Lecture # 9

Artificial Limbs I

Prosthetic Options for Persons with Upper-Extremity Amputation

IMPACT OF TECHNOLOGY

Prosthetic management of individuals with upper-extremity amputations presents all allied health professionals, including prosthetists, with a set of unique challenges. For those wearing an upper–extremity limb, the TD of the prosthesis is not covered or obscured by clothing in the same way that a lowerextremity prosthesis is "hidden" by pants, socks, and shoes. By the virtue of its level, the person with upper-extremity amputation must cope with not only physical appearance changes, but the loss of some of the most complex movement patterns and functional activities of the human body.

In addition, limb deficiency in the upper extremity deprives the patient of an extensive and valuable system of tactile and proprioceptive inputs that previously provided "feedback" to guide and refine functional movement. Even the simplest tasks related to grasp and release become challenging. The ability to position prosthetic limb segments in space, as well as the ability to maintain advantageous postures needed to manipulate objects, challenge the medical community to continuously improve the functional and aesthetic outcomes of prosthetic replacement for patients in this population.

Many of these challenges have been addressed with new and emerging technologies. These new technologies have made it possible, in some circumstances, to successfully “fit” a patient with high-level amputation who previously would have little or no reasonable expectation to succeed with traditional technology and fitting techniques. Advanced socket interface designs and material science have afforded prosthetists the ability to offer stronger, more stable platforms for all levels of amputation, while in most cases saving substantial amounts of weight. Similarly, more innovative suspension strategies and interface mediums have increased the functional ranges of motion a patient can comfortably achieve.

These advancements have had a profound and positive effect on the comfort, function, and compliance of both conventional body-powered and externally powered prostheses at all levels of amputation. Furthermore, the huge strides made in the externally powered arena have in large part been driven by these advancements and technological breakthroughs.

LENGTH OF THE RESIDUAL LIMB

Amputations to the upper extremity can be classified or named by the limb segments affected (Figure 1). The most distal are at the finger, partial hand or transcarpal levels. Amputations that separate the carpal bones from the radius and ulna are referred to as wrist disarticulations. Amputations that occur within the substance of the radius and ulna are classified as transradial amputations. When the humerus is preserved but the radius and ulna are removed, the amputation is referred to as an elbow disarticulation. Those that leave more than 30% of humeral length are designated as transhumeral amputations. Shoulder disarticulations are those in which less than 30% of the proximal humerus remains. More proximal amputations that invade the central body cavity, resecting the clavicle and leading to derangement of the scapula, are described as forequarter amputations or scapulothoracic amputations. In clinical prosthetic and rehabilitation practices, transradial and transhumeral amputations account for nearly 80% of all upperextremity amputations.

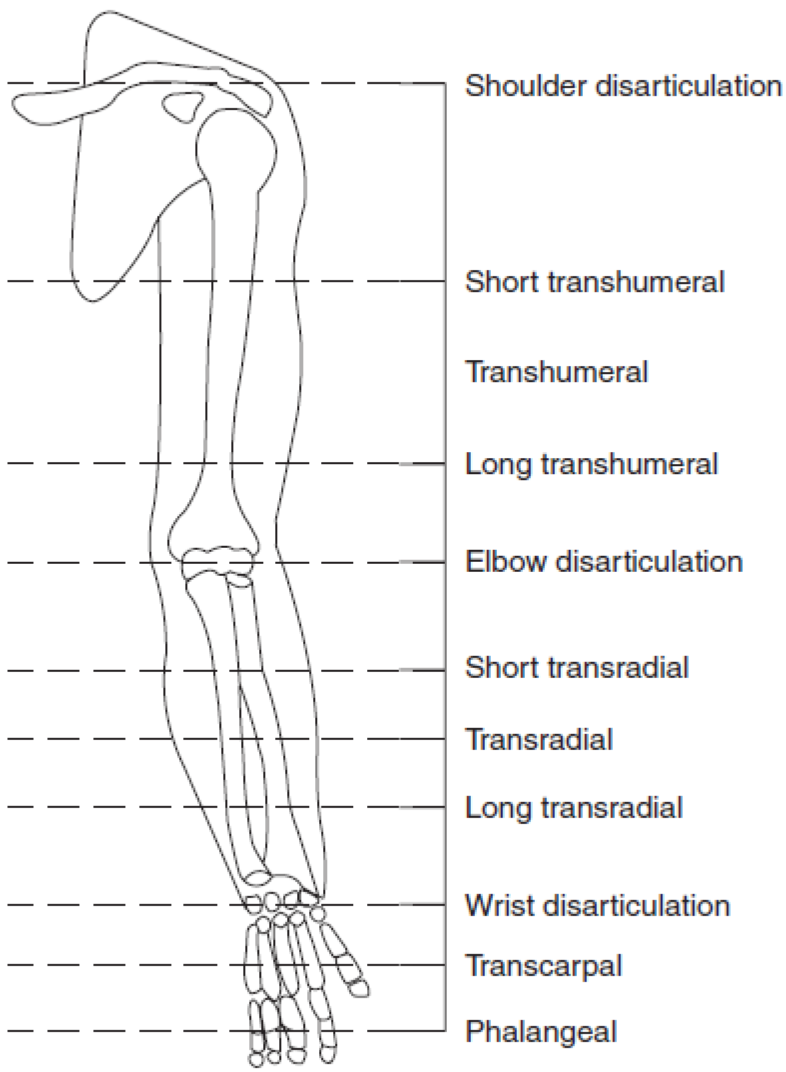

Figure (1): Classification of upper-extremity amputation and residual limbs. (From Murdoch G, Wilson AB, Amputation

All patients who have amputations of the upper extremity require a complete and thorough examination at the levels of involvement and of associated functional and physiological deficits associated with that specific amputation. For patients with partial hand amputations, the range of motion (ROM) of any remaining digits and the condition of the structural bones of the hand have a profound effect on the selection of possible prosthetic options. The inclusion or absence of an intact thumb also dictates the parameters of fitting.

For those with transverse amputations of the forearm, the length of the residual limb affects the amount of functional elbow flexion and forearm pronation and supination that will be retained independent of prosthetic intervention. Articulations between the radius and the ulna along the entire forearm are necessary to provide for natural anatomical movements in supination and pronation; as the level of amputation moves proximally from the styloid process of the radius toward the elbow, the ability to perform and to use pronation and supination during functional activities is progressively lost (Figure 2). When the residual forearm is extremely short, all transverse motion is essentially lost, and it is difficult to gain any active functional forearm rotation for prosthetic use.

Amputations at the level of the elbow (elbow disarticulation) derive little functional benefit from the added length because the length of the limb limits options for cosmetic and functional placement of elbow units within the prosthesis, without substantially improving functional leverage.

Although the primary concern of surgeons who perform an upper-extremity amputation is adequate closure of the wound, they must also consider the potential advantages of a fairly long lever arm, balanced by an understanding of the space requirements for prosthetic components. Provided that adequate skin and tissue viability are not compromised, consideration should be given to adequate room for a full array of prosthetic componentry.

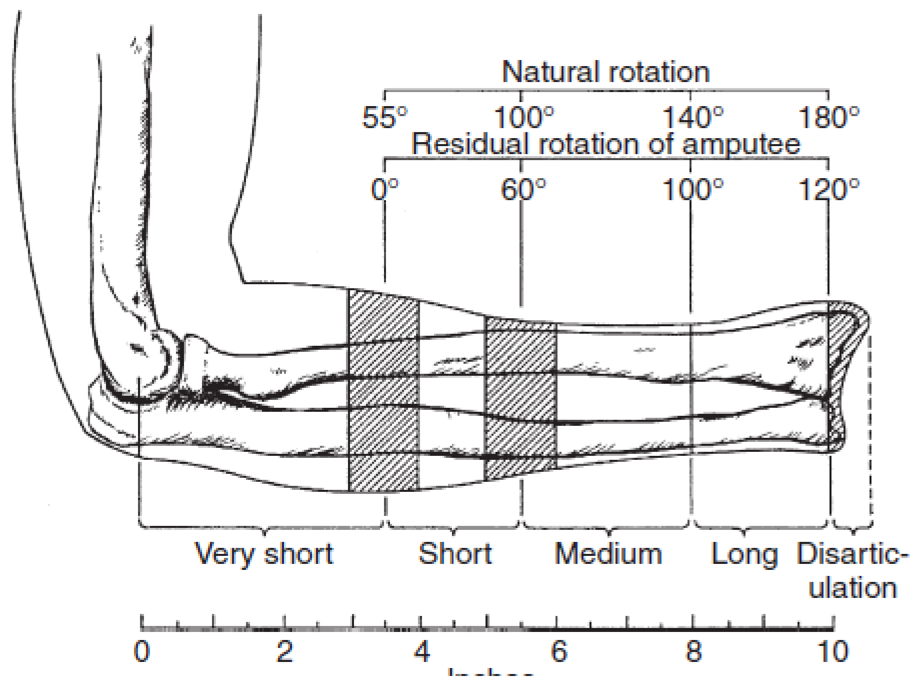

Figure (2): Potential for pronation and supination of transradial residual limbs of differing lengths.

UPPER-EXTREMITY PROSTHETIC COMPONENT

Prosthetic components can be thought of as a means to replace lost functional capacity associated with the anatomical loss of limb segments. A TD is employed to replace grasp and release. An elbow mechanism is used to replace the humeral-ulnar articulation; a shoulder mechanism is placed proximally to provide humeral orientation in space at the shoulder disarticulation and scapulothoracic amputation levels. Rotators can be placed in the forearm of the prosthesis to substitute for pronation and supination or above the elbow unit to substitute for internal and external rotation of the shoulder as well.

Partial Hand, Transcarpal, and Wrist Disarticulation

Until recently, patients with digit, partial hand, or transcarpal amputations were often offered passive (nonfunctioning) cosmetic prostheses (restorations). Depending on the characteristics of the residual limb, a functional prehensile post might have been fabricated to regain some grasp and release capability of the affected limb. Recent advances in technology and microprocessors have made externally powered options more readily available (Figure 3). These advances permit electric control despite the extremely distal amputation site. Consideration must be given preoperatively to any remaining functional digits. The status of sensation and mobility of these digits should not be understated. If functional range and sensation are inadequate, the surgeon considers a more proximal level of amputation.

Figure (3): Example of an externally powered prosthetic hand used for individuals with a partial hand amputation or wrist disarticulation.

The wrist disarticulation residual limb provides a long and functional lever for prosthetic use. If the radial and ulnar styloid processes are preserved, then the prosthetist can use a positive suspension strategy over these prominences to keep the prosthesis and stable suspended on the residual limb, making harnesses unnecessary. The disadvantage of wrist disarticulation, however, is limitation in room to fit a wrist and hand unit into a cosmetically acceptable prosthesis. If the styloid processes have been modified or removed during surgery, more aggressive proximal suspension strategies are necessary. In addition, the extra residual limb length leads to a difference in arm length once the wrist and prosthetic hand unit is in place, which might be cosmetically unacceptable to the patient. In such cases, a more proximal amputation would allow for a full complement of prosthetic options.

Transradial and Transhumeral Considerations

For most adult transradial prostheses, nearly 8 inches of space is necessary beyond the distal residual limb for the prosthetic wrist rotator and TD or hand. Similarly, at the transhumeral level, approximately 6 inches of space must be present beyond the distal residual limb to accommodate a mechanical elbow mechanism within the prosthesis. For patients with a short residual humerus, a conventional (body-powered) prosthetic system may not be realistic, and even an externally powered prosthesis may be difficult or problematic to fit, suspend, and control. When the residual humerus is short, it may be necessary to treat a transhumeral amputation functionally as a shoulder disarticulation (Figure 4).

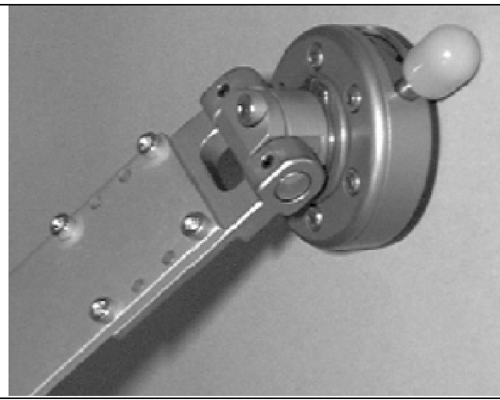

Figure (4): Example of a prosthetic shoulder joint used in individuals with a shoulder disarticulation or extremely short transhumeral residual limb.

Positive models to fabricate any contemporary prosthesis can be secured with conventional plaster direct molding techniques similar to those used for lower-extremity amputations. Model acquisition and data collection are also possible using computer-aided design. Both direct contact and optical methods are finding ever-increasing utility in modern practice. This technology is particularly valuable as a means to quantify and document volume and shape changes, enhancing fit and function for optimal clinical outcomes (Figure 5).

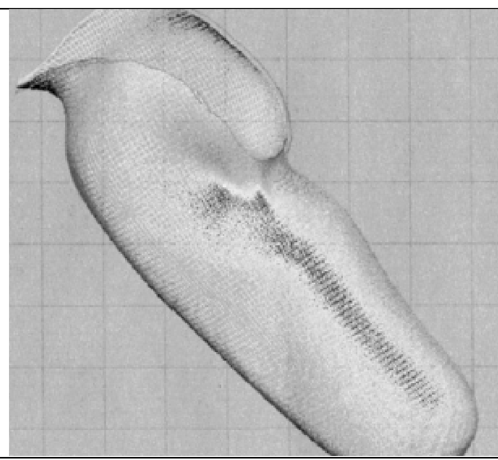

Figure (5): A computer-assisted design model of a transradial prosthetic socket. Note the aggressive anatomical contouring of the socket and the anteroposterior force system (between the anterior cubital fossa and olecranon) that will be used to suspend the socket on the residual limb.