Upper Extremity Amputations

Paul Henkel DO

Orthopaedic Trauma Surgery

Piedmont Athens Regional Medical Center

Athens, GA

Jeffrey Marchessault MD

Orthopaedic Hand Surgery

East Tennessee State University

Johnson City, TN

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]**

Hand Blast Injury

Photograph courtesy of
Jeffrey Marchessault MD

1. Zeigler-Graham K, MacKenzie EJ, Ephraim PL, Travison TG, Brookmeyer R. Estimating the prevalence of limb loss in the United States: 2005 to 2050. Arch Phys Med Rehabil 2008;89:422–429.
2. Pezzin LE, Dillingham TR, MacKenzie EJ. Rehabilitation and the long-term outcomes of persons with trauma-related amputations. Arch Phys Med Rehabil 2000;81:292–300.
3. Pasquina PF, Bryant PR, Huan ME, Roberts TL, Nelson VS, Flood KM. Advances in amputee care. Arch Phys Med Rehabil 2006;87(3 Suppl 1):S34–S43.

Initial Wound Management

- **Must take into account overall condition of the patient, most have multisystem injuries[4]**
- **Unique and vital function of the upper extremity require the surgeon to attempt salvage, including replantation when possible[8]**
- **When amputation is likely, it should be delayed until patient/family can be involved in the decision making process[9]**

Blast injury after debridement

Photograph courtesy of Jeffrey Marchessault MD

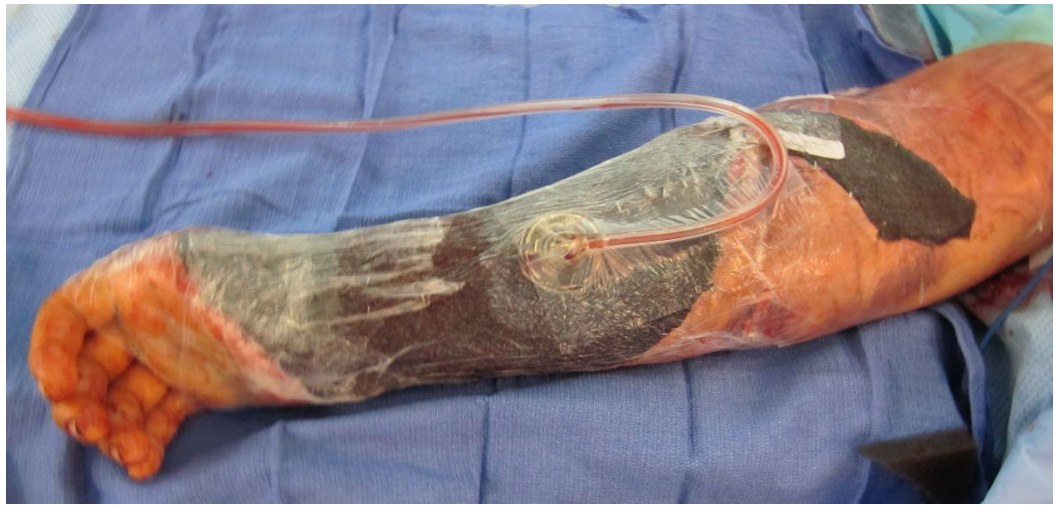
4. Potter BK, Scoville CR. Amputation is not isolated: an overview of the US Army Amputee patient care program and associated amputee injuries. J Am Acad Orthop Surg 2006;14(10 Spec No):S188–S190.

8. Graham B, Adkins P, Tsai TM, Firrell J, Bredenbach WC. Major replantation versus revision amputation and prosthetic fitting in the upper extremity: a late functional outcomes study. J Hand Surg 1998;23A:783–791.

9. Shawen SB, Doukas WC, Shrout JA, Ficke JR, Potter BK, Hayda RA, et al. General surgical principles for the combat casualty with limb loss. In: Lenhart MD, ed. Combat care of the amputee. Washington, DC: Borden Institute, 2009:117–150.

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[11]**



Photographs courtesy of
Jeffrey Marchessault MD

11. Tintle SM, Baechler MF, Nanos III GP, Forsberg JA, Potter BK. Traumatic and trauma-related amputations: Part II: Upper extremity and future directions. J Bone Joint Surg 2010;92A:2934–2945.

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[9]**
- **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**

Photograph courtesy of
Jeffrey Marchessault MD

9. Shawen SB, Doukas WC, Shrout JA, Ficke JR, Potter BK, Hayda RA, et al. General surgical principles for the combat casualty with limb loss. In: Lenhart MD, ed. Combat care of the amputee. Washington, DC: Borden Institute, 2009:117–150.

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…

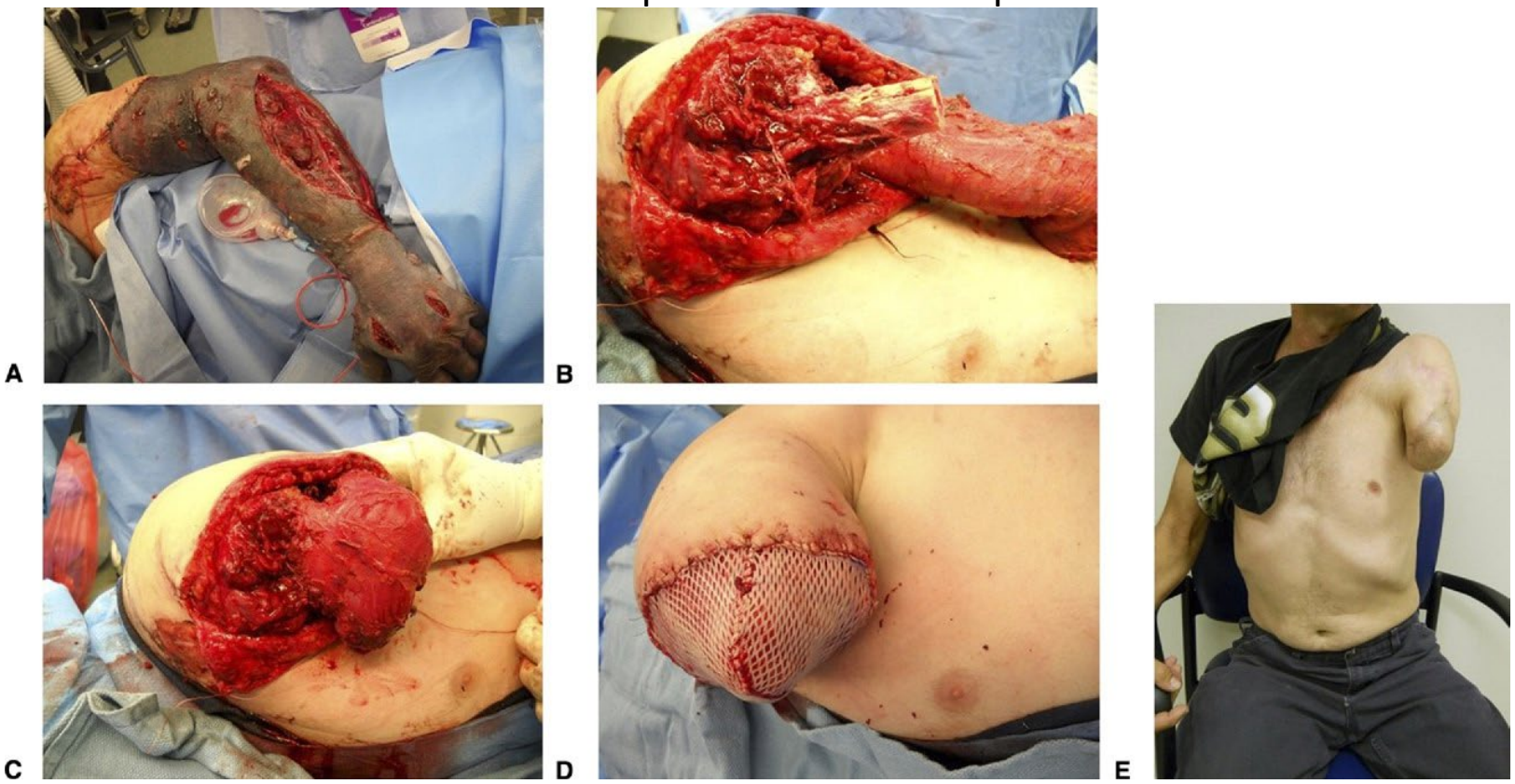
- **Preservation of length and joint function are of paramount concern**

- **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



From: Marchessault JA, McKay PL, Hammer WC. Management of upper limb amputations J Hand Surg Am. 2011;36A:1718-1726.

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

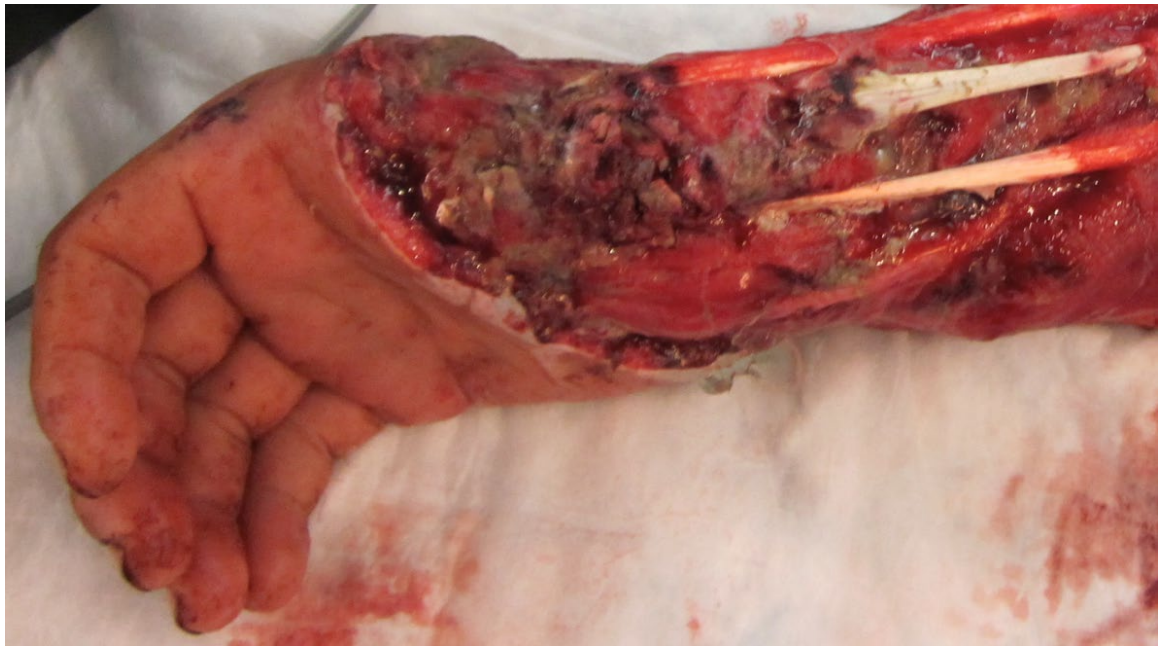
- **Injury often dictates level of amputation**
- **Fingers' primary function to bring objects to palm[17]**
- **Preserve metacarpophalangeal joint to preserve rudimentary finger flexion toward palm**
- **Resect digital nerves away from suture line**

Photograph courtesy of
Jeffrey Marchessault MD

17. Moran SL, Berger RA. Biomechanics and hand trauma: what you need. Hand Clin 2003;19:17–31.

Thumb Amputation

- **Thumb provides 40% of hand function.[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[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[17]**
- **Ray resection will reduce hand width, leading to decreased grip strength, but improving the appearance of finger loss[17]**
- **Try to "eliminate a gap" between adjacent fingers -(objects fall thought the hand: nails, screws, coins)**

From: Marchessault JA, McKay PL, Hammer WC. Management of upper limb amputations J Hand Surg Am. 2011;36A:1718-1726.

16. Eardley GP, Stewart PM. Early management of ballistic hand trauma. J Am Acad Orthop Surg 2010;18:118–126.

17. Moran SL, Berger RA. Biomechanics and hand trauma: what you ou need. Hand Clin 2003;19:17–31.

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 [21]**
- **Cons: Insufficient space for myoelectric hand prosthesis**

From: Marchessault JA, McKay PL, Hammer WC. Management of upper limb amputations J Hand Surg Am. 2011;36A:1718-1726.

21. Taylor CL. The biomechanics of control in upper-extremity prostheses. Artif Limbs 1955;2:4–25.

Transradial Amputation

- **Transradial forearm amputation is the most common level of upper extremity amputation[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[23]**

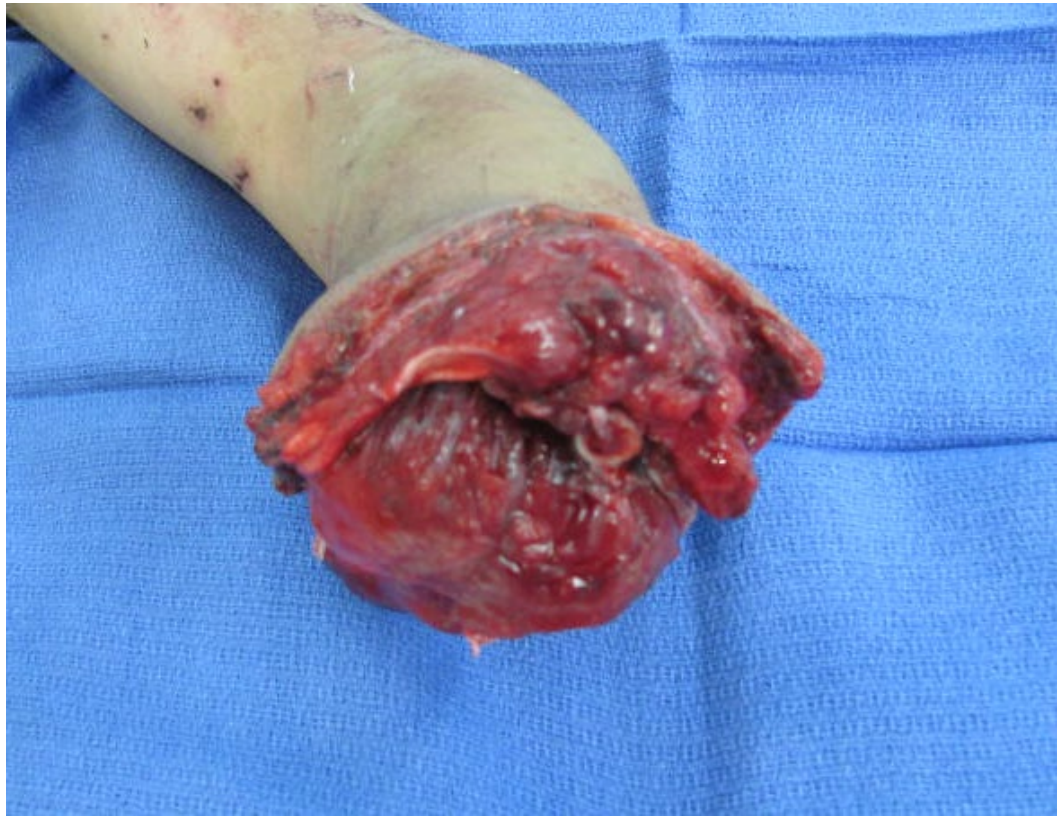
Photograph courtesy of
Jeffrey Marchessault MD

22. Lake C, Dodson R. Progressive upper limb prosthetics. Phys Med Rehabil Clin N Am 2006;17:49–72.

23. Singh R, Hunter J, Philip A. Fluid collections in amputee stumps: a common phenomenon. Arch Phys Med Rehabil 2007;88:661–663.

Transradial Amputation Basic Tenets

- **Myodesis – attachment of tendon/muscle to bone**
  - **Prevents bursa formation at distal end residual limb[23]**
- **Myoplasty – attachment of muscle layers to each other, allowing tension free skin closure**

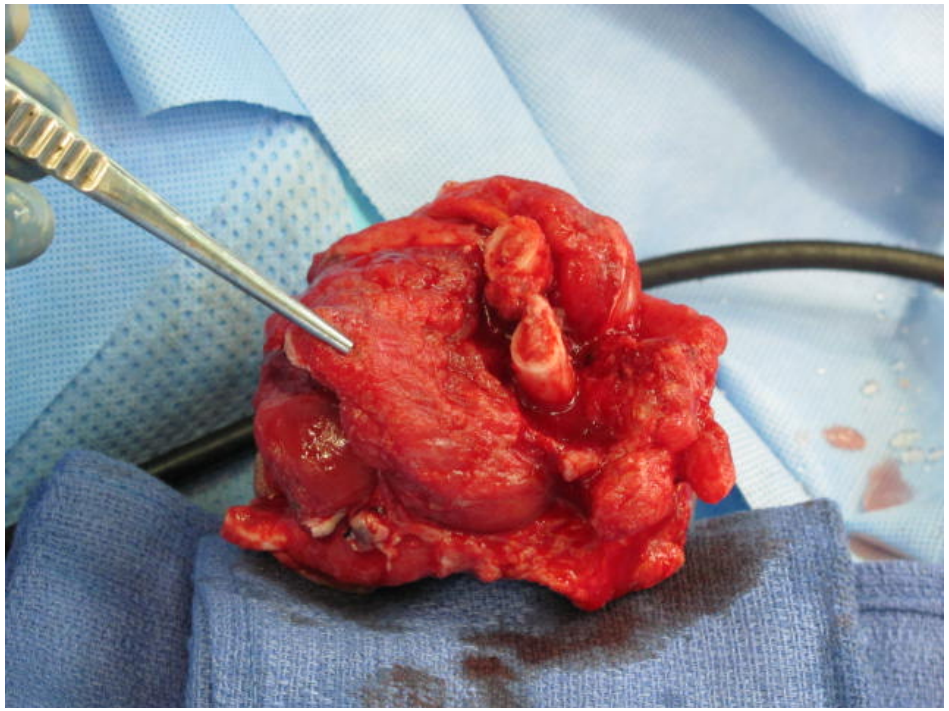


Photograph courtesy of
Jeffrey Marchessault MD

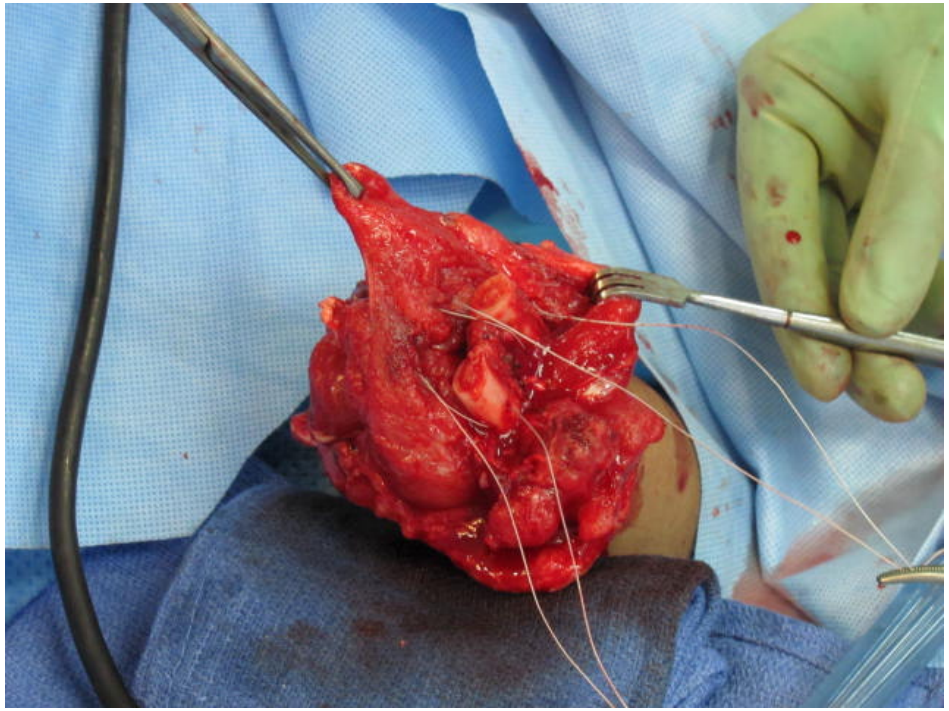
23. Singh R, Hunter J, Philip A. Fluid collections in amputee stumps: a common phenomenon *Arch Phys Med Rehabil*. 2007;88:661-663.

Transradial Amputation

Mobilization of deep flexor muscles



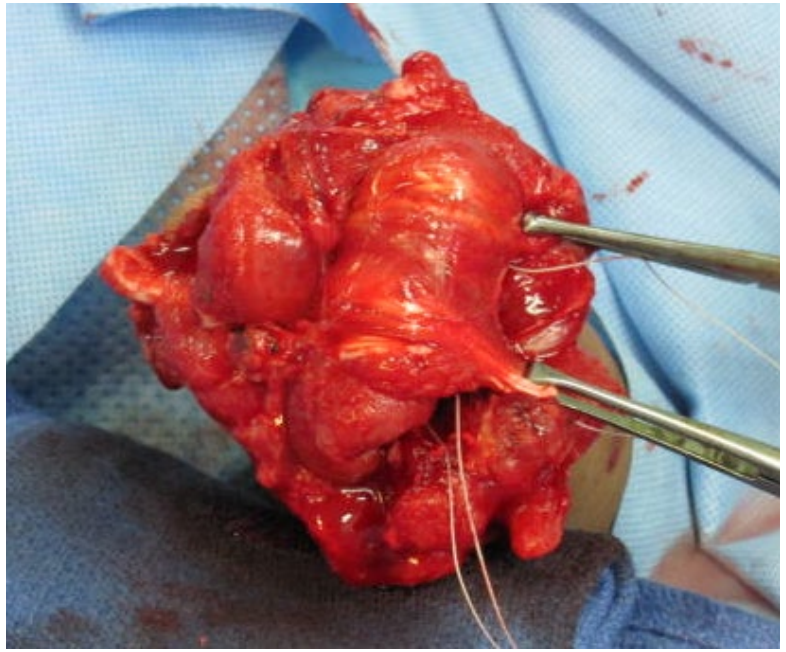
Myodesis of flexors to bone



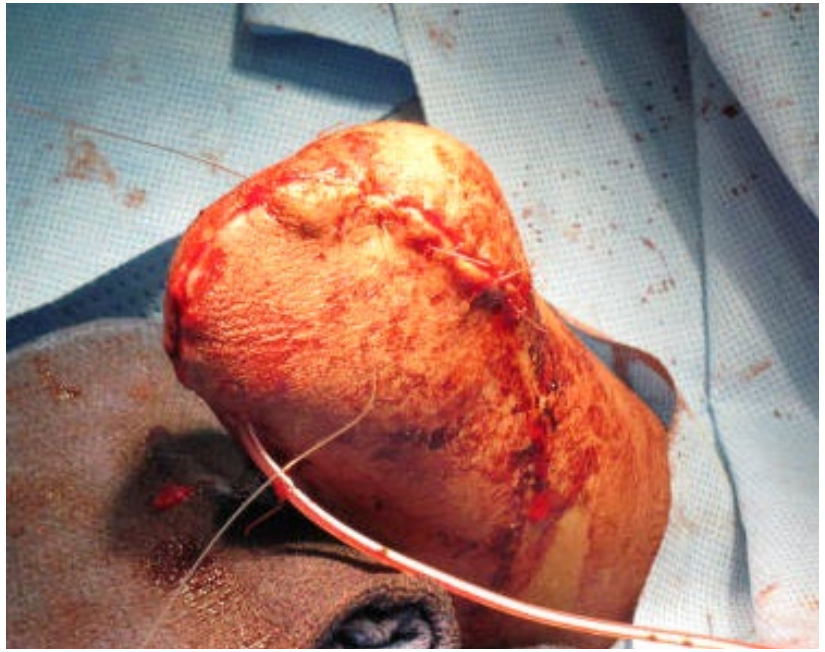
Photographs courtesy of
Jeffrey Marchessault MD

Transradial Amputation

Mobilization of deep flexors "over" distal bone ends



Closed irregular skin flaps, commonly required in traumatic amputations



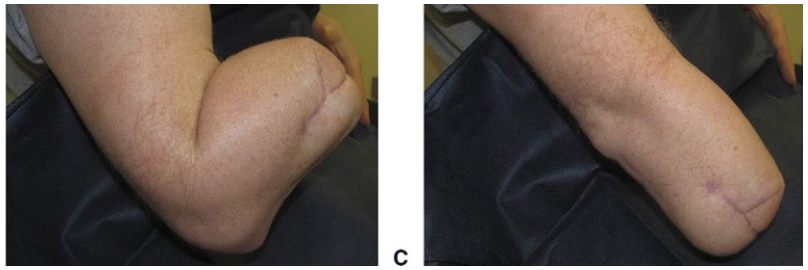
Photographs courtesy of
Jeffrey Marchessault MD

Transradial Amputation

- **10cm *proximal to the wrist* joint is advocated for increased prosthetics options[22]**
- **Forearm amputation at least 5cm *DISTAL to the elbow* will allow fitting of a prosthesis[24]**
  - **Short amputation reduces effective pronosupination**

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

From: Marchessault JA, McKay PL, Hammer WC. Management of upper limb amputations J Hand Surg Am. 2011;36A:1718-1726.



C

22. Lake C, Dodson R. Progressive upper limb prosthetics. Phys Med Rehabil Clin N Am 2006;17:49–72.

24. Daly WK. Elbow disarticulation and transhumeral amputation/shoulder disarticulation and forequarter amputations. In: Smith DG, Michael JW, Bowker JH, eds. Atlas of amputations and limb deficiencies: surgical, prosthetic, and rehabilitation principles. 3rd ed. Rosemont, IL: American Academy of Orthopaedic Surgeons, 2004; 243–249.

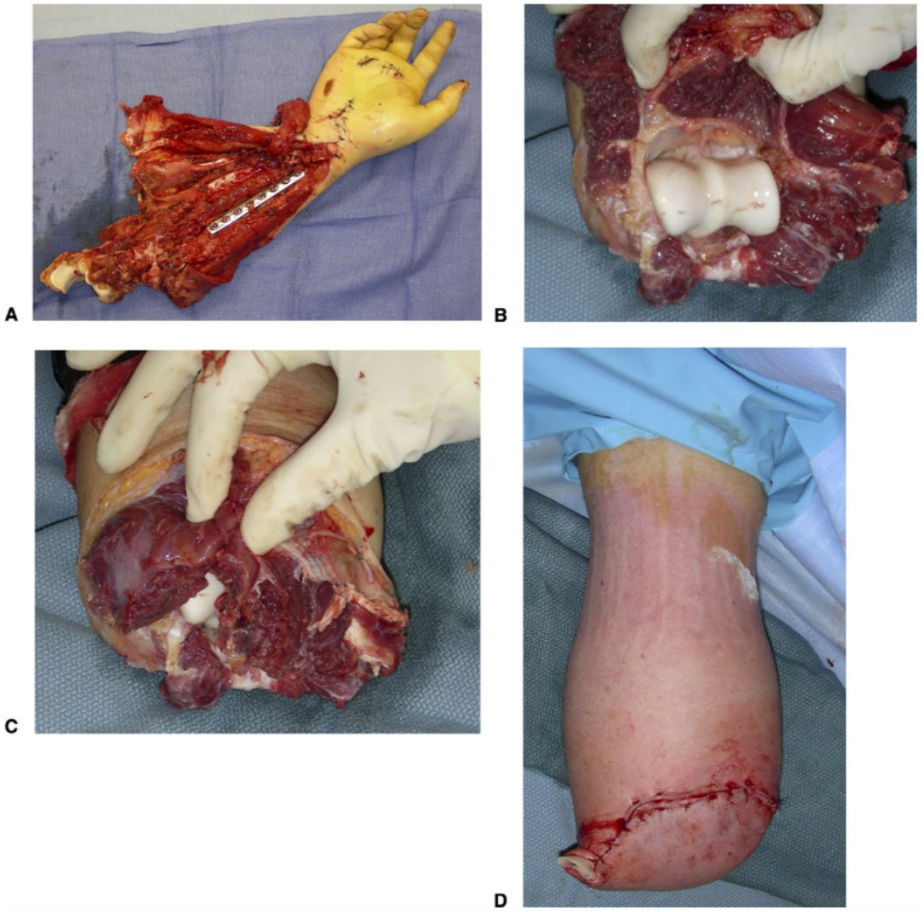
Elbow Disarticulation

- **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**

Photograph courtesy of
Jeffrey Marchessault MD

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**

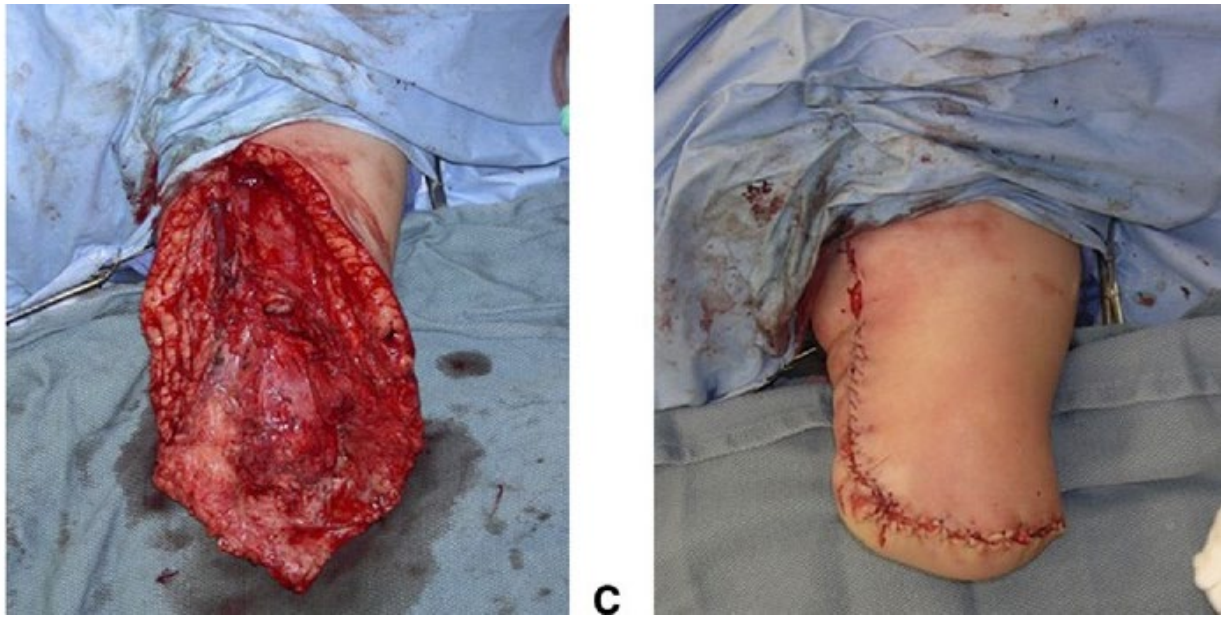


From: Marchessault JA, McKay PL, Hammer WC. Management of upper limb amputations J Hand Surg Am. 2011;36A:1718-1726.

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[24]**

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

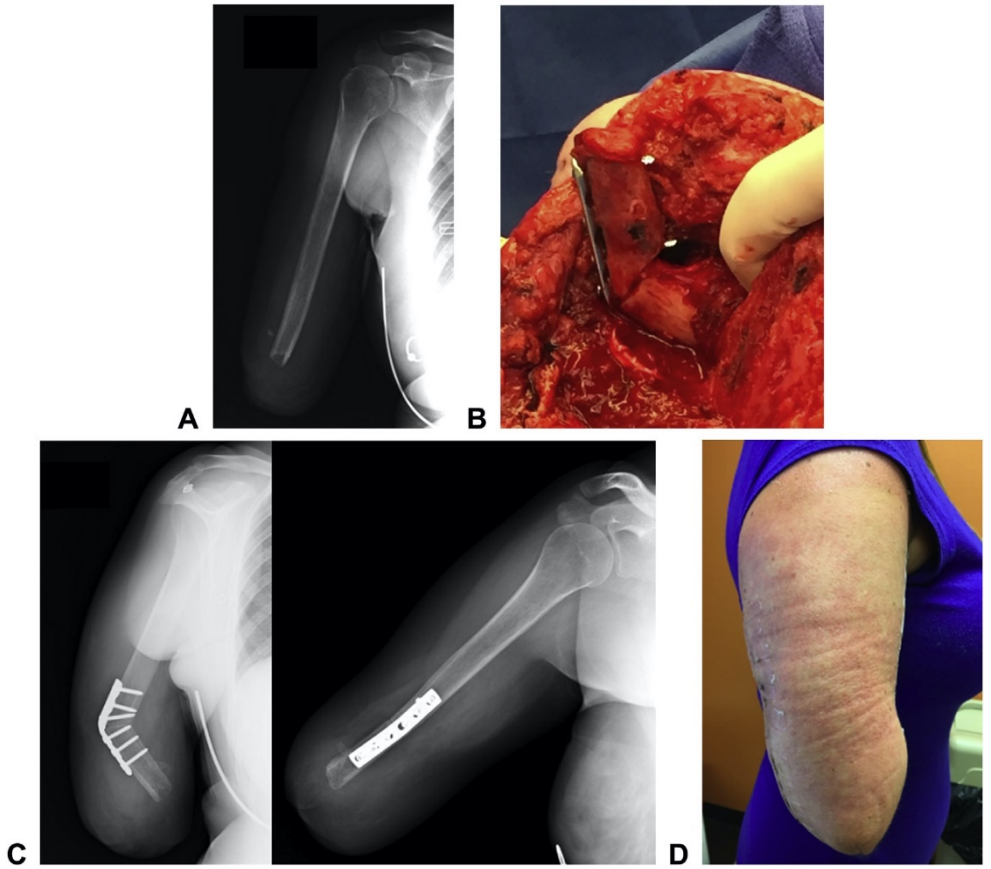


From: Marchessault JA, McKay PL, Hammer WC. Management of upper limb amputations J Hand Surg Am. 2011;36A:1718-1726.

24. Daly WK. Elbow disarticulation and transhumeral amputation/shoulder disarticulation and forequarter amputations. In: Smith DG, Michael JW, Bowker JH, eds. Atlas of amputations and limb deficiencies: surgical, prosthetic, and rehabilitation principles. 3rd ed. Rosemont, IL: American Academy of Orthopaedic Surgeons, 2004; 243–249.

Above-Elbow Amputation

- **Rotational control of the prosthetic at this level can be aided by a Marquardt angulation osteotomy**
  - **Creates an angle of 70º to 110º at the distal humerus through a dorsal or volar osteotomy[26]**
  - **Straightening of the osteotomy over time has been seen in patients less than 16 years of age[26]**



From: Pierrie AN, Gaston RG, Loeffler BJ. Current concepts in upper-extremity amputations. J Hand Surg Am. 2018;43(7):657-667.

26. Neusel E, Traub M, Blasius A, Marquardt E. Results of humeral stump angulation osteotomy. Arch Orthop Trauma Surg 1997;116:263-265.

Above-Elbow Amputation

- **Preservation of shoulder function improves the amputee's likelihood of prosthetic use[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[24]**

From: Marchessault JA, McKay PL, Hammer WC. Management of upper limb amputations J Hand Surg Am. 2011;36A:1718-1726.

25. Wright TW, Hagen AD, Wood MB. Prosthetic usage in major upper extremity amputations. J Hand Surg 1995;20A:619–622.

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]**

From: Marchessault JA, McKay PL, Hammer WC. Management of upper limb amputations J Hand Surg Am. 2011;36A:1718-1726.

30. Tintle SM, Baechler MF, Nanos GP, Forsberg JA, Potter BK. Operative complications following combat-related major upper extremity amputations. J Hand Surg 2010;35A(Suppl 1):S53-S54.

34. Ring D, Jupiter JB. Operative release of anklyosis of the elbow due to heterotopic ossification. J Bone Joint Surg 2004;86A(Suppl 1):2-10.

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)

Neuroma. Photograph courtesy of Jeffrey Marchessault MD

31. Pierrie SN, Gaston RG, Loeffler BJ Current concepts in upper-extremity amputations J Hand Surg Am. 2018;43(7):657-667. upper-extremity

32. Preemptive Treatment of Phantom and Residual Limb Pain with Targeted Muscle Reinnervation at the Time of Major Limb Amputation . J Am Coll Surg 2019;228:217e226.

Targeted muscle reinnervation (TMR)

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

TMR intraop. Photograph Courtesy of Jackie Geissler, MD.

32. Preemptive Treatment of Phantom and Residual Limb Pain with Targeted Muscle Reinnervation at the Time of Major Limb Amputation . J Am Coll Surg 2019;228:217e226.

33. Kuiken, Barlow, Hargrove, Dumanian. Tech Orthop. 2017 June ; 32(2): 109–116. Targeted Muscle Reinnervation for the Upper and Lower Extremity.

Psychological Considerations

- **94% patients with severe hand injury report signs/symptoms of PTSD[32] – don't ignore it**
- **PTSD is most common disabling non-amputation diagnosis in military amputees[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

34. Grunnert BK, Smith CJ, Devine CA, et al. Early psychological aspects of severe hand injury . J Hand Surg Br 1988;13:177-180.

35. Tennent DJ, Wenke JC, Rivera JC, Krueger CA. Characterization and outcomes of upper extremity amputations. Injury. 2014;45:965-969.

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

- Marchessault, Jeffrey A., Patricia L. McKay, and Warren C. Hammert. "Management of upper limb amputations." *The Journal of hand surgery* 36.10 (2011): 1718-1726.