Orthotics and Prosthetics, Vol. 31, No. 4, pp. 54—60, December 1977

REPORT
PANEL ON LOWER-LIMB PROSTHETICS

Membership:
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The panel was convened after the presentation of the position papers, and we considered the problems in light of the charges given; that is, to consider those devices currently available on the market, and those perhaps in need of clinical evaluation. We attempted to set some sort of priority in reference to the devices and techniques that are needed. We also made recommendations for research, development, educational efforts, materials development, fabrication and fitting techniques, and evaluation programs.

Surgical Phase

For the lower-limb amputee, it was the opinion of the group that there was a great need to improve the surgical technique or the performance of the amputations that are subsequently fitted and treated by the prosthetist and therapist. Ideas were expressed that for some patients the prosthetist should be involved in the decision as to the level of amputation prior to the actual procedure. Because a great number of lower-limb amputations are performed by general surgeons and vascular surgeons it was the consensus that a protocol should be established for amputations to yield the best possible results for subsequent rehabilitation. Since the Veterans Administration has been a leader in the field of prosthetics, it was suggested that such a protocol be established for the performance of amputations in VA Hospitals (with involvement of amputee clinic teams) and this technique could then move into the non-VA sector.

The question of selection of amputation level for the vascular amputee was also discussed. At present there are several ways of determining a satisfactory level of amputation that would be reasonably successful, such as the Xenon 133 technique, the thermograph, the angiograph, the oscilloscope, the Doppler technique with its variations; and as a clinical appreciation of satisfactory level, the bleeding at 3 minutes post-tourniquet time. This subject was of such importance in the performance of the amputation that a strong recommendation was made that a workshop be convened, consisting of surgeons knowledgeable in the field, who could then also establish a protocol for the various problems associated with surgery. These would include level determination in the vascular case, the place of disarticulation procedures, amputations in children, and amputations secondary to tumors. It is recommended that this same surgical workshop provide guidance in the post-surgical treatment of amputations prior to the fitting of a prosthesis.

Again recognizing the fact that the majority of the amputations are done by surgeons unfamiliar with rehabilitation techniques,

but rather in most instances by general surgeons and others, and that these individuals generally do not, as a rule, read the texts or books specifically related to amputation surgery, that an effort be made to reach the publishers of general surgical textbooks such as Christopher, implying in these notifications that there is a great deal of new information available in the area of amputations, and that when these books are revised that an update section on amputation surgery be included. This would then reach the medical students and those who are doing or will be doing the amputations, aside from the very small group that has adequate knowledge of the problems at the present time.

It was also brought to the attention of the group that although there are good methods of treating amputees prior to the fitting of definitive prostheses, and although there exists a period of time in the post-surgical phase where a temporary prosthesis is of great value, it has been the experience of the surgeons present that third party payers, including Medicaid and Medicare, will not reimburse the patient for the cost of such prostheses. These temporary prostheses are provided in large part by prosthetists, and as the costs involved can be considerable, there should be some communication with the third party payers that indicates that temporary prostheses are a part of continuing medical treatment of the amputee, and is needed as well as a definitive prostheses.

Prescription of Lower-Limb Prostheses

Prescription of lower-limb prostheses is probably best provided in the environs of an amputee clinic, or in a physician's office. There is a considerable number of new components and new techniques available to the lower-limb amputee during the past ten or fifteen years, and it was the opinion of the group that a workshop of those involved in teaching and determining prescription principles be held in order to standardize modern prescription criteria. In addition, particularly in the atmosphere of the amputee clinic, the prosthetist should be invited to designate a prescription recommendation for the particular patient prior to the involvement of the physician. This technique may accommodate the natural reticence of the prosthetist, who, as of now, ends up second-guessing the physician in the prescription of the prosthesis.

Levels of Amputation

Partial Foot and Syme's Levels of Amputation

The State of the Art at this level of amputation is anything from stuffing material into the toe of a shoe to providing molded plastic devices, indicating a rather wide divergence of prosthetic practice in amputations through the foot. It was recommended that the AAOP Newsletter include a questionnaire to explore the various solutions already in use for this problem, and that following this a small meeting of prosthetists who are involved in this area be held at the time of an AAOP meeting in order to establish a more workable solution to this problem. It was recognized that the Syme's amputation and prosthesis present no serious problems at the present time but this area might be involved in the same discussion.

The Below-Knee Level of Amputation

Considerable discussion was held on the state of the art. Discussion concerning the foot revealed that the SACH, the single axis, and the multi-axis (Greissenger) feet are in use at present. A hydraulic foot by Mauch is apparently nearing completion. This foot design incorporates a hydraulic joint which may improve many of the problems associated with artificial feet. It was further recommended that the designs of the foot be modified for the geriatric amputee and that part of this recommendation include the weight of such a foot. It was recommended that a mechanical foot be designed that allows dorsi- and plantarflexion, inversion and eversion, and transverse rotation. The existing multi-axis foot does not allow an effective range of transverse rotation. This foot should also include heel-height adjustment in order to enable patients to wear shoes with different heel-heights and to modify their alignment.

The subject of below-knee sockets invoked considerable discussion, revealing among other things, that the present state of the art did not allow for a definitive clinical decision as to when the residual limb is mature, and that perhaps a device to size or sense the limb is needed. Foort and Duncan in Canada and Herron in Houston are studying the problem using photographic techniques. This would also allow a more appropriate size of the cosmetic cover to approximate the size and shape of the opposite leg. The problem of socket adjustability was also discussed. Amputees who are children, are on chemotherapy, are alcoholics, or are geriatrics with weight fluctuation problems usually have frequent volume changes in their residual limbs, necessitating major socket modifications, new prostheses, or rejection of the prosthesis. The use of temporary prostheses is usually not economically feasible, and not practical for a chronic problem. Therefore, it is recommended that a method for easily adjusting definitive socket fit, particularly volume, be developed. The final technique should be able to make use of the already fabricated plastic socket-shank and foot of the prosthesis. A further problem noted, in addition to size and shape changes, was that in going from standing to sitting posture the below-knee amputation stump tends to ride out of the socket. This may be due to either inadequate fitting or perhaps the posterior trim lines of the socket are not adequate for change in position. A study of socket shape and fit to control this problem was also suggested.

Suspension of below-knee sockets was felt to be handled at this point rather well, utilizing the various methods of providing suspension such as the supracondylar strap with pelvic belt, removable wedge, or a supracondylar suprapatellar modification. Most below-knee amputees could be handled by one of these suspension techniques. For the few amputees who require hinges and thigh corset, there was also discussion suggesting use of plastic joints rather than metal, and it is probably in order to consider a clinical evaluation of such joints. Cosmetic covers for below-knee prostheses was also discussed with the trend toward modular prostheses, indicating that at present there was some difficulty in contouring the inside of the cover to accommodate the socket, although the outside contouring could be well handled by most tools in the limb facilities. However, the cover or cosmetic skin for cosmetic covers apparently is well on the way to solution under the direction of Dr. Fred Leonard at George Washington University with VA funding. Further, with the use of modular components a lightweight, good socket-to-pylon coupling device that is easily adjustable and inexpensive is required.

It is also suggested that weight of prostheses be considered a problem for geriatrics and active amputees and it is noteworthy that the polypropylene prostheses are a step in that direction. It is recommended that development of these lightweight prostheses be further encouraged for application of such problems. An evaluation of lightweight prostheses should be conducted, including possible suspension and energy consumption benefits.

The Above-Knee Level of Amputation

The quadrilateral-shape (Berkeley) above-knee socket has been in use for many years, but from the discussion in the group it is evident that there is a need for re-design of this type of socket in view of problems encountered concerning the difference between geriatric and young adult amputees. Patients who have large muscle masses may need better accommodation for the glutei, the rectus, and the adductor muscles. The height of the anterior and lateral wall is also a subject recommended for review. Since the majority of above-knee sockets are now plastic, there is also a need for a thorough review of the methods of obtaining the model used for the definitive socket cast.

Knee Joints

In the area of constant friction joints it was pointed out that the Northwestern "Varigait" knee has been improved with the use of better materials, and at present this is a very definite addition to the lower-limb armamentarium. There is a need for braking, or yielding, knees, and although the present de-

signs are reasonably good, those that are more efficient such as the Kolman knee, have a noise problem as well as function problems. However, it was brought to the attention of the panel that there is a group at Berkeley who are working on this problem and may come to a solution rapidly. Those in manufacturing at present have available materials that could solve the problem of maintenance at a quicker pace and with less effort than people who are primarily doing research in the field. It is recommended that funding of these manufacturers be considered in order to provide them with the stimulus to do this particular job.

Discussion concerning fluid control units revealed that the hydraulic units are at acceptable levels of development, the major drawback to hydraulic units at present being maintenance problems. Mr. Mauch indicated that this has been a continuing problem and may take a further period of time to solve.

Discussion also provided the information that eventually there well may be myoelectric control of knee units to provide locking in the stance phase and/or increase stance phase stability. There is some low priority research going on in this area at the present time, and it is recommended that this be continued on that priority level. This technique would have to have considerable safety features built in to it to prevent injuries that might provoke product liability suits.

Further discussion of the myoelectric situation revealed that an electronically controlled adjustable leg for the below-knee amputee as well as the above-knee amputee might be a significant advance in improving alignment procedures. This could provide dynamic alignment, so that minor changes could be accomplished by the patient or prosthetist while the patient is walking, rather than having the patient stop to change the alignment or rotation. This again is a low priority item. There are several centers working on this problem (University of Tennessee and Moss Rehabilitation) and it was recommended that this work be encouraged.

Knee Disarticulation

There are several systems now available to handle the knee disarticulation level with hydraulic yokes, outside knee hinges, and four bar-linkage mechanisms. Discussion revealed that eventually the four bar-linkage mechanism should be perfected to the point where it would probably replace most of the other mechanisms. Discussion as to surgical tailoring of the stump to provide better sockets revealed that this perhaps should be discouraged because one of the values of the knee disarticulation is the large bulbous distal portion providing end-bearing potential as well as rotatory stability. Any surgical technique that might eliminate these features, in our opinion, should be discouraged.

Hip Disarticulation

Discussion at this point indicated that the previous rigid plastic sockets have been modified by most prosthetists to provide more flexibility, particularly on the unaffected side and it is suggested that perhaps this information should be disseminated more widely than it is apparently known at present. Techniques for providing socket flexibility should also be included. Discussion about the hip-disarticulation hip joint revealed that they were probably too weak in as much as break-down is a significant problem. There is not enough control of hip motion, particularly during swing phase, and a device that will provide some cadence control to the hip motion needs to be developed. Furthermore, the size and shape of the hip joint should be modified to allow easier sitting.

Discussion also revealed that most of the hip-disarticulation prostheses today are being made with modular components, and this, in many cases, solves the problem of excess weight. Further discussion revealed that there was a tendency for instability of the plastic cover on the prostheses and this needs to be improved. Secondly, the question of "creep" of the flexed knee into extension because of the stretching of the anterior cos-

metic cover and the compression of the posterior cover, is a problem that is not readily solved. A further look at this area seems to be indicated.

Hemipelvectomy

Socket designs again have been modified slightly from the original concepts, and perhaps information about these modifications need dissemination. Additional suspension techniques for some of the hemipelvectomy sockets are also needed. This might be a shoulder strap. It is recommended that this area be investigated, perhaps through the questionnaire technique provided by the NEWSLETTER—Prosthetics and Orthotics Clinic recently inaugurated by the American Academy of Orthotists and Prosthetists.

Training

It was brought out that there were apparently many variations in the techniques of training lower-limb amputees and that perhaps a workshop composed of therapists, and those in the schools involved in training amputees, should be convened to restudy thoroughly the whole subject of training techniques. This workshop should include practicing prosthetists.

Children Problems

Some discussion was held on children's prosthetics. One of the problems noted is bony over-growth. This matter could be referred to the workshop on surgery to bring out the latest techniques for handling the over-growth problem in the growing child. Secondly, the question of growth and the required lengthening and increase in sizing of the prostheses were discussed briefly. The opinion was that modular components could probably solve the length problems significantly. The question arose of adaptation of sockets for change in shape and size. It was recommended that this be referred to a Rehabilitation Engineering Center that is working on children's problems, particularly in prosthetics. A further problem addressed is that of swing-phase control units for the children and adolescents. The Rehabilitation Engineering Center at the University of Tennessee at Memphis would be particularly suited to this task.

Recommendations

The following recommendations summarize the conclusions of the panel. They are classified by priority—high, medium, or low—and each class is then subdivided by priority, the highest being at the top of the list.

I. High Priority Recommendations
   A. Workshop on Lower-Limb Amputation Surgery
      1. Recommendations for techniques for predicting successful amputation levels.
      2. Recommendations for disarticulation procedures.
      3. Relative value of muscle stabilization techniques.
      4. Amputation procedures for cancer patients.
      5. Amputation procedures in children.
      6. Post-surgical management.
   B. Development of Adjustable Definitive Sockets to Accommodate Growth and Volume Fluctuations and Accurate Methods of Measuring Limb Volume
   C. Development of a Multi-Axis Foot That Provides Lateral Motion, Transverse Rotation, and Heel-Height Adjustability.
   D. Updating the Literature on Amputation Surgery
      1. Revising general surgery texts such as the Christopher text.
      2. Prepare a new text on amputation surgery.
      3. Determine authors of above publications.

E. Establishment of a Protocol for Amputations
   1. Establish optimum system for amputee rehabilitation.
   2. Stress clinic team approach.
   3. Recommend methods of determining amputation level.
   4. Recommend post-surgical procedures.
   5. Prosthetist consultation before surgery when possible.
   6. Prosthetist initiate prescription recommendations.

F. Development and Evaluation of Lightweight Prostheses
   1. Utilize new materials and fabrication techniques.
   2. Measure energy cost.
   3. Modify suspension techniques to take advantage of weight reduction.
   4. Evaluation training.

G. Development of a Hip Joint for Hip Disarticulation Prostheses
   1. More durable than existing models.
   2. Allow ease of sitting.
   3. Provide cadence control.

H. Workshop on Prescription Principles for Lower-Limb Prostheses
   1. To be attended by physicians, prosthetists, therapists, and representatives from teaching institutions.
   2. Review of existing prescription principles and teaching materials.
   3. Recommend new prescription principles based on updated surgical and prosthetic techniques and components.
   4. Prepare a brief manual to establish guidelines of prescription principles for the lower limb.

II. Medium Priority

A. Development of Improved Methods of Providing Cosmesis to Lower-Limb Prostheses
   1. Development of a prosthetic skin to coat foam cosmetic covers.
   2. Development of methods or materials to prevent rotation of foam covers and creep of these covers, particularly for above-knee and hip-disarticulation prostheses.
   3. Development of methods such as photogrammetry for accurate shaping of the cover of the prosthesis.

B. Improvement of Braking Knee Mechanisms
   1. Reduction of noise and maintenance problems.
   2. Manufacturers best qualified for this and should be encouraged through funding.

C. Development of Remote Control Dynamic Alignment Device
   1. Allow alignment changes while the patient is walking.
   2. Allow the patient to make his own alignment changes.
   3. Allow more variations of alignment to be tried during fitting procedure.

D. Working on AK Casting and Socket Fitting and Alignment Techniques
   1. Recommendations for improvement of existing casting fixtures.
   2. Recommendations for new cast modification techniques.
   3. Recommendations for new socket materials and designs.
   4. Recommendations for alignment.

E. Workshop on Physical and Functional Training of Lower-Limb Amputees
   1. Attended by therapists, prosthetists, and representatives from the educational institutions.
   2. Review existing texts and teaching materials.
   3. Recommend protocol for training.
   4. Prepare a manual providing guidelines for training of lower-limb amputees.

III. Low Priority
   A. Development of Electronic Knee Units
      1. Myoelectric controls.
      2. Switch controls.
      3. Electronic control of hydraulic knee units.
      4. Electromagnetic braking knee unit.
   B. Treatment of Partial Feet and Syme's Amputations
      1. Survey of present fitting techniques through the AAOP NEWSLETTER.
      2. Meeting of experienced practitioners at a national AAOP meeting.
      3. Publication of the results of such a meeting including recommendations for treatment.
   C. PTB Socket Modifications to Correct Sitting Discomfort
      1. Disseminate existing information concerning the solutions to this problem.
      2. Survey of the field to determine other solutions to this problem.
   D. Socket Designs for Hip Disarticulation and Hemipelvectomy Prostheses
      1. Survey of physicians, therapists, and prosthetists through the AAOP NEWSLETTER.
      2. Meeting of experienced practitioners at a national AAOP meeting.
      3. Publication of the results of the survey and meeting in a professional journal.