Current Concepts in Upper-Extremity Amputation

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Advances in motor vehicle safety, trauma care, combat body armor, and cancer treatment have enhanced the life expectancy and functional expectations of patients with upper-extremity amputations. Upper-extremity surgeons have multiple surgical options to optimize the potential of emerging prosthetic technologies for this diverse patient group. Targeted muscle reinnervation is an evolving technique that improves control of myoelectric prostheses and can prevent or treat symptomatic neuromas. This review addresses current strategies for the care of patients with amputations proximal to the wrist with an emphasis on recent advancements in surgical techniques and prostheses. *(J Hand Surg Am. 2018;■(■):■−■. Copyright © 2018 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Primary amputation, prosthetics, reinnervation, surgical reconstruction, upper extremity.

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INTRODUCTION

Major upper-extremity amputees account for only 8% of the 1.5 million individuals living with limb loss.[1] Upper-extremity amputation is an accepted treatment option for acute trauma or sequelae of traumatic injuries, chronic infection, bone or soft tissue tumors, certain brachial plexus injuries, and complex regional pain syndrome. Regardless of the underlying diagnosis, emphasis is placed on definitively treating the underlying condition, achieving a stable, functional extremity, and minimizing painful sequelae. Patients and providers benefit from a multidisciplinary team consisting of experienced upper-extremity surgeons, skilled prosthetists and/or orthotists, physiatrists, pain management physicians, and therapists.

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Received for publication May 9, 2017; accepted in revised form March 30, 2018.

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

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0363-5023/18/■■-0001$36.00/0
https://doi.org/10.1016/j.jhsa.2018.03.053

SURGICAL RECONSTRUCTION

Preoperative considerations

Upper-extremity amputation should be considered a reconstructive procedure rather than an ablative procedure, taking into account a number of considerations of the host and limb (Table 1). Definitive procedures require clean, well-vascularized wound beds with adequate soft tissue coverage; complex wounds or active infection necessitate a staged approach. When amputations are performed (semi) electively, preoperative nutritional status should be optimized and patients should be evaluated by a prosthetist before surgery when possible.

Primary amputation

The creation of a stable osseous and soft tissue envelope that will maximize function of a prosthesis and minimize pain is the principal goal of primary amputation. In contrast to weight-bearing and mobilization considerations in the lower extremity, the ability to interact with the environment is underscored for the upper extremity. Prosthetic fit and function between amputation levels have been assessed by few biomechanical studies or standardized trials, but clinical experience has highlighted several important considerations.[2−4]

TABLE 1. Factors Influencing the Decision to Proceed With Amputation and the Level of Amputation

Host factors
Concomitant injuries or illnesses
Preoperative functional status
Expectations
Limb factors
Level of injury or disease
Type of injury or disease
Presence of contamination or infection
Soft tissue coverage
Vascular supply
Neurologic status

Intuitively, the ability to optimally interact with the environment is positively associated with preservation of limb length. The most proximal amputations (shoulder disarticulation or forequarter amputation) require cumbersome prostheses, which necessitate considerable energy expenditure. In our clinical practice, we make every effort to salvage the elbow and shoulder joints when feasible to enhance post-amputation function. In short amputations through long bones (as with high transradial or high transhumeral amputations), the function of the adjacent (proximal) joint may be obviated. To enable prosthetic suspension, a minimum of 5 cm of bone distal to a joint is needed to preserve the function of that joint in a prosthesis.[5] While a distal third forearm amputation leaves the origin and insertion of the pronator teres and supinator intact, patients rarely exhibit functional rotation of the residual limb.

Successful lengthening of short upper extremity residual limbs to improve prosthetic function has been described in both children and adults[6,7,a] (Figs. 1, 2). Microsurgical free-tissue transfer (with free flaps or fillet flaps from unreplantable limbs) can be employed to preserve residual limb length, preserve joint function, and provide adequate soft tissue coverage.[5,8] These procedures should not be undertaken lightly, however, given the reported 38% complication rate. Complications such as flap necrosis, vascular impairment, and delayed union of a vascularized fibula flap have been described.[5] Free tissue transfer may also prolong soft tissue healing or change the residual limb shape, delaying prosthetic fitting and prolonging rehabilitation. Personal preferences and patient characteristics (particularly age, occupation, and medical comorbidities) should be considered before free tissue transfer using a shared decision-making strategy.

In contrast, disarticulations have their own drawbacks and benefits. Disarticulations create long residual limbs that adapt poorly to many modern prostheses and often require soft tissue augmentation or support (myodesis or myoplasty) to cover bony prominences and ensure a comfortable prosthetic fit. An important advantage of disarticulations, however, is improved suspension and rotational control of the prosthesis as a result of preserved distal condyles and intact muscle units. Diaphyseal humeral shortening, performed in conjunction with elbow disarticulation, can improve prosthetic fit and rotational control while preserving adequate space for the prosthesis.[9,10]

Much the same way that a long-arm cast is difficult to keep on a child without a good supracondylar mold, prosthetic suspension can be particularly challenging in short residual limbs without a distal condylar flare. The benefit of retained humeral condyles can be simulated in long transhumeral amputees with an angulation osteotomy (humeral flexion osteotomy).[11,12] In 1974, Marquardt and Neff[11] described 3 osteotomy techniques and outlined the advantages of these procedures, including improved functional shoulder rotation, augmented soft tissue coverage of the distal limb (through distal skin traction), and improved prosthetic stability. Neusel and colleagues observed that more than one-third of angulation osteotomies in skeletally immature patients straightened over time; however, loss of angulation occurred in none of the adult patients undergoing the procedure.[12] An angulation osteotomy may obviate the need for a shoulder harness to suspend a myoelectric arm and markedly improves rotational control of the arm (Fig. 3).

There are numerous other strategies for optimizing limb length and orientation, upper-extremity motion, and prosthetic fit (Table 2). To optimize limb length, soft tissue envelope, and functional outcomes, it is important that surgeons understand the technical specifications and requirements for current prostheses.[4] Regardless of amputation level, secondary procedures to address sequelae (wound complications, infection, bony overgrowth, elbow flexion contracture, or painful neuromas) are common.

Targeted muscle reinnervation

Targeted muscle reinnervation (TMR), the transfer of functioning nerves that have lost their operational target to intact proximal muscles that serve as biologic amplifiers,[13] has gained considerable momentum in tandem with advances in myoelectric prostheses. The "switch innervation" of a functioning nerve to a new muscle target creates a novel