emDocs

The EM Educator Series

The EM Educator Series: Compartment Syndrome Pearls & Pitfalls

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Case: A 24-year-old male was hit by a car at low speeds and suffered a tibia fracture. He suffered no other injuries and has been splinted. However, his pain continues to increase, despite repeated doses of morphine.

Questions for Learners:

1. When should you consider the diagnosis of compartment syndrome, and who's at risk?
2. What are the most common anatomic locations involved in compartment syndrome?
3. What is your differential for pain out of proportion? What other conditions cause severe pain?
4. What are the problems with the 6 P's? What about severe pain and/or paresthesias plus a risk factor for compartment syndrome?
5. How do you calculate delta pressure?
6. What is the management of compartment syndrome?
7. What are the complications if the diagnosis is missed?

Suggested Resources:

- Articles:
  - CoreEM
  - emDOCs
  - LIFTL
  - Emergency Medicine Cases
  - Orthobullets – Leg
  - Orthobullets – Hand and forearm
- PMID:
  - EM Clinics North America
  - Journal of Emergency Medicine

Answers for Learners:

1. When should you consider the diagnosis of compartment syndrome, and who's at risk?

ACS is most common in patients < 35 years of age. These patients have increased risk of high-energy injuries, stronger fascia, and greater muscle bulk. Males are 10x more likely to experience ACS compared to females. Elderly patients have reduced muscle mass and more commonly hypertension, which increases perfusion pressures. ACS most commonly occurs within 24 hours of the injury, but it can be delayed for days. Fractures are the most common cause, especially tibia fractures (2-9% of tibial fractures result in ACS). An open fracture does not mean ACS cannot occur, as the small fascial tears from these injuries do not decompress the compartment. Keep in mind that a variety of risk factors are associated with ACS:

- Blunt soft tissue injuries	- Insect bites
- Burns	- Intramuscular hematomas
- Casts	- Intraosseous infusions
- Deep venous thrombosis	- Intravenous infusions
- Electromyography	- Osteotomies
- Exercise	- Prolonged immobilization
- Extravasation of contrast media	- Punch biopsies
- Fractures	- Skin and skeletal traction
- Hematologic diseases	- Snake bites
- Incorrect patient position during surgery	- Vascular procedures
- Infections	

BOX 54-1 Causes of Compartment Syndrome

DECREASED COMPARTMENTAL VOLUME
Closure of fascial defects
Application of excessive traction to fractured limbs
Compressive devices (casts, splints, circumferential dressings)

INCREASED COMPARTMENTAL CONTENTS
Bleeding
Major vascular injury
Coagulation disorders
  Bleeding disorder
  Anticoagulation therapy
  Thrombolytic therapy
After placement of an arterial line

INCREASED CAPILLARY FILTRATION
Reperfusion after ischemia
  Arterial bypass grafting
  Embolectomy
  Ergotamine ingestion
  Cardiac catheterization
  Lying on the limb
Trauma
  Fracture
  Contusion
Intensive use of muscles
  Exercise or severe exertion
  Seizures
  Eclampsia
  Tetany
Burns
  Thermal
  Electric
Intraarterial drug injection
Cold
Orthopedic surgery
  Tibial osteotomy
  Hauser's procedure
  Reduction and internal fixation of fractures
Snakebite

INCREASED CAPILLARY PRESSURE
Intensive use of muscles
Venous obstruction
  Phlegmasia cerulea dolens
  Ill-fitting leg brace
  Venous ligation

DIMINISHED SERUM OSMOLARITY, NEPHROTIC SYNDROME

OTHER CAUSES OF INCREASED COMPARTMENTAL CONTENTS
Infiltrated infusion
Pressure transfusion
Leaky dialysis cannula
Muscle hypertrophy
Popliteal cyst
Carbon monoxide poisoning

EXTERNALLY APPLIED PRESSURE
Tight casts, dressings, or air splints
Lying on the limb
Pneumatic antishock garment
Congenital bands

Modified from Matsen FA. Compartmental Syndromes. *New York: Grune & Stratton, 1980.*

2. What are the most common anatomic locations involved in compartment syndrome?

In the lower extremity, ACS most commonly affects the anterior compartment. Concern for ACS within the proximal leg or thigh requires a check of the anterior compartment of the thigh (due to its more frequent involvement), but isolated posterior compartment involvement can occur. For ACS of the foot, the interosseous intracompartmental pressure should be measured, and for hindfoot injuries, the calcaneal compartment should be assessed. ACS is most common in the volar compartment of the

forearm for the upper extremity, but isolated dorsal ACS can occur. Monitoring of the arm anterior compartment and interosseous compartments of the hand is recommended.

3. What is your differential for pain out of proportion? What other conditions cause severe pain?

4. What are the problems with the 6 P's? What about severe pain and/or paresthesias plus a risk factor for compartment syndrome?

In the patient with severe trauma, the ABC's come first. The injured extremity can be assessed after the ABCs, but keep in mind the key risk factors (Table 1), as well as any change in symptoms. Findings are often subtle, and **early findings may only be found in alert patients**. Diagnosis is tough in patients with altered mentation, severe trauma, substance abuse, and patients at the extremes of age. Severe pain is the earliest symptom (often out of proportion to exam). **Patients often describe severe, burning, deep pain and worse with passive stretching, but pain is subjective and has poor sensitivity**. **Later symptoms include paresthesias, sensory deficits, and focal motor deficits. Pain can resolve in later stages with necrosis**. **Exam can reveal pain with palpation, pain with passive stretch, a tense or firm compartment, swelling of the affected limb, focal motor or sensory deficits, or decreased pulse or capillary refill.** Paralysis and lack of pulses are rare, and compartment firmness is not reliable. Swelling is common, but again, subjective. **The key to diagnosis is clinical suspicion and repeat exams**! Digital palpation of the compartment is unreliable, with 49% sensitivity and 79% specificity for ACS of the hand and 24% sensitivity and 55% specificity for ACS of the leg. Abnormal pulse oximetry suggests poor limb perfusion, but a normal reading does not rule out ACS.

Diagnostic Accuracy of Clinical Findings[9]

Finding	Sensitivity	Specificity	PPV	NPV
Pain	19%	97%	14%	98%
Pain with Passive Stretch	19%	97%	14%	98%
Paresthesia	13%	98%	15%	98%
Paresis	13%	97%	11%	98%

PPV, positive predictive value; NPV, negative predictive value

Overall, signs and symptoms can suggest the diagnosis, but they are not definitive. **Combining factors is better.** A combination of pain with rest, pain with passive stretch, paralysis, and paresthesias increases sensitivity to 93%.[9] Keep in mind that using clinical signs or symptoms alone is not recommended. Delayed diagnosis results in poor outcomes including infection, muscle necrosis, rhabdomyolysis, renal failure, muscle contractures, neurologic injury, chronic pain, fracture, amputation, and death. Missed diagnosis is associated with clinician inexperience, patient sedation, polytrauma, soft tissue injury, and reliance on signs and symptoms alone.

5. How do you calculate delta pressure?

What's this about using intracompartmental pressure alone versus differential pressure (ΔP)? The normal resting pressure within muscle is close to **8-10 mm Hg in adults and 10-15 mm Hg in children**. **Previous recommendations used an absolute intracompartmental pressure of 30-40 mm Hg as a threshold for fasciotomy**. The problem with using an absolute pressure is that patients can .vary widely concerning intracompartmental pressures, Also, different compartments have different pressure thresholds. Take the hand: an intracompartmental pressure > 15-20 mm Hg in the hand is a relative indication for fasciotomy. The key is perfusion pressure, but this can also vary based on many factors (age, pre-existing hypertension, vascular disease). **The differential pressure is the diastolic pressure minus the intracompartmental pressure**. Studies suggest that **differential pressures of <30 mm Hg are an indication for fasciotomy**, though critical ΔP is probably higher in muscle undergoing trauma or ischemia.

A dynamic relationship exists among blood pressure, intracompartmental pressure, and time of elevated pressures. **Higher pressures result in severe damage over a short period of time, but lower pressures sustained for long periods of time can cause similar damage**. Do you need multiple measurements? Some use repeat clinical assessments, while others recommend continuous monitoring with a catheter attached to an arterial transducer in patients for whom assessment is difficult. **The issue with single compartment measurement is that this can result in overdiagnosis and overtreatment**. Several different protocols can be used pressure measurement, with studies comparing continuous pressure monitoring with serial monitoring. For continuous compartment measurements, clinical symptoms in combination with ΔP (<30 mm Hg) results in a sensitivity of 61% and specificity of 97%, while using ΔP in isolation results in a sensitivity of 89% and specificity of 65%. **Diagnosing on single measures can result in unnecessary fasciotomies, with a false positive rate approaching 35%.** Monitoring pressures over 2 hours using ΔP < 30 mm Hg as diagnostic criterion for ACS displays a sensitivity of 94% and specificity of 98.4%. What should you do? **We recommend using a single measurement for patients who you can obtain a reliable history and exam, with repeat assessment if the first is normal and clinical suspicion for ACS still remains. If the patient cannot provide a reliable history and exam, use continuous monitoring over at least two hours or several repeat assessments**. A **ΔP < 20 mm Hg is a definitive indication for fasciotomy**, with < 30 mm Hg a relative indication. Using ΔP may also help diagnose ACS in hypotensive trauma patients. **Signs of ACS and absolute intracompartmental pressures > 30 mmHg also require fasciotomy**. If elevated pressures have been present for > 3 days, a fasciotomy is unlikely to help, and in these cases, no decompression is advised. Instead it should be allowed to form scar tissue.

6. What is the management of compartment syndrome?

The most important point is to consider ACS. Once you suspect ACS**, consult orthopedic or general surgery, remove any constrictive dressings, and avoid a dependent position of the extremity** (try your best to keep the extremity at the level of the heart). Removing external **compressive devices alone can**

reduce pressures by 65-85%. Reducing a displaced fracture will decrease edema. Analgesia is needed, but **regional blocks are not recommended** (they can make monitoring based on symptoms challenging). If the patient is hypotensive, resuscitation is needed to restore circulating volume.

Another important point is that **outcomes improve with rapid diagnosis and decompression**. **Rapid fasciotomy is correlated with improved outcomes**, including muscle and nerve injury and death. Unfortunately, a motor deficit due to ACS rarely improves with fasciotomy.

Fasciotomy Indications
- Clinical signs or symptoms strongly suggestive of ACS - Intracompartmental pressure > 30 mm Hg or $\Delta P < 20$ mm Hg with concern for ACS ($\Delta P < 30$ mm Hg is a relative indication) - Intracompartmental pressure > 20 mm Hg in the presence of hypotension - Interruption in arterial perfusion for ≥ 4 hours

7. What are the complications if the diagnosis is missed?

- gangrene or loss of limb viability requiring amputation
- ischemic contracture and loss of function
- rhabdomyolysis and renal failure