Orthotics and Prosthetics, Vol. 31, No. 4, pp. 47—53, December 1977

REPORT
PANEL ON UPPER-LIMB PROSTHETICS

Membership:
Chairman: Dudley Childress
Recorder: Maurice LeBlanc
Members: John Billock, Jack Hendrickson, Alfred Kritter, John Lyman, Carl Mason, Ray Mendrola, Raymond Pellicore, Wesley Prout, William Sauter, Carl Sumida, Bert Titus

It is estimated there are 100,000 upper-limb amputees in the United States of whom about half actually wear prostheses. Lack of acceptance of prostheses is a complex, multi-faceted subject, but it is known that prostheses are accepted for about four reasons:

(a) good appearance (cosmetic)
(b) useful function
(c) reliability
(d) comfort

Body-powered, cable-driven upper-limb prostheses have gone through a 25-30 year evolutionary process and, within their limitations, have functioned well. They will be important in upper-limb prosthetics for many years to come, but improvements in their function and appearance are needed. However, dramatic breakthroughs in this area seem to be unlikely.

Amputees today have high expectations for their prostheses and the goal of research and development should be to create improved prostheses which are functional and cosmetic while also being reliable (repair free for one-year intervals) and comfortable. Powered limbs offer potential for improved prostheses, but it is estimated that only one percent of the upper-limb amputees in the United States currently use powered prostheses of any form. Expanded growth in this area is expected.

State-of-the-Art

Current state-of-the-art in upper-limb prosthetics practice is defined to include devices (or systems) and techniques which are available today (1977) to the general amputee population. State-of-the-art is summarized in Tables 1, 2, and 3 which relate amputation levels with standard practice.

TABLE 1

Unilateral Upper-limb porstheses	STATE OF THE ART				Needs
	Socket	Components	Control	Other/ Comments	
Partial Hand	Plastic Laminated, Flexible or Rigid Socket	Robin-Aids Handy-Hook Passive	Cable Operated		
Wrist Disarticulation	Plastic Laminated Atmospheric Pressure Suspension (APS) Elastic Liner Suprastyloid Suspension	Standard Mechanical Hand or Hook Powered Electric Hands Passive Hand	Cable Operated Switch Control Myoelectric	Difficulty in Donning Length Problems	
Below-Elbow	Supracondylar Plastic Standard Flexible Sockets APS	Standard Mechanical Hand and Hook Powered Electric Hand Mechanical Wrist Rotator Powered Electric Wrist Rotator	Cable Operated Switch Control Myoelectric	Self-Suspended, Self-Contained, Myoelectric is the Most Desirable	More Efficient Mechanical Hand Inter-changeability of Powered Hook and Powered Hand

TABLE 2

Level of Upper-Limb Prostheses (Unilaterals)	STATE OF THE ART				
	Socket	Components	Control	Other/ Comments	Needs
Elbow Disarticulation	Elastic liner Screwdriver shape for rotation control Plastic Laminate	Powered Electric Hands Outside Locking Joint Powered Electric Wrist-Standard Mechanical Components	Cable Operated Elbow Only	Marquardt Angular Osteotomy	Improved Elbow Joint
Above-Elbow	Plastic Laminate - standard - over shoulder - open shoulder APS	Powered Electric Wrist Powered Electric Hands Endoskeletal System Powered Electric Elbow Cable Recovery Unit Standard Mechanical Components	Cable Operated Switch/Myoelectric Hybrid-External/ Body Power	Self-Suspended, Self-contained Most Desirable	Endoskeletal - Active Elbow Multifunction Control
Shoulder Disarticulation including Inter-scapulo-thoracic	"Frame" Socket Plastic Laminate	Shoulder Caps Passive Components Cable Recovery Unit Endoskeletal System Standard Mechanical Components	Cable Operated Switch Control	Success With Cable driven Components Is Low	Multifunction Switch Control Powered shoulder Improved socket Interface Multifunction Control

TABLE 3

High-Bilateral Upper-Limb Prostheses	STATE OF THE ART				
	Socket	Components	Control	Other/Comments	Needs
	Laminated Rigid Frame	TD's Wrist Elbow	Cable Driven Switch (Elec.) Hybrid	Simpson (CO_2) Provided by contract?	System Approach Better Special Center Multifunction Control System
	Plastic Laminate				
		Conventional Mechanical Joints		Wrist Rotation & Flexion	
		Coordinated Arms (Feeders)		Humeral Rotation	
		Simpson Arm System		Hand vs. Hook	
				FOOTNOTES:	FOOTNOTES:
				Lack of sensory feedback	Improved Sensory Feedback Improved Prosthetic Skin Improved Cosmesis Reduced Weight

Improvements have been made in upper-limb prosthetics during the last ten years although none of these have been significant enough to revolutionize the field. A partial list of improvements is as follows:

(1) Improved supracondylar below-elbow sockets.
(2) Improved above-elbow socket systems.
(3) Self-contained and self-suspended powered prostheses.
(4) Development of externally powered hands and other components.
(5) Myoelectric control systems.

Myoelectrically controlled hands for the below-elbow amputee are available through regular channels. Powered limbs for the above-elbow amputee and the higher level amputee are available in special centers. Electrically powered hooks, to provide hook-hand interchangeability are ready for clinical evaluation.

Improved prosthetics practice is not limited to technology. The technology is here, the biggest problem concerns the transfer of the technology to the field (clinical practice). This does not mean that technical improvements are not necessary with existing devices. It means that technology can out-race our ability to implement it in the field.

Recommendations

There are many recommendations which could be made in the field of upper-limb prosthetics. Only a few are listed here in order to emphasize their particular importance. They are listed in order of perceived importance.

1. It is strongly recommended that the delivery of available technology and techniques (e.g., below-elbow myoelectric prostheses) be promoted actively.
   (a) A TEST (Technology-Extension-Service-Testing) program should be instituted to implement the new developments. The TEST program could operate somewhat as an Extension service (e.g., The Agriculture Experiment Station System). This organization would transfer technology to the "grass roots" level through extension education programs and be involved with overseeing service problems and evaluation (testing). A catalog of available components and systems, as well as up-dated information on new developments, could be provided by this group to local prosthetists, therapists, and physicians.
   (b) New prosthetics techniques and systems that have been shown to be worthy should be taught in the basic and continuing prosthetics education programs of the U.S. These programs should be directed toward the clinic team, primarily the prosthetist, the physician, and the therapist.
   (c) The American Academy of Orthotists and Prosthetists should play an active role in this delivery program.
   (d) Third party payers (e.g., insurance companies, agencies, etc.) should be kept informed of the benefits and cost of new prosthetics practice.

2. It is recommended that a mechanism for the clinical evaluation of new and existing research developments be established. Provision should be made for a coordinated effort in this field to insure effective and efficient use of resources.
   (a) It is especially important for the school faculties and manufacturers as well as the developers to be involved in the evaluation cycle.
   (b) The functions of the former Committee on Prosthetics Research and Development (CPRD) should be reinstituted for this purpose.
   (c) The AAOP should be involved in evaluation of upper-limb prostheses.
   (d) Clinical evaluations should be performed by objective evaluators and not by the developers.

3. It is recommended that specialized centers be developed to provide service and to undertake research concerning the special problems of the high-bilateral amputee and other difficult cases.
   (a) Such centers should serve children and adults.
   (b) These centers should be few in number and capable of handling multimembral amputees.
   (c) The centers would provide information and consultation to the upper-limb prosthetics field.
   (d) These centers would focus on available technology, whatever its source. An immediate goal should be to obtain for evaluation the system developed for amelic children by Simpson in Scotland.

4. It is recommended that the achievement of self-suspended and self-contained prostheses be promoted strongly for the amputee population.
   (a) Emphasis initially should be directed toward above-elbow level prostheses.
   (b) The use of externally powered elbows should be studied and development expedited.
   (c) Dr. Marquardt's surgical technique of angular osteotomy, to increase suspension and rotational stability for above-elbow limbs, should be studied and recommendations made for clinical practice.

5. The development of improved prosthetic skin and soft tissue for arm prostheses is recommended.
   (a) Reference should be made to previous specifications prepared by CPRD for prosthetic skin and soft tissue.
   (b) Commercial enterprise should be funded to develop an improved prosthetic skin material.
   (c) Other efforts should be recognized and studied for possible interim or long range benefit for certain situations. These include efforts of Otto Bock (new glove), and of Dr. Leonard (acrylic coatings), Mr. Sauter (silastic), and Mr. Billock (latex).

6. It is recommended that the improvement of body-powered upper-limb prostheses not be neglected in a trend toward powered prostheses.
   (a) Improved harness techniques which optimize the effectiveness of body motions are needed.
   (b) Self-suspension techniques should be examined for use in many body-powered prostheses. Sockets, in general, have not been given adequate attention in development laboratories and in practice not enough concern is shown for intimacy of fit.
   (c) Creative experimentation with combinations of body power and external power (hybrid systems) is strongly encouraged.

Standards

Non-invasive, upper-limb prostheses are not life threatening and pose no more hazard than the non-amputee's normal physiological limb. Mechanical or electric failure of upper-limb prostheses normally pose no hazard to the user. Consequently, these devices should be exempt from regulations.

Future prostheses which might contain implantable or transcutaneous components (electrical or mechanical) would need to be considered separately.

Long-Range Considerations

1. The development of subconscious control of prostheses having multiple func-

tions is desirable. Such a system would relieve the amputee, as much as possible, of continuous monitoring of the prosthesis and permits the prosthesis to serve the amputee instead of the amputee serving the prosthesis. A number of technical systems are being developed for this purpose. These include:

(a) Extended physiological proprioception (e.p.p.).
(b) Trajectory control which directs the endpoint (hand) and automatically adjusts for changing torques and loads.
(c) Multiple and single myoelectric channel signal processing for control of multiple outputs.
(d) Neuroelectric control (multiple-channel) from nervous tissue.

Some of these techniques require complex electronics technology. However, recent advances in microelectronics make these systems potentially practical, from a technical standpoint.

2. The development of articulated and multifunctional hands appears promising.
3. Direct skeletal attachment is a laudable long-range goal in upper-limb prosthetics.
4. Improved battery design would be helpful in upper-limb prosthetics. High energy and power densities are desirable to reduce weight and size. Increased ruggedness and greater reliability are also needed.
5. The development of electric hands that are smaller than and larger than those currently available is desirable.
6. New prehension systems such as the hook proposed by Bottomley in 1966 should be investigated.