Lead Article

An Advanced Approach Toward Improved Prosthetic Fittings

by David F.M. Cooney, R.P.T., C.P.O.
Keith E. Vinnecour, C.P.O.

The importance of amputation surgery and dedicated follow-up cannot be underestimated by those clinicians who deal with the amputee population. A prosthetist who receives a patient with a residual limb that is of the optimum configuration to receive a prosthesis and permits the lowest energy cost with maximum unilateral weight bearing comfort, is too often the exception. A concerted effort by all professionals involved—physicians, nurses, physical and occupational therapists, psychologists, social workers, and prosthetists—is required for truly successful rehabilitation.

DELINEATION OF LEVEL

Successful primary healing in patients who have experienced a trauma related amputation is not as great a concern since the average age of this group is much younger than the dysvascular amputee. For the majority of patients who require prosthetic care due to vascular insufficiency, predictions for successful healing, and therefore level of amputation, is a critical consideration and of primary address here. The following discussion and techniques employed, however, can apply to all prosthetic fittings.

In the dysvascular patient, the correct assessment of tissue viability and level of limb amputation is paramount to successful rehabilitation. Correct assessment also serves to reduce the length of the hospital stay and, therefore, costs. Patient morbidity and mortality are also reduced.[21]

A number of methods are employed to determine amputation level. Absolute determinants include ischemia and necrosis. Skin temperatures, absence of hair, sensory deficits, and peripheral pulses are also clinical tools of relative, though unreliable, demarcation. A less direct way of determining level of amputation is the condition of the underlying tissues and skin bleeding during surgery.[1,20,31]

Objectively defined methods are being used to more accurately determine surgical level. Doppler pressure measurements use systolic pressure differentials between the level of concern and brachial pressure. The literature cited offers relative values for prediction of successful healing,[1,26] but also points out the Doppler method's fallibility.[22] Two other non-invasive tests, segmental systolic pressure readings and pulse-volume recordings, can provide a reasonably valid prediction of primary wound healing, but should not be used as the sole indicators for amputation site.[9]

Thermography has been used to estimate the optimal site of amputation. Infrared emissions from the involved extremity are displayed on a screen to show temperature differentials. One study claimed a 96 percent success rate with amputation levels recommended via thermography[12].

Skin blood flow by the Xenon-133 clearance techniques to predict primary healing levels in amputation surgery have shown positive results. A 100 percent primary amputation healing is claimed by these authors for surgeries where recommendations according to their standards were followed.[20,24]

The choice of any of the above methods rests with the abilities of the institution. Though most non-invasive means are available throughout the medical community, invasive techniques using radioactive isotopes, like Xenon-133, require the availability of a nuclear medicine department. Clearly, not all facilities have this capability.

Once the level of tissue viability and surgical healing have been determined, operative procedures commence. A residual limb offering optimal function should be a "well muscled, durable stump of effective length with a pliable skin cover that has adequate sensation." The means to this end requires careful attention to the handling of the bone, nerves, and soft tissues.[7]

SURGERY

Subsequent to determining the amputation level is the actual surgical technique, which is an important adjunct to successful rehabilitation of the amputee. Handling of the bone requires close attention to the residual cortical shaping, and in standard practice it should be beveled to prevent sharp margins and potential socket problems.[19]

The reaction of the bone to surgical handling of the periosteum is not fully understood, but when dealing with tissues that are compromised initially, one cannot fault a "kid-glove" approach to dissection and ligation. Delicate handling may avoid subsequent spurring along the bony margins.[31] It has generally been considered that fibular length should be less (approximately 2.0 cm.) than the length of the tibia.[19,31] The authors feel that fibular length should be equal to or no more than 5 mm. shorter than the cut tibia. It is felt that this improves prosthetic medio-lateral stability, provides greater distal bulk, and serves to prevent mature conical shaping and increase total tissue contact and weight-bearing.

In the procedure described by Ertl,[8] the lengths of the two bones are equal. A bony bridge, or periosteal flap, is then created to afford an end bearing residual limb. This synostosis also prevents any relative motion of the two bones. The tibiofibular osteoplasty closes the open medullary canals and can recreate the normal conditions of direct weight bearing pressures and circulation in the long axis of the bone. This can help prevent degeneration in the joints proximal to the amputation.[8,17,19] It would seem that this procedure should warrant greater attention in appropriately selected patients (especially in light of the much improved fitting techniques now available).

Establishing stabilization in the distal musculature at the selected site of amputation is important to provide a more physiologically effective residual limb. Where surgically feasible, the muscles should be sutured to each other as well as to the periosteum and/or bone without excessive tension or laxity. This allows for a well contoured and generally less prosthetically troublesome limb.[3]

Nerve tissue should be handled meticulously to avoid residual problems once prosthetic wear is initiated. Each nerve should be individually dissected and have adequate traction applied. Severing of the nerve with traction maintained will cause it to retract far enough up into the soft tissue so as to be well protected and less threatened by weight bearing pressures.[19,31] Prosthetically crucial are the smaller sural and saphenous nerves, as they are sometimes neglected in lieu of the more major posterior tibial, deep and superficial peroneal nerves.[31] Redundancy of soft tissues should be avoided, but adequate coverage of the remaining structures is a must in order to provide a good limb for weight bearing. Closure of the wound should include careful suturing and handling of the already compromised tissues and care should be taken to avoid traction at the suture line so as to prevent contractures of the joint.[3,19,31]

It has been shown again and again that immediate post-surgical fitting procedures can improve residual limb viability, reduce pain and edema, and prevent contractures.[4,7,21,31] Rigid dressings are common practice in immediate post-surgical fittings, but variations on this theme include the use of pneumatic devices that can also afford the advantages of their more rigid counterparts.[2,15] More tenuous situations that may not allow for early weight bearing and ambulation, secondary to healing problems, can be approached through the use of Una boot dressings[34] and an innovative removable rigid dressing technique.[37]

Invariably, the independent and/or conjunctive use of any one of these methods can enhance the post-operative management of even the most difficult rehabilitation patient. By improving a patient's physical and mental status and by providing mobility through this approach, the clinical team can increase a patient's rehabilitation potential.[4,21]

PROSTHETIC EVALUATION

Little has changed in the physical aspects of evaluation. Standard anthropometric measures are still used to provide an objective record for modifications and fabrication, and for comparative purposes related to future changes. Accurately determining the anatomical joint range of motion (both in the involved and uninvolved limb) and strength/stability can provide criteria for prescription and serve to mediate problems during fitting.

One new tool in the evaluative process is Xeroradiography®. Xeroradiography® is a process that yields an x-ray image on an opaque background. The picture records are easier to store than their x-ray counterparts and provide a clear definition of both the bony anatomy and soft tissue. Evidence of bone spurring, vessel calcification, and presence of vascular surgery staples is readily observed. Measurements are also easy to glean. The use of this information in the treatment of the amputee is obvious and can significantly improve and objectify the prosthetist's skills and, ultimately, improve patient management.[35]

CASTING

Adopting a "hands-on" technique in the quest of obtaining an anatomical replica of the residual limb should be the goal of the prosthetist. A careful volume study of the involved limb can serve to optimize the definitive results.

The growing use of static and dynamic test sockets, and the information provided by them, has yielded a twist on the time tested practices utilized by many prosthetists. The technique of automatic build-ups over sensitive areas has been found to be less than necessary. Reversing this thought process to promote negative model modifications over areas of weight bearing can provide better total-contact, total-weight bearing sockets. Doing this in the molding process can reduce the amount of relatively educated guesswork necessary in cast modification by producing better initial cast molds. Methods which have been developed to aid in this pursuit include vacuum casting[13] or a three to four stage alginate casting technique.[32]

Another method to improve fit from the initial casting is to work toward a more dynamic casting method. As the casting is predominantly done under non-weight bearing conditions, working toward more "dynamic" casting methods which equalize the weight bearing pressures is warranted consideration. Where an Ertl procedure has been performed, distal weight bearing casting is preferred to achieve maximum results. The same intent should be attempted with the non-Ertl distal end as well. Ultimately, the better the quality of the cast and the less initial modification guesswork, the better the test socket fitting.

TEST SOCKET

Use of clear test sockets for improving fit is well documented in the literature cited. Though the technology for transparent test sockets has been available since the 1950's, the current practice of direct weight bearing modifications to the socket are relatively new.[23,25,27,32,33]

During the initial static weight bearing period, areas of the residual limb are demarcated according to weight distribution and, therefore, load. This is evidenced by varying degrees of blanching or redness. The goal of a total tissue bearing socket is then pursued to decrease areas of excessive pressure (blanching) and to increase areas of inadequate loading (redness). This goal can be met through either static or dynamic test socket volume changes, or cast model modifications.

Under weight bearing conditions, loose areas are marked by redness, and tension analysis is accomplished via "poking" the tissue through holes made in the socket. Various injectable materials (glycerine, alginate, pour-a-pad) are then added to equalize weight bearing pressures. Areas of excessive weight bearing, if not relieved by the weight borne by the newly injected materials, are either relieved in the socket or modified on the master mold.

By achieving a careful stump-socket interface tension analysis as described, greater confidence in he ultimate result and an optimum fit is possible. Difficulty of fit dictates the number of check socket fittings. Unfortunately, fittings are also affected by the reimbursement source. The fact is undeniable, however, that a transition to the use of transparent test socket fittings can increase the level of prosthetic expertise and elevate the profession to a higher plateau of fitting success.

DYNAMICS

Advancements in prosthetic componentry and gait analysis techniques, when used in conjunction with improved evaluation tools and fitting methods, provides a greater arsenal for the prosthetist seeking to optimize his patient's abilities. An exciting variety of new techniques are surfacing throughout the country which not only render prosthetics more professionally demanding to the practitioner, but also challenging to the patient. Different socket styles and theoretical bends are adding to current thought and practice.

The above-knee amputee now has a variety of alternatives in not only socket material and construction, but in functional design as well. The Swedish flexible socket offers a lighter weight, more "natural" feeling socket to the AK amputee. It also allows for greater transmission of heat via the polyethylene or Surlyn® material, and therefore a cooler feeling. The flexibility of the socket also encourages physiological muscle activity and provides sensory feedback through the thin material.[11]

Contoured Adducted Trochanteric Controlled Alignment Method (CATCAM) is an exciting new above-knee socket design. Proponents claim it increases comfort secondary to total soft tissue weight bearing, because the ischial tuberosity is no longer on the "seat" of the conventional quadrilateral design, but contained within the socket. The CATCAM also allows for more natural muscle activity by virtue of both the flexible design (a la Swedish flexible socket) and inherent socket mechanics. By improving the socket's purchase on the femur, whereby the ischium, trochanter, and adductor longus tendon are in essence "locked-in," stabilization increases, which then decreases the Trendelenberg tendencies experienced by many above-knee amputees. By obtaining a definite position of adduction of the femur, one can take advantage of the muscle stretch of the gluteus medius and therefore increase pelvic control with unilateral weight bearing.[28]

Ultralight weight components continue to be preferred in the above-knee prosthesis. The availability of titanium, carbon graphite, and higher density plastics in the manufacturing of the pylons, joints, and attachment plates allow for lighter weight limbs and, ultimately, decreased energy costs for the amputee.

The below-knee amputee has a varied repertoire of options. A greater array of suspension methods—latex rubber, neoprene sleeves, total suction prostheses—are now available. The Flex-foot prosthesis[18] utilizes a sleeve suspension and is comprised of a carbon graphite and fiberglass pylon and a heel that is very strong, light weight, waterproof, and energy cost effective. The Flex-foot design provides "stored energy" upon weight bearing that "propels" the amputee forward, mimicking "normal" muscle activity in gait. This can also be used for the above-knee amputee. The Flex-foot is proving to be a great advance toward increasing the abilities of the athletic amputee and shows great promise for the elderly and less physically challenged.

New liner materials have also provided alternatives for the below-knee amputee, with greater comfort as a result. Silicone gel and leather liners,[9] Ipocon gel,[14] and injection molded silicone gel liners[16] offer the amputee who has minimal tissue coverage and/or scarring the benefit of shock absorption and a "new skin" type feel. The active, athletic below-knee amputee also captures the benefit of the gel system and suffers less trauma as a result.

Prosthetic feet, such as the Seattle[5] foot and S.A.F.E.[6] foot, appear to offer better gait characteristics and function, and also allow for increased activity by virtue of their functional, flexible designs.

Ancillary methods of evaluating and improving gait performance are making their way into the more aggressive practices. John Sabolich, C.P.O.† in Oklahoma City has been utilizing a bio-feedback device with his above-knee patients in an attempt to re-educate the gluteus medius muscle during gait training. Utilizing the system in a dynamic fashion, i.e. patient ambulating with the electrodes over the targeted muscle, provides the patient audible feedback of muscle activity.

Use of a video tape camera also provides patients with optimum benefits during the alignment and gait training period.[32] Careful analysis of the saggital and frontal views provides the practitioner with a better opportunity to critically analyze and improve his patient's gait. Improved problem-solving subsequent to delivery is also a benefit of this technique. The film serves as a learning tool for the new amputee and the practitioner, and also serves as a record of a patient's progress and delivery status for ironing out future fitting problems relative to gait induced complaints.

The Computer Aided Design, Computer Aided Manufacturing (CADCAM) technique[29,30] is presently available for use in designing below-knee prosthetic sockets and will soon be available for design of above-knee prosthetic sockets as well. Measurements are taken from the residual limb and entered into the program. A screen display then allows for modifications to be made relative to the entered data and design scheme. Once the design is created, the information is transmitted to a computerized milling device that then carves out a model of the residual limb. From this model a socket is fabricated from polypropylene.

In the future, "shape-sensing" will allow for modifications from the sensed data rather than the standard methodology. The ability to draw from the digitalized information of Computerized Axial Tomography (CATSCAN) or x-rays is also in the offing. This system is also an excellent, accurate record keeping tool. The potential to "sense" size and shape, store the information, recall, modify, or duplicate as desired is an enticing prospect. Further research is both warranted and forthcoming.

CONCLUSION

With the advent of better technology and methods, a concomitant increase in prosthetic professionalism occurs. Improved education must also follow. Industry-wide attention to continuing the trend will help prevent our field from lapsing into the mundane.

The practice of this increased professionalism and improved techniques also commands a higher cost. Jan Stakosa, C.P.'s‡ method of using a wide variety of componentry per patient during the fitting and alignment phases in order to optimize function not only serves to improve the patient's quality of life, but carries with it an increased time commitment and cost. Due to this increased input and component variability, thorough education of the public and professionals per the costs involved is required. Ultimately, third party payers and the government will also have to be addressed. Until such time as these practices and advancements become standard, there will not be reimbursement for them.[36]

How do you value human needs in a marketplace in which the trend is toward price reduction? The reality is that all these advances will increase the cost of prosthetic care. Prosthetists, the public, third party payers, and the government will need to be willing to improve the quality of life for this sector of the population, who deserve to be rehabilitated to the maximum and be allowed to perform as well as any able-bodied individual.

It is our hope that the prosthetic industry will take up the challenge to advance the profession and invest the time in testing preferred methods and improvements. Equally important is the quest to participate in their creation. Through improved knowledge of the mechanics of amputation surgery and the variables of follow-up care, combined with mutual professional dialogue, we can better serve the amputee population.

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AUTHORS

David F.M. Conney, R.P.T., C.P.O., is a senior vice-president at Beverly Hills Prosthetics and Orthotics, Inc.

Keith E. Vinnecour, C.P.O., is owner and president of Beverly Hills Prosthetics Orthotics, Inc., Beverly Hills, California.

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† John Sabolich, C.P.O., is Vice-President of Sabolich Orthotics-Prosthetics Center, Oklahoma City, Oklahoma.

‡ Jan Stakosa, C.P. is Director of the Institute for the Advancement of Prosthetics, Lansing, Michigan.