Revascularization, Replantation, Fingertip Injury

Kevin Lutsky, MD
Rothman Institute
Hand, Upper Extremity, and Microvascular Surgery
Director of Research
Trauma Symposium
Outline

• Definitions
• Evaluation
• Indications
• Operative technique
• Post-op protocol
• Outcomes
Definitions

• **Replantation**
  • Reattachment of a part that has been completely amputated with NO tissue connection to the patient
  
  • 1st replant (transhumeral): Malt/McKhann (1962)
  • 1st digital replant: Komatsu/Tamai (1968)

• **Revascularization**
  • Repair of an incompletely amputated part that has some intact soft tissue but no perfusion due to arterial injury
Evaluation - History

**History**
- Mechanism of injury
  - Sharp vs crush vs avulsion
- Time of injury
  - Ischemia time
- Care of part

**Handling of part**
- Wrap in gauze moistened with saline
- Place in a plastic bag or specimen container
- Place bag/container on ice
Ichemia Time

• **Warm ischemia time tolerance**
  • < 6 hours for amputations proximal to carpus
  • <12 hours for digital amputations

• **Cool ischemia time tolerance**
  • < 12 hours for amputation proximal to carpus
  • < 24 hours or more for digital amputations

• **Based on muscle oxygen demands**
Evaluation – PMH/SHx

**PMH:**
- Diabetes?
- Psychiatric diagnoses?
- Severe medical co-morbidities?
  - CAD, CHF, emphysema, PVD, hypercoagulopathy, etc.

**SHx:**
- Hand dominance
- Occupation
- Tobacco use
- Drug/EtOH use
Evaluation – PE/Imaging

• **PE:**
  • Determine level
  • Thorough neurological exam (2 pt)
  • Good vascular exam
    • Must use DOPPLER!
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• **PE:**
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  • Thorough neurological exam (2 pt)
  • Good vascular exam
    • Must use DOPPLER!

• **Imaging**
  • Radiographs of amputation site
  • Radiographs of amputation part
Indications

• No strict indications!

• Suitability of part

• Suitability of tissues

• Patient factors
  • Age/Medical co-morbidities
  • Need to return to work
  • Psychological stability

• Expected outcome

• Mechanism
  • Sharp > Crush > Avulsion
Ring Avulsion Injuries

• **Urbaniak Classification**
  - Class I: Circulation is adequate
  - Class II: Circulation is inadequate
    - IIa no additional injury
    - IIb bone, tendon injury
  - Class III: Complete degloving or amputation

• **Outcomes become progressively worse**
Relative Indications

• *When you should always try:*

  • Thumb

  • Children

• **Multiple digits**
  • Thumb > LF > RF > SF > IF

• **Hand/wrist/forearm level**
Relative Indications

• **When you can consider trying**
  • Single digit distal to the FDS insertion

• **Tamai classification**
  • Zone I: amputations distal to nail base
  • Zone II: amputation between DIP joint and nail base
  • Zone III: amputations between DIP joint and FDS

• **Controversial!**
  • Advantages: length, sensibility, cosmesis
  • Disadvantages: cost, morbidity, technical difficulty
Contraindications

• No strict contraindications!

• Mangled part
  • Consider spare parts

• Segmental injuries

• Life threatening injuries

• Poor patient compliance

• Poor expected outcome
Relative Contraindications

- Single digit in zone 2 (proximal to FDS insertion)
Relative Contraindications

- Single digit in zone 2 (proximal to FDS insertion)
Revascularization
Requirements

• **Must Haves:**
  • Tourniquet
  • Microscope
  • Micro-instruments
  • Non-crushing vascular clamps
  • Power and Mini C-arm for skeletal work
  • K-wires/steel wire
  • Heparinized Saline
  • Doppler
Revascularization Requirements

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• Consider:
  • Regional block
  • Papaverine
  • Hand plating system
  • Prepping the leg
Replant Preparation

- Take amputated part to OR
- Clean/Debride
- Exposure
  - Mid-lateral incisions
- Structure identification
  - Nerve
  - Artery
  - Vein
    - Reflect dorsal skin and dissect subdermal tissue
- Bone fixation
  - Retrograde wire insertion
Revascularization Sequence

• Macro before Micro

• BEFANV
  • Bone shortening/fixation
  • Extensor tendon repair
  • Flexor tendon repair
  • Artery anastomosis
  • Nerve repair
  • Vein anastomosis

• If multiple digits, follow “structure by structure”
  • NOT “digit by digit”
Revascularization Sequence

- **Macro before Micro**

- **On tourniquet, complete**
  - Nerve and vessel prep
  - Bone fixation
  - Tendon repairs
  - Nerve co-aptation
  - +/- Veins (my preference)

- **Off tourniquet, complete**
  - Artery (confirm inflow prior to anastomosis!)
  - +/- Veins
Bone Shortening/Fixation

• Shortening may be necessary to allow primary nerve/vessel repair and skin closure
  • Always shorten the distal skeleton

• Fixation methods:
  • K-wires: longitudinal vs crossed
  • Intra-osseous wiring: 90-90
  • Intramedullary fixation
  • Plates
    • Avoid excessive stripping!
    • Don’t waste too much time!
Tendon Repair

- **Standard techniques:**
  - Extensor: Multiple fig-8 or mattresses (4-0 Ethibond)
  - Flexor: Technique of choice
Nerve Repair
Vessel Repair

- Must bypass the zone of injury
  - Can extend 4cm in avulsion
  - Not always easily visible

- "Red-Line Sign"
  - Traction tears

- "Ribbon Sign"
  - Elastic recoil
Arterial Repair

- Resect damaged vessels

- Do NOT attempt to repair prior to achieving pulsating proximal arterial flow
  - Warm patient and environment
  - Hydrate patient and elevate BP (no vasopressors)
  - Intraluminal flushing with heparinized saline and papaverine
  - Wait!!!!
Arterial Repair

• Perform tension free repair or vein graft to uninjured vessels

• Vein grafting
  • Takes repair out of zone of injury
  • Can deliver ↑ pressure head
  • Can make anastomosis easier
  • Example:
    • Thumb ulnar digital artery to snuff box

• Consider a bolus of 5000U of IV heparin when beginning first anastomosis
Repair Technique

1st suture

2nd suture
Repair Technique
Vein Repair

- Attempt to anastomose 2 veins/artery
  - Consider vein grafts

- Outflow can be achieved by:
  - Dorsal veins
  - Volar veins
  - Nail bed scrapings
    - ALWAYS remove nail plate!!!
  - Transverse periungual stab incision
  - Medical grade leeches
    - Secrete hirudin
    - Cause Aeromonas hydrophila infections

- Do not leave room if any question of vessel patency!
Pearls

• Consider your tourniquet time

• Prepare most critical digits first
  • Consider spare parts

• Don’t let laceration force your exposure
  • BUT, if skin bridge exists, leave it alone!

• Dissect veins out under microscope

Recurring Theme
• Be prepared to take vein graft and/or nerve graft
• Macro before micro – Even if multi digits
• Structure by structure
  • All bone, all tendon, all nerve, vessel prep, then vessels
Closure and Dressings

- **Closure and dressing are as important as the microvascular repair**
- **Loose closure: less is more**
  - Can leave open to heal by 2° intention
- **Liberal use of skin graft if necessary**
- **No circumferential dressings**
  - Avoid the “blood cast”
- **No “weeners”**
Postoperative Anticoagulation

• No consensus or uniform protocol exists
  • Use is based on anecdotal evidence and experience
Postoperative Anticoagulation

- **Aspirin (Safe)**
  - Prevents platelet adhesion

- **Heparin (Safe)**
  - Inhibits fibrin formation by blocking thrombin
  - Associated with post-op bleeding complications

- **Dextran**
  - Mechanism of action is poorly understood
    - Plasma expander
    - Has both antiplatelet and heparin-like effects???
  - Risk of anaphylaxis and pulmonary edema

- **Botox (Safe)**
  - Unproven in replants/revasc
My Postop Protocol

- Admit for controlled environment
- No nicotine, caffeine, or chocolate
- Warm ambient temperature + bear hugger

- ASA (81mg)
- DVT prophylaxis (lovenox)

- Clinical/Doppler exam q1hr POD 1
- Clinical/Doppler exam q2hr POD 2, etc.
Monitoring

• If concerned, take down dressing
Monitoring

• If concerned, take down dressing

• Evaluate for signs of arterial/venous compromise

• Have low threshold for exploration

Table 1. Signs of Arterial and Venous Compromise

<table>
<thead>
<tr>
<th>Arterial Compromise</th>
<th>Venous Compromise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flap color</td>
<td>Pale, mottled, or bluish</td>
</tr>
<tr>
<td>Capillary refill</td>
<td>Sluggish (&gt;2 seconds)</td>
</tr>
<tr>
<td>Tissue turgor</td>
<td>Flat, turgor decreased</td>
</tr>
<tr>
<td>Temperature</td>
<td>Cool (&gt;2 degrees of difference compared with control)</td>
</tr>
<tr>
<td>Pinprick test</td>
<td>Scant amount of dark blood or serum</td>
</tr>
<tr>
<td>Doppler signals</td>
<td>Absence of pulsatile arterial signals</td>
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Replantation Outcomes
Scenario: The Good

- Sharp laceration
- Isolated digit
- Clean wound
- No bone involvement
- Dorsal skin intact
Scenario: The Bad

- Saw injury
- Multiple digits
- Dirty wound
- Bone and soft tissue involvement
Scenario: The Ugly

- Ring avulsion injury
- Multiple digits
- Extensive zone of injury
• Retro review of 1018 digital replantations or revascularizations at an avg f/u of 4.2 yrs

• Results
  • 92.9% success rate
  • Type of injury was the most important factor for immediate and long term outcome

• RFs for poor outcomes: smoking, PIP level injury, “no man’s land”
Replantation of Finger Avulsion Injuries: A Systematic Review of Survival and Functional Outcomes

Erika Davis Sears, MD, Kevin C. Chung, MD, MS

• Systematic review of 32 studies evaluating finger avulsion replantations

• Results
  • Survival rate 66%
  • Mean Static 2PD = 10mm
  • Total active motion (TAM) = 174°
• Meta-analysis of 8 studies evaluated 9 factors

• Results
  • Clean cut amp survival 5x more likely than crush/avulsion
  • P3 level amputations 2x less likely to survive
  • Thumb amputations 1.5x less likely to survive
  • Replants in nonsmokers 11.8x more likely to survive
  • Alcohol use no difference in survival
  • Digits of women 2x more likely to survive
  • Digits replanted <12hrs ischemia 2x more likely to survive
• Doppler evaluation of vessel patency in 75 fingers after successful replantation
  • Angio in 18pts

• Results
  • No doppler signal in 37% of arteries by 15 days
    • Angio confirmed doppler finding
  • Occlusion rate in sharp injuries 8%
  • Occlusion rate in crush injuries 43%
Conclusions

• With proper indications, most digits are salvageable

• However, some digits will fail regardless of technique

• No postoperative antithrombotic protocol has definitively been proven to be of clinical benefit
Questions?
Fingertip Injury
Fingertip Injuries

• Most do NOT require emergent treatment

• In ED:
  • Thorough irrigation
  • Tetanus/Antibiotics as indicated
  • Sterile, nonadherent dressing (over wound only)
  • Splint
  • Early outpatient follow-up

• PLEASE do not use clotting foam
  • It is PAINFUL and near impossible to remove for evaluation
Nail bed injuries

• **Nail plate/nail margin intact and not avulsed**
  • Leave alone unless hematoma > 50% and painful
  • Remove nail plate, repair nail bed, replace stent into nail fold
  • Decompression of hematoma
Nail bed injuries

- **Nail bed repair**
  - Remove nail plate
  - Repair nail bed
    - Dermabond faster than suture**
  - Replace stent into nail fold to avoid synechia

- **Associated distal phalanx fx**
  - Tuft fx’ s – leave alone
  - Diaphyseal fx’ s – can be displaced/unstable and need stabilization
Nail bed injuries

- **Beware Seymour fx**
  - Seen in kids (open physes)

- **Can mimic mallet finger**
  - Germinal matrix interposed in physis
  - Open injury

- **I&D**
- **Nailbed repair**
- **Stabilize fracture**
Fingertip amputations

• No bone exposed
  • Address nail bed injury
• Rx options
  • Healing by secondary intention
    • 1 cm x 1 cm commonly cited, not strictly necessary clinically
  • Defatting skin and replace as biologic dressing
  • Skin grafting - typically FTSG
  • Flaps
Reconstructive Ladder

- Free tissue transfer
- Distant flaps
- Local flaps
- Skin grafting
- Primary closure
- Secondary intention
Secondary Intention

• **Rationale:**
  - Loss of full thickness skin initiates wound contraction

• **Mechanism:**
  - Fibroblasts migrate into wound
  - Differentiate into myofibroblasts
  - Pull wound edges together
Secondary Intention

- **Advantages:**
  - No risk of infection
  - Good restoration of sensibility

- **Disadvantages:**
  - Long time to complete healing

- **Technique:**
  - Wet-to-dry or xeroform dressings BID/TID
Secondary Intention

- Vaseline dressing
  - Preferred technique for most fingertip injuries with tissue loss
  - Vaseline and coban
  - Shower daily
  - Wash with soap
  - Reapply Vaseline and Coban
Reconstructive Ladder

- Free tissue transfer
- Distant flaps
- Local flaps
- Skin grafting
- Primary closure
- Secondary intention
Primary Closure

- **Skin edges sutured together**
  - Must avoid too much tension
  - Edges should be everted

- **Requirements:**
  - Acute wound
  - Clean wound without debris

- **Advantages:**
  - Simplifies wound care
  - Wounds heal quicker
Primary Closure

• In the trauma/ER setting LOOSE or NO wound closure is almost always preferred in the hand
  • Decreased infection risk

• Xeroform dressing covering WOUND only
Reconstructive Ladder

1. Free tissue transfer
2. Distant flaps
3. Local flaps
4. Skin grafting
5. Primary closure
6. Secondary intention
Skin Grafting

• **Types**
  - STSG: Epidermis and varying levels of dermis
  - FTSG: Epidermis and full-thickness dermis

• **Indications:**
  - Any defect with good wound bed that cannot be closed

• **Contraindications:**
  - Poor wound vascularity
    - Grafts placed on bone, joints, or tendon (without epitenon) have lower survival
  - High bacterial content (>10^5 bacteria/gram)
Skin grafts

• No exposed tendon/bone*
  • Intact paratenon

• If bone/tendon exposed
  • Cannot use skin graft
Skin grafts

• **Full thickness**
  • For defects in palm of hand*
  • Contracts less, better reinnervation potential
  • Higher infection rate, less survival than STSG

• **Split thickness**
  • For defects on dorsum of hand
  • OK if contracts, sensibility not important, can cover more area if meshed
Reconstructive Ladder

- Free tissue transfer
- Distant flaps
- Local flaps
- Skin grafting
- Primary closure
- Secondary intention
Local Flaps

• Flaps from skin adjacent to the primary defect

• Types:
  • Advancement
  • Rotational
  • Transpositional

• Advantages:
  • Provide well vascularized, full thickness coverage
  • More durable to friction/stress than skin grafts
  • Ideal in terms of color/consistency match
Flaps

• **Classification by blood supply**
  • Random pattern – supply not from named artery
    • Most fingertip flaps
  • Axial - supply from named artery
    • groin flap
Z-Plasty

- Useful for breaking-up scar contractures (lengthens scars)
Z-Plasty

- All limbs of equal length (most important factor)*
  - A=B=C
- Increase in length of 75% with 60° angles (can be 30° to 90°)
Rotation Flaps

- Random pattern flaps

- Ischemia most likely at tip of flap*
Local Finger Flaps

• **Non-innervated**
  - Thenar flap
  - Cross-finger flap

• **Innervated**
  - V-to-Y Advancement Flaps
  - Moberg Volar Advancement Flap
  - Neurovascular Island Flap
  - Innervated cross-finger flap
  - Axial flag flap
• Provides palmar skin for fingertip injuries

• Position may lead to finger stiffness
  • Better for kids/younger
Cross Finger Flap

- Random flap that is raised from dorsum of the donor finger at the level of P1 or P2

- Indications:
  - Volar finger wound with exposed bone/tendon
  - Reverse cross finger is for dorsal wounds

- Contraindications:
  - Multiple injuries to hand
  - Vasospastic conditions
  - Pre-existing disabling contractures
Cross Finger Flap

- **Technique**
  - Avoid violating paratenon to allow skin grafting
  - Avoid extending flap beyond DIP/PIP midline
  - Divide/inset flap at 2-3 weeks
FM – Cross Finger Flap
Innervated Finger Flaps

- V-to-Y Advancement Flaps
  - Atasoy Volar Flap
  - Kutler Paired lateral Flaps
- Moberg Volar Advancement Flap
- Neurovascular Island Flap
- Innervated cross-finger flap
V-Y Advancement Flaps

• Useful flap for fingertip amputations

• Types:
  • Atasoy-Kleinert: Volar
  • Kutler: Lateral

• Technique
  • Can be performed using digital block
  • Must avoid undermining to maintain vascularity
Atasoy Volar V-Y Advancement

- Used for dorsally angled fingertip amputations
  - Dorsal loss is greater than palmar loss

- Better to preserve sensation (Eg musicians)*
JP – VY flap
Kutler Paired Lateral V-Y Advancement Flap

- Best for transverse amputations

- Scar left at tip of finger can be problematic
Moberg Flap

• Volar advancement flap

• Preferentially used for thumb tip amputation
  • Unlike fingers, thumb’s dorsal arterial blood supply is independent of the volar supply

• Defects up to 2.5 cm may be covered
Moberg Flap

**Technique**

- Mid-lateral incisions

- Advance all volar skin, subcutaneous tissue, and both NV bundles from the tip injury to MP joint

- Avoid significant IP flexion
  - Flexion contracture occurs

- FTSG or VY flap at the base
Moberg Volar Advancement Flap

- **Tips to success**
  - Indicated for thumb defects only

- **Disadvantages**
  - Flexion contracture of the IP joint
  - Dorsal thumb skin loss can occur if the dorsal vascular branches are not preserved
Neurovascular Island Flap

- Severe thumb pulp defects
- Provide sensation to digital n. or median n. deficits
- Donor site usually ulnar side middle finger (length) or ring finger

- Confirm Digital Allen test
Neurovascular Island Flap
Heterodigital Island Flap

• Disadvantages

• Donor site depression

• Loss of tip sensibility of donor finger

• Sensory re-education is difficult in adults

• Venous drainage may be impaired
Homodigital Island Flap

- Homodigital neurovascular island flap

**Indications:**
  - Repair of pulp defects

**Contraindications:**
  - Significant injury involving pedicle
RK - Homodigital Island Flap
First Dorsal Metacarpal Artery Flap

• FDMA ("Kite") flap was first described in 1950
  • Arises from the radial aa or the pinceps pollicis aa
  • Runs in the fascia of the interosseous mm
    • Exact location varies
  • Can be raised on an antegrade or reverse-flow pedicle

• Indications (Very Versatile):
  • Thumb coverage
  • Dorsal hand defects
  • Web space defects
FDMA Flap

• **Technique**
  • Consider doppler-ing vessel course
  • Make flap extremely wide at level of proximal phalanx
  • Center the flap around the vascular axis
  • Include the interosseous fascia as the vessel runs deep in this plane
    • Do NOT isolate pedicle from IO fascia
  • If tunneling, make sure there is no tension on pedicle
JM - FDMA Flap
JM - FDMA Flap
Axial flag flap

- Raised over the dorsum of the digit (proximal phalanx, near interdigital crease)
- Can be used to cover defect in the proximal aspect of an adjacent digit
- Good for coverage of defects with tendon exposed*
Rhomboid (Limberg) Flap

- Versatile flap that can be used to close defects almost anywhere on the body
  - Described by Limberg in 1963
  - Random pattern flap

- Advantages:
  - Defect is filled with tissue of same color/thickness
Rhomboid flap
Rhomboid flap
What’s Your Treatment?
Moberg Flap
Vaseline
Thank You