A 22-year-old female sailor arrives to you after her left leg was hit by a piece of flying debris on the deck of an aircraft carrier. She has an obvious open fracture of her proximal left calf and no palpable pulse. On plain film, she has a severely comminuted tibial plateau fracture. On angiogram, she has a popliteal artery injury.

1. How do you reduce and stabilize the fracture?
2. Should the person get fasciotomies? If so, how?
EWS Extremity Fractures

Objectives

- Describe the initial evaluation and management of extremity fractures of upper and lower extremities.
- Debride non-viable tissue in open fractures.
- Spare viable tissue in open fractures.
- Use early antibiotics with cephazolin.
- Give tetanus toxoid as soon as possible.
- Describe the diagnosis and management of compartment syndrome.
Perform early debridement & irrigation.

Administer early antibiotics for contaminated injuries – cefazolin 1-2 gm q8 – and tetanus toxoid ASAP.

Stabilize the bone.

Preserve viable bone fragments.
- Viable soft-tissue attachment or constitute a large portion of the joint.

Preserve maximal amount of viable soft tissue.
- Ensures greatest reconstruction options at Role 3 and 4 facilities.

Open lower extremity fracture with stabilization. Requires further debridement.
Avoid internal fixation.

Casts should not be used – may act as tourniquets.

Always evaluate the neurovascular status of an extremity and check repeatedly.

Check for compartment syndrome.

Source: Emergency War Surgery, 5th U.S. Edition
Splints and External Fixation

- Splinting may be the only far-forward option.
- Most appropriate for low energy and closed fractures.
- In general, intended to limit further injury and not to definitively treat.
  - Complete reduction may not be possible.
  - Neuro-vascular exam should be conducted post-splinting.
- Must be suitable for mode of transportation.
Splints and External Fixation *(continued)*

- Use caution against constrictive/circumferential splints (avoid compartment syndrome).
- Splint should immobilize the joint above and below the fracture.
- Apply adequate padding at pressure points to prevent injury.
- Address open wounds first.
- Document date and time of most recent debridement and irrigation on the splint itself.
External Fixation over Internal Fixation

- Internal fixation at definitive care location only.
- External fixation
  - Minimizes further soft tissue trauma.
  - Provides access for wound care and re-evaluation of compartments.
  - Early fracture stabilization blunts inflammatory mediators.
  - Benefit of pain control and ease of transport.

External fixation of left lower extremity fractures
External Fixation General Principles

- An understanding of anatomy for safe insertion of pins is critical.
  - May be done without use of plain films or fluoroscopy.
  - Can be done without power instruments.

- Place enough pins to adequately stabilize fracture for transport.
  - Usually 2 pins per multipin clamp, but 3 may be required.

- In austere environment (without fluoroscopy)
  - Surgeons should make small longitudinal incisions at pin sites and spread down bluntly to avoid neurovascular bundles.
  - Stop pin advancement once purchasing the far cortex.
  - Place pins both near and far from the fracture on both bone fragments.
  - Pins may be placed to span joints if fracture extends to articular surface.
External Fixation General Principles

Pins should be a minimum of 2-3 fingerbreadths from fracture.

Bicortical placement of pins

Addition of cross-bar and two bar clamps. Apply longitudinal traction to reduce fracture and tighten the frame in alignment.

Source: Emergency War Surgery, 5th U.S. Edition
Splinting preferred in most situations due to risk of nerve injury.

- **Humerus and shoulder fractures:** sling and swath or coaptation splint
- **Forearm and elbow injuries:** long arm posterior splint or double sugar-tong splint

If fixation required, pins should be placed using an open technique.
External Fixation of the Femur

1. Placing a towel underneath the thigh helps reproduce the bow of the femur.
2. Place a 1 cm longitudinal incision in line with mid-lateral axis of the femur.
3. Place pin outside of fracture hematoma and at least 3 fingerbreadths away from fracture.
4. Pins can be placed at any point along the anterolateral aspect of the femur.
5. Use multipin clamp as a guide to place second pin.
6. Repeat for distal fragment of the fracture.
7. Connect the two clamps with elbows, bar-to-bar clamps and two longitudinal bars placed parallel to each other.

Source: Emergency War Surgery, 5th U.S. Edition
External Fixation of the Tibia

- External fixations similar to femur, although pins placed over the anteromedial face of the tibia.
- Anteromedial surface is the safest location for pins.

Source: Emergency War Surgery, 5th U.S. Edition
External Fixation to Span Knee

- Indication: Proximal tibia fracture, distal femur fracture, extensive knee injuries or vascular repairs in popliteal fossa.

- Pins placed anteromedial on the proximal tibia and anterolateral on the distal femur.
  - Slight 10°-15° flexion at the knee
External Fixation to Span Ankle

- Indication: open distal tibia fractures and open ankle wounds.
- Pins should be inserted on the anteromedial surface of the tibia and medial aspect of the calcaneus.
  - Make a longitudinal incision over the calcaneus and dissect to the bone, avoiding the posterior neurovascular structures.
  - Check distal vascular status before and after – mark where the posterior tibial and dorsalis pedis artery pulses can be felt.
Can occur with any injury to any fascial compartment.

- Fascial defect, if penetrating, may not be adequate to fully decompress the compartment.

Mechanisms of Injury

- Open fractures
- Closed Fractures
- Penetrating wounds
- Crush Injuries
- Vascular Injuries
- And more...
Clinical Signs of Compartment Syndrome

- **Early**: Pain out of proportion, pain with passive stretch, tense/swollen compartment.

- **Late**: Paresthesias, pulselessness, pallor, paralysis.
## Risks for Acute Traumatic Compartment Syndrome

| Decreased Compartment Volume | 1. Tight cast or dressing, closure of prior fasciotomy, excess traction  
2. External limb compression or crush particularly in obtunded or incapacitated casualty  
3. Frostbite, burns or electric injury (may include escharotomy) |
|-------------------------------|----------------------------------------------------------------------------------------------------------|
| Increased Compartment Contents | 1. Edema accumulation: embolism, intravascular thrombosis, replantation, venous tourniquet, injections, extravasation, infiltration, ergotamine ingestion, ischemia-reperfusion, swelling, artery injury or spasm, revascularization procedures, prolonged arterial tourniquet use, shock hypoperfusion, angiography and catheterization, limbs positioned well above heart, mal-positioned joints (ankle dorsiflexion,) or stretched muscles  
2. Prolonged immobilization and limb compression particularly with obtunded or drugged casualty, some surgical positioning  
3. Hemorrhage, hemophilia, coagulopathy, anticoagulation, vessel injury  
4. Large volume crystalloid resuscitation  
5. Fractures particularly tibia fractures in adults, supracondylar humerus fractures in children displaced, comminuted, or open fractures increase hemorrhage, swelling, and CS risk  
6. Popliteal cyst, long leg brace |

Source: JTS Acute Extremity Compartment Syndrome (CS) and the Role of Fasciotomy in Extremity War Wounds, 25 Jul 2016
Clinical diagnosis

- Formal measurement is not necessary.
- Measurements may be helpful in obtunded patients.
- $\Delta P<30$ mm Hg is an indication for fasciotomy.

Prophylactic fasciotomies are indicated when:

- High energy injuries
- Vascular repair/shunt
- High index of suspicion and limited capacity for serial examination
  - Prolonged transport times are anticipated.
  - Traumatic brain injury
  - Intubated, comatose, sedated
Risk Assessment for Extremity Compartment Syndrome

- Warm ischemia duration >12 hours?
  - YES: Establish Compartment Syndrome?
    - YES: Therapeutic fasciotomy
    - NO: Capacity to closely monitor over time?
      - YES: Prophylactic fasciotomy
      - NO: Close monitoring: Periodic reassessments
        - YES: Inter-

Source: JTS Acute Extremity Compartment Syndrome (CS) and the Role of Fasciotomy in Extremity War Wounds, 25 Jul 2016
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Compartment Releases

- All named compartments on Compartment Syndrome CPG.
- **Leg**: Release all 4 compartments (medial and lateral “H” incisions)
- **Thigh**: Release anterior and posterior, +/- medial compartment
- **Gluteal**: Release gluteus maximus

**Upper extremity**

**Calf**
**EWS Extremity Fractures**

**Compartment Releases**

- **Forearm**: Release volar and brachioradialis (a.k.a. mobile wad) +/- dorsal compartment
- **Arm**: Release anterior and posterior
- **Shoulder**: Release shoulder
- **Hand**: Release carpal tunnel and 11 compartments (you may need to refer to a book or Google)
- **Foot**: Controversial and not routinely recommended. Reviewed in ASSET.
EWS Extremity Fractures
Compartment Releases

Delayed Diagnosis of Compartment Syndrome

- Casualties with > 12 hours of warm ischemia time should NOT receive fasciotomies.

- Medical treatment for rhabdomyolysis
  - Appropriate resuscitation (goal UOP 75-100 mL/hr) and intensive support
  - Role of amputation is currently unclear; use medical judgement.

*Right forearm fasciotomy*
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EWS Extremity Fractures

References

- Joint Trauma System (JTS), Orthopedic Trauma: Extremity Fractures Clinical Practice Guideline (CPG), 26 Feb 2020.

- JTS, Acute Extremity Compartment Syndrome (CS) and the Role of Fasciotomy in Extremity War Wounds CPG, 25 Jun 2016.


*Photos are part of the JTS image library unless otherwise noted.*