# Acute Extremity Compartment Syndrome

Stephanie Savage, MD

Editorial Review: Clay Cothren Burlew, MD
Marc de Moya, MD
Kimberly A. Davis, MD MBA

## Injury/Disease Demographics

- The incidence of acute extremity compartment syndrome (ECS) is 7.3/100,000 in men and 0.7/100,000 in women. It most commonly occurs in the lower leg but is also seen in the thigh, forearm, hand, foot, and gluteal region (in order of frequency).
- ECS may be induced by direct tissue injury, tissue hypoxia or ischemia reperfusion injury. Trauma is the most frequent inciting agent.
- ECS occurs when the interstitial tissue pressure overwhelms venous pressures resulting in collapse of venules, venous congestion and loss of the pressure gradient between venous and arterial systems. Cellular hypoxia results in increased vascular permeability with leak into the interstitium compounding the problem. It is a microvascular phenomenon.
- Nerves are the most sensitive to hypoxic insult. Initial changes may occur after as little as one hour of hypoxia. Permanent injury may be seen after 4 hours ischemia. Irreversible muscle necrosis may occur after 4 hours of ischemia.
- The anterior and lateral compartments are the most frequently affected in the lower leg.
- In trauma, ECS is most commonly associated with fractures. It is also seen in patients with dislocations and vascular injuries.
- Less common causes of ECS include thermal injury, electrocution, improper operative positioning (lithotomy position), external compression, envenomation, Streptococcal infections, extravasation of intravenous agents and some medical conditions (coagulopathy, nephrotic syndrome, rhabdomyolysis).

## Clinical Presentation

- ECS is commonly associated with fractures, with 36% of patients with tibial fractures developing associated compartment syndrome.
- The most common presenting sign is pain out of proportion to injury or pain poorly controlled by analgesics. Neurologic deficits in the affected leg should also raise clinical suspicion.
- The 5 P's are commonly taught and include pain, paresthesias, pallor, paralysis, and poikilothermia (some authors include pulselessness) for acute arterial occlusion. However, pallor, paralysis, poikilothermia, and particularly pulselessness are often late findings and should not be relied upon for diagnosis for ECS.
- Physical exam may reveal a distended or tense compartment and pain with passive flexion of the ankle. However, physical exam is not reliable, especially as many patients are unable to participate in the exam due to pain from tibial fractures or lack of mental status from a traumatic brain injury.
- Decreased sensation in the first webspace of the foot due to peroneal nerve ischemia is common.
- A sequela of ECS, rhabdomyolysis, is diagnosed using serum creatine kinase (CK) levels and evidence of myoglobinuria.

## Evaluation/Diagnostics

- A diagnosis of ECS is made with clinical history, physical exam, and a measurement of compartment pressures.
- There are several common methods for measuring compartment pressures:
    - arterial line arrangements with side-port needles
    - self-contained pressure measurement apparatuses (such as the Stryker)
    - slit catheters.
- Normal compartment pressures for adults are ~ 8 mmHg. Normal compartment pressures in children are 10-15 mmHg.
- Absolute compartment pressures may be measured and generally warrant intervention when 30 mmHg is reached. The indication for decompressive fasciotomy may be reached at a lower absolute pressure based on the clinical history and exam.
- The differential pressure ($\Delta P$) is generally considered a better indicator for the need for fasciotomy, as it takes into account the patient's native blood pressure. The equation is:

  Diastolic blood pressure – compartment pressure = $\Delta P$
- A $\Delta P \leq 30$ mmHg is considered diagnostic for compartment syndrome.
- Continuous pressure monitoring is possible via an indwelling catheter but is not widely adopted.

## Imaging

- Radiographs should be performed to evaluate for fracture.
- Some newer imaging methods have been used to diagnose acute extremity compartment syndrome:
    - near infrared spectroscopy works much like pulse oximetry to detect changes in oxygen tension
    - 99Tcm-methoxy-isobutryl isonitril scintigraphy
    - laser flowmetry
- No imaging technique is the considered standard of care for the diagnosis of acute ECS.

## Role of Conservative Management and Associated Conditions

- If concern exists for compartment syndrome the following measures should be considered before definitive treatment:
    - loosening constrictive bandages or devices
    - repositioning the patient
    - splinting the extremity if fractured
    - elevation of the extremity

- Muscle necrosis and cell death may result in hyperkalemia and acidosis. The clinician should monitor for these findings, which can lead to renal injury and cardiac arrhythmias.
- Tissue injury, muscle necrosis and cell death may lead to rhabdomyolysis. Measuring creatine kinase levels and urine myoglobin is indicated. If elevated, the optimal management is aggressive fluid resuscitation and monitoring of urine output with a foley catheter, with a goal urine output of 1-2 cc/kg/hr.
- Commonly associated conditions include fractures, dislocations and vascular injuries. Multi-system trauma may result in a diversity of injuries, which render the patient unable to respond to physical exam or clinical questions. Ability to properly monitor the patient should be considered when opting to pursue non-operative management.
- Surgical decompression is likely the most conservative approach and should be pursued if concern for compartment syndrome is high.

## Indications for Operative Treatment

- Acute extremity compartment syndrome is considered a surgical emergency.
- Fasciotomy for ECS should be considered in patients with any of the following:
    - clinical history and exam concerning for acute ECS
    - a $\Delta P \leq 30$ mmHg in a clinical setting concerning for acute ECS (alternatively an absolute compartment pressure > 30 mmHg)
    - an elevated clinical suspicion in a patient who is unable to participate in clinical exam or who will not be available for frequent evaluation (ie during long transport periods)
    - prophylactically following repair of a vascular injury in the setting of prolonged ischemia ($\geq$ 6 hours)
    - prophylactically for combined arterial and venous injuries
- Operative decompression should happen as soon as a compartment syndrome is identified. Studies indicate improved outcomes if decompression occurs within 8 hours, but irreversible tissue ischemia can occur much sooner.

## Pre-Operative Preparation & Impact of Associated Injuries

- Hyperkalemia and acidosis should be corrected.
- Appropriate fluid resuscitation should be instituted

## Operative Technique

- Widely opening of the fascia is required to ensure adequate decompression of the compartments. The muscle should be inspected for viability. if non-viable muscle is identified, debridement is required.

- The skin should not be closed and, in acute cases, minimally invasive techniques should be avoided. Intact skin may prevent adequate decompression of compartments due to considerable swelling
- In some cases, the fasciotomy should be performed prior to reperfusion. Placement of a vascular shunt permits temporary reperfusion for arterial injuries and should receive first priority.
- At the second exploration, fasciotomy sites may be dressed with crossing vessel loops to prevent retraction of the skin. Alternatively, negative pressure dressings may be used.

*Specifics of the Technique:*

- Lower extremity:
    - The leg has four compartments: anterior, lateral, superficial posterior and deep posterior.
    - Decompression is accomplished with two incisions.
    - The lateral incision should be made over the intermuscular septum, which is located approximately half way between the fibula and lateral edge of the tibia, just over 2 finger breadths posterolateral to the edge of the tibia. Care should be taken to avoid the superficial peroneal nerve. The incision should extend approximately 15cm to ensure wide skin opening. Suprafascial flaps are created and if the septum is not readily seen one may make a transverse incision in the fascia to easily identify both compartments. A common mistake is not decompressing both anterior and lateral compartments. The fascia should be opened the full length of the muscle. *tip: point the tip of the scissors away from the septum to avoid injuring the superficial peroneal nerve.
    - The medial incision should be made approximately 2 cm posterior to the subcutaneous border of the tibia.
    - The deep posterior compartment is located by removing the muscular attachments of the soleus to the medial surface of the tibia. Once passed these attachments one enters the deep compartment.
- Thigh:
    - The thigh has three compartments: anterior, posterior and medial.
    - Fasciotomy may be completed with a single or double incision. An incision is made along the lateral aspect of the thigh from the greater trochanter to the lateral aspect of the femoral condyle. Incision of the intermuscular septum, after reflecting the vastus lateralis, will release the anterior and posterior compartments. The medial compartment is most easily released with a separate anteromedial incision.
- Upper extremity:
    - Compartment syndromes of the arm are uncommon.
    - The upper arm has two compartments and the forearm has three.
    - The hand has ten compartments and will likely require a specialist for full decompression.
    - Care should be taken to release the carpal tunnel when addressing compartment syndromes of the upper extremity.

    - When decompression of compartments of the upper extremity require an incision that crosses a joint, a curvilinear incision is required. Straight incisions should be avoided as they may lead to late contracture.
- The foot:
    - Has nine compartments.
    - Compartment syndrome is uncommon and is often treated without surgical decompression.
    - A foot and ankle specialist should be involved in management of this problem.

## Post-Operative Management

- The skin should be left open and the muscle bellies should be visually inspected at least daily.
- If viability is in question, or CK continues to rise, evaluation in the OR is indicated to allow thorough inspection.
- Wounds may be managed with wet-to-dry dressings or negative pressure dressings.
- Attempts at closure should be delayed until swelling decreases, the patient is out of the acute injury period and is physiologically stable for a semi-elective procedure. Closure should never be rushed as it could lead to a recurrence of compartment syndrome if swelling recurs.
- Primary closure of the skin is ideal when possible; however, persistent swelling may make this impossible. In these cases, a split thickness skin graft is the management of choice. The fascia itself should not be reapproximated.
- Thigh incisions have a relatively high incidence of post-operative infectious complications, approaching 67%. Clinicians should remain vigilant and inspect wounds frequently.

## Complications

- Failure to release all compartments in the affected extremity may lead to muscle necrosis
- Long-term complications may include chronic pain, contractures, weakness and neurologic deficits. In the most severe cases, amputation may be required.
- Systemic complications may include renal failure if rhabdomyolysis remains untreated. Patients may develop cardiac arrhythmias, multi-organ failure or even progress to death if hyperkalemia and acidosis remains untreated.

## Considerations for Special Populations

- Children may be difficult to diagnose due to anxiety related to injury and difficulty communicating at early ages. In children, the 3 ‘A’s’ have been

described as signs of potential compartment syndrome : agitation, anxiety and increased need for analgesia. However, assessment, diagnosis and treatment are largely the same.

- Poly-trauma patients may have a constellation of injuries that make detection of compartment syndrome difficult (ie inability to communicate pain, dressings and splints which obscure exam). Extra vigilance is required and a lower threshold for surgical decompression may be indicated.

**Suggested Readings**


- von Kuedell AG, Weaver MJ, Appleton PT, et al. "Diagnosis and treatment of acute extremity compartment syndrome." *The Lancet* 386; 2015: 1299-1310.
- Farber A, Tan TW, Hamburg NM etal. "Early fasciotomy in patients with extremity vascular injury is associated with decreased risk of adverse limb outcomes: a review of the National Trauma Data Bank." *Injury* 43; 2012: 1486-91.
- Leversedge FJ, Moore TJ, Peterson BC & Seiler JG III. "Compartment Syndrome of the Upper Extremity." *J Hand Surg* 36A; 2011: 544-60.
- McQueen MM, Duckworth AD, Aitken SA etal. "The estimated sensitivity and specificity of compartment pressure monitoring for acute compartment syndrome." *J Bone Joint Surg Am* 95(8); 2013: 673-7.