Some Considerations in Management of the Above-Knee Geriatric Amputee

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The gradual increase in the life span of people in the developed countries of the world has resulted in a tremendous increase in the number of amputees in the older age, or "geriatric," group. A survey by Glattly in 1962 *(4)* showed that approximately 52 per cent of all amputees fitted with prostheses for the first time were over 50 years of age. Of these patients, 82 per cent had had amputations as a result of disease, 2 per cent because of tumor, and 16 per cent because of trauma. Most of these, of course, were lower-extremity cases.

As short a time as 10 years ago, only a relatively few geriatric amputees were provided with limbs, and not much attention was given to the special problems of older patients. However, it has now been demonstrated that, with expert care, older amputees can be fitted with functional prostheses and that the results obtained are well worth the extra efforts required. The below-knee case obviously presents fewer problems as a rule than does the above-knee case, but though surgeons are now saving more and more knee joints there will always be a certain number of above-knee cases that require attention.

Just as in the case of younger amputees, geriatric patients should be fitted as soon as possible. The longer the patient goes without a prosthesis, the greater the possibility for the development of contractures, edema, and other undesirable conditions. If the patient is not provided with a prosthesis immediately after the amputation, he should be fitted with a preparatory prosthesis as soon as he is seen by the clinic team.

When treating the geriatric amputee, the clinic team must keep in mind constantly that the patient's potential is far from that of an otherwise healthy person, and certain compromises must be made if optimum results are to be achieved. The primary factors to be considered are condition of the skin, muscle tone and strength, coordination and balance, and energy potential.

ANATOMICAL AND PHYSIOLOGICAL FACTORS

Skin loses its turgor and becomes more fragile as age increases, and although it does not necessarily become more sensitive to the touch it does become more subject to abrasion and breakdown. This is true especially for the below-knee amputee but also demands special consideration when fitting and training the above-knee patient, and every effort is made to limit relative motion and pressure between the socket and stump.

The older a person becomes the more likely he is to collect a fair number of scars, some of which may become supersensitive. The patient who has had an amputation secondary to vascular occlusion may well have scars present in the femoral triangle or abdominal scars from previous sympathectomies (Fig. 1). Particular care must be given to socket fit and suspension in order to avoid undue

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pressure and abrasion of these scarred areas. The presence of abdominal or inguinal hernias must likewise be taken into consideration and appropriate relief given if necessary.

Subcutaneous atrophy occurs in the elderly patient and may present difficulties with socket fitting. The loss of fatty tissue padding often gives rise to complaints of extreme discomfort in areas subjected to high pressure, such as the ischial tuberosity and the laterodistal end of the femur. It may also complicate socket fitting, because flabby tissues tend to roll and therefore provide less stability. Muscles also tend to atrophy with age and, in addition to becoming weaker, have correspondingly less tone and less bulk, as any surgeon knows who has operated through the muscles of an elderly patient. Loss of muscle tone and bulk further decreases the soft tissue padding over bony prominences and may contribute to socket discomfort. Loss of definition of muscle groups leads to loss of stump contour and hence less stability between socket and stump. The decrease in muscular strength which accompanies atrophy results in less strength for actuating the prosthesis; hence, the weight of the artificial limb becomes an extremely important factor.

Fig. 1. Sensitive scars in the inguinal area secondary to vascular reconstruction may require modifications in the quadrilateral socket.

Coordination and balance definitely are affected by the process of aging and rapidly become impaired when any degree of cerebral arteriosclerosis is present. Studies have shown that vestibular function decreases steadily after 50 years of age and, in addition, there is a general slowing of reflex motor action to proprioceptive stimuli which is irreversible *(3).* The prosthesis, therefore, must be modified frequently to provide increased stability.

The energy expenditure in the elderly above-knee amputee has been studied only recently, and is highly significant in the management of this class of patient. Miiller and Hettinger showed that energy expenditure was 25 per cent greater in above-knee amputees than in normal people (6). Bard and Ralston gave a figure of 20 per cent greater energy expenditure in the above-knee amputee over the normal person (2). Later, Ralston studied 17 above-knee amputees, all over 50 years of age, and found that the average energy expenditure was 55 per cent greater than for a normal elderly person (9). He further demonstrated that a normal subject walking at a comfortable speed consumed 580 cc. of oxygen per min., whereas the same subject at maximum walking speed consumed 715 cc. of oxygen per min. This figure coincided almost exactly with the figure of 700 cc. of oxygen per min. consumed by above-knee amputees walking at a slow speed. The average pulse rate in these elderly amputees walking at slow speed was 110 per min. From these studies it is obvious that energy expenditure is greatly increased when

an elderly person must use an artificial limb instead of his own.

The use of crutches without a prosthesis has been used in the past as a criterion for prescribing prostheses for the elderly. However, this not only demands more energy from the patient than the prosthesis itself, but also demands more balance and coordination, and therefore the use of this criterion has been discontinued. Many patients who are not able to use crutches without a prosthesis can achieve some functional activity with a prosthesis. Use of a temporary, or preparatory, prosthesis (Fig. 2) offers the best index to future function *(10).* This is to be distinguished from a pylon, which has no articulated knee joint and no prosthetic foot. The temporary, or preparatory, prosthesis has a completely formed, quadrilateral, total-contact socket on an adjustable knee with a positive knee lock, an aluminum shank, and an articulated SACH (solid-ankle, cushion-heel) foot.

SOCKET DESIGN

Hall has reviewed the principles which led to the development of the quadrilateral socket as we know it today (5):

1. Actively functioning muscles should have relief.
2. Stabilization forces should be applied where no functioning muscles exist.
3. Functioning muscles should be placed at slightly greater than rest length for maximum power.
4. Properly applied pressure is well tolerated by neurovascular structures.
5. Force is best tolerated if it is distributed over the largest available area.

For these reasons, the quadrilateral socket is relieved anterolaterally for the functioning rectus muscles and posterolaterally for the functioning gluteus maximus muscle; it is flattened along the lateral wall to provide the greatest surface area for the forces of abduction and along the posterior wall to provide a similar large area for the forces of extension, and is molded snugly into Scarpa's triangle to keep the ischial tuberosity displaced posteriorly on the ischial seat.

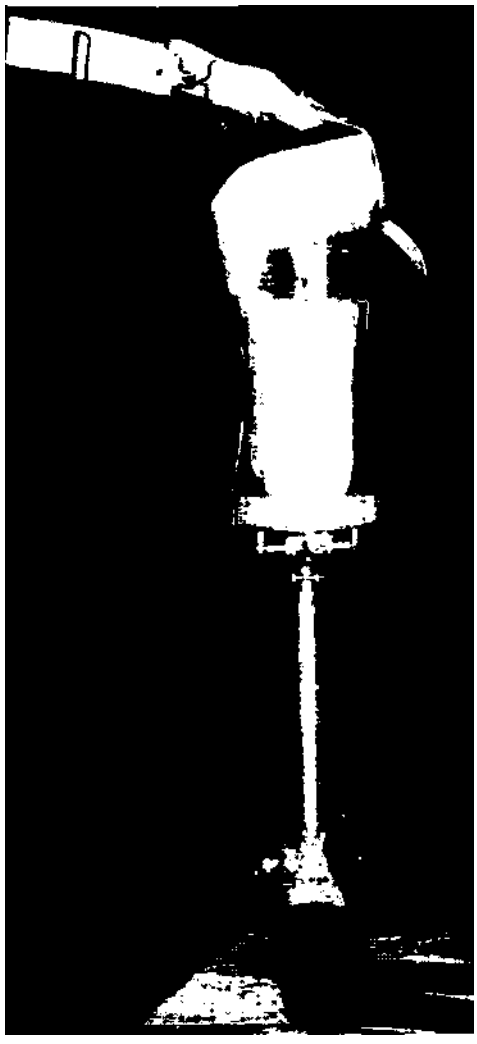

Fig. 2. A typical temporary above-knee prosthesis for determining the feasibility of a permanent prosthesis for the elderly amputee.

Although it may seem like fitting a round peg into a square hole, the quadrilateral socket has provided the most satisfactory union between stump and prosthesis ever achieved for the above-knee amputee, because its shape permits proper function of the muscles which move the stump. At the same time, the forces generated by this muscular activity are distributed over relatively large areas.

This is in contradistinction to the "plug-fit" socket which was used formerly and which did not take properly into consideration muscle action and the forces generated. The plug-fit socket, seemingly more compatible because it provides a round hole for a round peg, allows the ischium to slide inside the socket brim and the weight to be borne chiefly on the gluteal muscle mass and adductor region. Because the weight is borne chiefly by the soft tissues and because the socket is of a conical shape, there is a wedging effect of the stump in the socket and the distal tissues are pulled tightly over the end of the femur, frequently causing pain or stump breakdown. Stability about the long axis is poor because of its round cross section. In addition, the forces of abduction are distributed over relatively small areas as the femur is pushed out against the lateral wall.

The use of the plug-fit socket has been largely abandoned today, but some of its features are useful at times for the geriatric amputee, particularly when pressure is to be avoided over Scarpa's triangle because of a femoral bypass graft or because of inadequate circulation. In some geriatric patients there is justification for modifying the quadrilateral shape in the direction of a rounded or plug-fit shape, retaining, however, certain characteristics of the quadrilateral socket.

The quadrilateral socket is not made to a rigid pattern but is modified from a typical pattern in various ways to accommodate individual stumps. If the rectus femoris is unusually large, it may be accommodated by further relief. The same is true for the hamstring and gluteal groups. If the gluteal muscles are underdeveloped or atrophied, less relief can be given. In the elderly, because of tissue atrophy, ischial weight bearing is often uncomfortable and the posterior wall may be modified to distribute the load over the gluteal group. If it is necessary to have the Scarpa's-triangle area free from pressure, this can be accomplished by relief in this area, allowing the ischium to slide into the socket over a properly contoured posterior brim.

We must also reconcile ourselves to the fact that, as much as we delight in rehabilitating the geriatric amputee to an ambulatory status, he will, nevertheless, spend much of his time sitting, and certain socket modifications must be made to provide comfort during prolonged periods of sitting. The thickness of the posterior wall may be decreased so that pressure neuropathy of the sciatic nerve does not develop, and the anterior brim may be lowered so that excessive pressure does not develop in the region of the femoral neurovascular bundle or the anterior superior iliac spine.

There appear to be no contraindications to the fitting of total-contact sockets to the elderly above-knee amputee. With total contact, not only are the tissues supported evenly and edema and skin breakdown prevented, but a greater proprioceptive and kinesthetic sense is developed, a condition of even more importance to the geriatric amputee than it is to his younger counterpart. Total contact, however, is not as important with pelvic suspension as it is with suction suspension, and it is difficult to maintain, particularly when stump socks are used.

SUSPENSION

There is uniform agreement that suction provides the best suspension available. Suction suspension, however, has a limited use in the geriatric amputee because of the exertion required in donning the prosthesis and the fact that many elderly patients have a limited ability to bend forward.

The pelvic band is in wide use, but it has disadvantages. It is apt to create excessive pressure about the lower abdomen when the patient is sitting. It must be well padded to prevent the development of excessive pressure over the iliac crest and over any scarred areas on the abdomen. The location at the hip joint is critical.

The preferred method of suspension in the elderly above-knee amputee is the Silesian bandage or one of its modifications. When used with the quadrilateral total-contact socket, it provides comfortable suspension and gives good stability. It may be modified to include a shoulder strap, or may be modified further to incorporate an elastic webbing band from the posterior portion of the belt to the posterior wall of the socket to act as a hip-extensor aid *(8).*

The inability of most elderly above-knee amputees to don a suction socket properly has led to the development of a split-socket type of appliance at the University of Miami Prosthetic Laboratory (Fig. 3). In this type of prosthesis the intimate fit of the suction-type socket is obtained, yet it is donned easily by the geriatric amputee. [A complete description of the split-socket type of appliance will be published in the Spring 1969 issue of *Artificial Limbs.*—Ed.]

ALIGNMENT

The above-knee socket, in general, is adducted at least 5-10 deg. to restore the normal position of the femur and place the abductor muscles at their optimum functional length. Adduction of the socket also has the effect of narrowing the base of gait, an important factor in energy conservation (2). If the abductor muscles are not placed in their optimum position of function, if the socket is abducted too far, or if the prosthetic foot is located too far laterally, the center of gravity of the body must shift over the supporting leg in order to gain sufficient stability during walking. Conversely, if the adduction of the socket is sufficient to hold the femur in a normal position of adduction and to keep the abductor muscles at their optimum length, these muscles will act to stabilize the pelvis with a minimum amount of contraction while dissipating the force of stabilization by femoral pressure against the lateral wall of the socket. This ideal cannot always be achieved in the elderly patient and the socket sometimes has to be aligned in the neutral or slightly abducted position in order to gain the required stability, at the expense of increased energy consumption.

Fig. 3. The double-wall above-knee suction socket with anterior opening developed by the University of Miami Prosthetic Laboratory for easy application in the older amputee. The flexible inner socket is jointed to the outer by a lateral Velcro strap.

Aligning the socket in some degree of flexion increases the power of hip exten-

sion and voluntary knee stability. In general, the above-knee socket should be aligned in some degree of flexion, usually by 5 deg. in excess of the maximum amount of hip extension that can be obtained by the amputee while standing on his good leg without producing excessive lordosis. The amount of flexion will vary from 5 to 35 deg., depending on the length of the stump and the amount of hip-flexion contracture present. Alignment of the socket in flexion is limited by the length of the stump, and in the longer stump is minimal. As socket flexion is increased, the knee bolt must be moved somewhat more posteriorly in order to retain the same alignment stability at the knee *(7).*

Although adduction of the socket is quite efficient because there is very little excursion of the femur outward toward the lateral wall of the socket in walking, flexion is not nearly so efficient because the large posterior muscle mass allows considerable backward shift of the femur in the soft tissues prior to its exerting significant pressure on the posterior wall. This has been documented by the senior author in a cineradiography movie of above-knee stumps in sockets (Fig. 4). Because of this backward excursion of the femur in the soft tissues as the thigh is extended, it is felt that the femur should be set in the maximum amount of flexion consistent with cosmesis to give greater voluntary control of extension to the knee.

In the elderly patient with less voluntary control and deficiencies of balance and coordination, even a long stump may require the alignment characteristics of the medium or short stump.

STABILITY OF THE KNEE JOINT

Knee stability is usually achieved by a combination of voluntary control by the hip extensors and alignment of the knee axis so that it is posterior to the weight-bearing line (so-called alignment

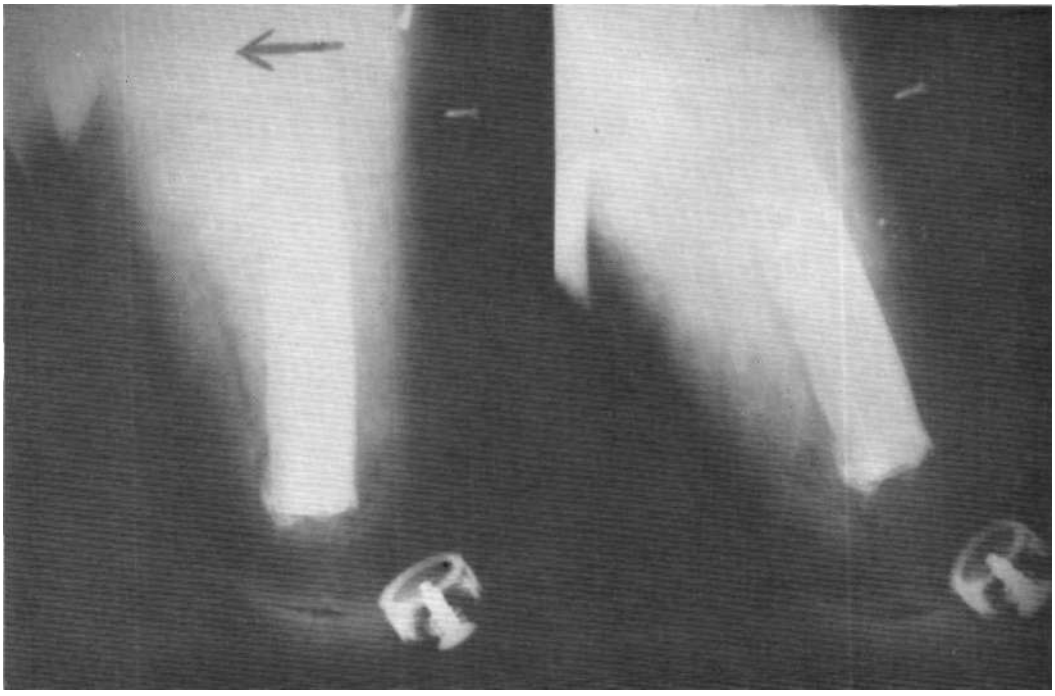

Fig. 4. Frames from a cineradiography film of an above-knee stump in the socket. *Left,* The femur displaces posteriorly in the soft tissues a considerable distance before effective force can be transmitted to the posterior socket wall to stabilize the knee. *Right,* The limb is at heel strike prior to hip-extensor thrust.

stability), or by a lock or brake. Voluntary control of knee extension is usually diminished in the geriatric amputee because of muscular weakness and poor coordination, and often an increased amount of alignment stability is necessary. This alignment stability, in combination with a single-axis constant-friction knee, the most standard type, is generally sufficient. However, there may be instances in which additional stability during weight bearing is necessary, and this can be provided by the use of a unit, such as the Bock Safety Knee, which gives a braking action during weight bearing. The chief disadvantage of this type of unit is the added weight of the mechanism.

For the elderly amputee with extreme instability and insecurity, such as a bilateral amputee, or one in whom there is a severe flexion contracture, some type of positive knee lock is usually necessary. The knee is locked in extension throughout all phases of gait, producing obvious gait deviation, but as someone once said, "an abnormal gait is better than no gait at all," which would otherwise be the case.

Hydraulic knee units can be used successfully by the elderly above-knee amputee, and offer many advantages when the amputee has sufficient muscle power to handle these necessarily heavier limbs. The chief advantage of the hydraulic unit in geriatric patients is that it allows more anterior placement of the knee joint without sacrificing stability, and less energy is consumed in hip flexion to initiate the swing phase of gait. The other primary advantage of the hydraulic knee unit, that of permitting rapid walking by faster and more reliable knee extension, is frequently lost on geriatric amputees as they usually walk with a slow, purposeful gait.

Until recently it has been a most difficult task to provide the knee-disarticulation and long above-knee stumps with adequate swing-phase control. DuPaCo recently introduced a set up so that the DuPaCo "Hermes" unit can be used with these long stumps.

Stability at heel strike is extremely important to prevent buckling of the knee or jack-knifing, which may occur in the elderly above-knee amputee with insufficient hip-extensor power. The less resistance to plantar flexion, the more stability there is at heel contact and shortly thereafter. Locating the foot anteriorly with respect to the knee also increases stability during the period just after heel contact.

The SACH foot is generally satisfactory for use by geriatric amputees, although in cases where weight is a real consideration a wooden foot with an aluminum ankle joint can be lighter than the SACH feet available commercially. For the elderly amputee the heel should be relatively soft in order to act as a shock absorber and enhance stability of the knee at heel contact. A single-axis wooden foot in which the softness of the plantar bumper can be varied can give greater stability than even the softest SACH heel available. However, excessive stability results in unnecessary expenditure of energy.

The foot must occasionally be outset more than usual to enhance lateral stability in the elderly. This again is another example of obtaining stability at the expense of increased energy consumption, for outset of the foot requires a greater lateral shift of the center of gravity in walking.

AMBULATION

While it is desirable to return all elderly above-knee amputees to an ambulatory status, it is often not practicable. Nearly all bilateral above-knee amputees over 50 years of age will find the wheelchair an easier and more practical means of locomotion than the use of prostheses. One must carefully evaluate the patient in terms of strength, endurance, balance, and coordination prior to prescribing a prosthesis. The patient and his family or, more likely, the government will be saved unnecessary expenditure by proper selection of patients for fitting. Often, one must accommodate the patient's own desire to

find out for himself whether or not he should be relegated to the wheelchair permanently. In the true geriatric amputee, once ambulation has been achieved it is best to continue the use of some type of external support, depending upon the patient. Usually a cane or single crutch on the opposite side will be sufficient support for the elderly amputee. In some extreme cases a walker may be used, which admittedly makes for poor gait pattern, but this is preferable to no gait at all. The use of external support not only gives increased mechanical stability but also provides the amputee with additional proprioceptive feedback from the terrain on which he is walking, thus leading to better balance. In determining the functional capacity of the bilateral amputee in the older age group, the use of "stubbies" is strongly recommended and the patient should graduate to nonarticulated pylons with increasing height, to a preparatory prosthesis, and, finally, to a permanent prosthesis. Needless to say, the bilateral above-knee patient must always use external support when walking, and a wheelchair should be considered the primary mode of locomotion.

SUMMARY

In order to provide optimum function in the elderly above-knee amputee, one must consider thoroughly certain anatomical and physiological characteristics of the patient which may indicate the necessity for modifications of the standard prosthesis. The characteristics are individual and vary greatly from one elderly amputee to another, but include skin condition, condition of the subcutaneous tissue, muscle strength and tone, coordination, and general factors relating to energy consumption. Modifications based on these factors may then be made in the prosthesis to ensure optimum functional performance. These modifications may include changes in socket shape and alignment, changes in the suspensory apparatus, provisions for increased stability at the knee, and provisions in the ankle to ensure over-all stability. In every instance an attempt should be made to provide the amputee with a minimum prosthetic weight. The future level at which the amputee will function can best be anticipated by the initial use of a temporary, or preparatory, prosthesis.

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