IC23-L: The Mangled Hand: From ER to Back to Work

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Session Handouts

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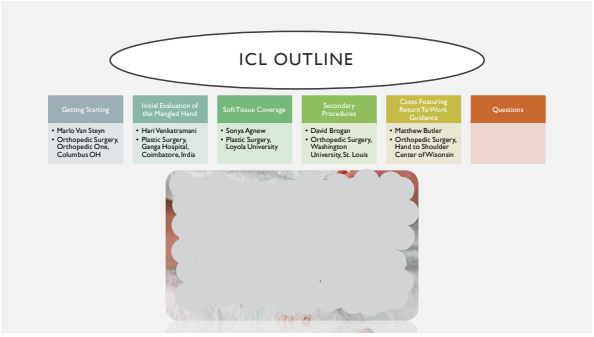
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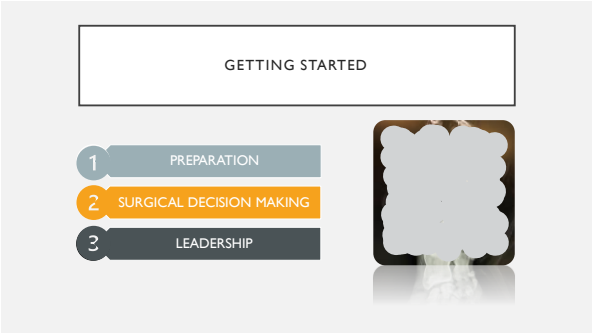
GETTING STARTED
1 PREPARATION
2 SURGICAL DECISION MAKING
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Maximize Training
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Focus on function
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Progress Efficiently
Avoid overburdening yourself
Tips and tricks
Do micro from dorsal
Apply lotion with vascular checks

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LEADERSHIP
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Provide Excellent post op care
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KEYS FOR GETTING STARTED
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• Maximize your training and be prepared
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• Work efficiently, focus on function
LEADERSHIP
• Set goals and guide the patient through rehabilitation

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Soft Tissue Coverage of the Hand and Upper Extremity: The Reconstructive Elevator

Erin Anne Miller, MD,* Jeffrey Friedrich, MD*

Continuing Medical Education

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Learning Objectives

Upon completion of this CME activity, the learner should achieve an understanding of:

- Wound assessment and choosing the best type of reconstruction to suit the functional and aesthetic requirements
- Technical guidelines to performing some of the more common flaps
- The available "intrinsic" flaps for wounds of the hand
- The available muscle and fascial flaps for larger wounds of the upper extremity

Deadline: Each examination purchased in 2016 must be completed by January 31, 2017, to be eligible for CME. A certificate will be issued upon completion of the activity. Estimated time to complete each JHS CME activity is up to one hour.

Soft tissue reconstruction of the upper extremity is a complex topic because every defect has multiple potential solutions. Whereas the often-cited reconstructive ladder advised selection of the simplest reconstruction of the defect, the newer concept of the reconstructive elevator allows freedom to choose a more complex reconstruction to account for specialized function and aesthetic outcome. An algorithm for assessment of the defect is presented and demonstrated in this review, using 6 case examples to highlight key concepts. Representative flaps are presented and a discussion of functional and aesthetic outcomes is undertaken to provide a

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framework for achieving the patient's and surgeon's goals of reconstruction. *(J Hand Surg Am. 2016;41(7):782–792. Copyright © 2016 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Hand reconstruction, perforator flap, reconstructive elevator, soft tissue.

THE UPPER EXTREMITY ALLOWS US TO interact with the world and, hence, is commonly exposed to injury. Unlike many parts of the body, critical structures of the hand lie just beneath the skin. Consequently, soft tissue injuries of the upper extremity pose a more difficult reconstructive problem for the surgeon than similar injuries elsewhere.

As our reconstructive techniques improve, so do our expectations. The concept of the "reconstructive elevator," proposed by Gottlieb and Krieger in 1994,[1] is uniquely applicable to the upper extremity, given its specialized function. In contrast to the reconstructive ladder, which recommends the simplest technique to close the wound, the elevator guides the surgeon to choose the closure method best suited to the defect. For example, a burn to the first web space could be reconstructed with a skin graft; however, subsequent scar contracture frequently creates a thumb adduction contracture. Alternatively, importing healthy tissue via a flap will maintain thumb mobility.

This "permission" granted by the elevator to skip rungs of the ladder poses a more complex task in reconstruction. This review provides a framework to help assess the defect and choose the best-suited reconstructive option.

TIMING OF RECONSTRUCTION

The first step for wound management is always debridement. Debridement may be performed under a tourniquet for better visualization, with wound edges assessed for viability once the majority of excision has been completed. Adjuncts to sharp debridement with scalpel or scissors, such as a water-powered debrider (Versajet; Smith and Nephew, London, UK), are useful in difficult to reach places such as web spaces.

It has been accepted since the 1980s that immediate coverage of soft tissue defects in the upper extremity with flaps is a safe and viable option,[2] although there is no evidence to suggest that delay in coverage leads to a higher rate of flap failure or wound infection.[3] Negative-pressure (NP) dressings are a useful tool to temporize wounds prior to reconstruction. An NP dressing may be placed as soon as the wound bed is clean, generally after serial operative debridement. The primary concern with prolonged NP therapy is formation of granulation tissue that develops into scar; thus, many authors have cautioned against use of this therapy in the hand for more than 48 hours.[4] However, if patient or institutional factors prevent expeditious reconstruction, NP therapy can be maintained for several weeks with serial dressing changes. Granulation tissue may be excised at the time of definitive coverage using sharp debridement, diminishing the propensity to form function-limiting scar.

WOUND ASSESSMENT

For this review, upper extremity defects are divided into 3 admittedly arbitrary groups:

1. Skin-only defects
2. Volume-loss defects
3. Functional tissue defects

The first step in any complex reconstructive problem is defining the problem, and in this, one must be as specific as possible. For example, is the patient missing skin only or is the defect more substantial? The next step is assessing the functional aspects of the tissue. For example, is tissue on the dorsum of the finger gone or is the patient missing the pulp of the thumb where sensation is required for manipulation of small objects? The last step is to assess options for reconstruction, some of which may be inappropriate. For example, a patient with loss of palmar tissues is unlikely to have an intact palmar arch, in which case, some reverse-flow flaps are not possible.

Key principles of hand reconstruction should be observed: the surgeon should strive to match like tissue with like, restore function, and preserve mobility and sensation. Once the reconstructive option has been selected and the wound adequately delineated through debridement, the flap should be designed to fit the defect (Table 1).[5–16]

Templating of defects is recommended. This can be done using an Esmarch bandage and transposing the template to ensure the flap has adequate size and reach. This key step ensures the surgeon does not design a flap that has inadequate length and allows assessment of the donor site for closure versus grafting, if required.

TABLE 1. Summary of Flaps Described Including Description of Pedicle

Flap	First Described	Blood Supply	Pedicle Location	Size (cm)	Coverage	Donor Site	Considerations*
Reverse homodigital island	Weeks & Wray, 1973[5]	Radial or ulnar digital artery	Reverse flow from contralateral digital connections located at proximal and distal cruciate ligaments and profundus insertion	2.5 × 3	Distal finger defects	Closes primarily	Caution patients re: neurapraxia
Reverse cross-finger	Morris, 1981[6]	Random pattern	NA	2 × 2	Dorsal finger defects	No defect, graft flap	Requires skin graft over flap
Flexor carpi ulnaris	Mathes, 1988[7]	Flexor carpi radialis branch from ulnar artery	Perforator found 6 cm distal to olecranon; reliable skin perforators over distal half of middle third of forearm	4 × 10	Defects about the elbow	Closes primarily	May be taken with or without a skin paddle
Paraumbilical perforator	Dumanian, 2010[8]	Paraumbilical perforators	Perforators Dopplered medial to linea semilunaris along line from umbilicus to scapular tip	8 × 30	Elbow to fingertips	Closes primarily	Requires second-stage procedure for division
Posterior interosseous artery	Zancoli & Angrigiani, 1988[9]	Posterior interosseous artery	Connection between proximal interosseous artery and anterior interosseous artery 2 cm proximal to dorsal wrist crease, proximal interosseous artery found between extensor carpi radialis and extensor digiti minimi	10 × 15	Radial side of hand/ fingers to metacarpophalangeal joints	Close primarily vs skin graft	Prone to venous congestion
Lateral arm	Katsaros & Acland, 1984[10]	Posterior radial collateral artery	One finger breadth posterior to line from deltoid to lateral epicondyle	6 × 15	Free: ad lib pedicled; proximal elbow reverse pedicled: distal elbow	Closes primarily	Can innervate flap with posterior brachial cutaneous nerve
Groin	Jackson, 1972[11]	Superficial circumflex iliac artery	Two fingerbreadths below inguinal ligament and medial to anterior superior iliac spine, running atop sartorius fascia	10 × 25	Wrist to fingertips	Closes primarily	Pedicle may be left untubed to prevent congestion
Radial artery perforator	Zhang, 1988[12]	Radial artery	Perforator found 2–4 cm proximal to radial styloid	12 × 20	Dorsal hand and palm to proximal phalanges	Close primarily vs skin graft	Avoid skeletonizing the pedicle to preserve venous outflow
Fascia-only radial forearm	Jin, 1985[13]	Radial artery	Artery runs between flexor carpi radialis and brachioradialis	12 × 30	Dorsal hand and palm to distal phalanges	No defect, graft flap	Allen test required before surgery to ensure hand perfusion

(Continued)

TABLE 1. Summary of Flaps Described Including Description of Pedicle (Continued)

Flap	First Described	Blood Supply	Pedicle Location	Size (cm)	Coverage	Donor Site	Considerations*
Anterolateral thigh	Song, 1984[14]	Descending branch of the medial femoral circumflex	Perforators found at distal outer quadrant of 3-cm circle at midpoint of line from anterior superior iliac spine to lateral patella, artery runs between rectus femoris and vastus lateralis	9 × 22	Anywhere within 7 cm of recipient vessels	Closes primarily	Can use as a flow-through flap to reconstruct radial or ulnar artery
First dorsal metacarpal artery	Braun, 1979[15]	First dorsal metacarpal artery	Connection between dorsal and palmar circulation found at apex of first and second metacarpal bases	3 × 5	Radial wrist, entire thumb	Requires skin graft	Sensory reinnervation more reliable in younger patients
Toe pulp free flap	Morrison, 1980[16]	Tibial digital artery of second toe	Artery and nerve run along volar tibial side of toe	2 × 3	Fingertip	Closes primarily	Advantage of using glabrous skin

*Describes key points to remember in harvesting or inserting a flap.

NONFUNCTIONAL SOFT TISSUE LOSS

These wounds require only the most basic of reconstruction efforts; they are only "skin deep" and do not require additional volume or functional tissue. Frequently, these can be allowed to heal by secondary intention or covered with a skin graft. However, wounds with exposed "white structures" (tendon, bone, nerve) require more robust coverage. In preparation for potential tendon grafts, tenolyses, or joint releases, a skin graft would not provide sufficiently durable soft tissue coverage.

Finger degloving injury with open proximal interphalangeal joint and exposed extensor tendon: Figure 1A demonstrates this type of wound, which needs durable soft tissue coverage that is thin and pliable. There are no special functional considerations or essential innervation to take into account. Whereas there are many options to obtain soft tissue coverage, the exposed white structures make a local flap the ideal solution.

Reverse homodigital island flap

This is a versatile flap for coverage of small defects on the both dorsal and volar fingers, the maximum size of which is 2.5 cm × 3 cm (Fig. 1B–D). The main advantage of this flap is that all defects are confined to 1 finger, avoiding sacrifice of healthy tissue from uninjured fingers. An axial pattern flap, it derives its blood supply from reverse flow of the radial or ulnar digital artery. There are 3 connections between the radial and the ulnar digital arteries: at the proximal and distal cruciate ligaments and at the fingertip just distal to the profundus insertion. The flap can be adequately perfused by any one of these.[17,a]

One of the more technically demanding flaps, it requires meticulous dissection of the nerve from the artery. Given the need to retract the nerve, most patients will have a transient neurapraxia following the procedure. Modifications include neurotizing the flap by taking the ipsilateral nerve as part of the flap and coapting it distally. The flap can also be designed as a heterodigital flap for adjacent finger defects.[4,18]

Like the reverse-flow homodigital flap, the heterodigital flap has multiple degrees of freedom for its arc of rotation and so can be used for both volar and dorsal finger defects.[b]

Reverse cross-finger flap

The reverse cross-finger flap is an excellent solution for small defects up to 2 cm on the dorsal finger. The size of this flap is limited because it is a random pattern flap, but as an adipofascial flap, it has the advantage of being thin and pliable. It does require a skin graft. Cleland's

FIGURE 1: **A** Example of a dorsal finger wound with exposed proximal interphalangeal joint and extensor tendon. **B** Markings for a reverse homodigital island flap on the index finger. **C** Island flap after inset on the index finger; island flap is also used to reconstruct the middle finger wound. **D** Postoperative views of reverse homodigital island flaps demonstrate good contour and color match.

ligament must be divided during flap harvest to ensure adequate mobility.[c]

The biggest drawback of this flap is the need for multiple procedures. During the interim between operations, the fingers are immobile and interphalangeal contractures can develop; therefore, aggressive postoperative mobilization should be pursued after division of the flap.[4,18–20]

Open olecranon fracture with exposed bone and hardware: This wound of the forearm as pictured in Figure 2A, requires durable coverage owing to the presence of bone and hardware. Because no specialized tissue is needed, complex reconstructions such as free flaps are not required. Both local and pedicled options exist and are excellent tools to have in the reconstructive repertoire.

Flexor carpi ulnaris flap

The flexor carpi ulnaris (FCU) flap is a robust flap that is relatively easy to harvest and may be utilized with or without a skin paddle. The main drawback is its smaller size: because it is only 4 cm wide, it is best suited for narrow defects. Harvestable length ranges from 6 to 10 cm, stretching around the olecranon if necessary. Blood supply is from a reliable pedicle to the FCU from the ulnar artery that enters the muscle in the proximal third of the forearm, approximately 6 cm from the olecranon.[21]

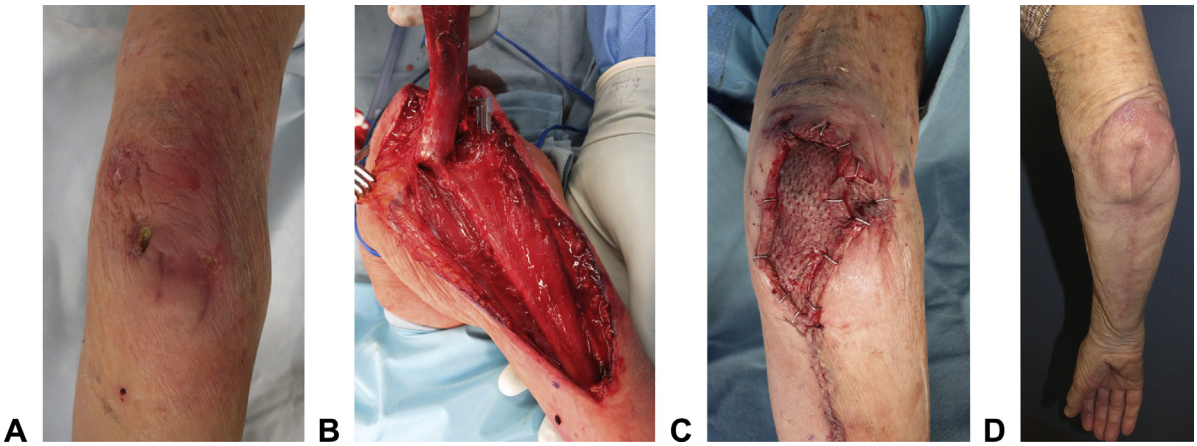

FIGURE 2: **A** Example of elbow wound with a sinus tract overlying a chronically draining wound from an olecranon bursa excision. **B** Flexor carpi ulnaris flap after elevation with the perforator visualized on the undersurface of the muscle belly. **C** Flexor carpi ulnaris flap after inset into the debrided elbow wound; the surface of the muscle is covered with a split-thickness skin graft. **D** Postoperative views of the FCU flap notable for excess bulk to protect the olecranon; the donor site incision is well healed in a straight-line scar.

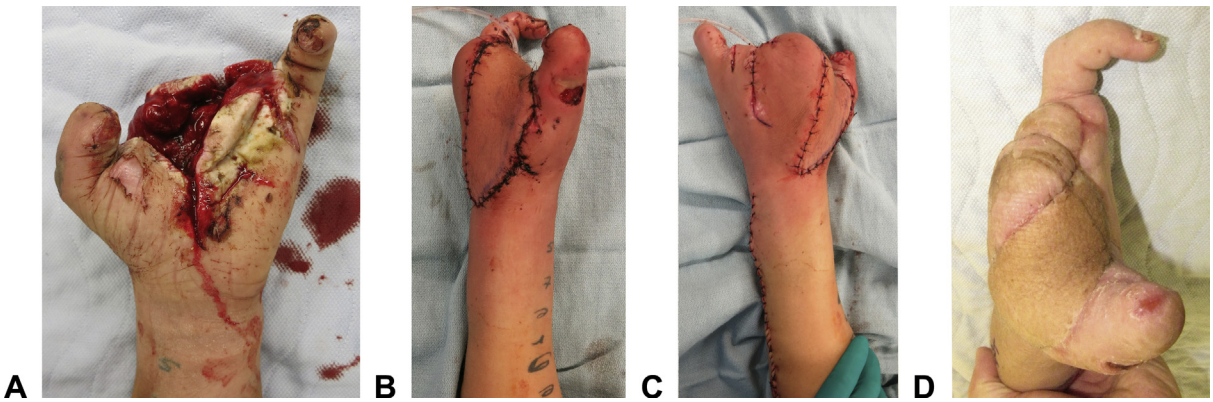

FIGURE 3: **A** Example of a first web space injury caused by a mortar blast. **B, C** Proximal interosseous artery flap for reconstruction of the first web space; the donor site closed primarily. **D** Postoperative views of the proximal interosseous artery flap with good preservation of the web space.

For extra stability, the FCU tendon can be anchored to the olecranon to prevent slippage of the flap. Variations of this flap have also been described, such as a hemi-FCU in which only the ulnar half of the muscle belly is harvested to preserve strength in wrist flexion.[21] The loss of a powerful wrist flexor (and of the chief motor of the "dart-thrower's motion") is the main drawback of the flap.

Paraumbilical perforator flap

In the era of the free flap, the pedicled flap is often overlooked. However, 1 of these, the paraumbilical perforator flap, is an extremely versatile flap that has been used in many creative ways to fill large soft tissue defects in the arm. The flap is based on perforators from the deep inferior epigastric artery system and the rich plexus they form with the intercostal perforators. Flaps may be 6 to 8 cm in width and 28 × 30 cm in length with a recommended length to width ratio of 3:1.[22,d]

A downside to any pedicled flap is relative immobility. The paraumbilical perforator flap, by virtue of its long reach, affords patients reasonable range of motion. The abdominal scar does tend to be more visible than other options, although it hides easily in normal clothing.

SOFT TISSUE WITH VOLUME LOSS

More thorough assessment of wounds in this category is required to fill defects with appropriate tissue type and volume. They may require thin tissue to allow adequate function because excess bulk of tissue would limit mobility via steric hindrance. Other wounds, when covered with a skin graft or thin amount of tissue,

FIGURE 4: A Example of a partial thumb amputation and index amputation. The thumb required coverage prior to definitive reconstruction, and the index finger was treated with ray amputation. **B** Thumb wound is covered with groin flap after second stage shows division of the flap. **C** Groin flap following debulking; this is notable for preservation of first web space/thumb mobility with good final contour.

would lead to inadequate function of the hand due to malposition or scar contractures.

Blast injury with first web space involvement: Any wound in the first web space, such as is seen in Figure 3A, has the potential to lead to adduction contracture, thus limiting the mobility of the thumb. Although these wounds can appear to have adequate tissue to close primarily or a healthy wound bed to skin graft, this path to reconstruction may yield poor outcomes from a tight first web space. Typically, volume is necessary to fill the space for the best reconstruction.

Posterior interosseous artery flap

The posterior interosseous artery flap (Fig. 3B–D) avoids sacrifice of a major artery and has the advantage of a more proximal blood supply than a radial forearm flap, making it reliable when the zone of injury extends to the wrist crease. It is based on a fairly reliable perforator between the anterior and the posterior interosseous arteries 2 cm proximal to the wrist crease; it is found in the septum between the extensor carpi ulnaris and the extensor digiti minimi muscle/tendon units. The perforator is robust enough to support a flap 8 to 10 cm in width and 12 to 15 cm in length, which reaches to the metacarpophalangeal joints, first web space, and radial palm.[23]

Meticulous dissection is required throughout the elevation of this flap to preserve venous outflow.[e] Venous congestion may be prevented by avoiding skeletonization of the perforator, taking a skin bridge around the perforator and not tunneling the flap.[19,23,24] The donor site may be closed primarily if skin laxity allows, avoiding a skin graft.

Free lateral arm flap

When adequate tissue does not exist in the forearm owing to concurrent injuries or concern of local flap integrity given the zone of injury, a free flap may be required. The free lateral arm flap has good color match in the hand and is keel-shaped, providing volume of tissue in addition to skin. The blood supply to this flap is via perforators from the posterior radial collateral artery, which has a 7- to 11-cm pedicle. A large swath of tissue can be harvested—6 cm wide × 15 cm long—and the donor often closed primarily.[25,f]

Additional modifications of the lateral arm flap can yield an innervated flap using the posterior brachial cutaneous nerve.[2,25] In addition to being useful for free tissue transfer, the lateral arm flap has been used as a pedicled flap for defects of the elbow as a reverse-flow flap utilizing the posterior radial recurrent artery.

Thumb amputation with exposed metacarpal base: Goals in soft tissue coverage of a thumb amputation, seen in Figure 4A, exemplify the concept of the reconstructive elevator. If the patient and surgeon are considering a future thumb reconstruction, a robust soft tissue base must be created to allow toe transfer or osteoplastic reconstruction. Bringing volume of healthy tissue and preservation of recipient vessels for future reconstruction are key.

Groin flap

Pedicled flaps are "complementary to microsurgery" in that they preserve options for future reconstruction.[26] The groin flap is an axial flap based on the superficial circumflex iliac artery. It allows harvest of tissue up to 10 cm wide and 25 cm long. The flap is centered 2 finger-breadths below the inguinal

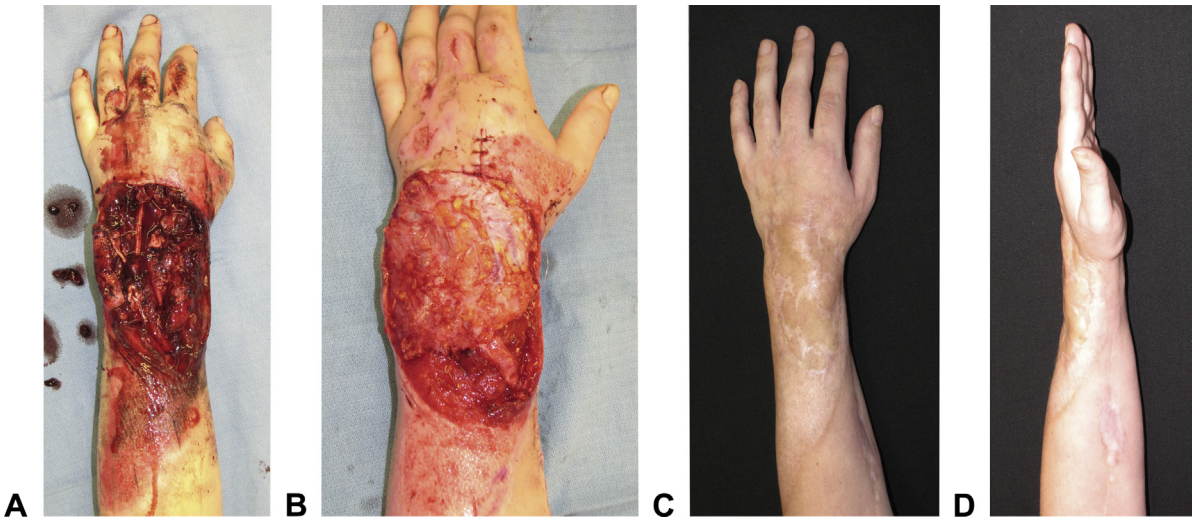

FIGURE 5: **A** Example of a dorsal hand wound with exposed tendons. **B** Dorsal hand wound with a radial forearm fascia flap inset, prior to skin graft placement. **C** Dorsal view of the radial forearm fascia flap after surgery with good skin graft healing. Note minimal donor site visible and a straight-line scar. **D** Lateral view of the radial forearm fascia flap demonstrates excellent contour and lack of excess bulk.

ligament with its bulk medial to the anterior superior iliac spine because the blood supply lateral to this point is random (not axial).[g]

If pedicle closure is tight, it is safest to not tube the base of the flap and perform daily dressing changes on the open areas. Flap division is safe after 3 weeks. Appropriate positioning of the hand during the planning and adequate pedicle length to allow pronation and supination are important, but these must be balanced to avoid waste of well-vascularized flap on the pedicle. A narrower base of the flap can also assist in ease of inset.[20,26]

Radial artery perforator flap

Perforator flaps are among the newest arrivals on the reconstructive scene and have gained popularity with work on the perfasome theory.[27] Although perforator flaps are more technically demanding to harvest, they have the advantage of avoiding sacrifice of a major artery to the hand, which recent studies have suggested is not as complication-free as previously believed.[19,28]

This flap is based on a perforator found 2 to 4 cm proximal to the radial styloid. Because it is not an axial flap, the size that can be harvested is somewhat smaller—8 to 12 cm in width by 15 to 20 cm in length. Rotation of the flap after harvest may be up to 180°, which allows coverage of moderate-sized defects of the dorsal hand and palm, reaching to the proximal phalanges.[h]

Many authors recommend avoiding a subcutaneous tunnel and instead incise the skin where the pedicle will lie to prevent compression.[29] Similar to the radial forearm flap, this may also be taken as an adipofascial flap if desired.

FUNCTIONAL TISSUE LOSS

Given the specialized function of the hand, it is not surprising that many wounds lead to a loss of functional tissue—tissue that is important for gliding, tissue required for sensation, or even tissue contribution to mobility. Specialized tissue requires specialized reconstruction; functional donor tissue must be chosen to restore the lost function. For example, an innvervated pedicle latissimus dorsi flap can be used for both upper arm soft tissue coverage down to the antecubital fossa and restoration of biceps or triceps function.[i]

Dorsal hand wound with exposed tendons: Tendon gliding is essential for hand function, and in any wound where there is exposed tendon, such as we see in Figure 5A, consideration should be taken to cover the wound with a surface that promotes gliding. Exposed tendon is frequently associated with tendon injury, and a flap choice that allows easy reelevation for secondary procedures (eg, grafting, tenolysis) is also important.

Fascia-only radial forearm flap

The radial forearm flap has long been a useful tool in upper extremity reconstruction; however, the donor site it leaves on the forearm is somewhat unsightly.[j,k] The fascia-only variation has the same reach as the traditional radial forearm—out to the fingertips. Up to two-thirds of the arm circumference can be taken for a total of 10 to 12 cm in width and 20 to 30 cm in length.[19] The fascia provides an excellent gliding surface for tendons and tendon repairs. The fascial flap minimizes the unsightly donor site in the forearm that usually requires a skin graft.[l]

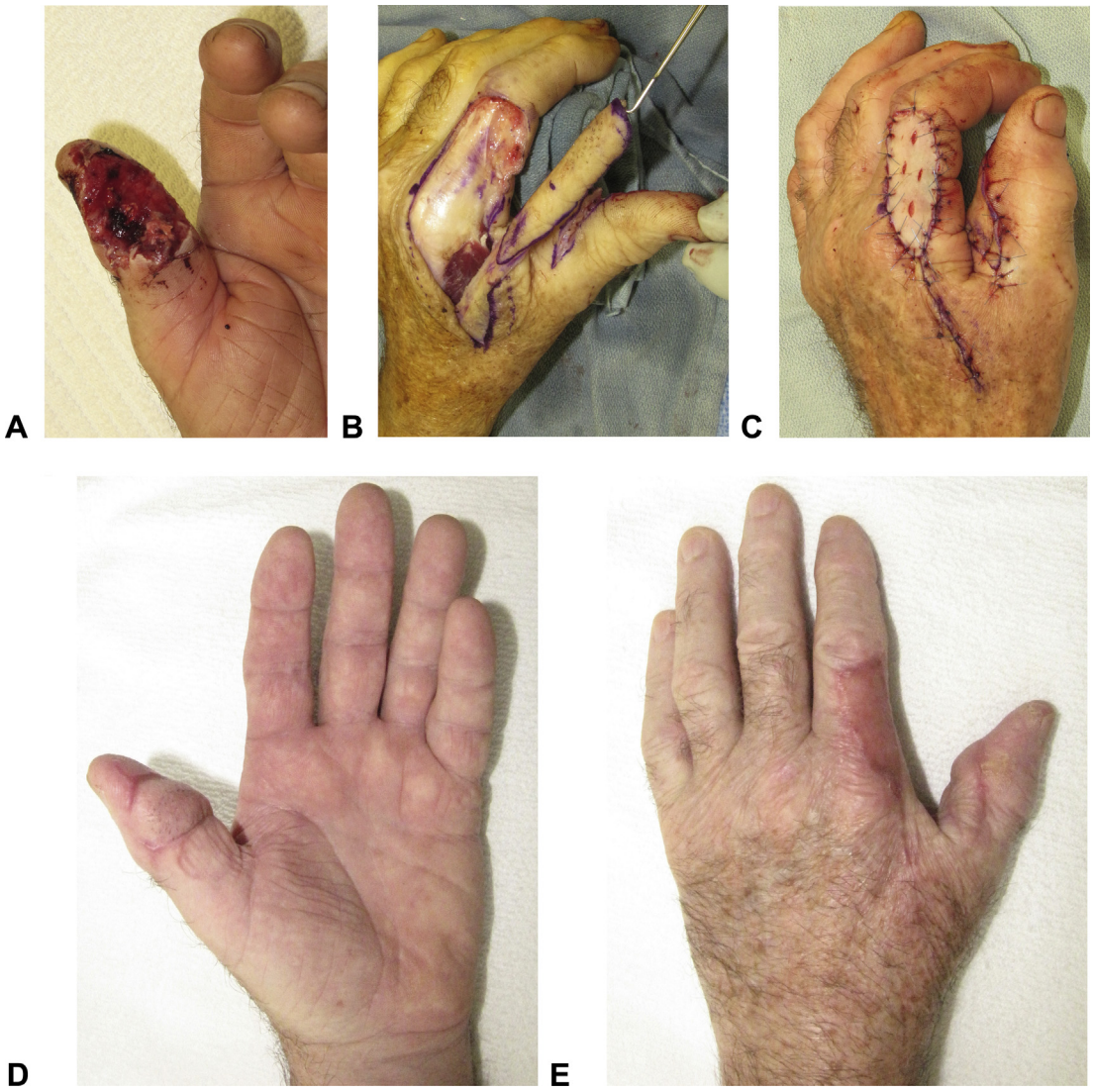

FIGURE 6: **A** Example of a thumb pulp wound with loss of palmar soft tissue. **B** First dorsal metacarpal artery flap is rotated to cover the palmar thumb defect; this is notable for a wide swatch of tissue around the perforator at the base of the flap. **C** Flap after inset and donor site coverage with a full-thickness skin graft with several vent holes to avoid meshing of graft. **D** Postoperative views of first dorsal metacarpal artery flap inset into thumb pulp defect. **E** Postoperative views of first dorsal metacarpal artery donor site with good healing.

Unlike the traditional flap, the fascia-only variant cannot be innervated because no skin end-organs are included.[19] The main drawback of the fascia-only flap is sacrifice of the radial artery—recent studies have demonstrated alteration in the microcirculation of the hand, differences in arterial waveforms of the fingers, and chronic changes in the intima of the remaining ulnar artery.[28]

Anterolateral thigh flap

The anterolateral thigh (ALT) flap has become a popular flap for many types of reconstruction in recent years. It is another perforator flap based off the descending branch of the lateral femoral circumflex artery that allows a large amount of skin and fascia to be taken; flaps 7 to 9 cm wide and 22 cm long may survive on 1 perforator. Dissection is difficult because 87% of the perforators are musculocutaneous, rather than septocutaneous as initially believed.[24,m]

The fascial component of this flap provides an excellent gliding surface to cover tendons or tendon repairs that is superior to a muscle flap. If this surface is not needed, the flap may be dissected in the suprafascial plane to provide thinner coverage. With its long pedicle that can be carried distally, the ALT flap offers the option of use as a flow-through flap if needed for vessel reconstruction in the upper extremity. As a fasciocutaneous flap, it can be debulked in subsequent surgeries and provides an easy surface for reoperation if futures surgeries are needed.[19,24]

Thumb degloving resulting in pulp loss: Thumb injuries such as seen in Figure 6A always cause concern given the key role of the thumb in hand function. Whereas basic soft tissue coverage of the thumb may be easy to achieve, an insensate thumb causes problems for the patient where sensory feedback is key, such as tasks involving fine-object manipulation. Reconstructive solutions for the thumb should attempt to return sensation to the pulp whenever possible.

First dorsal metacarpal artery flap

The first dorsal metacarpal artery (FDMA) flap has a surprisingly long reach with an average pedicle length of 7 cm. It can cover defects up to 3 cm wide by 5 cm in length and is most commonly used for injuries about the thumb. Its blood supply is based on the connection between the palmar and the dorsal circulation, which is found at the apex of the first and second metacarpal bases.[4,n]

Avoidance of skeletonizing the pedicle is vital to prevent venous congestion—the pedicle should not be visualized during this dissection. Sensory reinnervation has been reported to be in the range of 6 to 10 mm.[5] One of the difficulties seen with sensation is age-related; whereas young patients experience rapid cortical reorientation, older patients reinnervate less reliably. The main disadvantage of this flap on the thumb is the lack of glabrous skin.[4,20]

Toe pulp free flap

Although free tissue transfer for a small defect may seem extravagant, it can be an efficacious and elegant solution in the patient who relies on accurate fingertip sensation. This flap is based on the fibular digital artery of the great toe and allows a 2- × 3-cm flap of sensate, glabrous tissue to be harvested and transplanted to the fingertip for reconstruction.

The largest case series demonstrates 8-mm 2-point discrimination, which is similar to skin grafting or healing by secondary intention.[20] The toe pulp has the advantage of bringing glabrous skin to the finger, which provides a no-slip surface that local flaps fail to do.[17,30]

Aesthetic considerations

Previously, obtaining stable coverage of a wound was the primary goal and function a close second. As reconstructive techniques have improved through a better understanding of tissue vascularity, however, success is no longer measured merely on flap survival or Disabilities of the Arm, Shoulder, and Hand scores: patients also expect a good aesthetic outcome to their reconstruction.[31]

Scar location is of critical importance. The aesthetic subunits of the hand provide easy landmarks in which to hide scars. Color match is crucial and most easily achieved by using a local flap because the skin will have similar qualities.[31] Skin type can be easily modified to provide a better overall aesthetic outcome: although the hypothenar region is an excellent donor when a small full-thickness graft is needed, transporting glabrous skin to a dorsal defect will result in graft that looks thick. By transposing the hypothenar donor site dorsally to harvest nonglabrous skin, this difference can be avoided.

Mismatch of volume causes visible defects and may also have functional implications—excess bulk may limit range of motion. Flaps that allow repeated elevation for modification and debulking are ideal to achieve more normal form, as well as thinner flap selection—such as a suprafascial ALT. At the other end of the spectrum, wounds reconstructed with a skin graft only may appear too thin and a local flap should be considered in place of a graft at the time of initial operation.

The last consideration in planning reconstruction is the donor site. Whereas the surgeon did not create the initial injury, any scars from the reconstruction are owned by the surgeon. A skin graft on the volar forearm to cover a radial forearm flap donor site is not aesthetically pleasing, especially in women. Alternatives, such as a fascia-only radial forearm flap, might be preferred.[19] When skin grafts must be used, nonmeshed grafts on the hand and forearm are preferred.

DISCUSSION

Every defect has multiple options for reconstruction; consideration of tissue type as well as functional and aesthetic goals will yield the best outcome for the patient.

REFERENCES

1. Gottlieb LJ, Krieger LM. From the reconstructive ladder to the reconstructive elevator. *Plast Reconstr Surg*. 1994;93(7):1503–1504.
2. Saint-Cyr M, Gupta A. Indications and selection of free flaps for soft tissue coverage of the upper extremity. *Hand Clin*. 2007;23(1):37–48.
3. Gupta A, Lakhiani C, Lim BH, et al. Free tissue transfer to the traumatized upper extremity: risk factors for postoperative complications in 282 cases. *J Plast Reconstr Aesthet Surg*. 2015;68(9):1184–1190.
4. Biswas D, Wysocki RW, Fernandez JJ, Cohen MS. Local and regional flaps for hand coverage. *J Hand Surg Am*. 2014;39(5):992–1004.
5. Weeks PM, Wray RC. *Management of Acute Hand Injuries: A Biological Approach*. 2nd ed. St. Louis, MO: Mosby; 1973:1403.
6. Morris AM. Rapid skin cover in hand injuries using the reverse-dermis flap. *Br J Plast Surg*. 1981;34(2):194–196.

7. Parry SW, Ward JW, Mathes SJ. Vascular anatomy of the upper extremity muscles. *Plast Reconstr Surg*. 1988;81(3):358–365.
8. O'Shaughnessy KD, Rawlani V, Hijjawi JB, Dumanian GA. Oblique pedicled paraumbilical perforator-based flap for reconstruction of complex proximal and mid-forearm defects: a report of two cases. *J Hand Surg Am*. 2010;35(7):1105–1110.
9. Zancolli EA, Angrigiani C. Posterior interosseous island forearm flap. *J Hand Surg Br*. 1988;13(2):130–135.
10. Katsaros J, Schusterman M, Beppu M, Banis JC Jr, Acland RD. The lateral upper arm flap: anatomy and clinical applications. *Ann Plast Surg*. 1984;12(6):489–500.
11. Smith PJ, Foley B, McGregor IA, Jackson IT. The anatomical basis of the groin flap. *Plast Reconstr Surg*. 1972;49(1):41–47.
12. Zhang YT. The use of reversed forearm pedicled fascio-cutaneous flap in the treatment of hand trauma and deformity (report of 10 cases). *Zhgonhua Zheng Xing Shao Shang Wai Ke Za Zhi*. 1988;4(1):41–42.
13. Jin YT, Guan WX, Shi TM, Quian YL, Xu LG, Chang TS. Reversed island forearm fascial flap in hand surgery. *Ann Plast Surg*. 1985;15(4):340–347.
14. Song YG, Chen GZ, Song YL. The free thigh flap: a new free flap concept ased on the septocutaneous artery. *Br J Plast Surg*. 1984;37(2):149–159.
15. Foucher G, Braun JB. A new island flap transfer from the dorsum of the index to the thumb. *Plast Reconstr Surg*. 1979;63(3):344–349.
16. Hamilton RB, Morrison WA. Microvascular segmental thumb reconstruction: a case report. *Br J Plast Surg*. 1980;33(1):64–67.
17. Eberlin KR, Chang J, Curtin CM, Sammer DM, Saint-Cyr M, Taghinia AH. Soft-tissue coverage of the hand: a case-based approach. *Plast Reconstr Surg*. 2014;133(1):91–101.
18. Chim H, Ng ZY, Carlsen BT, Mohan AT, Saint-Cyr M. Hand flaps. *Hand Clin*. 2014;30(4):487–499, vi–vii.
19. Page R, Chang J. Reconstruction of hand soft-tissue defects: alternatives to the radial forearm fasciocutaneous flap. *J Hand Surg Am*. 2006;31(5):847–856.
20. Friedrich JB, Katolik LI, Vedder NB. Soft tissue reconstruction of the hand. *J Hand Surg Am*. 2009;34(6):1148–1155.
21. Andre A, Bonnevialle N, Grolleau JL, Mansat P. Soft-tissue coverage of olecranon with musculocutaneous flexor carpi ulnaris flap. *Orthop Traumatol Surg Res*. 2014;100(8):963–966.
22. Gutwein LG, Merrell GA, Knox KR. Paraumbilical perforator flap for soft tissue reconstruction of the forearm. *J Hand Surg Am*. 2015;40(3):586–592.
23. Fong PL, Chew WYC. Posterior interosseous artery flap: our experience and review of modifications done. *Hand Surg*. 2014;19(2):181–187.
24. Friedrich JB, Pederson WC, Bishop AT, Galaviz P, Chang J. New workhorse flaps in hand reconstruction. *Hand (N Y)*. 2012;7(1):45–54.
25. Wettstein R, Helmy N, Kalbermatten DF. Defect reconstruction over the olecranon with the distally extended lateral arm flap. *J Plast Reconstr Aesthet Surg*. 2014;67(8):1125–1128.
26. Sabapathy SR, Bajantri B. Indications, selection, and use of distant pedicled flap for upper limb reconstruction. *Hand Clin*. 2014;30(2):185–199. vi.
27. Saint-Cyr M, Wong C, Schaverien M, Mojallal A, Rohrich RJ. The perforasome theory: vascular anatomy and clinical implications. *Plast Reconstr Surg*. 2009;124(5):1529–1544.
28. Higgins JP. A reassessment of the role of the radial forearm flap in upper extremity reconstruction. *J Hand Surg Am*. 2011;36(7):1237–1240.
29. Ho AM, Chang J. Radial artery perforator flap. *J Hand Surg Am*. 2010;35(2):308–311.
30. Lee DC, Kim JS, Ki SH, Roh SY, Yang JW, Chung KC. Partial second toe pulp free flap for fingertip reconstruction. *Plast Reconstr Surg*. 2008;121(3):899–907.
31. Rehim SA, Kowalski E, Chung KC. Enhancing aesthetic outcomes of soft-tissue coverage of the hand. *Plast Reconstr Surg*. 2015;135(2):413e–428e.

EDITOR'S SUGGESTIONS FOR MORE INFORMATION

a. Reverse homodigital flap [See Video]. In: Rayan GM, Chung KC, eds. *Flap Reconstruction of the Upper Extremity: A Master Skills Publication*. Rosemont, IL: American Society for Surgery of the Hand; 2009.
b. Pham D, Netscher DT. Vascularized heterodigital island flap for fingertip and dorsal finger reconstruction. *J Hand Surg Am*. 2015;40(12):2458–2464.
c. Atasoy E. The reverse cross finger flap. *J Hand Surg Am*. 2016;41(1):122–128.
d. Gutwein LG, Merrell GA, Knox KR. Paraumbilical perforator flap for soft tissue reconstruction of the forearm. *J Hand Surg Am*. 2015;40:586–592.
e. Posterior interosseous flap [See Video]. In: Rayan GM, Chung KC, eds. *Flap Reconstruction of the Upper Extremity: A Master Skills Publication*. Rosemont, IL: American Society for Surgery of the Hand; 2009.
f. Lateral arm flap [See Video]. In: Rayan GM, Chung KC, eds. *Flap Reconstruction of the Upper Extremity: A Master Skills Publication*. Rosemont, IL: American Society for Surgery of the Hand; 2009.
g. Groin flaps [See Video]. In: Rayan GM, Chung KC, eds. *Flap Reconstruction of the Upper Extremity: A Master Skills Publication*. Rosemont, IL: American Society for Surgery of the Hand; 2009.
h. Ho AM, Chang J. Radial artery perforator flap. *J Hand Surg Am*. 2010;35(2):308–315.
i. Latissimus dorsi flap [See Video]. In: Rayan GM, Chung KC, eds. *Flap Reconstruction of the Upper Extremity: A Master Skills Publication*. Rosemont, IL: American Society for Surgery of the Hand; 2009.
j. Radial forearm flap [See Video]. In: Trumble TE, Budoff JE, eds. *Hand Surgery Update IV*. Rosemont, IL: American Society for Surgery of the Hand; 2007.
k. Radial forearm flap [See Video]. In: Rayan GM, Chung KC, eds. *Flap Reconstruction of the Upper Extremity: A Master Skills Publication*. Rosemont, IL: American Society for Surgery of the Hand; 2009.
l. Taghinia AH, Carty M, Upton J. Fascial flaps for hand reconstruction. *J Hand Surg Am*. 2010;35(8):1350–1355.
m. Anterolateral thigh flap [See Video]. In: Rayan GM, Chung KC, eds. *Flap Reconstruction of the Upper Extremity: A Master Skills Publication*. Rosemont, IL: American Society for Surgery of the Hand; 2009.
n. First dorsal metacarpal artery flap [See Video]. In: Germann G. Workhorse upper extremity flaps: first dorsal metacarpal artery flap. Seattle, WA: ASSH Annual Meeting; 2015.

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1

Initial Evaluation of the Mangled Hand

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GANGA

2

12 year old girl presenting at midnight

3

Take a deep breath and think calmly

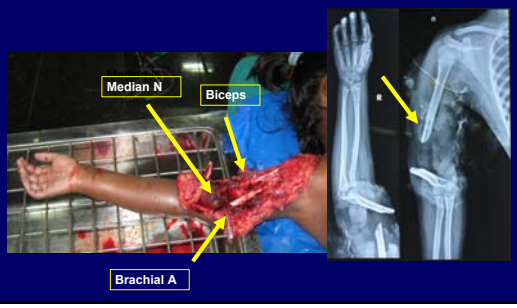
- How ever bad a situation is , there is a way out
- First person to see the patient plays a very significant role
- Call for help early
- Make a complete plan

4

Inspect
Think
Plan
Act

5

Think about the final result and the work backwards



6

What the child needs

- Resuscitation
- Radical Debridement
- Fixation of Humerus
- Brachial artery repair with vein graft
- Median nerve repair

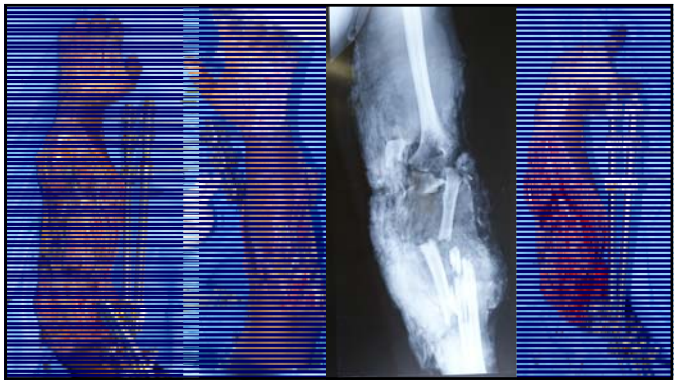
and then

- ***Pedicled LD flap for cover and elbow flexion***

7

2 years later

8



9

10

11

12

Hand Surgeon is Like a Kintsugi master

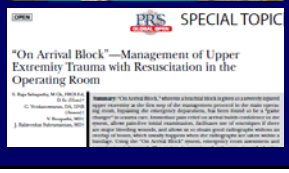
In fact, Kintsugi often makes the repaired piece even more beautiful than the original, revitalizing it with a new look and giving it a second life.

13

Kintsukuroi

14

On arrival block


PRS SPECIAL TOPIC

"On Arrival Block"—Management of Upper Extremity Trauma with Resuscitation in the Operating Room

PRS Glob Open. 2020 Oct 29;8(10):e3191.

15

Can you make a useful hand ?

16

Heterotopic Replantation
Index to Thumb

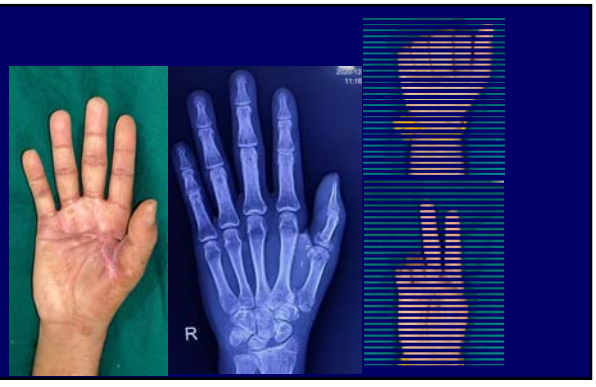
17

18

Mentally put all the tissues back in place

19

20



21


We prefer the Index finger Position

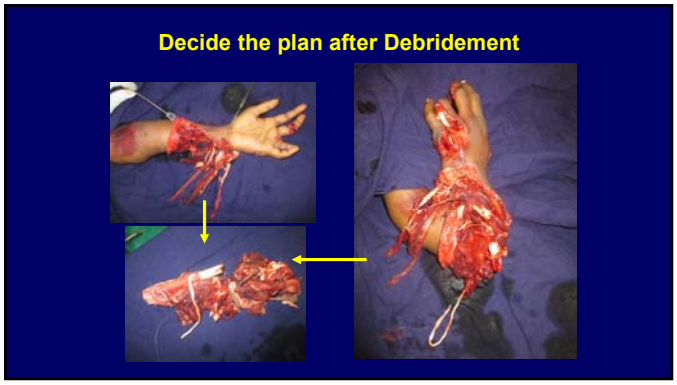
22


1 year old Infant

23


Heterotopic replantation of ring on the Index
Tripod Pinch is achieved

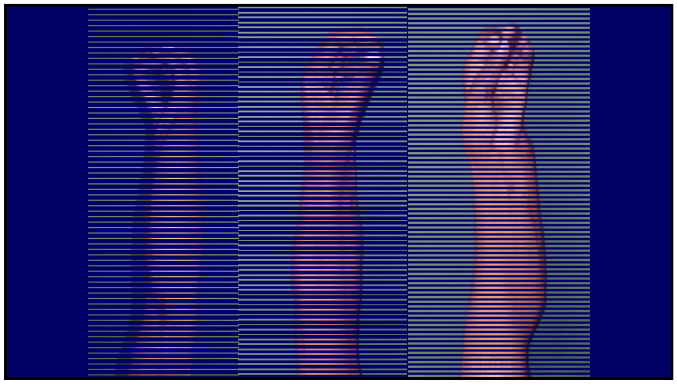
24


Decide the plan after Debridement

25


Plan the type flap cover after Skeletal Stabilization

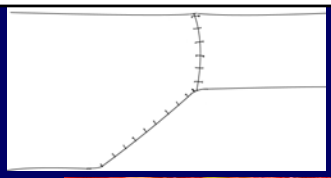
26



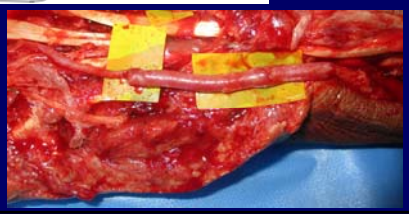
27

Avascular Hand

28



Be prepared for size discrepancy



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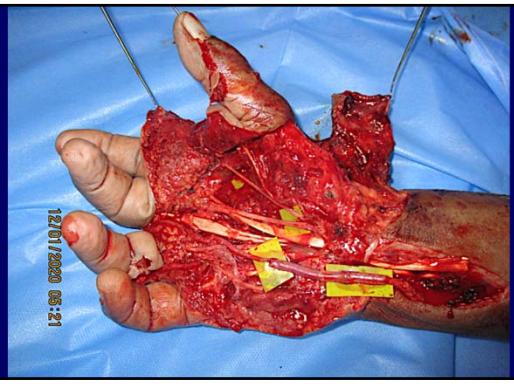


30

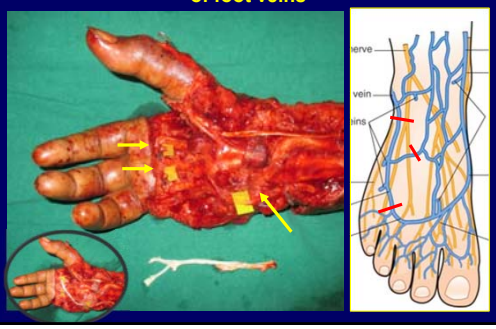
The vein graft needs cover

31

Reconstructing the Palmar Arch

32

Be prepared for harvesting dorsum of foot veins



33

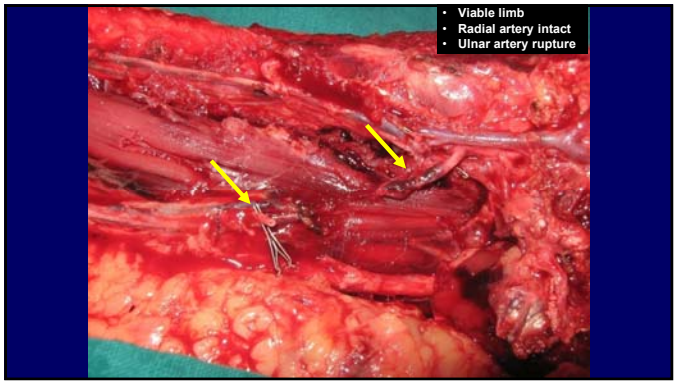
34

Augment blood supply whenever possible

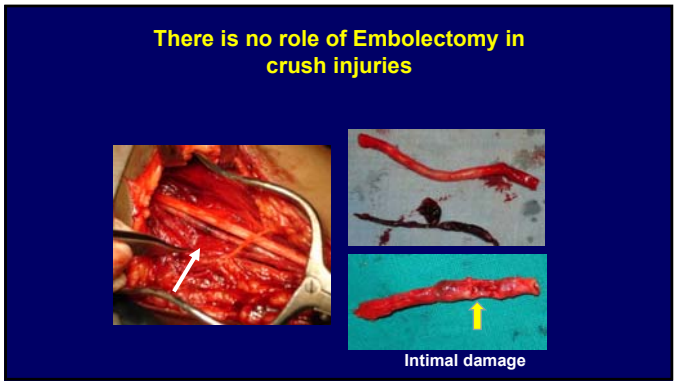
- Ensures survival
- Ensures better survival of local flaps

35

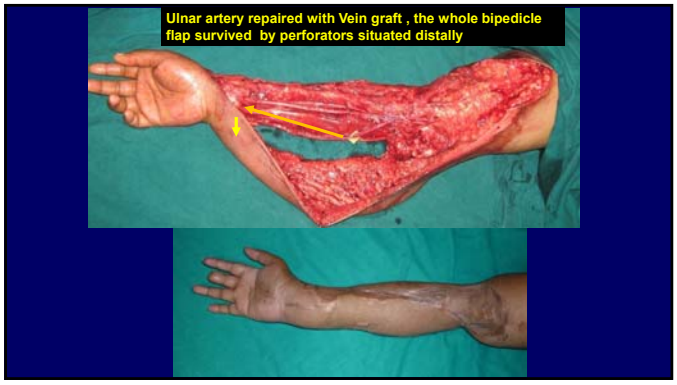
36


• Viable limb
• Radial artery intact
• Ulnar artery rupture

37


There is no role of Embolectomy in crush injuries
Intimal damage

38


Ulnar artery repaired with Vein graft , the whole bipedicle flap survived by perforators situated distally

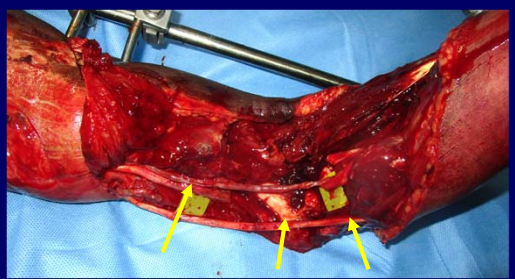
39

Debride Radically

40

41

Provide soft tissue cover early



All the critical structures are exposed

42

43

44

"If you leave them to dry, they die"

Venkatramani H, Sabapathy SR. Collagen sheets as temporary wound cover in major fractures prior to definitive flap cover. Plast. Reconstr. Surg. 2002; 110: 1613-14

45

When multiple digits involved

46

Separate flaps are always better

47

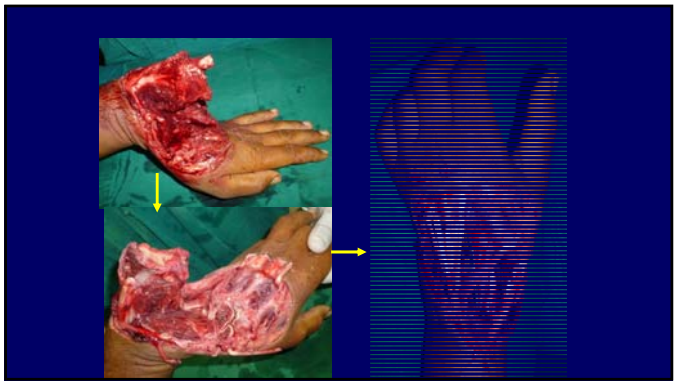
48

Stable Fracture fixation

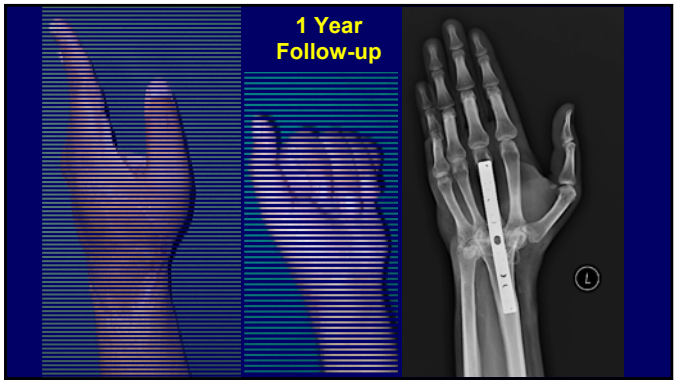
A loose or poor fixation is the beginning of the end

- Must not have non union
- Think of function while fixing the bone

49



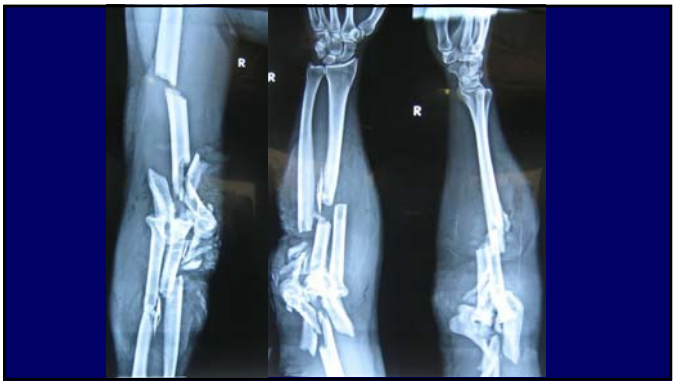
50



51

Stable Skeletal Fixation is the foundation of successful Reconstruction

52



53

Primary fixation of all fractures

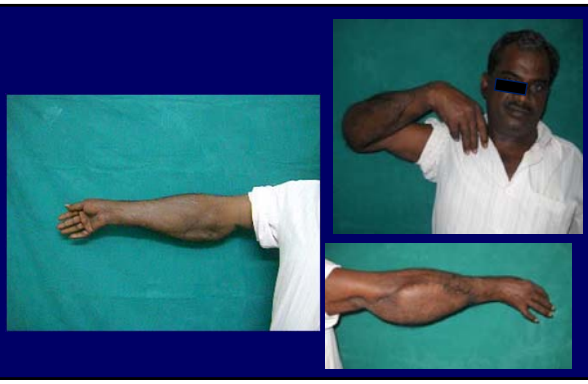
54

Early flap Cover

55

Primary Bony Union

56



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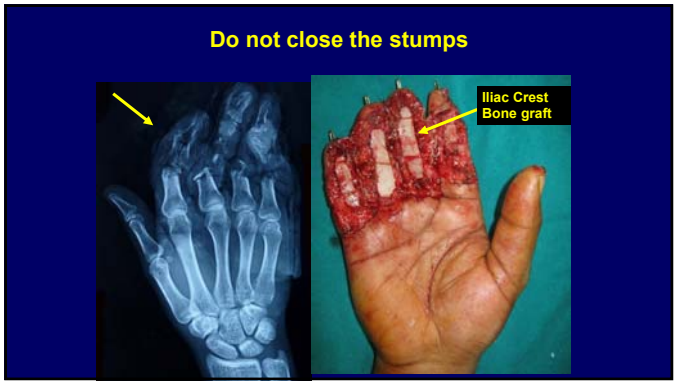
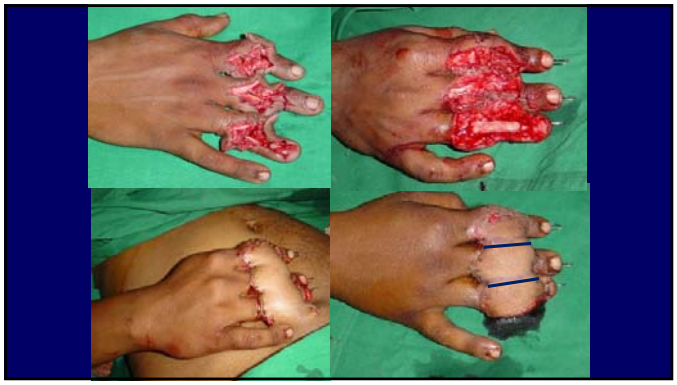

Do not close the stumps
Iliac Crest
Bone graft

58

59

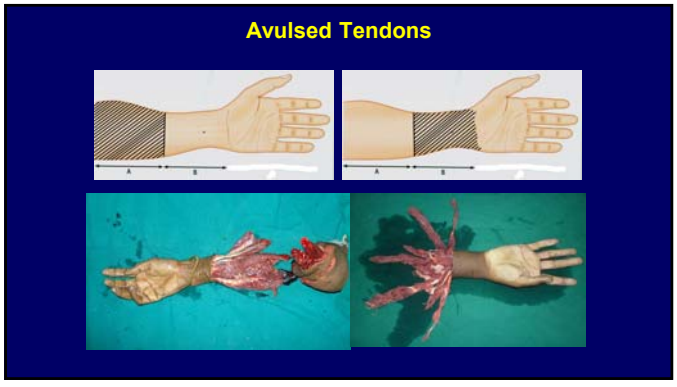

Raja Sabapathy S, Venkatramani H, Giesen T, Ullah SA. Primary bone grafting with pedicled flap cover for dorsal combined injuries of the digits. The Journal of Hand Surgery (Brit & European Vol), 102008; 33E:65-70

60



61

62



63

Avulsed Tendons

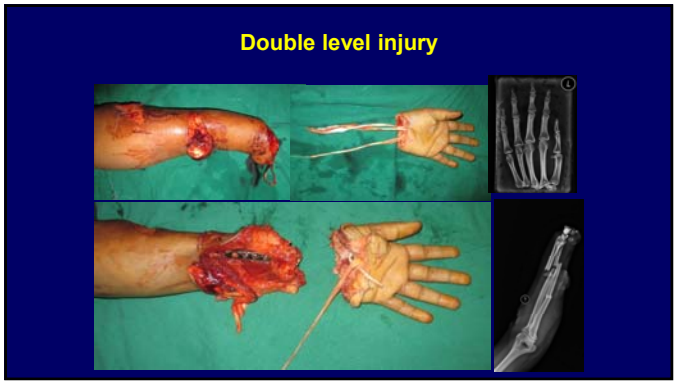
Mass weaving of Avulsed Tendons

64

65

10 Year Follow-up

66



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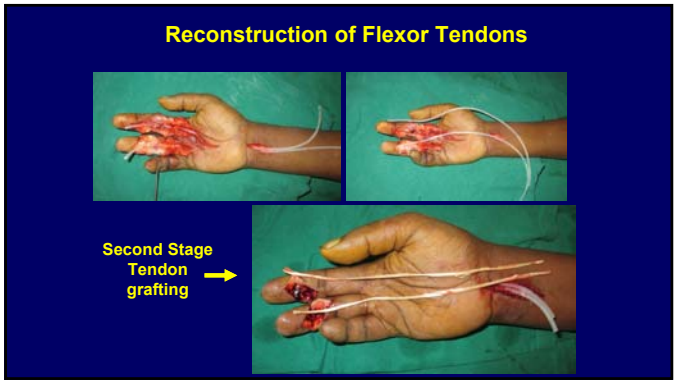
Secondary Reconstruction

71


Reconstruction of Flexor Tendons
Second Stage
Tendon
grafting

72

73

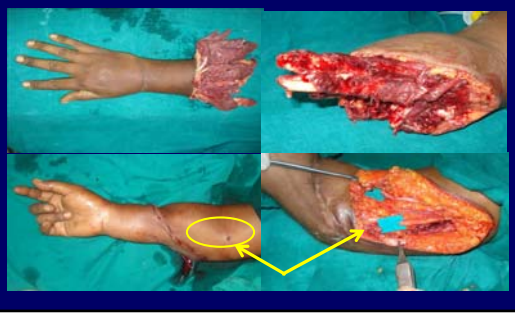
Reconstruction of Avulsed Nerves

74

Secondary nerve grafting

75

Nerves can be tunnelled and brought proximally



76

2 Year result

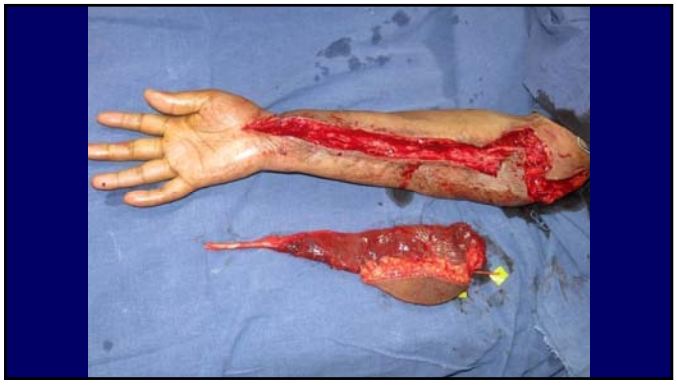
77

Graft or Flap
Role of VAC?

78

79

80



81

82

Take home message

- Remain calm ,but think hard
- However bad it looks , there is a way out
- Make a plan and walk the path
- Keep all reconstructive options available
- Think of global function
- Aim for dynamic aesthetics
- Staged reconstruction if safer is a better option

83

The Mangled Hand
Post Operative Treatment

Matt Butler MD
Hand to Shoulder Center of WI

1

Now What?

How to care for a patient who has been through a life changing injury

2

Objectives of Care

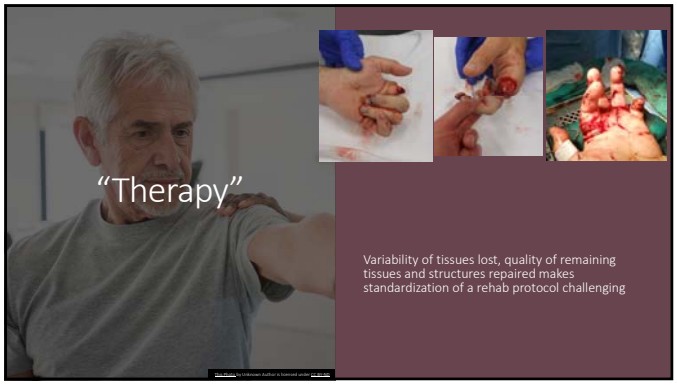
Minimize the direct and psychosocial effects of the injury

- Maximize objective limb function – prioritized by our training process
- Minimize damage to patients psyche and body image

Considerations

- Patient livelihood
- Life activities and quality of life

3



4

Occupational Therapy

- Early referral
- Frequent visits
  - Dressing changes
  - Splint adjustments
- Good communication
  - Allows changes in treatment
  - Early ability to intervene if complications arise

5

"One Wound, One Scar"

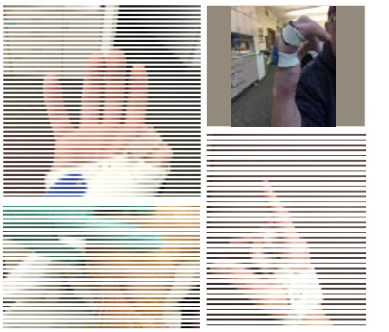
Edema Control

- Tissue pliability decreases early in the healing process

Motion

- Maintain joint mobility
- Active motion, when possible, to generate differential gliding of tissue layers and tendon gliding

6



Later Stages

- Dynamic splints
- Modalities
- Work simulation
- Return to daily life and recreation

7

Psychologic Impact of Hand Trauma

Pre-morbid mental status

PTSD

8

PTSD

Intense disturbing thoughts related to the trauma long after the event, frequently reliving the event "flashbacks"

1. Intrusion
2. Avoidance
3. Alterations in cognition/mood
4. Alterations in arousal or activity

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Survival Mechanism

Pathologic vs normal response to trauma

From an evolutionary standpoint these are the exact responses that would impart a survival advantage in life threatening situations

- Vigilance
- Avoidance of danger
- Swift reaction
- Light sleep
- Anger
- Flashbacks as reminder of danger and threats to life

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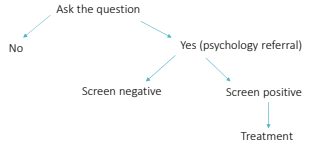
Prevalence and Screening

1/3rd of patients will meet criteria for PTSD after hand trauma (Smith et al JHS 2009)

Screening tools

Ask patient "Are you willing to meet with someone to discuss your feelings?"



Return to Work

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Role of Prosthetics

Early prosthetics referral

Incorporating prosthetic use into rehab process

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Case Example

- 32 Year old RHD female
- No PMH
- Right hand crushed in a press at work

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Crush injury



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Outcome



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Thank you

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