upper-extremity prosthetics program, arm amputees can now be provided with reasonably comfortable, functional prostheses. Studies indicate that between 80 and 90 percent of the arm amputees fitted during the UCLA Case Study Program and the Chicago Project continue to wear and use their prostheses. When this is compared with the 10-percent figure estimated for arm amputees throughout the country who wear prostheses, it appears that some measure of success has been achieved. But it is apparent to workers in this field that the progress made to date is merely a step in the proper direction and that we can expect continued improvement in all aspects of upper-extremity rehabilitation.