

# Chapter 13

## Acute Compartment Syndrome in Children



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Compartment syndrome can occur due to a number of different etiologies, but most frequently occurs following high-energy trauma, which is less frequent in children than it is in adults. While the pathophysiology of compartment syndrome is the same as in adults, unique aspects of pediatric compartment syndrome include the challenges in examining and communicating with very young children. In addition, because the condition occurs uncommonly in children, providers caring for children may be unfamiliar with the signs of symptoms of patients developing compartment syndrome. While acute compartment syndrome in adults typically is observed to develop with the first 24 hours after injury, it has been suggested that the time between injury and development of peak compartment pressures may be longer in children [1]. Even longer times from inciting event or symptoms onset has been reported in children developing non-fracture-related compartment syndrome [2].

### Epidemiology

Trauma is the most common etiology for the development of compartment syndrome in both children and adults. Additional non-traumatic causes of compartment syndrome include vascular injuries, surgical positioning, infections, and envenomation.

Compartment syndrome can affect children of any age. In children <10 years of age who develop compartment syndrome, the etiology is usually due to a vascular injury or infection, while in children >14 years of age, the etiology is usually due to trauma or surgical positioning [2–4]. Compartment syndrome occurs more commonly in males, especially adolescent males, and is associated with a higher rate of high-energy traumatic injuries in these patients who have a larger muscle mass [1–3, 5, 6].

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Historically, compartment syndrome was most frequently seen in children with supracondylar humerus, forearm, and femoral shaft fractures [7]. Treatment of supracondylar humerus and femoral shaft fractures has changed over time, leading to a decrease in the associated incidence of compartment syndrome following these injuries. Supracondylar humerus fractures that historically were treated with closed reduction and casting in hyperflexion now undergo closed reduction and percutaneous pinning without the need to immobilize in hyperflexion. Femur fractures that historically were treated with 90-90 skeletal traction are now treated in a spica cast or with surgical fixation (flexible nailing or percutaneous plate fixation).

Currently, the most common condition causing development of compartment syndrome in children, as it is in adults, is trauma, resulting in tibial shaft fractures. Approximately 40% of pediatric compartment syndromes are due to tibial shaft fractures [4, 8].

## Diagnosis

The diagnosis of acute traumatic compartment syndrome in children less than 5 years of age is especially challenging [1]. Very young children may not be able to accurately verbalize their symptoms, increasing the challenge in accurately diagnosing compartment syndrome. Young children may also have difficulty cooperating with the physical examination for compartment syndrome. While diagnosis is typically based on clinical examination findings in the setting of an injury placing the child at risk for compartment syndrome, measurement of compartment pressure may be required. This can be difficult or impossible in a young awake child and will often require some form of conscious sedation.

While the five Ps (*pain out of proportion or increasing in severity, pain with passive stretch, palpable tenseness, paresthesia, and paralysis/motor weakness*) remain a common criteria for diagnosing compartment syndrome in adults, a mnemonic of three As has been suggested for use in children. These findings include increasing anxiety, increasing agitation, and increasing analgesic requirements [9].

## Tibia Fractures

Tibia fractures, especially high-energy injuries, represent the most common condition in which children develop compartment syndrome. In a review of 43 acute compartment syndromes associated with pediatric tibial fractures, 83% of cases were caused by motor vehicle accidents [1]. Development of compartment syndrome has been reported to occur in 4% of children sustaining an open tibial fracture [10]. A more recent review reported an 11.6% rate of compartment syndrome in 216 pediatric patients sustaining tibial fractures [3]. An increased use of compartment pressure measurement in this series may explain the higher rate of

compartment syndrome diagnosis. Multivariate analysis in this study found that injuries due to motor vehicle accidents and children >14 years of age are at a higher risk for developing compartment syndrome. The rate of developing compartment syndrome was 48% in the subset of children >12 years of age with a tibia fracture due to a motor vehicle accident. In a large series examining the National Pediatric Trauma Registry, the incidence of compartment syndrome for open tibia fractures was 6.2% and for closed tibia fractures was 3.3% [5].

Tibial tubercle fractures represent a unique increased risk for the development of compartment syndrome in children. Associated injury to the anterior tibial recurrent artery can result in compartment syndrome of vascular compromise in as many as 10% of children sustaining tibial tubercle fractures [11].

A unique form of compartment syndrome centered in the region of the extensor retinaculum was reported in six children with distal tibial physeal fractures [12]. These patients presented with classic signs and symptoms of compartment syndrome including severe pain and ankle swelling, first web space hypoesthesia, extensor hallucis longus and extensor digitorum communis weakness, and pain with passive toe flexion. Compartment pressure measurements beneath the extensor retinaculum were > 40 mm Hg, while measurements in the anterior muscle compartment were < 20 mm Hg. These patients underwent release of the superior extensor retinaculum and stabilization of their fractures, resulting in rapid resolution of their symptoms.

## Supracondylar Humerus Fractures

The reported incidence of compartment syndrome with contemporary treatment of supracondylar humerus fractures is only 0.1%–0.3% and most commonly involves the volar compartment of the forearm [13, 14]. While the volar forearm compartment is most commonly affected in cases of compartment syndrome following supracondylar humerus fracture, compartment syndrome involving the anterior arm, posterior arm, and mobile wad has also been reported [15, 16]. The diagnosis of compartment syndrome can be challenging in patients with supracondylar humerus fractures and median nerve palsy since the nerve injury may impair the child's pain sensation.

Increased risk of compartment syndrome occurs when supracondylar fractures are immobilized in greater than 90° of elbow flexion. Elbow flexion >90° was identified as a contributing factor in 8 of 9 cases of volar forearm compartment syndrome that occurred following closed reduction of a supracondylar humerus fracture [7].

Associated vascular compromise, in which swelling may be exacerbated during reperfusion, also increases the risk for development of compartment syndrome. In a series of supracondylar humerus fractures in which pulses were absent, compartment syndrome developed in 2 of 9 children without adequate hand perfusion, while no cases developed in 24 children with a pulseless but perfused hand [17].

Urgent treatment of displaced supracondylar humerus fractures had previously been recommended, but several studies have shown that an 8–12-hour delay in their treatment does not increase the risk of compartment syndrome [18–21]. Urgent treatment is still recommended for patients who present with a significant neurovascular deficit, and close monitoring is recommended in patients with severe swelling [22].

## Forearm Fractures

Compartment syndrome has also been described in children sustaining both bone forearm fractures. In a large series examining the National Pediatric Trauma Registry, the incidence of compartment syndrome for open forearm fractures was 2.3% and for closed forearm fractures was 0.72% [5]. In smaller series, the incidence of compartment syndrome in children sustaining open forearm fractures has been reported to range from 7.7% to 11% [6, 23].

One study has suggested that extensive closed manipulation, as measured by length of operative time, increases the risk for development of postoperative compartment syndrome in children whose forearm fractures are treated by intramedullary nailing [24]. Investigators in this study reported the development of forearm compartment syndrome following intramedullary nailing occurred in 6% of open fractures and 10% of closed fractures. In comparison, they reported no compartment syndromes in 205 forearm fractures treated by closed reduction and casting. The use of a small incision has been advocated to minimize the amount of manipulation and facilitate reduction during intramedullary nailing of closed forearm fractures [6]. Using this technique in approximately half of their cases, they reported no compartment syndromes in 74 operatively treated closed forearm fractures.

Early surgical fixation may increase the risk of developing compartment syndrome. Two cases of compartment syndrome occurred in 30 children with forearm fractures treated with intramedullary nailing within 24 hours of injury, while none occurred in 73 patients treated more than 24 hours after injury [25].

## Ipsilateral Humerus and Forearm Fractures

Children sustaining floating elbow injuries, ipsilateral distal humerus and forearm fractures, may have an increased risk for compartment syndrome. In one small series of nine patients, the incidence of compartment syndrome in this injury pattern was reported as 33% [26]. In another small series, two cases of compartment syndrome and four cases of impending compartment syndrome were reported in ten patients with floating elbow injuries in which the forearm fractures were treated by closed reduction and circumferential cast immobilization. In contrast, closed reduction and k-wire fixation of both the distal humerus and forearm fractures was safely

performed in six cases without the development of compartment syndrome [27]. The increased swelling associated with this combined injury suggests that circumferential cast immobilization should be avoided.

Whether the floating elbow injury represents a significantly increased risk for compartment syndrome is questioned by a much larger series reported by Muchow et al. No cases of compartment syndrome were reported in this series of 150 cases of ipsilateral distal humerus and forearm fractures; however, they noted a higher rate of neurologic injury in the floating elbow injuries compared to that seen in isolated distal humerus fractures [28]. However, because there is an increased risk of nerve injury that can impair the diagnosis of compartment, increased vigilance for the possibility of a missed compartment syndrome is warranted in children sustaining a floating elbow injury.

## **Femur Fractures**

The development of compartment syndrome has been described in young children treated with a particular 90-90 spica cast technique [29]. In most of these cases, a short leg cast was first applied and then traction was applied to the leg, and the authors speculated that this leads to impingement on the posterior compartment of the leg.

## **Neonatal Compartment Syndrome**

A compartment syndrome-like condition involving the upper extremities that is thought to be caused by a combination of low neonatal blood pressure and birth trauma has been described and termed neonatal compartment syndrome [30]. This is a rare condition in which the diagnosis is often delayed [31]. A sentinel skin lesion of the forearm has been described as a clinical sign to identify this rare condition.

## **Non-traumatic Causes of Compartment Syndrome in Children**

Although less common, it's important to understand that compartment syndrome can occur in the absence of fractures and remain vigilant in these scenarios of atypical presentation. In 12 cases of non-traumatic compartment syndrome, 10 patients were obtunded and treated in an intensive care unit [32]. The most common etiology was iatrogenic due to intravenous infiltration or failure to remove a phlebotomy tourniquet, and four cases resulted in an amputation.

Other non-traumatic causes of compartment syndrome include coagulopathy due to hepatic failure, renal failure, leukemia, and hemophilia [33–36]. Correction of the

coagulopathy is necessary in conjunction with fasciotomy. Envenomation by snake-bites is another non-traumatic cause of compartment syndrome in children. The use of antivenin has been reported to eliminate the need for fasciotomy following rattlesnake bites in the majority of patients [37]. Exercise-related compartment syndrome can also occur, typically in adolescent males who are competitive athletes [2].

## Treatment

External sources of compression should be removed in patients with an impending compartment and the limb maintained at the level of the heart (not elevated). Routine close clinical examination and/or compartment pressure measurement should be performed in these patients. Prompt diagnosis and fasciotomy is essential in avoiding tissue necrosis and functional deficits in patients with an established compartment syndrome. As described elsewhere in this textbook, the pressure threshold for fasciotomy is debatable. At least one study has found that normal compartment pressures are higher in children than in adults. In children, the mean compartment pressure of the lower leg ranged from 13.3 mm Hg to 16.6 mm Hg, while in adults it ranged from 5.2 mm Hg to 9.7 mm Hg [38].

## Summary

The diagnosis of compartment syndrome in children is primarily based on clinical examination and knowledge of injury pattern. Increasing need for pain medication following a traumatic injury should alert the clinician to the possibility of compartment syndrome. Additional findings to consider in children include increasing anxiety and agitation. Compartment pressure measurement can be used in cases in which the diagnosis is uncertain or in noncommunicative patients, but in children this typically requires sedation, and these values should be interpreted with caution since normal compartment pressures have been shown to be higher in children than in adults. Children with tibial fractures are at the highest risk for developing compartment syndrome, but several traumatic and non-traumatic injuries can result in compartment syndrome.

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