Upper Extremity Amputations

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Epidemiology

• Of the 1.6 million people in the US with limb loss, 34% (541K) have an upper extremity amputation\(^1\)

• 92% of upper extremity limb loss is due to trauma\(^2\)

• Multispecialty care is necessary for these patients including PM&R, surgery, internal medicine, occupational/physical therapy, mental health/social work, nursing, and prosthetics.

• Inclusion of patient and family in the decision-making process, treatment, and rehab is key to successful outcomes\(^3\)

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Initial Wound Management

• Must take into account overall condition of the patient, most have multisystem injuries

• Unique and vital function of the upper extremity require the surgeon to attempt salvage, including replantation when possible

• When amputation is likely, it should be delayed until patient/family can be involved in the decision making process


Early Surgical Management – 3 Basic Tenets

• Thorough sharp debridement of contaminated tissue

• Retention of all viable tissue for subsequent reconstruction amputation coverage

• Maintenance of the highest potential for patient function with/without a prosthesis\(^\text{11}\)

Early Surgical Management

• Initial focus is often on the bony injury, but the status and handling of soft tissues are often the best predictors of limb length and final closure options.

• Nerve injuries can be addressed later with repair, reconstruction, or nerve/tendon transfer.

• Ultimately, decision to amputate is made when limb salvage results in a less functional outcome than the amputation AND the patient understands/agrees with the surgical decision.
Early Surgical Management

• Best to delay upper limb amputation until patient and family are in agreement
  • But, surgeon input into need for amputation carries weight
  • Patients getting prosthesis <60 days from amputation more likely to use it

• Multidisciplinary approach best in non-emergency situations
  • Prosthetist and patients with prosthetic are invaluable resources

Photograph courtesy of Jeffrey Marchessault MD
Once Amputation is Chosen...

• Preservation of length and joint function are of paramount concern

• Techniques to preserve limb length when residual soft tissue is inadequate to allow stump closure:
  • Skin grafts
  • Dermal substitutes
  • Filleted flaps
  • Free tissue transfer

Photograph courtesy of Jeffrey Marchessault MD
Latissimus Dorsi Flap to Preserve Length

Preservation of length following failed arm replantation using latissimus dorsi flap to accommodate upper extremity prosthesis. Consultation with a prosthetist to determine level of amputation can be helpful if available.

Finger Amputation

• Consider primary amputation when 4 or more of 6 basic components injured
  • Bone
  • Vessels
  • Tendons
  • Nerves
  • Skin
  • Joint

Revascularization of this severely injured finger will result in stiff, insensate finger later requiring amputation

Photograph courtesy of Jeffrey Marchessault MD
Finger Amputation

• Injury often dictates level of amputation
• Fingers’ primary function to bring objects to palm
• Preserve metacarpophalangeal joint to preserve rudimentary finger flexion toward palm
• Resect digital nerves away from suture line

Thumb Amputation

• Thumb provides 40% of hand function.\textsuperscript{17}

• Multiple options for soft tissue coverage

• Preserve carpometacarpal joint to improve thumb function

• Consult hand surgeon colleagues to discuss reconstruction plan

Photograph courtesy of Jeffrey Marchessault MD
Partial Hand Amputation

- Preservation of two sensate digits, able to oppose each other, will allow some prehension\textsuperscript{16} – the ability to approach, grasp and release objects with the hand

- Salvage of a third digit allows for a more stable terminal pinch, improving precision motions\textsuperscript{17}

- Ray resection will reduce hand width, leading to decreased grip strength, but improving the appearance of finger loss\textsuperscript{17}

- Try to “eliminate a gap” between adjacent fingers -(objects fall thought the hand: nails, screws, coins)


Wrist Disarticulation

• Controversial level with pros and cons that requires patient education and input.

• Pros: Increased limb length serves as better assist to opposite hand
  • Amputation through the wrist preserves $100^0$ to $120^0$ of pronosupination

• Cons: Insufficient space for myoelectric hand prosthesis

Transradial Amputation

• Transradial forearm amputation is the most common level of upper extremity amputation\textsuperscript{22}
  • Remaining muscles serve to trigger myoelectric prosthesis

• Residual soft tissue (muscle) must provide adequate soft tissue coverage of the radius and ulna

• Myodesis of deep forearm muscles to the radius and ulna provide stable bone coverage and prevents bone-on-muscle motion that can lead to bursitis\textsuperscript{23}


Transradial Amputation Basic Tenets

• Myodesis – attachment of tendon/muscle to bone
  • Prevents bursa formation at distal end residual limb\textsuperscript{23}

• Myoplasty – attachment of muscle layers to each other, allowing tension free skin closure


Photograph courtesy of Jeffrey Marchessault MD
Transradial Amputation

Mobilization of deep flexor muscles

Myodesis of flexors to bone

Photographs courtesy of Jeffrey Marchessault MD
Transradial Amputation

Mobilization of deep flexors “over” distal bone ends

Closed irregular skin flaps, commonly required in traumatic amputations

Photographs courtesy of Jeffrey Marchessault MD
Transradial Amputation

10 cm proximal to the wrist joint is advocated for increased prosthetics options\(^\text{22}\)

Forearm amputation at least 5 cm distal to the elbow will allow fitting of a prosthesis\(^\text{24}\)

- Short amputation reduces effective pronosupination

Irregular flaps utilized to spare length of this short below the elbow amputation, preserving elbow function


Elbow Disarticulation

• Controversial level with pros and cons, need to discuss with patient

• Pros – condyles provide rotational control of prosthesis

• Cons - Length makes fitting pre-made prosthetic elbow difficult without extending limb length
Elbow Disarticulation

- **A** – Failed attempt at replantation
- **B** – Biceps, brachioradialis provide coverage over cartilage
- **C** – Leave flexor/extensor muscles attached for additional padding of distal end
- **D** – Leave long posterior skin flap to rotate anteriorly over muscle

Above-Elbow Amputation

• When the condyles cannot be preserved, amputation of the humerus 10cm proximal to the olecranon tip enables the use of all available prosthetics\(^2\).

• Allows fitting of a variety of passive, body-powered, myoelectric, and activity-specific elbows with adequate length to suspend and control the prosthesis.

Above-Elbow Amputation

- Rotational control of the prosthetic at this level can be aided by a Marquardt angulation osteotomy
  - Creates an angle of 70° to 110° at the distal humerus through a dorsal or volar osteotomy
  - Straightening of the osteotomy over time has been seen in patients less than 16 years of age

Above-Elbow Amputation

• Preservation of shoulder function improves the amputee’s likelihood of prosthetic use\(^\text{25}\) because the shoulder girdle will stabilize the limb while in space

• Transhumeral amputations should preserve at least 5-7 cm of the proximal humerus to maintain deltoid muscle function, improve prosthetic fit, and provide a more acceptable shoulder contour\(^\text{24}\)

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Surgical Complications

- Causes for revision surgery in 42 of 100 combat upper limb amputees:\(^{30}\)
  - Heterotopic ossification (HO) – most common
  - Infection
  - Painful neuromas
  - Scars
  - Joint contracture

- HO can cause pain, interfering with prosthetic wear, and joint stiffness
  - Prophylactic radiation and NSAID adjunct treatments are not standardized\(^{34}\)

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Surgical Complications

• **Neuroma formation/Phantom Pain**
  - Any nerve lacerated with amputation can become painful
  - Many treatments, including resection, bury in muscle

• **Emerging techniques for decreasing Amputation Nerve Pain**
  - Targeted Muscle Reinnervation (TMR)
  - Regenerative peripheral nerve interface (RPNI)

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Targeted muscle reinnervation (TMR)

- Nerve transfer/Rerouting decreases pain, provides intuitive myoelectric control
  - Initially used for proximal arm amputations, now transradial level too\(^\text{31}\)
  - Decreases neuroma pain and amputation pain
  - Emerging evidence for prophylactic TMR\(^\text{32}\)
- Amputation tips allowing for TMR:
  - Avoid aggressive traction neurectomy so nerves have enough length for transfer
  - Bury nerve ends into muscle for later


Psychological Considerations

• 94% patients with severe hand injury report signs/symptoms of PTSD\textsuperscript{32} – don’t ignore it

• PTSD is most common disabling non-amputation diagnosis in military amputees\textsuperscript{33}

• Surgeon should:
  • Be hopeful, informative about amputation
  • Recognize need for mental health consultation for PTSD, depression with persistent/chronic pain


Photograph courtesy of Jeffrey Marchessault MD
UE Amputation Summary

• Upper limb amputation is the final result when surgical salvage is not possible

• Preserving bony length, as well as shoulder/elbow function, improves the successful use of a prosthesis by the patient and can be accomplished with a multitude of techniques

• The ULTIMATE goal of amputation surgery is to:
  • Provide a sensate residual limb that can best interact with the patient’s environment with and without a prosthesis

Photographs courtesy of Jeffrey Marchessault MD
Other References