Mangled Extremity and Vascular Repair

Jason Sulkowski, MD
Case Presentation

• 9:50AM – 34 y F BIBEMS as pedestrian struck, + LOC, GCS 15 in field

• Primary Survey:
  – A: intact, speaking
  – B: bilateral breath sounds, O2 saturation 100%
  – C: SBP 90s, HR 130s, distal pulses on ¾ extremities
  – D: Numbness and paralysis of left foot

  – FAST: negative
  – CXR: no pneumothorax, no effusion
• **Secondary Survey:**

  - **Neuro:** sensation and motor absent in left lower leg
  - **Head:** laceration on posterior scalp, above right eye, and right mandible, numerous broken teeth
  - **Neck:** + midline tendernessness
  - **Chest:** left chest tendernessness
  - **Pelvis:** unstable, exquisite tendernessness
  - **Back:** large superficial abrasion along left back
  - **LLE:** open tibia fracture with 20cm skin defect, dislocated knee joint
  - **RLE:** mid femoral deformity
Before All Else…

2+ 2+

2+ 0+

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*aorta*

*iliac artery*

*superficial femoral artery*

*popliteal artery*

*tibial arteries*
Imaging Summary:

- **CT Head**: neg
- **CT C-spine**: C1 nondisplaced inferior anterior arch fracture
- **CT Chest**: small L PTX, L 2\(^{nd}\), 4\(^{th}\), 6\(^{th}\), 7\(^{th}\) rib fracture
- **CT Abd**: neg
- **CT TLS-spine**: L2-4 transverse process fractures, comminuted fracture of upper sacral alae to sacroiliac joint, comminuted L acetabular fracture, bilateral inferior and right superior pubic rami fractures
- **CTA RLE**: pseudoaneurysm of SFA, femur fracture
- **CTA LLE**: cutoff of distal popliteal artery with minimal reconstitution of posterior tibial, cuts off again at tibia fracture, peroneal and anterior tibial arteries not seen
• **ED Interventions:**
  - Foley placed
  - Bilateral LE splints
  - 2L fluid bolus
  - **Massive transfusion protocol**
    - 3u PRBC
    - 1u FFP
    - 1u Plt
  - Intubation

  - Taken to OR
11:30AM – Initial OR Course:
- Pelvic binder
- Ex-fix to LLE and pelvis

12:30PM – Bypass:
- Peroneal artery exploration
- On table angiogram showed good flow from peroneal artery to foot
- L SFA to peroneal bypass
- Non-reversed translocated greater saphenous vein, harvested from contralateral side
- On table angiogram showed runoff via peroneal bypass
- EBL: 400
- Fluids: 3000mL crystalloid, 6u PRBC, 9u FFP, 1u Plt
• **10:30PM – Orthopedic Intervention:**
  – Adjustment of LLE ex-fix
  – Pelvic reduction, fixation
  – Irrigation and debridement of L grade IIIc open tibia fracture

• **12:30AM – Interventional Radiology:**
  – Angiogram: No contrast extravasation seen
  – LLE: Abrupt cutoff of flow at distal popliteal artery with occlusion of popliteal-peroneal bypass, no reconstitution of flow distal to the popliteal artery
  – RLE: 1.2cm pseudoaneurysm seen in SFA
  – IVC filter placed
• HD2 – Left above knee amputation

• HD4 – Right femur nailing, removal of ex-fix

• HD5 – ORIF L sacroiliac joint, R superior pubic ramus, L acetabulum, pubic symphysis; CRIF R sacroiliac joint; removal of ex-fix

• HD9 – ORIF L acetabulum revision

• Since then…
  – Multiple trips to OR for hematoma evacuations, VAC changes
Questions?
Before All Else…
Lower Extremity Anatomy

- Vascular anatomy
- Nerve distribution
- Compartments
Vascular Anatomy

External iliac
Inguinal ligament
Deep femoral
Lateral femoral circumflex
Common iliac
Internal iliac
Lateral sacral
Internal pudendal
Obturator

Femoral
Genicular
Popliteal
Anterior tibial
Posterior tibial
Fibular
Dorsalis pedis
Dorsal arch

Right external iliac
Deep femoral
Lateral femoral circumflex
Femoral
Genicular
Popliteal
Peroneal
Anterior tibial
Posterior tibial
Fibular
Lateral plantar
Medial plantar
Plantar arch
Vascular Anatomy

The Venous Anatomy of the Legs
Deep System - light blue  Superficial System - dark blue
Relative Frequency of Vascular Trauma

B

Penetrating

Blunt

Rutherford’s Vascular Surgery, 8th Ed.
Compartments – Upper Leg

- Rectus femoris muscle
- Vastus medialis muscle
- Vastus lateralis muscle
- Sartorius muscle
- Adductor longus muscle
- Medial intermuscular septum
- Gracilis muscle
- Adductor magnus muscle
- Lateral intermuscular septum
- Biceps femoris muscle
- Semimembranosus muscle
- Semitendinosus muscle
Vascular Injury – Physical Exam

• **Hard signs**
  – Absent distal pulses
  – Palpable or audible thrill
  – Expanding hematoma
  – Pulsatile bleeding

• **Soft signs**
  – Diminished distal pulses
  – History of significant bleeding
  – Neurologic deficit
  – Proximity of wound to vessel

• **Hard signs present in only 30% with vascular injury**
Vascular Injury – Imaging

- Plain x-ray: evaluate for orthopedic injuries

- CTA: evaluate arterial system
  - Extravasation
  - Dissection
  - Thrombosis

- Angiography
Evaluation of Orthopedic Injuries

• Neurovascular status

• Open vs Closed

• Location

• Alignment / Articular involvement

• Rotation

• Displacement
## Gustilo Open Fracture Classification

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>Clean wound, &lt;1 cm</td>
</tr>
<tr>
<td>Class II</td>
<td>Wound &gt;1 cm, no significant tissue loss</td>
</tr>
<tr>
<td>Class III</td>
<td>Wound &gt;5 cm, tissue loss</td>
</tr>
<tr>
<td>IIIA</td>
<td>Periosteal coverage</td>
</tr>
<tr>
<td>IIIB</td>
<td>Significant periosteal loss</td>
</tr>
<tr>
<td>IIIC</td>
<td>Associated vascular injury</td>
</tr>
</tbody>
</table>

- **Early stabilization**
  - Provide comfort
  - Easier transport
  - Improve neurovascular compromise
Infection Prophylaxis

• Tetanus
  – Toxoid
  – Immunoglobulin

• Antibiotics

<table>
<thead>
<tr>
<th>Category</th>
<th>Likely Organism</th>
<th>Antibiotic</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>G+ cocci</td>
<td>1st gen cephalosporin</td>
<td>24 hours</td>
</tr>
<tr>
<td>Class II</td>
<td>G+ cocci</td>
<td>1st gen cephalosporin + gentamicin</td>
<td>24-48 hours</td>
</tr>
<tr>
<td>Class III (all)</td>
<td>G+ cocci, G- rod</td>
<td>1st gen cephalosporin + gentamicin</td>
<td>48-72 hours</td>
</tr>
</tbody>
</table>

– Add penicillin if “barnyard” or soil contamination is present
Mangled Extremity

• Damage to multiple tissue types
  – Skin
  – Muscle
  – Bone
  – Nerve
  – Blood vessels

• Primary amputation or salvage?
Mangled Extremity Severity Score

- **Retrospective analysis, 26 limbs**
  - 17 salvaged
  - 9 amputated
  - Used to develop the MESS

- **Prospective analysis, 26 limbs**
  - 14 salvaged
  - 12 amputated
  - MESS ≥7 predicted amputation in 100% of cases

# Mangled Extremity Severity Score

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Musculoskeletal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-energy</td>
<td>Stab wounds, closed fractures, low-caliber GSW</td>
<td>1</td>
</tr>
<tr>
<td>Medium-energy</td>
<td>Open or multi-level fractures, moderate crush injury</td>
<td>2</td>
</tr>
<tr>
<td>High-energy</td>
<td>Shotgun, high-caliber GSW, crush injury</td>
<td>3</td>
</tr>
<tr>
<td>Very high-energy</td>
<td>Above + contamination, tissue avulsion</td>
<td>4</td>
</tr>
<tr>
<td><strong>Shock</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>BP stable in field and in OR</td>
<td>0</td>
</tr>
<tr>
<td>Transient hypotension</td>
<td>BP unstable in field, responsive to IV fluids</td>
<td>1</td>
</tr>
<tr>
<td>Prolonged hypotension</td>
<td>SBP &lt;90 in field, responsive to IV fluids in OR only</td>
<td>2</td>
</tr>
<tr>
<td><strong>Ischemia (score x2 if &gt;6hrs)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Pulsatile limb, no ischemia</td>
<td>0</td>
</tr>
<tr>
<td>Mild</td>
<td>Pulse reduced or absent, no ischemia</td>
<td>1</td>
</tr>
<tr>
<td>Moderate</td>
<td>Pulseless, diminished cap refill; parasthesia</td>
<td>2</td>
</tr>
<tr>
<td>Advanced</td>
<td>Pulseless, absent cap refill; paralyzed, numb</td>
<td>3</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;30</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>30 to &lt;50</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>50+</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

Other Mangled Extremity Classifications

- **Predictive Salvage Index (PSI)**

- **NISSSA**

- **Limb Salvage Index (LSI)**

- **Hannover Fracture Scale (HFS)**

### TABLE 1 Components of Lower-Extremity Injury-Severity Scoring Systems

<table>
<thead>
<tr>
<th></th>
<th>MESS</th>
<th>LSI</th>
<th>PSI</th>
<th>NISSSA</th>
<th>HFS-97</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shock</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm ischemia time</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Bone injury</td>
<td>X</td>
<td></td>
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<tr>
<td>Muscle injury</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Nerve injury</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Deep-vein injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Skeletal/soft-tissue injury</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contamination</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Time to treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

*MESS = Mangled Extremity Severity Score; LSI = Limb Salvage Index; PSI = Predictive Salvage Index; NISSSA = Nerve Injury, Ischemia, Soft-Tissue Injury, Skeletal Injury, Shock, and Age of Patient Score; and HFS-97 = Hannover Fracture Scale (1997 version).*
Lower Extremity Assessment Project

• Prospective, multicenter trial (LEAP trial)
  – >600 patients 16-69 years with significant lower extremity injuries

• Analysis of 5 scoring systems’ ability to predict amputation
  – Evaluated with immediate amputations included and excluded

• Sensitivity, specificity, area under the receiver-operator curve

• Conclusion: all performed poorly

The performance of the indices in all of the injury-pattern groups indicates that these lower-extremity injury-severity scoring systems have limited usefulness and cannot be used as the sole criterion by which amputation decisions are made. Scores at or above the amputation threshold should be used cautiously by a surgeon who must decide the fate of a lower extremity with a high-energy injury.
Adapted from “Treatment Approaches to the Severely Injured Extremity”, published by American College of Surgeons Committee on Trauma, 2008.
Vascular Repair

• Ischemia time significant predictor of limb salvage or amputation

• Addressing arterial injuries early will improve salvage

• Options
  – Intraluminal shunt
  – Definitive reconstruction
Shunt: Pro & Con

• **Pro:**
  - Restore blood flow distal to injury while more life threatening thoracic / abdominal injuries are managed
  - Skeletal stabilization can protect subsequent definitive reconstruction

• **Con:**
  - Extra step that takes time and delays definitive reconstruction
  - May cause vessel complications (e.g. dissection, thrombosis)
Shunt: Pro & Con

• Pro:

• Con:
Multicenter Shunt Study Group

• Multicenter, retrospective review
  – 201 patients had temporary intravascular shunt (TIVS)
    • Included extremity and trunk injuries

• Shunt indications
  – Damage control: 63.4%
  – Combined orthopedic injury: 36.1%

• Type of shunt
  – Argyle: 81.2%
  – Pruitt-Inahara: 9.4%
  – Chest tube / Feeding tube: 9.4%

Complications prior to shunt removal:
- Thrombosis: 5.6%
- Compartment syndrome: 4.2%
- Dislodgement: 1.4%
- Amputation: 3.5%

Predictors of graft failure (after shunt):
- Noncommercial vs commercial shunt
  • Adjusted odds ratio: 6.3 (1.2-32.0)
- Damage control vs combined orthopedic surgery
  • AOR: 3.3 (1.0-10.6)

Predictor of mortality
- ISS >25
  • AOR: 16.2 (1.6-162.1)
- Notably no factors related to the shunt!

This is the largest multicenter aggregate of patients in the civilian literature who had TIVS. Both damage control and staged reconstruction for combined orthopedic and vascular injuries are common indications for this procedure. In austere environments or the rural hospital setting, surgeon or infrastructure limitations may also be mitigated by the use of shunts. With an acceptable burden of morbidity and no mortality directly attributable to the use of this technique, shunting should be considered a viable treatment option.
Upper Leg Fasciotomy
Definitive Vascular Reconstruction

- Arteriorrhaphy
- Patch angioplasty
- Resection and end-to-end anastomosis
- Resection and interposition graft
- Bypass graft
- Extra-anatomic bypass
Autogenous vs Graft

- 3 year patency for infrapopliteal reconstruction:
  - 70-80% with autogenous vein
  - 30-50% for prosthetic graft

- Autogenous: contralateral saphenous vein

- Prosthetics
  - Dacron
  - PTFE

- Vein cuff at distal anastomosis improves patency (52% vs 29% at 2 years)
Venous Repair

- Venous ligation better tolerated than arterial

- Repair *should* be attempted when possible
  - Reduce acute venous hypertension
  - Reduced phlegmasia
  - No increase in thrombosis or thromboembolism

- Ligation is best when:
  - Patient is in poor physiologic condition
  - Multiple injuries
  - Requires long segment interposition grafting or synthetics

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Summary

- **Life > Limb**

- **Primary amputation considered when**
  - Organ failure or severe shock is present
  - Crush injury, severe soft tissue loss, segmental bone loss

- **Limb salvage starts with re-establishing arterial inflow with shunt or definitive reconstruction**
Additional References


