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COMPARTMENT SYNDROME AND CRUSH SYNDROME

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SCENARIO

Your EMT type 2 just set up 48 hours after an earthquake has struck. There are five patients on stretchers with closed lower limb fractures requiring your care.

The first patient, a 24-year-old girl, has a mid-tibia and possibly fibula fracture.



The leg is swollen and tender and the distal status is difficult to fully assess, although there seems to be a faintly palpable posterior tibial pulse. She can, with pain, slightly move her toes and has sensation, but the translation regarding her sensation is not exact.

The remaining four patients have similar status; they have all had extremities crushed under the rubble with varying degrees of functional distal status. You suspect that they all have compartment syndrome, but what to do? At home, all the patients would get an acute fasciotomy. But here, in this context, and more than 2 days after the injury?

CASE CONTROVERSIES:

- » Will fasciotomy benefit the patient and save the limb or create more suffering?
- » What is your surgical strategy?
- » How accurate is the clinical examination in diagnosing compartment syndrome?
- » Is there any role at all for compartment pressure testing in SOD's?

 TYPE 1	<ul style="list-style-type: none"> • Analgesia & Splinting. • Record the neurovascular status of the limb. • Elevate on maximum 1 pillow. • Urgent transfer to surgical facility.
 TYPE 2	<ul style="list-style-type: none"> • Fasciotomy if indicated and less than 24 hours since time of injury. • Minimal limb elevation to reduce compartment blood flow.
 TYPE 3	<ul style="list-style-type: none"> • Delayed closure or coverage of fasciotomy incisions.

DIAGNOSIS

Early diagnosis of compartment syndrome must be made based on the clinical picture and the suspicion that acute compartment syndrome may be present.

Early symptoms include:

- » Pain out of proportion to exam (i.e. excessive pain)
- » Less than expected response to analgesia
- » Pain with passive stretching
- » Tense swelling over the compartment
- » Distal paraesthesia in peripheral nerve distribution

SPECIAL CONTEXTS

Compartment Pressure Checks in Disasters and Conflicts

- » Measuring compartment pressures cannot exclude compartment syndrome.
- » Measurement and interpretation requires experience and equipment that is not always present.
- » The value of implementing these checks in an austere setting has never truly been evaluated.
- » **Conclusion:** unless in very experienced hands, in specific situations, compartment pressure measurements are not recommended in the disasters and conflicts.

PATHOPHYSIOLOGY

- » Increased muscle compartment pressures result in impaired cellular oxygenation.
- » Any movement that increases the volume of the compartment or stretches the ischaemic fibers results in pain.
- » Subsequent fluid extravasation results in increased pressure on sensory nerves yielding distal paraesthesia. Further pressure increases overcome the protective barrier of the motor neuron's myelin sheath yielding loss of motor function.
- » Further pressure increases can overcome arterial pressures resulting in limb ischaemia and loss.

There are 2 treatment options following the diagnosis of acute compartment syndrome: fasciotomy and immobilization.

These need to be guided by the context with regard to resources as well as the overall clinical picture.

SPECIAL CONTEXTS AND COMPARTMENT SYNDROME TREATMENT

In a SOD, patients may present with compartment syndrome in a very delayed fashion. Fasciotomy will create wounds requiring care and make a closed fracture into an open fracture.

Thus, fasciotomy should not be a “knee-jerk response” to any suspected compartment syndrome. The factor of time since injury **must be included in the decision on type of treatment**.

- » **0–8h:** An injury with clinical signs of compartment syndrome should receive an urgent fasciotomy.
- » **8–24h:** It remains controversial whether fasciotomy will benefit the patient. Careful assessment should be done for signs of extremity viability (e.g. pain on passive stretching of compartment, some sensation, capillary refill) and how the patient has progressed before a decision is made regarding fasciotomy.
- » **>24h:** injuries at this time point are treated by observation and splinting in a functional position, with slight elevation (i.e. one pillow).

MISSED OR VERY LATE PRESENTING COMPARTMENT SYNDROME:

For patients with clinical evidence of muscle necrosis and possible clinical evidence of crush syndrome, urgent and massive debridement of muscle tissue may be required.

Additionally, these patients may require **intensive care and renal protective strategies**. In these cases an amputation and EMT type 3 level care may be the only option to spare the patient’s life.

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TYPE 3

KEY POINT

- » Late sequelae of “missed” compartment syndrome may cause fibrosis and contracture of muscles.
- » In the forearm this may result in “Volkmann’s contracture.”

LOWER LIMB FASCIOTOMY

Perform a two incision, four compartment fasciotomy by:

- » **A:** Make an incision through the skin 2 cms medial to the subcutaneous posteromedial edge of the tibia from the tibial flare to just behind the medial malleolus. Without undermining the skin, deepen this incision through the fascia.

This will open the superficial posterior compartment. Identify the posterior tibial neurovascular bundle and incise the thinner fascia over it. Extend this along the whole length of the fasciotomy wound to open the deep posterior compartment. In the more proximal part this will involve incising through the tibial origin of the soleus muscle.

- » **B:** Make the second incision through the skin 2 cms anterolaterally to the subcutaneous anterior edge of the tibia from the tibial flare to just above the lateral malleolus. Without undermining the skin, deepen this incision through the fascia. This will open the anterior compartment. Sweep the muscle bellies anteromedially to identify the intramuscular septum. Incise this along the whole length of the wound. This will open the lateral compartment.

This technique preserves the vascularity of fasciocutaneous flaps that can be used for later reconstruction.

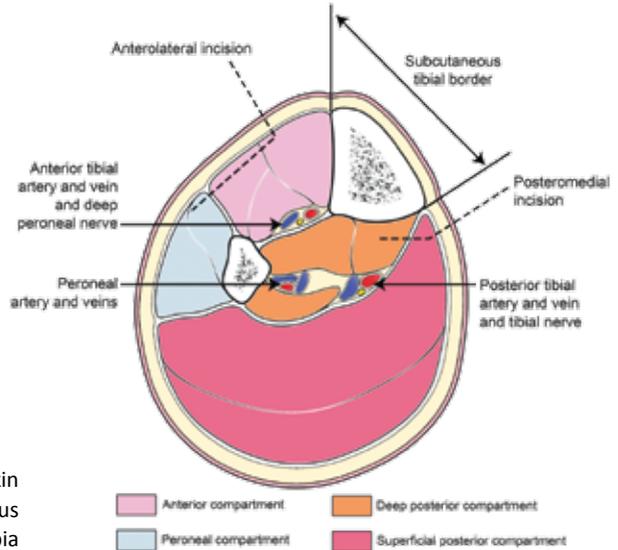


Figure 2. Illustration of the compartments of the lower leg, as well as the incisions required for performance of a 2 incision, four compartment fasciotomy. (BOA/BAPRAS)

FOREARM FASCIOTOMY

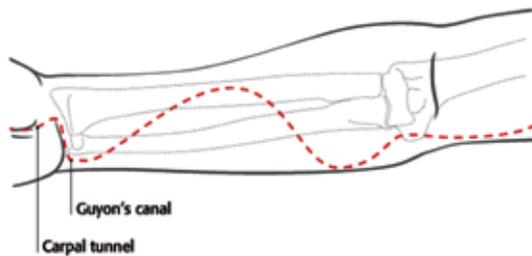


Figure 3. The standard anterior fasciotomy incision extends over the carpal tunnel and Guyon's canal distally (in order to decompress the median and ulnar nerves), continues with a curved incision towards the radial side of the mid-forearm and back to the ulnar side of the proximal forearm. It may be extended proximally across the elbow if wider access is required.

(AO Foundation, Switzerland)

POST OPERATIVE MANAGEMENT OF FASCIOTOMY INCISIONS

- » Dressing care is similar to other open wounds. Dry gauze dressings with or without a non-stick dressing on the muscle bed are reasonable.
- » Negative pressure wound therapy is also appropriate if resources are available.
- » Most fasciotomy wounds can be closed with delayed primary closure. This can be assisted by utilizing a variety of techniques designed to gradually close the wound.
- » If delayed primary closure is not possible then split thickness skin grafting (STSG) may be required.

PITFALL

FASCIOTOMY

- There is no role for subcutaneous fasciotomies in a disaster or in conflict, nor in acute trauma.
- Do not be tempted to close the wounds in the absence of early swelling—reperfusion after the fasciotomy will result in more swelling than observed at the time of fasciotomy.

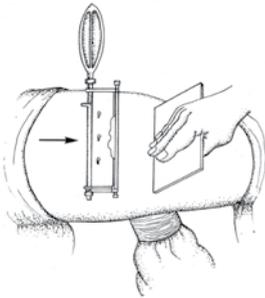


Figure 4. Dermotome being used to harvest skin from the medial thigh. Note the assistants hand applying upward pressure to flatten the donor surface. (ICRC)



Figure 5. Scalpel being used to mesh a split thickness skin graft. (ICRC)

SPLIT THICKNESS SKIN GRAFTING

- » Take small split thickness grafts with a razor blade held with forceps, for larger grafts use a skin graft knife (pictured). Apply traction using the grafting board and have an assistant apply counter traction. The graft knife is used with a back and forth sawing motion.
- » Exposed fat indicates full thickness graft, the area should have a homogenous bleeding surface if the depth is appropriate for a split thickness graft.
- » The graft can be perforated in order to prevent hematoma formation under the graft.
- » After cleaning the recipient area, lay the graft in and suture it at a few points for alignment then suture all graft edges. The sutures can be removed in 7-10 days.
- » It is preferable to leave skin graft donor site dressings in place until the area has healed, even for several weeks.

CRUSH SYNDROME

- » Crush syndrome is the severe systemic manifestation of trauma and ischemia involving soft tissues, principally skeletal muscle, due to prolonged crushing of tissues.
- » The prolonged muscle ischaemia increases cell membrane permeability and leads to the release of potassium, enzymes and myoglobin from cells.
- » This, combined with systemic hypotension, results in renal dysfunction with acute tubular necrosis and uremia.



Figure 6. Woman crushed and entrapped by rubble. This patient required a field amputation of the upper right arm in order to extricate her. (Bar-On)

SPECIAL CONTEXT: EARTHQUAKE

- » Crush syndrome can be a common presentation following an earthquake and can present in advanced stages due to the length of time required to locate and extricate victims.
- » Late presentations of crush syndrome include:
 - hypovolaemic shock
 - hyperkalaemia
 - metabolic acidosis
 - disseminated intravascular coagulation (DIC) in very late cases



Figure 7. A swollen leg with sloughing skin, concerning for underlying muscle necrosis (Bar-On)

CRUSH SYNDROME

Management of crush syndrome can require high level resources including intensive care and renal replacement therapy.

Thus, the progression of care for these patients is often dependent on appropriate management at each EMT level of classification and proper transfer between the levels depending on available resources.



TYPE 1

The type 1 EMT receiving crush patients is often a search and rescue team (SAR). These units should be prepared to:

- Secure the airway.
- Secure vascular access and commence resuscitation with normal saline 1000-1500 mL/h modified by weight.
- Monitor urine output. If no output for 3 hours following initiation of fluids then give furosemide 40 mg or 1 mg/kg IV. Repeat the dose if no output one hour after administration.
- Monitor pulse and BP. If there are signs of congestion or anuria then slow the infusion to 500-1000 mL/24hr, beyond the patient's calculated losses.
- Placement of a urinary catheter is not recommended at this level.
- Provide basic wound care and splinting if necessary.

CONTROVERSY!

When transfer to a higher level of care is available, tourniquet application to the crushed limb may prevent loss of life from hemorrhage or electrolyte abnormalities secondary to crush syndrome.



TYPE 2

- Continue fluid replacement with crystalloid and sodium bicarbonate
- Electrolyte management to control hyperkalaemia and hypercalcaemia
- Continue to force diuresis with furosemide, mannitol, or acetazolamide.
- Monitor urine output and urine myoglobin.
- Assess injury for need for possible fasciotomy, debridement, or amputation.



TYPE 3

- Continue all medical and surgical management as at levels 1 and 2.
- Consider peritoneal dialysis
- Consider transfer to a center where haemodialysis is available.
- Assess and plan for reconstruction or completion of advanced wound care for injured limb.

SUGGESTED RESOURCES

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AO/ICRC/WHO Training Resources: <http://www.aofoundation.org/icrc>