

# Compartment Syndrome in Children: Diagnosis and Management

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## Abstract

Compartment syndrome (CS) can present differently in children than in adults. Increased need for analgesics is the first sign of evolving CS in children. Children with supracondylar humeral fractures, floating elbow injuries, operatively treated forearm fractures, and tibial fractures are at high risk for CS. Elbow flexion beyond 90° in supracondylar humeral fractures and closed treatment of forearm fractures in floating elbow injuries are associated with increased risk for CS. Prompt diagnosis and treatment with fasciotomy in children result in excellent long-term outcomes.

Compartment syndrome (CS) is one of the true orthopedic emergencies. Identifying the high-risk patient, making a prompt diagnosis, and initiating effective treatment are the crucial steps in avoiding a poor outcome. A physician's inability to communicate with young children can interfere with diagnosing CS in a timely fashion. Many young patients in hospitals are admitted to pediatric floors where routine orthopedic care is not the norm and staff are unfamiliar with the signs and symptoms of evolving CS. As orthopedic surgeons are often involved in caring for these patients, they should be aware of the aspects of CS that are unique to children and should be able to identify patients who are at risk and would benefit from close monitoring. In addition, given the consequences of late diagnosis, early diagnosis is important from a medicolegal standpoint. Only 44% of cases of adult and pediatric CS are decided in favor of treating physicians, compared with 75% of cases in other orthopedic malpractice claims.<sup>1,2</sup>

## Risk Factors for Posttraumatic Compartment Syndrome Supracondylar Humeral Fracture

CS is a well-described complication of this injury. CS develops in 0.1% to 0.3% of children who present with supracondylar humeral fracture.<sup>3,4</sup> Casted elbow flexion beyond 90° and concomitant vascular injury put these children at increased risk for CS. Mubarak and Carroll<sup>5</sup> reported 9 cases of CS in

the volar compartment of the forearm after an extension-type supracondylar humeral fracture and attributed 8 of them to elbow flexion beyond 90° after closed reduction. In 29 children with supracondylar humeral fracture, Battaglia and colleagues<sup>3</sup> found the highest compartment pressure in the deep volar compartment, especially near the fracture site, as well as a significant increase in pressure with the elbow flexed beyond 90°.

In a study of children with supracondylar humeral fracture, Choi and colleagues<sup>6</sup> found 2 cases of CS among 9 patients who presented with a pulseless, poorly perfused hand and no cases of CS among 24 patients who presented with a pulseless but well-perfused hand.

Studies have found that a treatment delay of 8 to 12 hours did not increase the rate of CS in Gartland type 2 and type 3 fractures.<sup>7-10</sup> The investigators in these studies did not recommend delaying treatment of patients with neurologic deficit and absent radial pulse. Ramachandran and colleagues<sup>4</sup> reported 11 cases of CS in patients with low-energy supracondylar humeral fracture and intact radial pulse at presentation. The patients who developed CS presented with severe swelling, and their mean treatment delay was 22 hours (range, 6-64 hours). Given the data, we do not recommend delayed treatment for children with supracondylar humeral fracture and neurologic deficit or absent pulse. We do recommend close inpatient preoperative monitoring of patients with severe swelling.

CS after supracondylar humeral fracture is mostly seen in the volar compartment of the forearm, but it has also been reported in the mobile wad, the anterior arm compartment, and the posterior arm compartment.<sup>11,12</sup>

## Floating Elbow

CS has been reported in children with ipsilateral humeral and forearm fractures. Blakemore and colleagues<sup>13</sup> reported a 33% rate of CS in children with displaced distal humeral and forearm fractures. A retrospective review of 16 cases of floating elbow treated at Boston Children's Hospital found CS in 2 patients and incipient CS in 4 of 10 patients with forearm fractures treated with closed reduction and plaster casting. There were no signs of CS in 6 patients with distal humeral and forearm fractures stabilized with Kirschner wires.<sup>14</sup> Given the data, we do not recommend circumferential casting for forearm fractures in children with floating elbow.

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### Forearm Fracture

Haasbeek and Cole<sup>15</sup> reported CS in 5 (11%) of 46 children with open forearm fracture. Yuan and colleagues<sup>16</sup> reported CS in 3 (6%) of 50 open forearm fractures and 3 of 30 closed fractures treated with closed reduction and intramedullary nailing. They found increased risk for CS in patients with longer operative time, indicating prolonged closed manipulation of these fractures as a risk factor for CS. They did not find any cases of CS among 205 forearm fractures treated with closed reduction and casting.

Flynn and colleagues<sup>17</sup> reported CS in 2 of 30 patients treated with intramedullary nailing within 24 hours of injury and in 0 of 73 patients treated after 24 hours.

Blackman and colleagues<sup>18</sup> reported CS in 3 (7.7%) of 39 open forearm fractures and 0 of 74 closed fractures treated operatively. In their series, a small incision was made to facilitate reduction in 38 (51.4%) of 74 closed fractures to decrease closed manipulation and operative time. The rate of CS after intramedullary nailing of closed forearm fractures was lower in this series than in similar reports in the literature.

Reported data indicate increased risk for CS in children with open forearm fractures and fractures treated with closed reduction and intramedullary nailing, especially performed within 24 hours of injury, and prolonged closed manipulation performed during surgery. We recommend close monitoring of all children with operatively treated forearm fractures and, in particular, children with the risk factors mentioned.

### Femoral Fracture

Although CS after femoral shaft fractures is not common, CS has been reported after 90/90 spica casting of femoral shaft fractures in children. Mubarak and colleagues<sup>19</sup> reported on 9 children who developed calf CS after treatment of femoral shaft fracture in 90/90 spica casts. The technique used in 7 of the 9 reported cases involved initial application of a short leg cast and then traction applied to the leg—believed to cause impinging of the cast on the posterior compartment of the leg. The authors recommended an alternative method of applying spica casts, which is beyond the scope of this review.

### Tibial Fracture

Children with tibial fracture, especially a fracture sustained in a motor vehicle accident, are at risk for CS. Hope and Cole<sup>20</sup> found CS in 4 (4%) of 92 children with open tibial fracture.

Children with tibial tubercle fracture are at increased risk for CS because of concomitant vascular injury. Pandya and colleagues<sup>21</sup> reported CS or vascular compromise in 4 of 40 patients with tibial tubercle fracture. We recommend close monitoring for signs of impending CS in children who present with high-energy tibial shaft fracture and tibial tubercle fracture.

Flynn and colleagues<sup>22</sup> reported outcomes of 43 cases of acute CS of the leg in children treated at 2 pediatric trauma centers. Mean time from injury to fasciotomy was 20.5 hours (range, 3.9-118 hours). Functional outcome was excellent at time of follow-up; 41 of 43 cases had no sequelae, and the 2

patients who lost function underwent fasciotomy more than 80 hours after injury. Despite the long interval between injury and surgery, excellent results were achieved with fasciotomy, suggesting an increased potential for recovery in the pediatric population.

Mubarak<sup>23</sup> reported on 6 cases of distal tibial physis fracture in patients who presented with severe pain and swelling of the ankle, hyposthesia of the first web space, weakness of the extensor hallucis longus and extensor digitorum communis, and pain on passive flexion of the toes. In all these patients, intramuscular pressure was more than 40 mm Hg beneath the extensor retinaculum and less than 20 mm Hg in the anterior compartment. All patients experienced prompt relief of pain and improved sensation and strength within 24 hours after release of the superior extensor retinaculum and fracture stabilization.

### Miscellaneous and Nontraumatic Causes of Compartment Syndrome

Neonatal CS is very rare, and diagnosis is often missed. Neonatal CS is thought to be caused by a combination of low neonatal blood pressure and birth trauma.<sup>24</sup> Ragland and colleagues<sup>25</sup> reported on 24 cases of neonatal CS; in only 1 case was the diagnosis made within 24 hours. They described a “sentinel skin lesion” on the forearm of each patient as the sign of neonatal CS. Late diagnosis results in contracture and growth arrest of the involved extremity. In their series, only 1 patient underwent fasciotomy within 24 hours, and it resulted in a good functional outcome. High clinical suspicion is the key to early diagnosis and treatment of this rare pathology.

Medical problems that cause intracompartmental bleeding (hepatic failure, renal failure, leukemia, hemophilia) have been cited as causing CS.<sup>26-28</sup> CS may be the first symptom of occult hemophilia.<sup>29</sup> Correction of the coagulation defect may take priority over surgical treatment in these cases, though the decision should be made on a case-by-case basis.<sup>26</sup>

CS in children can also be caused by snakebites. Shaw and Hosalkar<sup>30</sup> reported on successful use of antivenin in preventing the need for surgical treatment in 16 of 19 patients with rattlesnake bites. Two patients had limited surgical débridement, and 1 underwent fasciotomy for CS. The authors recommended using antivenin to prevent CS in children with snakebites.<sup>30</sup>

Prasarn and colleagues<sup>2</sup> reported on 12 cases of upper extremity CS in children in the absence of fractures. Of the 12 patients, 10 were managed in an intensive care unit and had an obtunded sensorium. Etiology in 7 (58%) of the 12 cases was iatrogenic (intravenous infiltration, retained phlebotomy tourniquet). In this series, 4 amputations were performed on affected extremities.

### Diagnosis

Identification of evolving CS in a child is difficult because of the child's limited ability to communicate and anxiety about being examined by a stranger. Orthopedists are trained to look for the 5 Ps (pain, paresthesia, paralysis, pallor, pulselessness)

associated with CS. Examining an anxious, frightened young child is difficult, and documenting the degree of pain is not practical in a child who may not be able or willing to communicate effectively.

In a series of 33 children with CS, Bae and colleagues<sup>31</sup> found that the 5 Ps were relatively unreliable in making a timely diagnosis. The authors also found that increased analgesic use was documented a mean of 7.3 hours before a change in vascular status and that it was a more sensitive indicator of CS in children. The resulting recommendation is that children at risk for CS be closely monitored for the 3 As (increasing analgesic requirement, anxiety, agitation).<sup>32</sup>

Regional anesthesia is used to control postoperative pain in adults and children.<sup>33,34</sup> Injudicious use may mask the primary symptom (pain) of CS.<sup>32,35-38</sup> Use of regional anesthesia in patients at high risk for CS is highly discouraged.

Although CS is a clinical diagnosis, compartment pressure measurements can be useful in making decisions in certain clinical scenarios. In an obtunded child or in a child with severe mental and communication disability, such a measurement can help confirm or rule out the diagnosis.

Normal compartment pressures are higher in children than in adults. Staudt and colleagues<sup>39</sup> compared pressures in 4 lower leg compartments of 20 healthy children and 20 healthy adults. Mean pressure varied from 13.3 mm Hg to 16.6 mm Hg in children and from 5.2 mm Hg to 9.7 mm Hg in adults—indicating higher normal pressure in lower leg compartments in children.

Compartment pressures were reported highest within 5 cm of the fracture site.<sup>40</sup> When clinically indicated, they should be measured in that area in an injured extremity. The pressure threshold that requires fasciotomy is debatable. Intracompartmental pressures of 30 to 45 mm Hg, or measurements less than 30 mm Hg of diastolic blood pressure (pressure change = diastolic blood pressure – compartment pressure), have been recommended as cutoffs by some authors.<sup>41-44</sup> As resting normal compartment pressures are higher in children, these cutoffs cannot be used as reliably in children as in adults. Direct measurement of intracompartmental pressure is invasive and can be difficult in an agitated, awake child. The potential utility of near-infrared spectroscopy in the diagnosis of increased compartment pressure has been reported.<sup>45,46</sup> This method uses differential light absorption properties of oxygenated hemoglobin to measure tissue ischemia—similar to the method used in pulse oximetry. Compared with pulse oximetry, near-infrared spectroscopy can sample deeper tissue (3 cm below skin level). Shuler and colleagues<sup>45</sup> reported near-infrared spectroscopy findings for 14 adults with acute CS. Lower tissue oxygenation levels correlated with increased intracompartmental pressures, but the authors could not define a cutoff for which near-infrared spectroscopy measurements would indicate significant tissue ischemia. Use of this method in diagnosing CS in children was described in a case report.<sup>46</sup>

CS remains a clinical diagnosis. Informing family and staff about the signs and symptoms of this syndrome and closely monitoring analgesic use in these patients are crucial. Com-

partment pressure measurements can be used when the diagnosis is unclear, particularly in noncommunicative patients, but these values should be interpreted with caution.

## Treatment

Once CS is diagnosed, emergent fasciotomy and decompression are indicated. Surgeons planning fasciotomy should be aware of the definitive treatment of the CS etiology. Treatment of clotting deficiency in cases caused by excessive bleeding, fracture fixation, and vascular repair may be indicated during fasciotomy and decompression.

## Summary

Increased need for analgesics is often the first sign of CS in children and should be considered the sentinel alarm for ongoing tissue necrosis. CS remains a clinical diagnosis, and compartment pressure should be measured only as a confirmatory test in noncommunicative patients or when the diagnosis is unclear. Children with supracondylar humeral fractures, forearm fractures, tibial fractures, and medical risk factors for coagulopathy are at increased risk and should be monitored closely. When the diagnosis is made promptly and the condition is treated with fasciotomy, good long-term clinical results can be expected.

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