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Exertional Compartment Syndrome

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Introduction

Exertional compartment syndrome is often a diagnosis of exclusion and occurs secondary to increased pressures in a muscular compartment with resultant ischemia manifesting most commonly as pain.[1] There are two distinct forms of exertional compartment syndrome, acute and chronic types.

Chronic exertional compartment syndrome (CECS) occurs in the setting of recurrent, reversible ischemic episodes following the cessation of activity resulting in the predictable decrease in fascial compartment pressures.[2] Although benign, the refractory nature of CECS often results in a substantial portion of patients ultimately electing to proceed with fasciotomies.[3]

Acute exertional compartment syndrome (AECS) is a rare entity that, unfortunately, its diagnosis often delayed. Just as in acute compartment syndrome (ACS), the diagnosis implies a surgical emergency requiring fasciotomies to help mitigate the risks of ensuing irreversible muscle ischemia and neurovascular injury, which can occur after just a few hours alone.[4][5][6] ECS typically occurs in the lower leg but can also occur in other areas like the forearm, thigh, or hand.[6] The article provides an overview of the hallmarks and diagnostic considerations surrounding both forms of ECS, including the importance of clinicians maintaining a high index of suspicion to avoid delays in diagnosis.

Etiology

The major differentiating clinical variable separating the two forms of ECS from ACS is the absence of a specific traumatic event in the former. The literature consistently reports the clinical underappreciation of ECS types, particularly the acute subtype, given that there is most commonly an atraumatic presentation.[7]

Multiple etiologies underlie CECS. During exercise, specific muscle compartments swell up to 20% secondary to increased blood flow and fluid volume.[8][9] In the setting of CECS, there is ultimately a rise in the pressure within one or multiple musculofascial compartments which impedes further muscle expansion, eventually compromising blood flow once the volume and pressure reach a level that overrides the capillary perfusion pressure.[7] This pressure buildup causes pain and sometimes subtle motor weakness and/or paresthesias in the corresponding neurovascular sensory and motor distributions.[10] For example, CECS affecting the anterior and lateral compartment of the lower leg will often present with pain, tingling, and/or reduced sensation on the dorsum of the foot suggesting superficial peroneal nerve (SPN) involvement

The pathophysiologic cascade following this abnormal increase in intracompartmental pressure results in reduced myocyte oxygenation, and ultimately resulting in myonecrosis and neurologic damage [11]. Depending on the compartment affected, symptoms will vary depending on the specific muscles and/or nerves affected during the pathophysiologic cascade.

Other etiologies of CECS include various overuse injuries or repetitive mechanisms where tissue degeneration or scar formation occurs as a result of microtrauma. Another predisposing risk factor may occur in individuals with inherently decreased elasticity of the fascia which predisposes to nerve entrapment and quicker rises in pathologic pressures overriding the capillary perfusion pressure of the corresponding compartment.[10]. Amendola et al. in their study felt that CECS was secondary to increased fluid content, which impaired muscle or nerve function in a tight compartment.[9][12]. Braver, in his review article, believed that CECS was secondary to "neurogenic claudication" where nerves were not getting appropriate perfusion secondary to compromised small capillary flow from the elevated pressures.[9] Regardless of the exact mechanism, what is known is that the pathology is related to elevated intracompartmental pressures and it seems to affect those performing repetitive activities, i.e., runners, dancers, speed skaters, and those in military training.[9][13]

Epidemiology

Chronic exertional compartment syndrome is typically considered a rare cause of lower extremity pain, with a reported incidence rate in active patients presenting with exercise-induced leg pain to be 33%.[14]

Waterman et al. in their retrospective study involving a military population showed an average annual incidence of 0.49 per 1000 at-risk person-years. CECS is relatively common, especially amount young adult athletes involved in running, endurance training, soccer, field hockey, and lacrosse.[15] CECS predominantly affects the anterior compartment, representing up to 70% of cases in some series.[16] Other reports cite the anterior and deep posterior compartments are the most frequently affected compartments (25% each), and simultaneous anterior and deep posterior involvement can happen in 8% to 10% of cases.[17] There are reports of bilateral limb involvement in 37% to 82% of symptomatic athletes.[18][19]

In a retrospective study, Brujin et al. looked at 1411 heterogeneous patients who had complaints of lower extremity pain and had dynamic intracompartmental pressures performed. Of the 1411 patients included in the study, 698 patients had a diagnosis of CECS.[20] CECS demonstrated a peak prevalence at 20 to 25 years of age and a higher likelihood in males than females and was present bilaterally in the majority of cases. It occurred in patients that participated in sports like running or skating and higher activity intensities correlated with a higher likelihood of CECS. However, it is important to note that CECS may occur in patients not involved in sporting activity.[20]

History and Physical

A strong index of clinical suspicion is needed to rule out ACS and AECS; it is particularly crucial given the latter condition occurs in the absence of a traumatic injury or fracture. AECS is essentially a hybrid of ACS and CECS and is often overlooked or diagnosed in a delayed fashion. AECS patients often present following sport-related activity or exertion with nonspecific leg pain during and often persisting after strenuous or repetitive activity. CECS clinically differentiates in that symptoms will predictably abate following activity cessation. While CECS is often a diagnosis of exclusion, AECS should be ruled out first before

considering other diagnoses, which one accomplishes by measuring the patient's compartments in question.

The diagnosis of CECS has its basis in a thorough clinical history, paying particular attention to a patient's characterization of pain during strenuous activity, well-localized to a specific compartment and the pain/symptoms disappear quickly after the cessation of activity.[2] Patients will generally complain of discomfort that they describe as squeezing, cramping, aching or burning that typically begins within 15 to 20 minutes of an exertional type activity, i.e., running, marching, etc.[5][6] The discomfort resolves completely with rest, although the duration may vary.

In 70 to 95% of cases, the pain is bilateral.[5][6] Generally, the physical examination is unremarkable as patients do not undergo evaluation during or immediately after exercise. If this condition is suspected, a physical examination should take place pre- and immediately post-exercise.[5] After exercise, the affected compartment may be tender, bulge, or feel tight. Passive stretching of the involved compartment may elicit pain. Additionally, there may be focal neurological findings, i.e., decreased sensation, paresthesias, or weakness.[6]

Formal CECS testing following stress-testing gets confirmed by compartment pressure measurements before and after exercise utilizing the Stryker pressure monitoring system as described previously.[21] Upon obtaining baseline measurements with the patient resting supine, the patient is often asked to perform a period of exercise activity in a controlled environment to facilitate later post-testing. A common exercise period consists of running on a treadmill with a minimal degree of incline until the onset of severe symptoms. At that time, the patient rests for 5 minutes, followed by the measurement of compartment pressures.

Evaluation

History is key to suspecting this diagnosis as this condition is easy to overlook or fail to consider. Once CECS is suspected, diagnosis is confirmed by dynamic intra-compartmental pressure measurement at rest and then after exercise.[5]

The Pedowitz criteria are often used to obtain or rule out a diagnosis of CECS in each compartment of interest[22]:

- A resting pressure of greater than or equal to 15 mmHg and/or a pressure of greater than or equal to 30 mmHg at 1 min post-exercise in any compartment, and/or;
- Post-exercise pressure greater than 20 mmHg at 5 minutes post-exercise

Treatment / Management

Just as in the setting of ACS, emergent fasciotomies must be performed in a patient presenting with AECS. Otherwise, CECS is typically managed nonoperatively for a one- to three-month duration and surgical management may often be delayed and/or electively performed after having a discussion with the patient (or athlete) regarding the ideal timing given the athletes current sport-specific requirements.

Conservative management consists of rest, activity modification, stretching, orthotics, and physical therapy, but these measures are generally ineffective.[6] Nonoperative modalities include, but are not limited to:

- NSAIDs
- Botulinum toxin injections

- Limited efficacy

- Gait training
  - Diebal et al. published two case series of patients with CECS prospectively treated with a gait training optimization program focusing on forefoot strike patterns[23][24][23]:
    - One study analyzed 10 study participants, concluding that none of the ten subjects required surgery at 1-year post-intervention

In refractory cases, or following at least a multiple month trial of nonoperative management modalities, operative management is discussed keeping in mind the patient/athlete's expectations for return to baseline activity and/or sport.[25][26]

Open fasciotomy is the predominant technique. However, other minimally invasive endoscopic techniques are also options.[27] The latter may include a smaller incision; by comparison, however, complication rates are reportedly similar in the literature

In general, for the lower leg:

- Dual incision technique
  - Lateral[28]:
    - Anterior and lateral compartment access for release
    - 12 to 15 cm proximal to the lateral malleolus
    - Caution to protect/avoid the SPN
  - Medial[29]:
    - Superficial and deep posterior compartment access for release
    - Release at the middle of the tibia along the posterior border

Differential Diagnosis

The differential diagnosis for CECS can be quite broad. Most commonly, CECS initially gets misdiagnosed as shin splints or medial tibial stress syndrome (MTSS).[30]

Other considerations include[10]:

- Vascular pathologies
  - Intermittent claudication
  - Popliteal artery impingement.
- Tibial stress fractures
- Tendon pathologies (tendinitis, tendinosis, or tendon rupture)
- Nerve entrapment

Prognosis

In general, patients with isolated anterior and/or lateral compartment (over 80%) involvement generally report superior outcomes compared to their deep posterior compartment counterparts

(60%).

Campano et al. in his systematic review of 24 articles showed a 66% success rate and an 84% satisfaction rate (short and mid-term follow up) after surgical repair.[27] Beck et al. in his retrospective study of 155 pediatric patients showed a 79.5% return to sports rate with 18.8% requiring additional surgical revision.[25] Prognosis also depends on the involved compartment as the anterior compartment (the most common location) has better outcomes. Additionally, a single compartment CECS has a better surgical success rate than CECS involving multiple compartments.[27]

Complications

Where CECS is a relatively benign condition characterized by resolution of symptoms with rest, AECS is a true surgical emergency where the symptoms do not resolve.[7] Like CECS, AECS correlates with repetitive type activities such as endurance sports, military training, and not associated with acute trauma. This condition typically affects adolescent and young men.[7][31] Some believe that this population is at risk secondary to the developing muscle mass in a restrictive fascial space. Like CECS, there are elevated compartment pressures, but in AECS, it can result in irreversible myonecrosis and nerve injury.[7][31] Treatment is surgical intervention with fasciotomy. Unfortunately, because this entity is rare, and there is a lack of familiarity with this diagnosis, intervention is typically delayed.[7][31] The key to making the diagnosis is awareness of this entity. The examination is significant for pain out of proportion, and pain with passive stretch. Tenderness remains generally isolated to the affected compartment. Pressure measurement can confirm the diagnosis. Normal pressures are between 0 and 8mmHg. An intracompartmental pressure of 30mmHg or a delta pressure less than 30mmHg (delta pressure = diastolic blood pressure - compartment pressure) is an indication for fasciotomy. It is worth mentioning that if a Stryker intracompartmental pressure monitor is unavailable, an 18g or 20g needle or catheter can be attached to an arterial line monitor to determine pressures.[32]

Deterrence and Patient Education

Knowledge is key. In the setting of an underdiagnosed and easily missed clinical entity, educating providers and patients is paramount. Any patient that with a history of exertional extremity pain which resolves with rest should trigger consideration of CECS and seek medical attention. Additionally, any patient with atraumatic extremity pain with findings of the pain out of proportion, pain on a passive stretch, and tender compartments merits consideration of AECS and should seek care.

Enhancing Healthcare Team Outcomes

Exertional compartment syndrome (ECS) requires awareness by a multitude of providers in various fields. Physical therapists, advanced providers, nurses, and physicians may all encounter this entity in fields like primary care, emergency medicine, sports medicine, and orthopedics. These various disciplines need to work collaboratively across interprofessional lines to help bring about optimal outcomes for these patients. [Level V] Ultimately, once suspected, the condition would need confirmation and definitive management with surgical fasciotomy by a specialist like an orthopedic surgeon. Primary care and emergency medicine practitioners must be especially aware of the limb-threatening form of acute exertional compartment syndrome (AECS).

Questions

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