Compartment Syndrome

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Definition

Compartment syndrome is a condition that typically presents with limb pain. It is attributed to an increase in pressure within an anatomical space that may cause compression of nearby blood vessels and compromise blood flow to muscles and nerves [1–3]. This often results in pain, paresthesias, and weakness and, if left untreated, may possibly lead to rhabdomyolysis, paralysis, limb ischemia, and muscle necrosis. That is why it is imperative to identify this diagnosis and treat it as soon as possible. The most common site for compartment syndrome to occur is the distal leg. There are four compartments in the distal leg. They are the anterior, lateral, superficial posterior, and deep posterior compartments [1, 4, 9].

Compartment syndrome is classified as either acute or chronic. Acute compartment syndrome is usually due to a traumatic event such as a fracture, crush injury, or hematoma. The most common fracture to cause an acute compartment syndrome is a tibial diaphyseal fracture [6, 7]. However, it can also be from external causes such as compression from a tight cast or prolonged positioning on a limb rest during a surgery [6].

Chronic compartment syndrome (often referred to as chronic exertional compartment syndrome or CECS) also presents with pain but is exercise induced. Symptoms are usually bilateral and present itself during the activity or immediately after the activity is completed and eventually resolve after minutes of rest [1]. For CECS, the exact pathophysiology is unclear. Similar to acute compartment syndrome, it is thought to be due to an increase in pressure attributed to increased muscle volume during exercise leading to impaired blood flow and ischemia to muscle cells [1–3]. However, several studies question whether ischemia is the actual contributing factor to the limb pain. Another proposed mechanism is that fascia may become hypertrophied and less compliant over time. Thus, an increase in muscle volume during exercise increases compartment pressure stimulating sensory receptors on these hypertrophied fascias producing perception of pain [1].

Diagnosis

History is important for increasing the suspicion of this diagnosis, especially with chronic exertional compartment syndrome, since the most common presentation is leg pain. Leg pain has a broad differential, and history may help distinguish compartment syndrome from other causes of leg pain. Asking questions of any falls or direct trauma to the leg should be asked. With CECS, symptoms are often predictable by the patient so it is important to ask the patient questions such as activity intensity and type of activity during presentation. Other questions to consider include whether there is a specific amount of time within an activity that symptoms begin, as well as the length of time of rest before their symptoms resolve.

On inspection, the involved leg may be swollen, tense, shiny, ecchymotic, and tender to palpate. However, for acute compartment syndrome, the involved leg may look normal especially immediately after a trauma despite the patient complaining of pain out of proportion to their gross presentation. Even with chronic exertional compartment syndrome, the leg may appear normal, and the patient may be asymptomatic in the rested state. Sensory findings are typically

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affected first prior to motor findings. Patients may present with decreased vibratory sensation as well as decreased two-point discrimination. Range of motion of the ankle joint may help illicit pain in the involved compartment. Compromise of the anterior compartment and lateral compartment may present with pain and weakness during active dorsiflexion/eversion or pain during passive plantar flexion/inversion as well as paresthesia to the dorsum of the foot. Compromise of the posterior compartments (deep and superficial) may present with pain and weakness during active plantar flexion and inversion or during passive dorsiflexion/eversion as well as paresthesias to the plantar aspect of the foot [1, 2].

The "gold standard" for diagnosis has been intramuscular compartment pressure measurements using various monitors. For acute compartment syndromes, it is suggested that a difference in pressure (Δp) of <30 mmHg when comparing the compartment pressure with the diastolic pressure is more reflective of a true diagnosis of acute compartment syndrome than increased compartment pressures alone [6, 7]. If there is suspicion for rhabdomyolysis, a BMP to evaluate renal function, CPK, CK, urinalysis, and urine myoglobin should also be collected.

For chronic exertional compartment syndrome, Pedowitz et al. suggest that the diagnosis is made if one of the following is positive [1, 3, 5]:

- Pre-exercise ≥15 mmHg
- 1 min post-exercise ≥30 mmHg
- 5 min post-exercise ≥20 mmHg

Studies are being investigated that suggest dynamic monitoring of intramuscular compartment pressures, with a higher diagnostic cutoff pressure (>105 mmHg), may be more accurate to help increase specificity and point out those who would benefit from fasciotomy. [8, 10]

Other less invasive mechanisms for diagnosis are being researched on, such as MRI, laser Doppler flowmetry, near-infrared spectroscopy, and ultrasound. Most show promise, especially for chronic exertional compartment syndrome.

Imaging

- Imaging studies currently are used mostly to rule out other causes of distal leg pain. However, as mentioned above, various imaging studies are being investigated as a means of noninvasive diagnosis of compartment syndrome.
- X-rays of the tibia/fibula in AP, lateral, and oblique or CT scan can help evaluate for acute fractures [5, 15].
- Ultrasound of the leg can evaluate for the presence of hematoma, muscle tears, and tendinopathies; Doppler studies can evaluate for the presence of DVT [5, 15].
- Ultrasound as a noninvasive diagnostic tool for compartment syndrome using compartment thickness is currently being investigated [13].
- Ultrasound laser Doppler may reveal perfusion pressure gradients in compartment syndrome but has mixed sensitivity and specificity [14].
- MRI of the leg can evaluate for stress fractures not clearly seen on X-ray or the presence of muscle tears and tendinopathies [5, 15].
- For compartment syndrome, MRI T2-weighted images may show increased signal intensity throughout the compartment. Diffusion tensor imaging may show microstructural changes within muscle and fascial fibers of affected compartments based on physiological changes from hypoxic conditions and engorgement of muscle compartment. Its utility is being investigated further [11, 12].

Differential Diagnosis

- Medial tibial stress syndrome
- Stress fracture tibia/fibula
- Achilles tendinopathy
- Gastrocnemius/soleus strain
- Popliteal artery entrapment
- Deep vein thrombosis
- Cellulitis
- Restless leg syndrome

Treatment

- For CECS, cessation of activity has been the only definitive conservative treatment that has been shown to improve symptoms. However, for most of the population, this is not a reasonable solution.
- Myofascial release, stretching, and orthotics have been studied with no proven efficacy.
- Activity modifications are currently being investigated, such as forefoot running, decreasing stride length, decreasing vertical oscillation, and decreasing ground contact time to help reduce ground reaction force and promote efficiency during running [20, 21].
  - Running mechanisms which lead to a more midfoot strike position with the tibia more vertical during foot contact may cause less eccentric forces on the tibialis anterior resulting in less fatigue by the muscle and therefore less lactic acid buildup and less muscle edema.
  - It is also suggested that increased hip flexion and a higher knee during swing phase may allow a runner to achieve that vertical tibia alignment [21].

- The overall definitive treatment for both acute and chronic compartment syndrome is a fasciotomy.
- Concerning fasciotomies, surgeons would decide to do a one-incision or two-incision technique which would involve either the anterior/lateral and/or posterior compartments. Some may also include a deep posterior compartment fasciotomy. Most of these techniques are approached superficially [4, 18, 19].
- Some of the risks of fasciotomy include post-op hematoma, wound infection, poor wound healing, nerve injury, and recurrence due to inadequate release [16–19].
- Endoscopic techniques are available, mainly for chronic exertional compartment syndrome, to see if it would help minimize these risks. [16, 17]. However, thus far, endoscopic technique has not shown to decrease these risks. Heinz's study showed even greater risk when addressing the deep posterior compartment with risk of injury to the saphenous vein.

Return to Play After Fasciotomy

- Val Irion et al. [22] conducted a study with the following rehab protocol on 13 elite-level athletes and demonstrated an 84.6% return to sport at the previous level.
- Week 1: Patient is weight bearing as tolerated. Wound care with dry sterile gauze is applied.
- Weeks 2–6: Initiate a rehabilitation program including gait training, knee and ankle ROM exercises, extremity edema/swelling control, and gentle isometric strengthening.
- Weeks 6–8: Patients are advanced to progressive strengthening, with gradual increase to running, jumping, and sport-specific drills.
- Most patients (about 80%) after a fasciotomy were able to return to full activity without restrictions at about 12 weeks.
- However, about 20–30% of patients did have a recurrence of their symptoms.
- Of note, the sample size is too small as well as too great a variability in the sports the players participated in to make generalizations. However, research continues to investigate long-term outcomes of fasciotomies that may help us come closer to a standardized RTP guideline.

When to Refer

- When acute compartment syndrome is suspected
- When exercise-induced compartment syndrome becomes recurrent

Referral

- Primary care physicians, sports medicine, and physiatrists are important for detection of this diagnosis.
- However, all these patients will need a surgical evaluation for possible need of fasciotomy.

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