Injuries to the Extremities: Compartment Syndrome and Fasciotomy

In this chapter, anatomical considerations and techniques for performing fasciotomies of the upper and lower extremites will be discussed. Additionally the pathophysiology and diagnosis of compartment syndrome will be presented.

Considerations:

- Compartment syndrome (CS) is a limb-threatening and potentially life-threatening condition.
- Long bone fractures and vascular injuries are the most frequent antecedent events. Burns, crush injury, bleeding in enclosed spaces, external compression of the limb, small thrombotic or embolic events, envenomation, allergy, intravenous infiltration, muscle overuse, nephritic syndrome, and intramuscular injection have all been implicated.
- Current knowledge unequivocally reflects that if untreated, CS leads to tissue necrosis (Figure 1), permanent functional impairment, and, if severe renal failure and death.

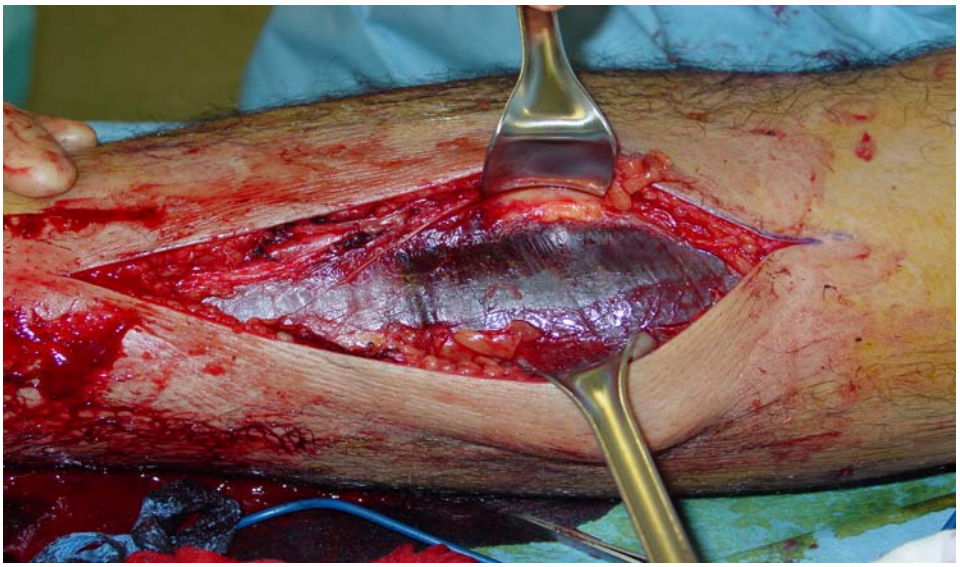


Figure 1: Necrotic muscle seen below fascia during fasciotomy for Compartment syndrome.

- CS has been found where-ever a compartment is present: Hand, forearm, upper arm, abdomen, buttock and the entire lower extremity. The lower extremity below the knee is most commonly involved.

Pathophysiology:

- Groups of muscle (with associated nerves and vessels) are surrounded by rigid osseofascial structures that define various compartments in the extremities. These osseofascial compartments have a relatively fixed volume.

- If fluid is introduced into a fixed volume, pressure rises. Introduction of excess fluid or extraneous constriction increases pressure and decreases tissue perfusion, until no oxygen is available for cellular metabolism. This can happen by one of the following mechanisms:
    - Reduction in volume – from application of a tight cast, constrictive dressings, or pneumatic anti-shock garments
    - Increase in the contents – hemorrhage secondary to fracture, blunt trauma, coagulopathy, IV infiltration, etc.
    - Vascular Reperfusion- after arterial repair

- The general consensus is that intracompartmental pressures (ICPs) greater than 30mm Hg require intervention.

- Patients with low blood pressures suffer irreversible injury at lower absolute tissue pressures than patients with normal blood pressures. Therefore poly-trauma patients are at ***increased*** risk of CS from associated hypotension.

Diagnosis:

Clinical Assessment

- Maintain a high level of suspicion in any injury that causes limb pain.

- The five Ps – pain, pallor, paresthesias, paralysis, and pulselessness are pathognomonic of compartment syndrome. However, **these are usually late signs and extensive and irreversible injuries may have taken place by the time they are manifested.**

- *The earliest and most important symptom of CS is pain greater than expected due to the injury alone.*

- Severe pain at rest or with any movement should raise a red flag.

- Pain with certain movements, particularly passive stretching of the muscles is the earliest clinical indicator of CS.

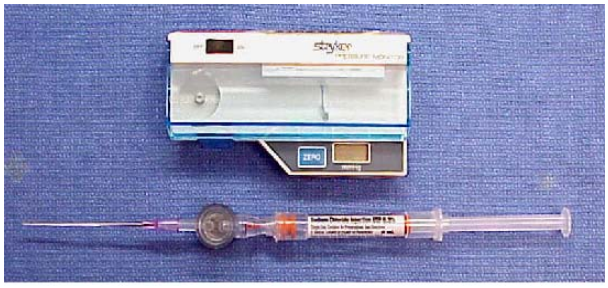
- In the anterior compartment of the lower leg, the superficial peroneal nerve is usually affected early with loss of sensation in the web space between the first two toes.

- The affected limb/compartment may begin to feel tense or hard.
- Compare the affected limb to the unaffected limb.
- *The presence of pulses and normal capillary refill does NOT exclude CS.*
- Open wounds do not exclude CS.
- Must have higher index of suspicion in polytrauma patients with associated head injury, drug and alcohol intoxication, early intubation, spinal injuries, use of paralyzing drugs, extremes of age, unconsciousness, and low diastolic pressures.
- Ultrasound is not helpful in the diagnosis of CS.

Tissue Pressure Measurements

- Measurement of tissue pressure (compartment pressure) should be dictated by history, clinical signs, and index of suspicion.
- "If one starts to think about tissue pressure measurements, one should probably be doing them."
- Pressures can be measured using Stryker STIC® Monitor (Figure 2) or by using a needle attached to an arterial line set up.

Figure 2- The Stryker STIC® Monitor is a commercial product designed to measure compartment pressures.



- The pressure threshold for Fasciotomy is controversial
  - A number of authors recommend 30 mm Hg (Most commonly used)
  - Others cite as high as 45 mm Hg.
  - Some urge prophylactic fasciotomy in high risk patients at normal pressures to prevent CS
- Other factors to consider are length of time of transport to definitive care and ability to do serial exams.
- "Normal" compartment pressures should not preclude fasciotomy in patients with obvious clinical findings of CS.

- All compartments in the affected extremity should be measured, as one compartment can be high while the others are not.

- Knowledge of compartment anatomy is necessary to measure all compartments.

SURGICAL FASCIOTOMY

Lower Leg Fasciotomy

- The lower leg is the most common site for CS requiring fasciotomy.

- The lower leg has four major tissue compartments bounded by investing muscle fascia (see Figure 3).

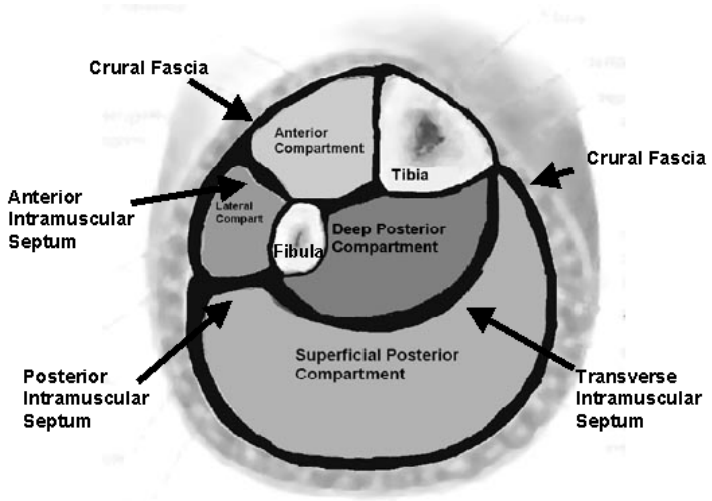


Figure 3: Cross sectional anatomy of the mid-portion of the right lower leg depicting the four compartments that must be released when performing a lower leg two incision four compartment fasciotomy.

- The lower leg is the most common and most reliable technique for treating or preventing CS in the lower extremity is a two incision four compartment fasciotomy.

- Proper fasciotomy requires a through understanding of the underlying anatomy and the landmarks for each incision should be marked prior to incision as distortion of the anatomy is likely to occur once the incision is made.

- The lateral incision is made in a line one finger breadth (1-2 cm) anterior to the edge of the fibula. In the swollen extremity the fibular may not be easily palpable and therefor a line is drawn from the fibular head to the lateral malleolus to mark the course of the fibula (figure 3).

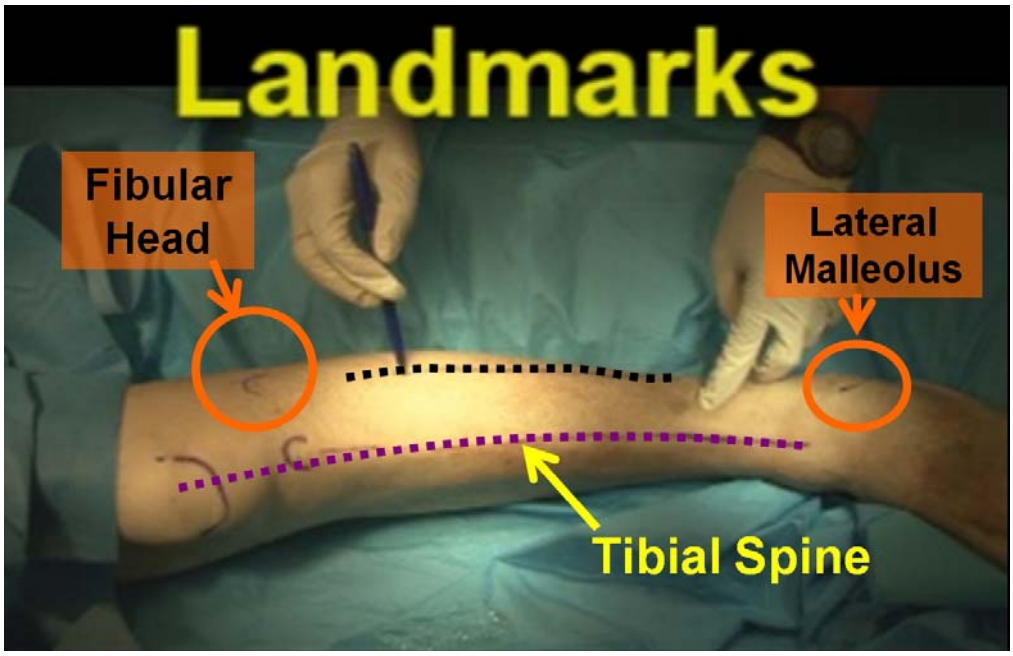


Figure 3. The fibular head & lateral malleolus are used reference points to mark the edge of the fibula & the lateral incision is made one finger breadth anterior to this. The tibial spine serves as a midpoint reference between the two skin insicions.

- The medial incision is made one fingerbreadth just posterior to the medial edge of the tibia and should be generous in length (Figure 4).

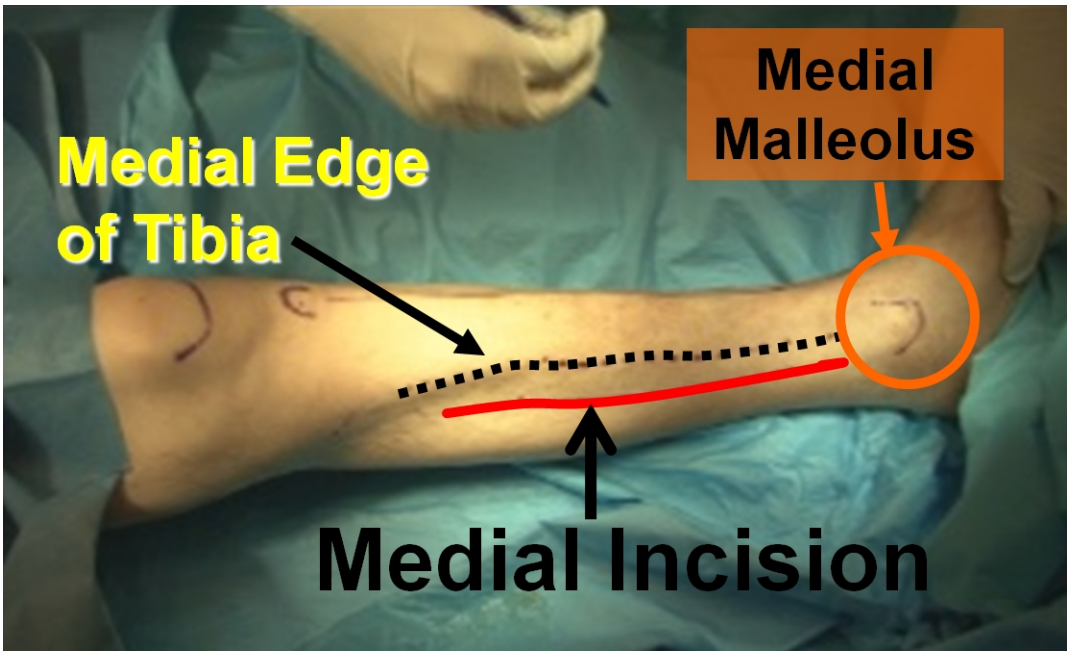


Figure 4. The medial incision is made one finger breadth below the medial edge of the tibia.

- Proper selection of the site of the incision makes access to all four compartments much easier to achieve (Figure 5).

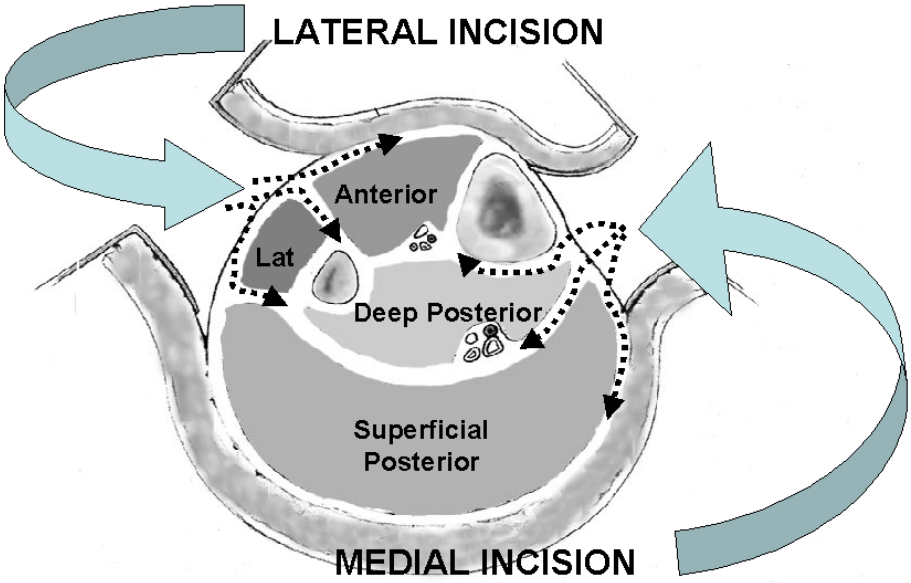


Figure 5: Two incision four compartment fasciotomy. The lateral incision provides access to the lateral and anterior compartments. The medial incision provides access to the superficial and deep posterior compartments.

The Lateral Incision:

- The lateral incision of the two incision four compartment fasciotomy is carried down though the skin and subcutaneous tissues until the fascia is exposed with care taken to avoid the lesser saphenous vein and the peroneal nerve.

- The intermuscular septum is identified which serves as a landmark dividing the anterior and lateral compartments (Figure 6).

- The Intramuscular septum can be very difficult to appreciate in the swollen of damaged/deformed extremity. In this setting it is useful to follow perforating vessels to the fascia as they enter at the intramuscular septum and will thus help identify it.

- The Fascia of both the anterior and lateral compartments are opened with scissors classically in an “H” shaped fashion with the cross piece of the “H” made across the intramuscular septum and the legs of the “H” extending the full length of the fascia compartments (Figure 7).

- Upon completion of the fasciotomy , identification of the septum and the Deep peroneal nerve ensures entry into both the lateral and anterior compartments (Figure 8).

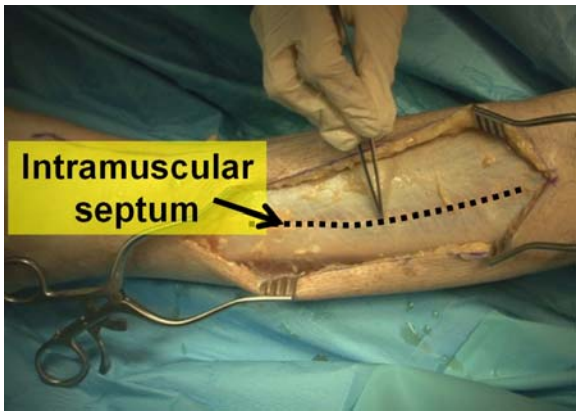


Figure 6: The lateral incision on this left lower extremity nicely demonstrates the intramuscular septum which separates the anterior and lateral compartments of the lower leg.

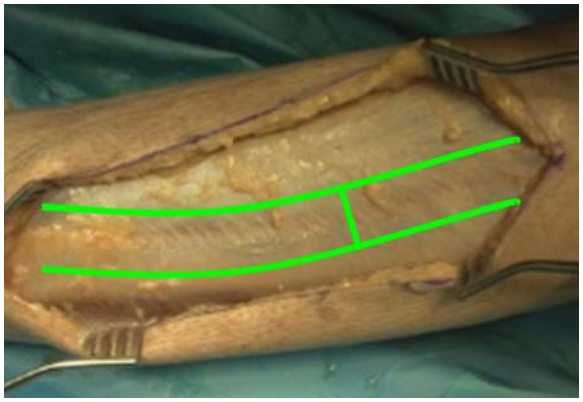


Figure 7: The fascia of the lateral lower leg is classically opened in a "H" shaped fashion for the length of the compartments

Figure 8: Once the fascia have been opened identification of the septum and deep peroneal nerve confirms entry into both compartments

The Medial Incision:

- The medial incision is made posterior to the medial edge of the tibia and the incision is carried down through the skin and subcutaneous tissues taking care to both identify and preserve the saphenous vein (figure 9).

- The fascial underlying the inscision is open the length of the compartment decompressing the superficial posterior compartment (Figure 10).

- Entry into the deep psosterior cpompartment is accomplished by bluntly and sharply taking down the fibers of the soleus muscle off the edge of the tibia (Figure 11).

- Identification of the neurovascular bundle confirms entry into the deep posterior compartment (Figure 12).

Figure 9: The medial incision is made below the edge of the tibia and the saphenous vein seen just below the retractor is preserved.

Figure 10: The fascia below the incision is opened decompressing the superficial posterior compartment.

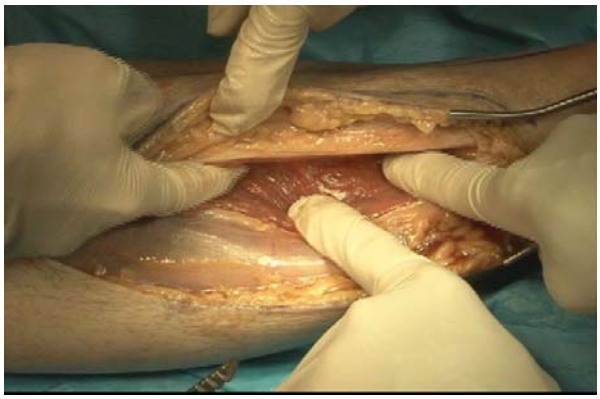


Figure 11: dissecting the soleus muscle fibers off the undersurface of the tibia allows entry into the deep posterior compartment.

Figure 12: Identification of the neurovascular bundle further confirms that the deep posterior compartment has been entered.

- Swollen edematous muscle will protrude though the fascial incisions once the compartments are decompressed (Figure 13).

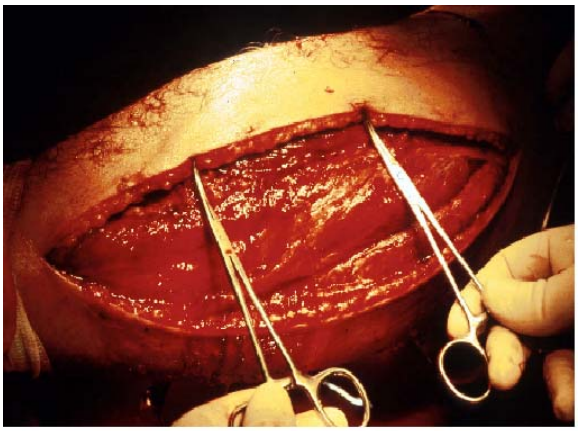


Figure 13: Swollen edematous muscles from posterior compartment following medial incision for fasciotomy of lower leg. This muscle appears to be viable.

- The muscle in each compartment should be assessed for viability. Viable muscle is pink, contracts when stimulated, and bleeds when cut.

Pitfalls of Lower Extremity Fasciotomy:

- The anterior and deep posterior compartments are the most commonly missed when performing fasciotomies and increase morbidity and mortality (figure 14).
- Skin incisions should be generous as the skin can act as a constricting element to an otherwise well performed Fasciotomy.
- Fascial incisions should be carried the full extent of the fascial compartment.
- Avoid injury to saphenous vein and peroneal nerve.

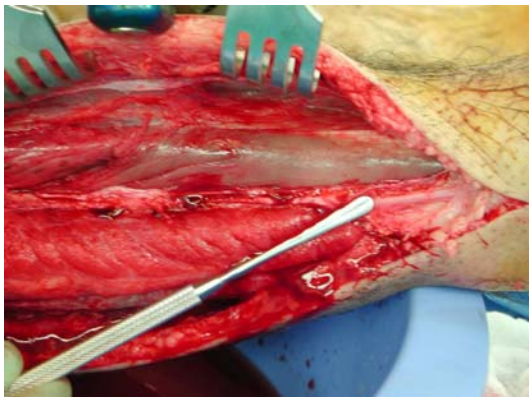


Figure 14: Dead muscle in the anterior compartment on re-exploration for incomplete fasciotomy

COMPARTMENT SYNDROME OF THE FOOT:

- Compartment syndrome of the foot can occur in up to 10% of calcaneal fractures and in up to 41% of crush injuries of the foot.
- Unlike the leg or forearm, there are no classic signs in the foot. Pain on passive stretch and diminished pulses are not consistent physical findings.
- Tense tissue bulging may be the most reliable finding.
- Must maintain a high index of suspicion.
- Pressure measurement of all major compartments is required. Absolute pressures > 30 mm Hg or pressures less than 20 mm Hg below the diastolic blood pressure requires decompression.

- All four compartments of the foot must be released. (Figure 15)
  - Interosseous or Intrinsic compartment
    - Contains the 4 intrinsic muscles between the 1st & 5th metatarsals
  - Medial compartment
    - Contains the abductor hallicus and the flexor hallicus brevis
  - Central or calcaneal compartment
    - Contains the flexor digitorum brevis, quadratus plantae, and the adductor hallicus
  - Lateral compartment
    - Contains flexor digiti minimi brevis and abductor digiti minimi

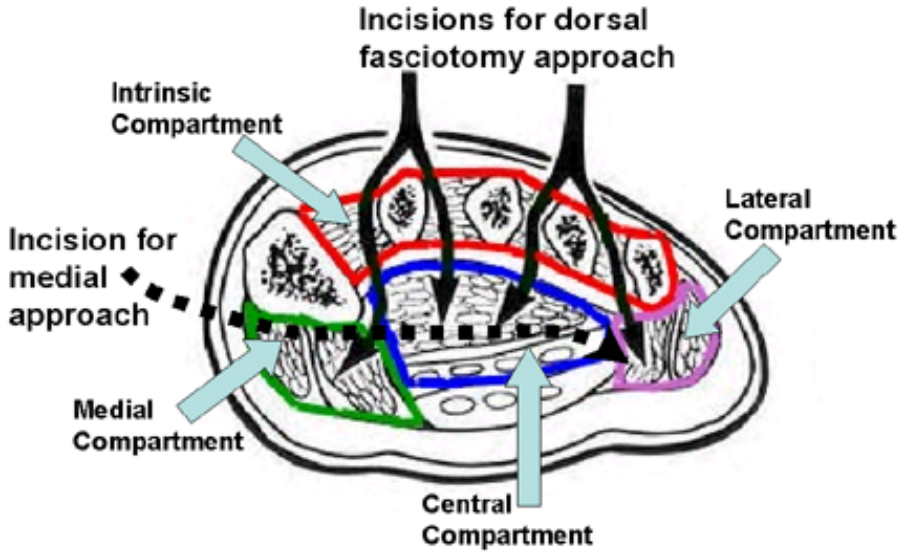


Figure 15: Dorsal and medial approaches to foot for four compartment fasciotomy. Two incisions just medial to the 2nd metatarsal and just lateral to the 4th allows for access and decompression of all four compartments of the foot. A Medial incision allows easier approach to medial & central compartments.

COMPARTMENT SYNDROME OF THE THIGH

- Compartment syndrome of the thigh is uncommon in the thigh because of the large volume that the thigh requires to cause an increase in interstitial pressure

- The fascial compartments of the thigh blend anatomically with the hip allowing for extravisation of blood or fluid outside the compartment

- Predisposing factors include: Intra-medullary nailing of femoral fractures, severe blunt trauma/crush injury to thigh, vascular injury, iliofemoral DVT, and use of military antishock trousers or other external compression of the thigh.

- The thigh contains three compartments – Anterior, posterior & medial (Figure 16A)

- A lateral incision of the thigh is performed first (Figure 16B). This is usually sufficient to relieve compartment syndrome of the thigh. Occasionally a medial incision will be needed as well.

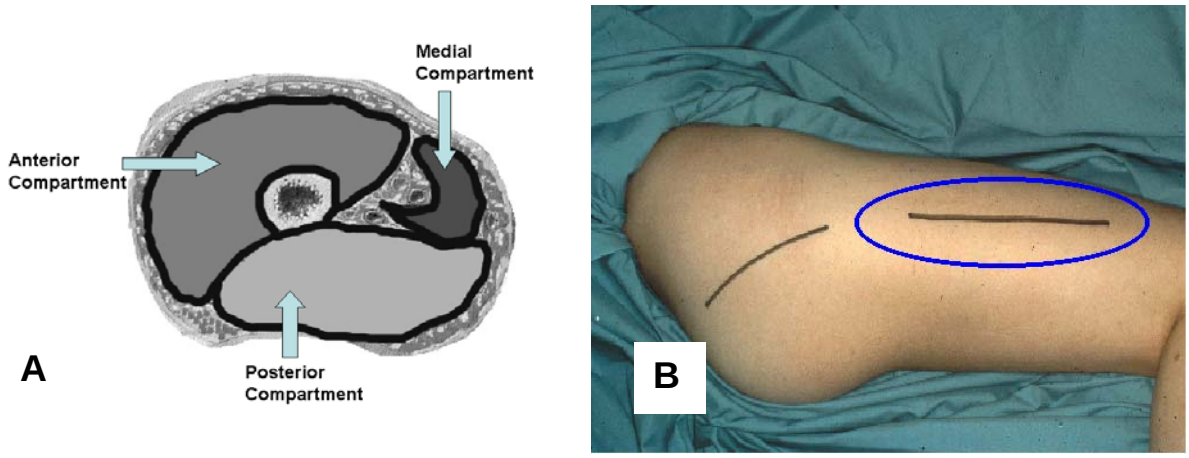


Figure 16: The thigh has three compartments as depicted in A. Fasciotomy of the thigh begins with a lateral incision as seen in the circle (B).

COMPARTMENT SYNDROME OF THE FOREARM AND HAND

- Compartment syndromes of the hand and forearm are much less common than in the lower extremity.

- Antebrachial CS may follow supracondylar fracture of the humerus

- Forearm CS may be associated with fractures, crush injury, burns or vascular injury.

- The anterior compartment of the forearm including the carpal tunnel is released via a volar incision first (Fig. 17a), followed by a dorsal incision for posterior compartment if needed (Fig. 17b).

- CS of the hand can occur from trauma but most often occur from iatrogenic injuries (A-line or infiltration of IV medications)

- The hand contains 10 separate osseofascial compartments which typically can be released with carpal tunnel release (fig. 17a & 17b) and 1 to 2 dorsal incisions (fig 17c & 17d).

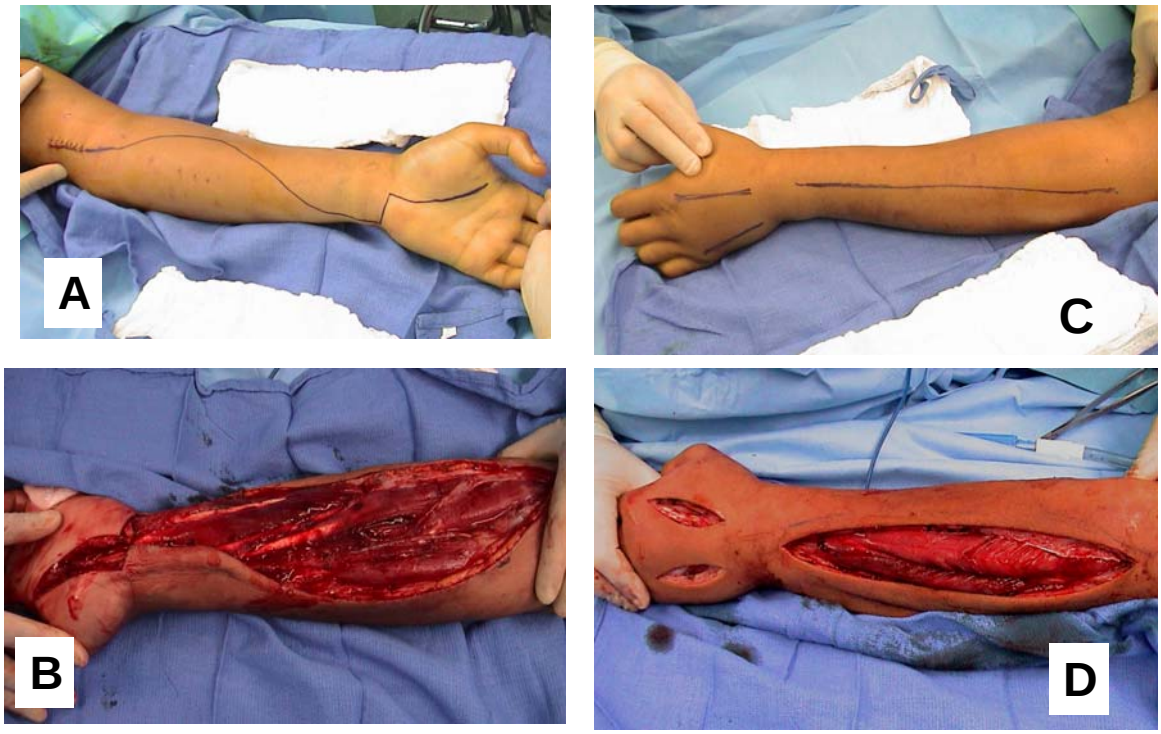


Figure 17. The volar incison (landmarks A & resultant exposure B) allows for decompression of the anterior compartment and may be carried down to the carpal tunnel or up onto the arm. The dorsal incision (landmarks C & resultant exposure D) decompresses the posterior compartment of the forearm and can be used to decompress the hand.

- Symptoms in the hand do not include abnormalities of sensory nerves as there are no nerves within the compartment.

- The pressure threshold for CS in the hand is much less than in the legs (15-20 mm Hg is indication for release)

- Involve a hand surgeon early if hand CS is suspected.

- Must maintain high index of suspicion.

AFTER CARE

- Necrotic muscle should be debrided at time of original fasciotomy.
- Open wounds should be covered with non-adherent dressing or moist gauze.
- The wound should be re-evaluated 24-48 hours later with further debridement as indicated
- Delayed primary closure or split thickness skin grafting may be performed after acute process subsides.
- Be on the look-out for rhabdomyolysis and treat if present.

COMPLICATIONS

- Infection
- Incomplete Fasciotomy
- Loss of limb
- Permanent nerve damage
- Cosmetic deformity from fasciotomy
- Multi-system Organ failure and Rhabdomyolysis
- Death