[37] Scott, R.N., Brittain, R.H., Caldwell, R.R., Cameron, A.B., and Dunfield, V.A., "Sensory Feedback System Compatible with Myoelectric Control," *Med. & Biol. Eng. & Comp.*, Vol. 18, No. 1, pp. 65–69, 1980.

[38] Seamone, W., "Development and Evaluation of Externally Powered Upper-Limb Prosthesis," *Bull. of Prosthetics Research*, BPR 10–13, pp. 57–63, 1970.

[39] Simpson, D.C., "An Externally Powered Prosthesis for the Complete Arm," in *The Basic Problems of Prehension, Movement and Control of Artificial Limbs*, The Institution of Mechanical Engineers, Proc. 1968–69, Vol. 183, Part 3J, pp. 11–17, 1969.

[40] Sorbÿe, R., "Myoelectric Controlled Hand Prostheses in Children," *Int. J. of Rehab. Research*, Vol. 1, pp. 15–25, 1977.

[41] Spaeth, J.P., *Handbook of Externally Powered Prostheses for the Upper Extremity Amputation*, Charles C. Thomas, Springfield, Ill., 1981.

[42] Stevenson, D.A., and Lippay, A.L., "Hydraulic Powered Arm Systems," in *The Basic Problems of Prehension, Movement and Control of Artificial Limbs*, The Institution of Mechanical Engineers, Proc. 1968–69, Vol. 183, Part 3J, pp. 37–44, 1969.

[43] "The Application of External Power in Prosthetics and Orthotics," Report of Conference at Lake Arrowhead, California, Publication 874, National Academy of Sciences, National Research Council, September, 1960.

[44] *"The Basic Problems of Prehension, Movement and Control of Artificial Limbs,"* The Institution of Mechanical Engineers, Proc. 1968–69, Vol. 183, Part 3J, 1969.

[45] "The Control of External Power in Upper-Extremity Rehabilitation," Report of Conference held at Warrenton, Virginia, April, 1965, Publication 1352, National Academy of Sciences-National Research Council, 1966.

[46] *The Control of Upper-Extremity Prostheses and Orthoses,"* based on a conference held in Göteborg, Sweden, 1971, Charles C. Thomas, Springfield, Illinois, 1974.

[47] VAPC Research Report, Development (Components), Powered Hook developed by C. Mason, *Bull. of Prosthetics Research*, BPR 10–16, pp. 217–219, 1971.

[48] Williams, T.W., "Clinical Applications of the improved Boston Arm," *Proc. Conf. on Energy Devices in Rehab.*, Boston (Tufts), 1976.

[49] Wilms, E., "Die Technik der Vaduzer Hand," *Orthopädie Technik*, 3, 7, 1951.

[50] Wilson, A.B., Jr., "Externally Powered Upper Prostheses," *Newsletter . . . Prosthetics and Orthotics Clinic*, Vol. 2, No. 1, pp. —4, 1978.

[51] Wirta, R.W., Taylor, D.R., and Finley, F.R., "Pattern-Recognition Arm Prosthesis: A Historical Perspective—A Final Report," *Bull. of Prosthetics Research*, BPR 10–31, pp. 8–35, 1978.

AUTHOR

Dudley S. Childress, Ph.D. is Director of the Prosthetics Research Laboratory and Director of the Rehabilitation Engineering Program at Northwestern University, Room 1441, 345 East Superior Street, Chicago, Illinois 60611.

Innovation and Improvement of Body-Powered Arm Prostheses: A First Step

by Maurice A. LeBlanc, M.S.M.E., C.P.

INTRODUCTION

Standard body-powered upper-limb prostheses have not changed significantly since developments in the 1950's which were spurred by World War II. They still employ aircraft technology using shoulder harnesses and steel cables for operation. If one looks at the *Manual of Upper Extremity Prosthetics* first edition (1952)[2] and the *Orthopaedic Appliance Atlas—Artificial Limbs* first edition (1960)[9] compared with 1985 state of the art, one will not find a great deal of change.

It is the consensus of several leading prosthetists in the U.S. that many arm amputees are being led into purchasing externally powered arm prostheses because they look more modern and "hi-tech." Present body-powered arm prostheses simply do not offer a good alternative. They look more archaic, and the shoulder harnesses are uncomfortable and restrictive.

Body-powered systems have more sensory feedback and generally are more functional (for unilaterals) than externally powered sys-

tems.[1, 10] However, little or no research is being conducted to improve body-powered arms. More and more amputees are opting for externally powered prostheses,[11] and the gap is getting larger between the two types.

Estimates of population in the U.S. place the number of upper-limb amputees at about 100,000.[8] Of the 50,000 arm amputees estimated to be wearing prostheses, surveys of prosthetic facilities suggest the following levels of amputation: 58% below-elbow, 27% above-elbow, and 15% at the hand/wrist and shoulder.[6] Of prostheses being worn, educated guesses suggest that the percentage of externally powered prostheses has increased from five to 10% in the past five years.[3]

It is the desire of the author to undertake work to effect innovation in body-powered arm prostheses toward the ultimate goal of increasing the acceptance and use of "conventional" upper-limb prostheses for arm amputees in the U.S. Other people have stated this need.[4, 5, 12]

The author has received support to conduct a one-year study of feasibility for accomplishing the above goal. As a first step, the author has conducted a survey to verify needs and priorities of arm amputees in order to give guidelines for future work.

CONDUCT OF SURVEY

Arm amputees and professionals were contacted to assess what wearers like most and like least about their prostheses. Also, ideas for change were solicited.

A questionnaire was prepared to provide a standard format, and 30 people were contacted in person or by phone to complete the questionnaire. The people were:

17 amputees
8 prosthetists
3 occupational therapists
2 VA prosthetic reps
(also arm amputees)

30 total

Of the 17 arm amputees, there were:

10 adults and 7 children
13 males and 4 females
14 unilaterals and 3 bilaterals

RESULTS OF SURVEY

The survey included 11 questions. Results are reported below with the numbers of responses shown. (Some totals exceed 30 because respondents gave two or three answers per question.)

1. *What do you like most about your prosthesis?*

   Most frequent answers:

Function	17
Reliability	9
Symmetry/body image	6

2. *What do you like least about your prosthesis?*

   Most frequent answers:

Axilla/harness uncomfortable	10
Appearance poor	9
Socket hot	5

3a. *Is the harness/cable control system satisfactory?* 13 Yes 16 No

3b. *Does this type of control system need improvement?* 25 Yes 4 No

4a. *Are the harness and socket comfortable?* 12 Yes 17 No

4b. *Does the general comfort need improvement?* 25 Yes 4 No

5a. *Do the motions and terminal device give you enough function?* 11 Yes 18 No

5b. *Does the function of the prosthesis need improvement?* 29 Yes 0 No

6a. *Are you pleased with the appearance?* 11 Yes 19 No

6b. *Does the general appearance need improvement* 25 Yes 5 No

7. *Rate the following four aspects of your prosthesis in importance to you (1 = most important and 4 = least important)*

   Average Scores:

Function	1.53
Comfort	1.85
Appearance	2.79
Control system	3.53

8. *Any other general complaints of this type of prosthesis?*—Text answers to these questions were combined with text answers to questions 3–6 and will be discussed later.

9. *Any other ideas for improvement you would like to see worked on?*—Text answers to these questions were combined with text answers to questions 3–6 and will be discussed later.

10. *If you could dream and create your own perfect prosthesis, what would it look like?*

Most frequent answers:

Natural/normal	12
Soft/smooth endoskeletal	11
More function in fingers & wrist	9

11. *Do you want your prosthesis to look as normal as possible or would you prefer to have some fun with the appearance in colors and designs?*

Most frequent answers:

Want it to look normal	21
Want to have some fun with it	4

MISCELLANEOUS CONSIDERATIONS

In talking with each of the 30 people surveyed, a number of interesting comments were made which deserve consideration.

- The prosthesis is not a second best arm but something different to itself and should have form and beauty for its own sake.
- While most people stated the goal of having a prosthesis which looks natural, they asked for one which is smooth, inconspicuous, natural in motion, fast, quiet, and streamline rather than asking for a prosthesis which looks human.
- Several people visualized having an arm transplant or regeneration.
- A couple of people talked about "functional appearance" or having a prosthesis which is dynamically alive and not dead looking.
- Many people expressed a desire for a prosthesis which is soft inside, adjusts to the body, feels like part of the body, and feels flexible.
- Cleanliness is a big issue with a harness, sockets, and prosthesis exterior. Some expressed the desire for throw-away parts and coverings. Also, it is difficult for bilaterals to clean their prostheses when doffed.
- Bilateral amputees stressed the importance of using their feet as well as the prostheses. There is more dexterity and sensory feedback for function and a preference for using feet except where social situations dictate using the prostheses.
- Several amputees stressed the importance of the sensory feedback/proprioception inherent in body-powered arm prosthesis. A few voiced the opinion that increased sensory feedback would provide increased function even with present components.
- A few parents confirmed the desire for very early fitting of infants for various reasons: body image, balance, symmetry, acceptance and function. One parent felt strongly that an infant should have an arm prosthesis because "the brain is looking for a hand" and it affects the growth/development of the child.
- While the author was conducting interviews with amputees, many of them asked the author for current information about arm prostheses and components. It was clear that some prosthetists are not fully informing amputees of their options and including them in the decision-making process.
- A few prominent professionals stated very strongly the importance of the prosthetist conducting a very thorough evaluation with the amputee prior to any prosthetic prescription and fitting. It provides the opportunity for the prosthetist to use his/her ingenuity to truly meet the needs of the amputee.
- Clinic teams sometimes make decisions on prosthetic fitting in five minutes, which is insufficient time to conduct a thorough evaluation.
- Central fabrication also can be a detriment to successful prosthetic fitting because standard components are applied by a third party without direct amputee contact, thereby reducing the incentive and likelihood for creative and individual solutions to amputees' needs.
- Education of prosthetists focuses mainly on the mechanics of fabricating prostheses with available components rather than looking comprehensively at the amputee as an individual with special needs. They "follow the book" too much and are "too rigid in prescribing."
- The success of upper-limb prostheses depends heavily on the skills of the prosthetist. It is too dependent on individuals. It would be beneficial if systems were more modular whereby they would be easier to fit, and performance could be predicted better.
- Two trends which seem to be gathering professional concurrence are (1) to fit an arm amputee within the "Golden Period" of 30 days after amputation and (2) to fit all arm amputees with a conventional, body-powered prosthesis first.[7]

CONCLUSIONS

Function is clearly the most important feature which amputees want and expect from upper-limb prostheses. While the results may be biased beause the survey was of body-pow-

ered wearers versus myoelectric wearers with hands, the numbers and opinions overwhelmingly emphasize function first.

Uncomfortable harness and poor appearance were a close first and second for the most negative feature of arm prostheses. Body-powered arm prostheses need improvement across the board. When making changes, the upper-limb prosthesis should be viewed as a whole system rather than just looking at components. Amputees want a natural moving, pleasant appearing, inconspicuous prosthesis which does not necessarily have to look human.

The questionnaire demonstrated a good cross check in validating what amputees and professionals said with how they rated the various aspects of upper-limb prostheses. There has been a great deal of encouragement from amputees and professionals to work on the improvement of body-powered systems. All are anxious to see some innovation and positive change.

REFERENCES

[1]Agnew, P.J., "Functional Effectiveness of a Myo-Electric Prosthesis Compared with a Functional Split-Hook Prosthesis: A Single Subject Experiment," *Prosthetics Orthotics International,* Vol. 5, No. 2, August 1981.

[2]Aylesworth, R. Deane, Editor, *Manual of Upper Extremity Prosthetics,* Artificial Limbs Project, University of California at Los Angeles, 1952.

[3]Childress, Dudley S., Ph.D., Director, Rehabilitation Engineering Center, Northwestern University, Chicago, Illinois, personal communication, April 1984.

[4]Cottenden, A.M.; B. Stocking; N.B. Jones; S.L. Morrison and R. Rothwell, "Biomedical Engineering—Priorities for Research in External Aids," *Journal of Biomedical Engineering,* Vol. 3, October 1981.

[5]Epps, Charles H., Jr., M.D., "Prosthetic-Orthotic Research—A New Thrust Is Needed: A Clinician's Perspective," *Clinical Prosthetics and Orthotics,* Vol. 8, No. 1, Winter, 1984.

[6]LeBlanc, Maurice A., M.S., C.P., Patient Population and Other Estimates of Prosthetics and Orthotics in the USA," *Orthotics and Prosthetics,* Vol. 27, No. 3, September, 1973.

[7]Malone, J.M., M.D.; L.L. Fleming, M.D.; J. Roberson, M.D.; T.E. Whitesides, Jr., M.D.; J.M. Leal, C.P.; J.V. Poole, O.T.R. and R. Sternstein Grodin, O.T.R., "Immediate, Early, and Late Postsurgical Management of Upper-Limb Amputation," *Journal of Rehabilitation Research and Development,* Veterans Administration, May, 1984.

[8]National Center for Health Statistics, US Department of Health and Human Services, "Prevalence of Selected Impairments—United States—1977," Series 10, No. 134, February, 1981.

[9]*Orthopaedic Appliance Atlas—Volume 2—Artificial Limbs,* American Academy of Orthopaedic Surgeons, J.W. Edwards—Publisher, 1960.

[10]Stein, R.B. and M. Walley, "Functional Comparison of Upper Extremity Amputees Using Myoelectric and Conventional Prostheses," *Archives of Physical Medicine,* Vol. 64, No. 6, June, 1983.

[11]Trost, Francis J., M.D., "A Comparison of Conventional and Myoelectric Below-Elbow Prosthetic Use," *Inter-Clinic Information Bulletin,* Vol. 18, No. 4, Fall, 1983.

[12]Veterans Administration, Rehabilitation Research and Development Service, National Workshop on Prosthetics and Orthotics, Washington, D.C., April 27–28, 1983.

ACKNOWLEDGMENT

This work is being supported by Research Fellowship #133FH40021 from the National Institute of Handicapped Research, US Department of Education.

AUTHOR

Maurice A. LeBlanc, M.S.M.E., C.P. is with the Rehabilitation Engineering Center at Children's Hospital at Stanford, Palo Alto, California 94304.