Bilateral Compartment Syndrome of the Anterior Thigh Following Functional Fitness Exercises: A Case Report

LCDR Lucas S. McDonald, MC USN; ENS Ronald J. Mitchell, MC USN; LCDR Travis G. Deaton, MC USN

ABSTRACT We present a case of delayed, acute bilateral exertional compartment syndrome of the anterior thigh induced by callisthenic exercise. Symptoms consisted of pain out of proportion to examination findings, inability to ambulate, and severe pain with knee flexion. Treatment consisted of bilateral thigh fasciotomies and supportive therapy for concomitant rhabdomyolysis. Full strength, range of motion, and return to all military duties were achieved by 4 months postinjury.

INTRODUCTION

In 1912, Dr. Edward Wilson, while a member of Captain Scott’s Antarctic expedition, described left leg pain in his tibialis anterior muscles worsened by daily marching. Though describing a bruise to the leg, he reported no trauma and provided several explanations for the symptoms, but questioned his own diagnosis. This retrospective historical account was described in 1953 and was likely the earliest description of ischemic muscle necrosis following exertion. The first published report of ischemic necrosis of muscles in the leg following exercise was in the Scandinavian literature in 1943 by Severin, the same year that unpublished research was read before the Oregon State Medical Society by Vogt. Sirbu et al subsequently published a report of a soldier who developed pain and necrosis following a long march without any fracture or trauma, and was the first published in the English literature. These authors attributed the necrosis to repeated microtrauma suggesting the condition be named “march myositis” though were not able to rectify the infarction seen on pathology with the suspected cause. In 1945, Horn further expanded on what he described as a vascular disturbance of the anterior compartment of the leg in soldiers without proceeding trauma. He believed that the anterior tibial artery was the cause of the inflammation seen on pathologic evaluation, though these changes were likely the result, not the cause, of the muscular atrophy. Hughes again described this condition and his described dissections refuted Horn’s thought that the margin of the interosseous membrane could damage the anterior tibial artery since it was one to two centimeters away. In 1957, Blandy et al used the term “march gangrene” to describe the ischemic necrosis found in the anterior muscles of the leg in combination with paralysis of the extensor digitorum brevis and the anesthesia of the first web space of the toe following exercise. They hypothesized that increases in muscle size caused an increase in pressure and subsequent ischemia. These early cases all describe the leg with no descriptions of compartment syndrome of the thigh.

There are few reports of extreme exertion causing an acute compartment syndrome (ACS) in the thigh. More commonly, compartment syndrome of the thigh presents following prolonged compression, thigh contusions, and trauma with or without subsequent surgical treatment of fractures. The first case of bilateral, exercise-induced ACS of the thigh in the English literature was published by Kahan in 1994, though it had been described 4 years earlier in German literature by Kmen. Compartment syndromes of the thigh are typically associated with fracture and, less commonly, blunt trauma. Diagnosis is primary clinical, with definitive treatment being operative compartment release. Although this condition remains rare, it needs to be considered as part of a differential diagnosis in patients presenting with injuries following “functional fitness” exercise programs. We present a unique case of bilateral exertional anterior thigh compartment syndrome in the absence of trauma. The case was followed until the patient’s full recovery 4 months after surgery.

CLINICAL CASE

A 23-year-old active duty U.S. Marine presented to his primary care provider 36 hours after extensive callisthenic training, including high repetitions of lower extremity exercises. These “functional fitness” exercises have become popular in the military because of the lack of gymnasium or equipment requirements. His 2-hour exercise period incorporated several hundred squats, leg raises, and lunges using his own body weight for resistance. Although the patient described a high level of baseline physical conditioning, this exercise session was significantly longer and more intense than his normal routine.

The following day he had increasing anterior thigh pain and began self-directed stretching. Two days postsinsult, his pain became severe, rendering him unable to ambulate without assistance, and he sought medical attention. Physical examination demonstrated bilateral knee range of motion limited to 20 degrees of active flexion, secondary to thigh...
pain, and severe bilateral anterior thigh pain with passive stretch. No neurovascular compromise was present. The posterior and medial thigh remained pain free and soft to palpation. Transfer to the Emergency Department was arranged for further evaluation and surgical consultation.

Initial laboratory analysis was significant for an elevated creatine phosphokinase (CPK) of 269,054 U/L, consistent with rhabdomyolysis. Compartment pressures in the thighs were attained using a commercially available intracompartmental pressure (ICP) monitor system and found to be 46 mm Hg in the right anterior compartment and 38 mm Hg in the left anterior compartment. Bilateral pressures in the posterior and adductor compartments were measured and remained below 15 mm Hg.

An orthopaedic surgery consultation was obtained for the diagnosis of compartment syndrome. Bilateral anterior thigh compartment fasciotomies were performed within 3 hours of initial presentation. Muscle tissue on the left thigh was viable with contraction to stimulus, whereas the right thigh muscle required minimal debridement to a healthy muscle bed. The wound was irrigated, and the surgical incisions were packed open with sterile dressings.

The patient was admitted to a surgical ward for wound care, pain control, and medical treatment of his rhabdomyolysis. On hospital day 1, the day of surgery, his BUN/creatinine ratio was 17/1.2. By postoperative day 1, the BUN/creatinine ratio had returned to baseline at 8/0.9. Medical treatment consisted of aggressive hydration with isotonic crystalloid fluids and did not require renal dialysis. CPK levels peaked at 342,880 U/L immediately following surgery, but began a downward trend 2 days postoperatively (Fig. 1). During this time period, he returned to the operating room for repeat irrigation and debridement with subsequent negative pressure wound therapy. On postoperative day 7, fasciotomy sites were closed primarily without the need for skin grafting. The CPK value continued to trend down to 7,400 U/L before discharge without evidence of acute tubular necrosis. Hospital discharge occurred 9 days after his initial presentation and he started a progressive physical therapy program. At final laboratory follow-up, CPK values continued to trend to normal. He made a full return to unrestricted active duty within 4 months as a Force Reconnaissance Marine.

**DISCUSSION**

The extremities are divided into compartments containing muscles, nerves, arteries, and veins enclosed by fascial and bony boundaries. Normal ICP typically falls between 0 and 10 mm Hg. Elevations of ICP above 20 mm Hg often result in pain and paresthesia, with pain being the most reliable complaint on presentation. Compartment syndrome occurs when the pressure inside these compartments rises and causes decreased tissue perfusion. ACS is defined as “an elevation of intracompartmental pressure to a level and for a duration that without decompression will cause tissue ischemia and necrosis.”8 The exact mechanism responsible for blood flow reduction is unknown, but is likely at the level of tissue capillary beds.8,9

The average annual incidence of ACS is 3.1 per 100,000, though it is significantly higher in males, with the most common underlying cause being a fracture.10,11 Exercise is a rare, but reported condition that can cause ACS. ACS of the thigh is less common than that of the leg because of the large potential space available to accommodate swelling before rises in pressure begin to affect perfusion.6,12 No data was found comparing rates of bilateral compartment syndrome in the thigh to that of the leg.

Previous cases of ACS of the thigh have been reported following intense exercise, generally in a format that is new to the patient.6,8,13–24 Patients often present hours, sometimes even days later with pain and swelling of one or both thighs.
after participating in a new rigorous exercise routine. ACS of the thigh secondary to exertion most commonly involves the anterior compartment, followed by the posterior compartment and least often the medial (adductor) compartment. \(^{13,16}\) Pain out of proportion to the stimulus and pain with limited passive flexion at the knee should raise suspicion for a compartment syndrome of the thigh.

As this condition progresses, ischemic necrosis of muscle within the affected compartment causes massive release of myoglobin. Excess myoglobin is excreted from the bloodstream through the renal tubules, clinically signified by darkening of the urine. Laboratory values commonly show an increase in CPK up to or above 100,000 U/L, hypocalcemia, hyperphosphatemia, and myoglobinuria, all indicating concomitant rhabdomyolysis. \(^{16}\) Leppilahiti found that over half of the cases of acute exercise-induced compartment syndrome presented with signs and symptoms of rhabdomyolysis and CPK values well above 100,000 U/L. The combination of tense compartments with rhabdomyolysis should initiate immediate surgical compartment releases.

The thigh has three primary compartments; the anterior compartment, the posterior compartment, and the adductor compartment, which are separated by the medial, posterior, and lateral intermuscular septa and bounded by the fascia lata. \(^{6,19}\) (Fig. 2). ICP measurement in these compartments is performed laterally for the anterior and posterior compartments and medially for the adductor compartment, though the medial compartment is rarely affected by compartment syndrome. Absolute pressure for indication to perform surgical decompression ranges between 30 mm Hg and 50 mm Hg, depending on the study reviewed, but it is now recognized that a better definition of compartment syndrome is based on systemic blood pressure. The difference between diastolic pressure and the ICP is known as Delta P. As tissue pressure increases, Delta P decreases, and when Delta P is less than 30 to 40 mm Hg, the likelihood of tissue damage and compromised tissue perfusion increases. In cases of ACS, Delta P less than or equal to 30 mm Hg is accepted as a threshold for surgical decompression. \(^{8}\)

Surgical decompression is performed by fasciotomy and remains the standard of care for ACS, though some advocate nonoperative treatment for athletes with thigh compartment syndrome without neurological compromise. These cases, however, were all following blunt trauma. \(^{25-27}\) Skin incisions should be made along the entire compartment allowing complete visualization of muscles to inspect for viability and ensure complete release. Any necrotic tissue must be debrided to decrease the risk of infection. In the thigh, both the anterior and the posterior compartments can be approached via a single lateral skin incision from the intertrochanteric line to the lateral epicondyle of the femur. The entire iliotibial band is incised and the vastus lateralis muscle reflected superomedially, exposing the lateral intermuscular septum. The lateral intermuscular septum is incised the entire length of the incision, which releases the posterior compartment. \(^{28}\) To access the adductor compartment, a separate medial incision can be made running...
the course of the saphenous vein. The sartorius muscle is rotated and the medial intermuscular septum is released. Postoperatively, fasciotomy incisions should not be closed primarily because of the risk for continued elevation of ICP and recurrent compartment syndrome. Wounds are left open and dressed with sterile gauze or negative pressure dressings, allowing a repeat debridement 48 hours postoperatively to ensure all necrotic muscle has been removed. If all muscle groups remain healthy and a tension free closure is possible, delayed primary closure may be performed at the repeat surgery. Other closure options include split skin grafting, dermato-traction techniques, and vacuum-assisted closure for temporization until delayed primary closure can be performed.

This patient’s presentation to a Military Treatment Facility allowed a multidisciplinary team approach for care. Internal medicine specialists treated the patient for rhabdomyolysis and monitored for potential for renal failure, orthopedic surgeons performed the decompression and all subsequent surgical care, and physical therapists started early, functional rehabilitation. The patient further benefited from the rehabilitation regimen under the “Wounded Warrior” program. This administrative and social support greatly contributed to his rapid healing and return to full, unrestricted military duty.

Early recognition, diagnosis, and surgical decompression of ACS of the thigh are critical to reduce residual functional deficits and yield optimal outcomes. Given the implementation of functional fitness exercise regimens throughout many military training units, a high suspicion for ACS after these sessions is essential to preventing future morbidity and possible mortality in symptomatic patients. This case is one example of how injury following a functional fitness routine may cause ACS and how early recognition and treatment resulted in a favorable outcome.

REFERENCES