Chronic Exertional Compartment Syndrome

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**Introduction**

Exercise related leg pain is a frequent problem seen in recreational and competitive athletes. There is a broad differential in the diagnosis of leg pain in athletes, however the majority is related to overuse. Chronic exertional compartment syndrome is a relatively common cause with an incidence ranging from 27-33%, second only to medial tibial stress syndrome (13-42%)(1, 2). Chronic exertional compartment syndrome (CECS) is defined as reversible ischemia within a closed fibro-osseous space, which leads to decreased tissue perfusion and ischemic pain. CECS is often recurrent and associated with repetitive physical activity. It is most commonly seen in athletes, with a high incidence in runners as well as athletes in jumping and cutting sports. Symptoms occur at an exertion level where the elevation in pressure exceeds the rate of metabolism and tissues become tight and painful. The pain typically disappears quickly with rest, and no permanent damage to the tissue within the compartment occurs.

The first report of CECS was by Mavor in 1956, where a soccer player was successfully treated with fasciotomy and was able to return to sport(3). Other reports published in the 1960-70s continued to highlight the clinical features of CECS, and importantly the good results seen with early surgical intervention(4, 5). There has been continued progress in the diagnosis and treatment of CECS over the past decades.

Chronic exertional compartment syndrome is a distinct condition from acute compartment syndrome. Acute compartment syndrome is associated with a traumatic event and patients present with severe pain that is worsened with passive stretch of the muscles and does not improve with rest. Acute compartment syndrome requires emergent surgical intervention to prevent limb ischemia and permanent tissue damage.
The most commonly affected area by CECS is the lower leg. It can also occur in other locations and has been described in the thigh and forearm. This review will concentrate on the lower leg as it is the most common area, however the clinical features, diagnosis and treatment strategies are similar for all locations.

Anatomy

The lower leg is divided into four compartments: anterior, lateral, superficial posterior and deep posterior (Table 1). In addition to the respective muscles in each compartment, they all contain one major nerve and two of the compartments contain a major blood vessel. The anterior compartment contains the deep peroneal nerve and the anterior tibial artery. The lateral compartment contains the superficial peroneal nerve. The superficial posterior compartment contains the sural nerve. The deep posterior compartment contains the posterior tibial nerve and the posterior tibial artery.

The anterior compartment is most commonly affected in CECS (45%), followed by the deep posterior compartment (40%)(6). Less commonly affected are the lateral (10%) and superficial posterior compartments (5%)(6). In addition to a tight compartment and pain, the associated symptoms the patient reports are related directly to the contents of the affected compartment.

Pathophysiology

With physical activity, up to a 20% increase in muscle volume can be seen due to normal muscle physiology(7). This leads to an increase in the pressure within the compartment from the restriction on volume expansion due to noncompliant fascial and osseous boundaries. After a certain pressure threshold the blood flow becomes insufficient for the metabolic requirements of the muscle and individuals begin experiencing pain. The
most important intracompartmental pressures are when the muscle is in a noncontractile state, as muscles receive blood flow during the relaxation phase. Patients will continue to experience pain until the intracompartmental pressure falls to the level that blood flow can again meet the demands, which typically requires cessation of activity and a period of rest.

Anatomic variations can also play a significant role in the incidence of CECS. Fascial defects of the anterolateral leg have been observed in up to 40% of individuals with CECS, compared with <5% of asymptomatic individuals(8). The most common location of fascial defect is near the intramuscular septum of the anterior and lateral compartments, at the exit of the superficial peroneal nerve. The nerve may be compressed by the edge or the defect or secondary to bulging of the muscle. During exercise, a palpable bulge may be felt and localized tenderness may occur.

There are likely other factors contributing to the symptoms and pathology of CECS, aside from limited compartment expansion. This is evidenced by the fact that fascial hernias are not seen in all patients, and the total intramuscular pressure usually remains higher than in normal individuals even after fasciotomy(9). Other factors thought to contribute include changes in arteriolar regulation and blood flow.

**Evaluation**

A thorough and detailed history is paramount in the evaluation of patients with suspected CECS, as patients classically have no pain or symptoms while at rest. Typical patients with CECS are athletes, commonly runners, who are under 30 years old. The characteristic complaint is recurrent, exercise-induced pain that occurs at a well-defined and reproducible point during exercise(10).
Pain often begins as a dull aching or burning over the involved compartment and increases to the point where exercise must be stopped. A majority of patients present with bilateral symptoms, and there is an equal incidence between males and females (11). Affected individuals are able to reliably predict the duration or intensity of exercise where symptoms will occur, as well as how long the pain will last after cessation of exercise. The period of rest before resolution tends to increase in length as the symptoms become more severe. There is generally no history of trauma or injury at the onset of symptoms. Symptoms tend to reoccur even after a period of discontinuation of their sport.

Physical examination of the extremity at rest is typically normal. Re-examination after an exercise challenge is necessary for a complete exam. After exercise, the affected compartment may reveal tenderness and increased tension. Palpation of the leg may identify an area of muscle herniation, typically at the junction of the middle and distal one-third of the leg. A thorough neurologic exam will identify paresthesias or areas of decreased sensation. Muscle weakness can be appreciated in severe cases and atrophy may be present in unilateral cases.

There are many other conditions causing leg pain in athletes and should be considered in the differential diagnosis during evaluation (Table 2). Especially in cases where the history, physical exam and diagnostic measurements are inconsistent with CECS, further testing should be considered to evaluate for these other conditions. Indeed, occasionally overlapping diagnoses can occur, such as a stress fracture leading to periosteal and soft tissue swelling which becomes just enough of a trigger to throw a previously asymptomatic patient into a symptomatic CECS. The underlying pathology must be identified and addressed to assure a successful outcome.
**Diagnostic Testing**

Similar to acute compartment syndrome, the diagnosis of CECS is largely clinical. When objective data is desired, measurement of intracompartmental pressure may be completed. Measurement of pressure during exercise is difficult, and post-exercise and resting measurements have become the standard for confirmation of the diagnosis. The type and duration of exercise prior to measurement must be sufficient to provoke the onset of pain symptoms.

There are many different methods that have been described for measuring compartment pressure including needle manometer(12), slit catheter(13), microtip pressure method(14), wick catheter(15), and microcapillary infusion(16). Assuming correct techniques for each, they show equal effectiveness in pressure measurement. The Stryker Intracompartmental Pressure Monitor (Stryker Corp, Kalamazoo, MI, USA) is a convenient, hand-held, battery operated device that is easy to use in the clinical setting. Use of this particular monitor has shown good reproducibility between examiners(17).

The pressure criteria described by Pedowitz et al have been generally accepted in the diagnosis of CECS(18). One of the following criteria must be met in addition to a consistent history and physical exam. A resting, pre-exercise pressure \( \geq 15 \text{ mm Hg} \); 1 minute post exercise pressure \( \geq 30 \text{ mm Hg} \); 5 minute post exercise pressure \( \geq 20 \text{ mm Hg} \). The pressure may remain elevated for 30 min or longer in patients with CECS. Additionally, the criteria of Whitesides and Heckman in acute compartment syndrome has been applied to CECS(19). Critical compartment ischemia occurs when the compartment pressure rises to within 20 mm Hg of the diastolic pressure.
Care must be taken during pressure measurement, as there are several factors that may affect the accuracy of measurement. These include use of proper equipment, correct and consistent location when measuring pressure, proper depth of needle insertion, consistent orientation of the measuring device and position of the extremity during measurement. The limb should be placed in a relaxed and consistent position for accurate and reproducible measurements. Measurement of pressure in the anterior, lateral and superficial posterior compartments is relatively simple, however the deep posterior compartment is more challenging as the exact location of the needle tip may vary. Some authors have advocated the use of ultrasound during pressure measurements as a guide to consistent needle placement(20).

There has been increased interest in the use of alternative methods in testing for elevated compartment pressure. Near-infrared spectroscopy and MRI have shown promising results. Near-infrared spectroscopy demonstrates deoxygenation of muscle during exercise and delayed reoxygenation post exercise in patients with CECS(21, 22). With the use of MRI, the affected compartment shows increased signal intensity on T2-weighted sequence during exercise. Failure of the compartment to return to baseline appearance within 25 minutes post exercise is considered diagnostic of CECS(23, 24). Other modalities can be used to evaluate for other conditions in the differential of CECS including triple phase bone scans and single-photon emission computed tomography (SPECT) scans(24, 25). These are best used to diagnose reactive or active bony processes such as medial tibial stress syndrome or stress fractures.

Treatment
Initial management of CECS should start with conservative methods. A treatment plan generally includes reduction or cessation of inciting activities, anti-inflammatory medication, stretching, foot orthotics when appropriate and introduction of an alternative exercise program. Conservative measures are continued for a period of 6-12 weeks prior to recommending more aggressive treatment. Nonsurgical management is typically successful only with stoppage or significant reduction in athletic activity. However, the majority of patients with CECS who seek treatment are not willing to give up athletic activity, and an expedited timeline to surgical intervention is often considered.

Subcutaneous fasciotomy of the involved compartment remains the foundation of surgical treatment(26). Fasciotomy is successful in relieving pain and allowing for return to full activity(27). Multiple surgical techniques have been described in the treatment of CECS. Regardless of technique, when a fascial herniation is present, it must be included in the release for successful outcomes.

Single and double incision techniques have been described. The single incision technique uses a centrally based incision to release the fascia both proximally and distally. Dual incision techniques use two smaller incisions at the proximal and distal end of the limb, with the intervening fascia incised using Metzenbaum scissors or a fasciotome. For anterolateral compartment release, the superficial peroneal nerve can be visualized in the distal incision and protected during release. On the posteromedial side, the compartments should be released directly off the posterior border of the tibia to avoid neurovascular injury. Minimal incision techniques have also been described which use multiple small incisions to accomplish compartment release(28). Some surgeons have advocated a
combination of techniques, with a dual incision for anterolateral release and single incision for posteromedial release.

Endoscopically assisted fasciotomy is an alternative technique which has been shown to be as safe and effective as open fasciotomy(29). Advantages of endoscopic techniques are access to the entire length of the compartment and visualization of the superficial peroneal nerve and other anatomic structures that are at risk during surgical release(29, 30).

Current recommendations are for isolated release of the affected compartment only. Schepsis et al. showed that in cases of isolated anterior compartment involvement, release of only the anterior compartment had equivalent results to release of the anterior and lateral compartments(31). Preoperative testing, including compartment pressure measurement, is critical in identifying the affected compartment(s) and planning for appropriate surgical release.

The immediate postoperative period is aimed at pain control and limiting swelling. Compressive wraps, ice and elevation are used in the first few days following surgery. Full weight bearing is allowed immediately after surgery, however crutches are typically used for a short period. Active range of motion exercises should also be initiated immediately after surgery to limit scarring of the released fascia. Return to sport specific activity may resume as seen as tolerated. Full return to activity is generally accomplished within 8-12 weeks.

Outcomes
There are no controlled trials in the literature that directly compare surgical and nonsurgical treatment. Similarly, there are no studies comparing the different surgical techniques.

Surgical treatment for CECS is associated with high levels of pain relief and patient satisfaction. Successful outcomes have been reported in 80-100% of patients (11, 26, 27, 31, 32). However, when compartments are evaluated individually, success rates are markedly better for the anterior compartment compared to the deep posterior compartment. Successful release of the deep posterior compartment ranges from 50-65% (26, 31, 32). This difference has been attributed to incomplete or neglected release of the deep posterior compartment. Involvement of the deep posterior compartment may also be multifactorial, and fasciotomy may not fully relieve all symptoms (31). Single incision techniques have shown slightly lower success rates than dual incision (33). Female athletes may respond less favorably to fasciotomy, and have shown lower success rates with surgery compared to males (34).

**Complications**

Reported complications of surgical treatment include hematoma or seroma formation, wound infection, peripheral nerve injury, and deep venous thrombosis. Incidence of postoperative complications ranges from 2-13% (11, 26, 30, 31).

Recurrence of symptoms has been reported in 2-17% of patients after fasciotomy (26, 31). Recurrence may be due to either incomplete release of an affected compartment, failure to release all affected compartments or fascial scarring during healing after fasciotomy. Revision surgery may be necessary in patients with recurrent symptoms.

**Summary**
Chronic exertional compartment syndrome is a relatively common, but often-overlooked cause of leg pain in athletes. A careful history and physical exam is essential in the diagnosis of CECS. Affected individuals have recurrent, activity related leg pain that recurs at a consistent duration and/or intensity, and is only relieved by rest. Measurement of baseline and post-exercise compartment pressures confirms the diagnosis and helps in the planning of treatment. Surgical treatment with fasciotomy of the involved compartments is successful in allowing patients to return to full activity levels. With surgical treatment, it is critical to address all affected compartments, as well as releasing any fascial defects, both of which may cause recurrent symptoms if neglected. With appropriate diagnosis and treatment, excellent outcomes can be achieved and allow athletes to return to full, unrestricted activity levels.
Table 1. Structures within each anatomic compartment of the lower leg

<table>
<thead>
<tr>
<th>Anatomic Compartment</th>
<th>Structures</th>
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<tbody>
<tr>
<td>Anterior</td>
<td>Tibialis anterior muscle</td>
</tr>
<tr>
<td></td>
<td>Extensor hallucis longus muscle</td>
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<tr>
<td></td>
<td>Extensor digitorum longus muscle</td>
</tr>
<tr>
<td></td>
<td>Peroneus tertius muscle</td>
</tr>
<tr>
<td></td>
<td>Deep peroneal nerve</td>
</tr>
<tr>
<td></td>
<td>Anterior tibial artery and vein</td>
</tr>
<tr>
<td>Lateral</td>
<td>Peroneus longus muscle</td>
</tr>
<tr>
<td></td>
<td>Peroneus brevis muscle</td>
</tr>
<tr>
<td></td>
<td>Superficial peroneal nerve</td>
</tr>
<tr>
<td>Superficial Posterior</td>
<td>Gastrocnemius muscle</td>
</tr>
<tr>
<td></td>
<td>Soleus muscle</td>
</tr>
<tr>
<td></td>
<td>Sural nerve</td>
</tr>
<tr>
<td>Deep Posterior</td>
<td>Flexor hallucis longus muscle</td>
</tr>
<tr>
<td></td>
<td>Flexor digitorum longus muscle</td>
</tr>
<tr>
<td></td>
<td>Tibialis posterior muscle</td>
</tr>
<tr>
<td></td>
<td>Posterior tibial nerve</td>
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<tr>
<td></td>
<td>Posterior tibial artery and vein</td>
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Table 2. Differential diagnosis of leg pain in athletes

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Distinctive Features</th>
<th>Diagnostic Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress fracture</td>
<td>Localized pain directly over tibia</td>
<td>Bone scan, MRI</td>
</tr>
<tr>
<td></td>
<td>Recent increase in activity level</td>
<td></td>
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<tr>
<td>Medial tibial stress syndrome</td>
<td>Pain along posteromedial border of tibia</td>
<td>Bone scan, MRI</td>
</tr>
<tr>
<td></td>
<td>Diffuse pain along length of tibia</td>
<td></td>
</tr>
<tr>
<td>Peripheral nerve entrapment</td>
<td>Tingling and numbness in a specific anatomic distribution</td>
<td>EMG, NCV</td>
</tr>
<tr>
<td>Popliteal artery entrapment</td>
<td>Pain and cool sensation in limb</td>
<td>Angiogram</td>
</tr>
<tr>
<td></td>
<td>Paradoxical claudication</td>
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