Compartment Syndrome in Children

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KEYWORDS

• Compartment syndrome • Intracompartmental pressure • Fasciotomy • Volkman ischemic contracture • Near-infrared spectroscopy

KEY POINTS

- Increased analgesic needs is the first sign of compartment syndrome in children.
- Children with supracondylar humerus fractures, floating elbow injuries, and tibial shaft fractures are at high risk for compartment syndrome.
- Excellent outcome can occur with a timely diagnosis.

INTRODUCTION

Compartment syndrome is one of the true orthopedic emergencies. Regardless of the cause, the combination of rapid influx of fluid into a closed fascial compartment causes elevated intracompartmental pressure. Rising tissue pressure causes decreasing perfusion pressure and ultimately muscle and nerve ischemia. Prolonged ischemia can result in long-term morbidity due to the irreversible damage to muscles, nerves, blood vessels, and skin. Identifying at-risk patients, prompt diagnosis, and treatment are of significant importance. Most cases of compartment syndrome are caused by fractures. Soft tissue injuries in the absence of fractures (especially in children with bleeding disorders) can also lead to compartment syndrome.

Compartment syndrome is a clinical diagnosis, and patient-reported symptoms play a crucial role in recognition of a developing compartment syndrome. Young children cannot properly communicate pain and paresthesia, which can potentially impact the ability of the physician to make the diagnosis of compartment syndrome in a timely fashion. These patients may be admitted to pediatric floors that routinely do not care for orthopedic patients and whose staff may not be familiar with signs and symptoms of increased intracompartmental pressures. Physicians and other health care professionals (nurses, physician assistants, and others) taking care of children should be aware of unique features of compartment syndrome in children and should be able to identify at-risk patients that benefit from close monitoring.

The best approach to compartment syndrome relies on constant vigilance and decisive action to avert irreversible tissue damage. In addition, from a medicolegal standpoint, early diagnosis is very important. Only 44% of cases of compartment syndrome are closed in favor of treating physician compared with 75% of cases in other orthopedic malpractice claims.[1,2]

CLASSIFICATION

Compartment syndrome can be classified into the following types.

Acute Compartment Syndrome

Acute compartment syndrome is the most common form of compartment syndrome caused by an acute increase in the intracompartmental pressure, causing tissue ischemia. Currently,

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acute compartment syndrome of the leg is the most commonly seen scenario in children.

Exercise-induced Compartment Syndrome

Exercised-induced compartment syndrome is caused by reversible tissue ischemia caused by noncomplaint fascial compartment that cannot accommodate muscle expansion in exercise. It has been reported in both upper and lower extremities.

Neonatal Compartment Syndrome

Neonatal compartment syndrome is a rare form of compartment syndrome caused potentially by birth trauma and low perfusion of the extremities. It has only been reported in the upper extremity.

Volkmann Ischemic Contracture

Volkmann ischemic contracture is the consequence of prolonged ischemia and irreversible tissue loss, which is most commonly associated with supracondylar humerus fractures in children.

PATHOPHYSIOLOGY

Acute compartment syndrome can be caused by either fracture or reperfusion injury with unique pathophysiology regarding both causes. This article focuses on compartment syndrome relating to fracture. Acute compartment syndrome is caused by either bleeding or edema within a closed osseofascial compartment, leading to a reduction in perfusion of the contained muscles and nerves. Most studies of compartment syndrome have been undertaken as retrospective reviews of adult trauma patients or induced within animal models.

Early studies sought to determine the pathophysiology of compartment syndrome in hopes of determining the critical thresholds before it must be addressed. The underlying pathogenesis, however, has remained elusive, and still some controversy exists as to the underlying cause. Initially, 3 main theories persisted. Some have hypothesized its origin is from venous obstruction.[3–5] Others thought the basic problem was that of diminished arterial inflow.[6,7] Finally, others thought the root cause to be obstruction of inflow due to arterial spasm.[8,9] Recently, the underlying root cause of compartment syndrome was elucidated with the use of a novel animal system using hamster-striated muscle and in vivo fluorescence microscopy. The main determinant of diminished compartment perfusion was determined to be due to increasing intracompartmental pressure causing venular compression. This compression thereby causes a diminution in the arteriovenous pressure gradient, thus decreasing blood flow and perfusion to the compartmental skeletal muscle and nervous tissue.[10] Normal cellular metabolism requires an oxygen tension of at least 5 to 7 mm Hg to sustain life. Once blood flow decreases and oxygen is used up, the oxygen tension quickly decreases, resulting in ischemia, and normal cellular metabolism can no longer be sustained.

As a result of ischemia, muscle and nerve tissue quickly lose their function. Nerve demonstrates the most sensitivity to initial ischemia with functional abnormalities, including paresthesia and hypoesthesia within 30 minutes of ischemic onset. However, irreversible functional loss does not occur until after 12 to 24 hours of continued ischemia.[11–14] Muscle, on the other hand, demonstrates prolonged functional capacity for at least 2 to 4 hours following onset of ischemia; however, muscle begins to exhibit irreversible functional loss beginning at 4 hours after ischemic onset.[13,15,16] Because of these landmark studies, the authors have been able to determine optimal time to treatment for this limb- and sometimes life-threatening complication.

DIAGNOSIS

Compartment syndrome is a clinical diagnosis, and patient-reported symptoms play a crucial role in the recognition of a developing compartment syndrome. Identifying an evolving compartment syndrome in a young child is difficult because of the child's limited ability to properly communicate and the potential anxiety during examination. Orthopedic surgeons have been trained for generations to look for the 5 Ps (pain, paresthesia, paralysis, pallor, and pulselessness) associated with compartment syndrome. Pain out of proportion and pain with passive stretch are known as the first signs of an evolving compartment syndrome. Examining an anxious young child is difficult, and documenting the amount of pain may not be practical in children.

In a retrospective report of 33 children diagnosed with compartment syndrome at Boston Children's Hospital, Bae and colleagues[17] reported the traditional 5 Ps to be relatively unreliable in children. They reported that increasing analgesic need was found on average 7 hours before change in the vascular status and was a more sensitive indicator of compartment syndrome in children. They recommended that