Lecture # 8

Artificial Limbs I

Prosthetic Options for Persons with Bilateral Lower-Limb Amputation

Introduction

The loss of both lower limbs complicates the rehabilitation process, especially if the loss occurs simultaneously. In North America, simultaneous bilateral loss is infrequent; such cases are typically the result of traumatic transportation or industrial accidents or electrocution. In the developing world, simultaneous limb loss is more frequent; in areas of armed conflict and postwar zones, roadside bombs and landmines are a major cause. Fortunately, most patients with traumatic amputation are healthy and strong and generally have a good prognosis for the successful use of prostheses.

The major cause of bilateral lower-extremity limb loss is dysvascular disease. The Centers for Disease Control reports the number of hospital discharges for nontraumatic lower-extremity amputation with diabetes as a listed diagnosis increased from 45,000 in 1991 to 86,000 in 1996, when it peaked, and then decreased to 66,000 in 2006. From 1988 to 2006, the number of discharges increased by 20%.39 when vascular disease affects both limbs, as is often the case, patients with a single dysvascular amputation face a significant risk of eventual bilateral limb loss. An incidence as high as 50% for contralateral limb loss over a 5-year period has been reported.36,40 Clinical followup suggests that successful use of a unilateral prosthesis increases the likelihood of success with bilateral artificial limbs. For this reason, early fitting after initial amputation is strongly advocated, even when amputation of the opposite limb seems imminent.

The rehabilitation of persons with bilateral lower-extremity limb loss is similar to the rehabilitation of persons with unilateral amputation. One major difference is that using two artificial limbs is physically more difficult; thus, the pace of advancement is slower and must be individualized according to the patient's strength, balance, and ability. Breaking down complex skills into small incremental tasks that can be more readily mastered is generally useful. Without the benefit of a sound limb, patients with bilateral loss can be expected to walk slowly and cautiously, often with a relatively wide-based gait that maximizes their sense of stability. Su and colleagues investigated the gait characteristics of persons with bilateral transtibial amputations and found that persons with amputations walked at slower speeds and lower cadences, had shorter step lengths and wider step widths, and displayed hip hiking during swing phase. Bilateral transfemoral amputees have even greater energy expenditure and lower rates of full time prosthetic use for functional ambulation.

The use of balance aids such as canes are common, but not universal, in the gait training and mobility rehabilitation process for persons with bilateral amputation. Environmental barriers such as ramps, hills, irregular surfaces, and curbs or stairs present special challenges that must be identified and overcome. Specific training in sitting down, rising from a chair, falling in a controlled manner, and recovering from a fall are all important tasks to be mastered. Transfer with and without artificial limbs is also an important skill to foster independence. Persons with bilateral lower-limb amputation require a wheelchair for mobility for independent toileting in the night and for times when the prosthetic legs need repair.

The rehabilitation of persons with bilateral lower-limb amputation occurs in various phases, including a preoperative phases, if time permits, an immediate postoperative phase, and acute rehabilitation phase. The rehabilitation process is patient centered and should be individualized for each patient, taking into account physical condition, biomechanical loss, and prosthetic needs. The reason for the amputations influences the pace and level of rehabilitation. Otherwise healthy individuals who sustain traumatic limb loss may be able to advance rapidly unless skin trauma is present on the residual limbs. Early prosthetic fitting is a critical factor in the long-term successful outcome for functional prosthetic use.

Energy Cost

The effort required to use a unilateral prosthesis increases in direct proportion to the level of amputation: the longer the residual limb, the lower the energy cost of walking with a prosthesis. Saving as much functional limb length as possible is therefore an axiom in amputation surgery. Although preservation of the anatomical knee joint is important for patients with unilateral amputation, it is a critical consideration when bilateral limb loss is present: When at least one biological knee joint remains, the chances for practical ambulation significantly increase.

Energy cost of ambulation is also related to the reason for limb loss. In general, patients with dysvascular amputation have lower energy reserves and expend more effort walking than those with traumatic amputation (Figure 1). Long-term use of bilateral transfemoral prostheses is uncommon, but not impossible, for elderly patients with dysvascular amputation. In contrast, a significant number of those with traumatic bilateral transfemoral amputation successfully use prostheses long term.48 Patients with bilateral transtibial ambulation tend to do well with prostheses regardless of reason for amputation. Interestingly, bilateral transtibial prostheses require less effort than a unilateral transfemoral prosthesis; this finding emphasizes the importance of retaining biological knee function whenever possible.

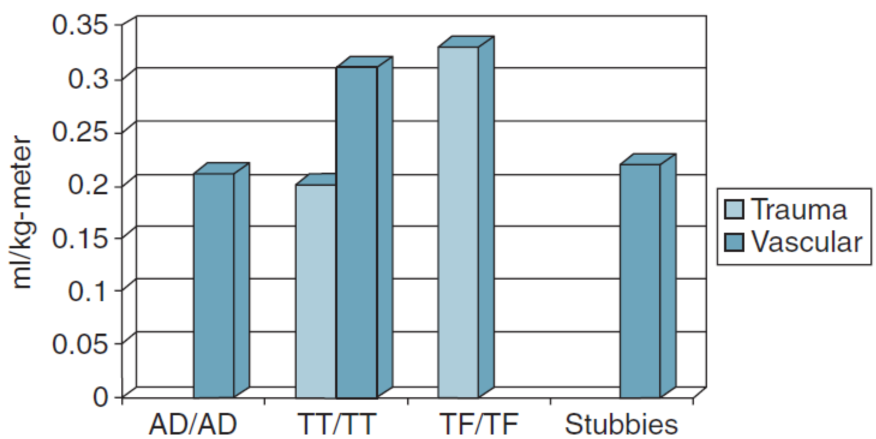

Figure (1): The energy (oxygen) cost of ambulation with bilateral prosthesis compared for patients with ankle disarticulation (AD), transtibial amputation (TT), and transfemoral amputation (TF) when using traditional transfemoral prostheses and stubbies (simplified prostheses consisting only of the transfemoral sockets attached to a stable base, without any prosthetic knee). Note that energy costs increase as the level of amputation moves proximally. Energy cost is also higher in dysvascular amputation compared with traumatic amputation. Ambulation requires less effort for patients with at least one anatomical knee joint than for those with bilateral Transfemoral amputation. Preservation of an anatomical knee joint increases likelihood of independence in ambulation.

Component Selection

Selection of components for patients with bilateral lower limb amputation is made by the same guidelines as for unilateral limb absence. There are no unique or distinct components specifically designed or intended for use in bilateral prosthesis. The prosthetist should consider both prostheses together rather than simply generate a “right-side” and a “left-side” prescription recommendation. Prosthetists generally recommend that the same ankle-foot device be used on both sides so that gait mechanics are consistent, but this is not an absolute necessity. Some patients ambulate best with different prosthetic feet, depending on the level of amputations, the length and condition of the residual limbs, the nature of their preferred activities, and other individual characteristics.

The range of physical differences between two patients with bilateral lower-limb loss makes each patient and each prosthetic fitting a unique challenge. During the dynamic alignment procedure, a brief clinical trial with the recommended components is often helpful in confirming suitability for a specific individual before the prescription details are finalized. This trial is particularly helpful for experienced ambulators, who commonly develop strong preferences for a specific component after walking with it for many years.

Bilateral Transtibial Amputations

In North America, a solid-ankle, cushion-heel prosthetic foot is often chosen for patients with bilateral transtibial amputation because such feet offer predictable standing balance. Most patients with bilateral amputation are concerned about falling backward. The prosthetist often chooses to use a slightly stiffer heel resistance to minimize the risk of backward falls. When concern about forward falls also exists, the prosthetist may also choose to use a slightly stiffer keel to offer additional resistance to falling forward. Patients classified as limited ambulators, those with poor postural responses, and those who walk with a very slow cadence often find this approach useful.

Active patients walk well with elastic keel and dynamic response feet or with multiaxial designs as long as they have sufficient strength and postural responses to manage these flexible components. Theoretically, single-axis feet are designed to generate an abrupt hyperextension moment at midstance, which loads the cruciate ligaments of the residual limb. In practice, little evidence exists that this loading is harmful; some patients with bilateral transtibial amputation prefer single-axis feet, choosing them over solid-ankle or dynamic-response designs. Patient preference is an important consideration in prosthetic prescription; preference is even more critical for patients with bilateral amputation who, literally, have no “good foot” to stand on other than prosthetic devices. If a patient expresses a definite dissatisfaction with a particular foot during the fitting process, an alternative component should be tried before proceeding further.

The consideration of ancillary components, such as torque absorbers or shock-absorbing pylons, is important for all patients with bilateral amputation. Because patients with bilateral amputation must bear all their body weight on prosthetic devices all the time, components that increase comfort or protect the skin are particularly appropriate. Lessening the weight of the prostheses, particularly at the ankle-foot area, is also important because lighter-weight prostheses are easier to control and increase acceptance of the device. Whenever possible, heavier components should be placed as close to the socket as possible.

Bilateral Transfemoral Amputation

Postural responses are compromised in patients with bilateral transfemoral amputations because of the loss of both anatomical ankles and knees. For this reason, a primary goal of prosthetic prescription is stability in the stance phase of gait. One of the most effective prosthetic components for stance phase stability during level walking is a polycentric knee unit. For those patients who have the potential to walk at varying speeds, the addition of fluid swing-phase control is recommended. Hydraulic stance and swing control units are also quite successful for this population. In recent years, microprocessor- controlled hydraulic knees offering both stance and swing-phase control have been well received clinically by this population, and many experts believe this technology offers more reliable stability and better mobility under real-world conditions than strictly mechanical knee mechanisms. The risk of injury in a fall is greater if locking or stance control knees are used in both prostheses. For patients with significant stability issues, a locking or stance control knee may be used on one side. Because single-axis knees are stabilized by muscle control and postural responses at the hip, bilateral single-axis knees are often difficult to use safely in older adults with dysvascular amputation. Bilateral single-axis knees may be appropriate for small children because their short stature reduces the balance required to manage such components.

Ankle-foot components that emphasize stability and standing balances are typical for this group with bilateral loss. Solid- ankle designs predominate. Articulating designs are used less often; only those with very long transfemoral residual limbs and good muscle strength are typically able to control the added mobility provided by articulating ankle components. Many patients with bilateral transfemoral amputation use crutches or canes to assist with balance and postural control. Single-axis or multiaxial feet become easier to control if the patient leans forward slightly, shifting the center of gravity forward, so that the weight line falls anterior to the ankle axis at all times, eliminating the risk of falling backward.

Ancillary components, such as torque absorbers, often make walking easier and more comfortable for patients with bilateral transfemoral amputation. Some evidence exists that including components that permit controlled transverse rotation improves the gait kinematics of patients who wear two lower limb prostheses. Locking rotation devices make many activities of daily living easier to accomplish. Because the weight of such ancillary components must be considered, the perception of the artificial limb feeling heavy is minimized if the devices are positioned as far proximally within the prosthesis as possible.

Transfemoral–Transtibial Amputation

For patients with one transfemoral and one transtibial amputation, the preservation of one biological knee makes prosthetic use much easier and successful ambulation more likely. For most patients, the transtibial side is the propulsive and balance limb and the transfemoral side supplements these functions. On the basis of these functional differences, the prosthetist may choose to use different prosthetic feet. When the transfemoral amputation is relatively short, for example, a single-axis foot and stance control knee might be recommended for the transfemoral prosthesis, whereas a dynamic response foot might be used in the transtibial prosthesis.

Socket Designs and Suspension

The person with bilateral lower-limb loss is constantly bearing full weight on artificial limbs while walking or standing. All options to increase skin protection and comfort should be actively considered, and suspension must be as secure as possible. A soft insert and flexible sockets may be used to enhance comfort during wear and reduce the likelihood that shear forces will be problematic for the skin. Suction suspension, with silicone sleeves or inserts as necessary, minimizes pistoning during swing and should be considered for the majority of patients with bilateral amputation.

Cotton or wool prosthetic socks are often used as an interface between the residual limbs and the sockets when suction suspension is not feasible. In that event, supracondylar wedge or cuff suspensions are typically used in transtibial prostheses; Silesian belts are often used in transfemoral designs. Because most patients with bilateral amputation use a pair of prostheses, suspension belts are usually integrated into a single assembly. Because thigh corsets with metal side joints, hip joints and pelvic bands, and waist belts can be cumbersome for donning and doffing, they are typically avoided unless absolutely necessary.

Ischial containment sockets are as effective for patients with bilateral amputation at the transfemoral level (of one or both limbs) as they are for patients with a single transfemoral amputation. Patients who have previously worn a quadrilateral transfemoral socket, and those who are limited ambulators, may be satisfied with a traditional quadrilateral design. Total contact of the residual limb in the socket is important for both ischial containment and quadrilateral socket skin integrity.

The loss of both feet and both knees makes the use of bilateral transfemoral prostheses quite challenging. For many adults with acquired limb losses, an initial fitting with sockets attached to special rocker platforms may be advocated to facilitate initial gait training (Figure 2). Such “stubbies” require less energy and balance than full-length prosthetic limbs and give the patient new to bilateral prostheses the best chance for successful ambulation. Once the patient is able to balance effectively on the stubbies, the prostheses can be converted to use artificial feet with solid pylons, which are gradually lengthened to increase the height of the prostheses. If the patient is able to manage full-length prostheses, prosthetic knees can be incorporated and definitive prostheses with full components provided.

Not all patients with bilateral transfemoral amputation choose to pursue ambulation with prostheses. Some are unable to build the necessary muscular strength or postural control for a safe gait. Others find the energy cost of ambulation with prostheses excessive. In these cases, patients choose wheelchair mobility as a much less strenuous means of mobility and willingly adopt wheelchair use for the independence it provides.

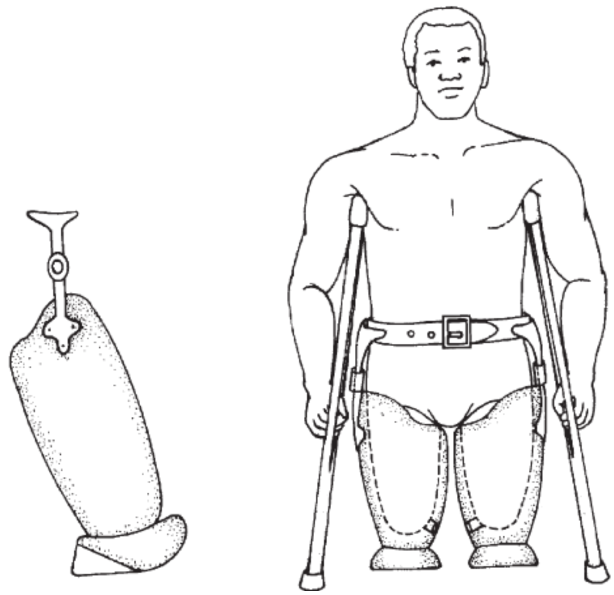

Figure (2): A pair of shortened prostheses, sometimes called stubbies, for early gait training for patients with bilateral traumatic transfemoral amputation. In these prostheses, patients can develop postural control without having to worry about the stability of prosthetic knee units.

Many patients with bilateral transfemoral amputation find a wheelchair most practical for long-distance mobility and use their limbs for walking short to moderate distances at home and work. Some patients accept the stubbies for longterm use, particularly if these devices allow them to remain independent in their home setting. Others choose to use their stubbies at home because they take less effort but wear full prostheses in public.