Compartment Syndrome After Low-Energy Tibia Fractures Sustained During Athletic Competition

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Objective: The purpose of this study was to determine whether patients who sustain tibia fractures during athletic competition are at an increased risk of developing acute compartment syndrome (ACS).

Design: Retrospective review.

Setting: University Level I trauma center.

Participants/Patients: Acute tibia fractures in 626 patients between July 2006 and June 2009.

Methods: A retrospective review of 626 consecutive tibia fractures treated by our department between July 2006 and June 2009 was performed. We recorded the mechanism and type of fracture as well as whether or not ACS developed. Soccer and football injuries were analyzed as specific groups. Chi square was used to analyze our results.

Main Outcome Measurements: The rate of ACS in patients injured during sporting events versus that of all patients with a tibia fracture.

Results: Thirty-four patients (5.4%) developed ACS, which is consistent with the published literature. Nine patients sustained the injury while playing soccer (1.4% of patients), whereas 11 patients (1.7%) were injured playing football. Five of the nine soccer players (55%; \( P < 0.001 \)) and three of the football players (27%; \( P < 0.001 \)) developed ACS. Collectively, tibia fractures sustained in football and soccer led to 25% of ACS cases despite accounting for only 3.1% of all tibia fractures.

Conclusions: Tibia fractures sustained during soccer and football had a statistically significant association with development of ACS in our patient population during this time period. Such patients should be monitored closely and followed with high clinical suspicion for ACS.

Key Words: acute compartment syndrome, tibia fracture, soccer, football, athletics

INTRODUCTION

Acute compartment syndrome (ACS) is a well-recognized complication of tibial fractures with potentially devastating consequences. Identification of at-risk individuals to facilitate expeditious diagnosis and management of elevated compartment pressures may limit damage to the limb resulting from compartment syndrome, as well as known long-term sequelae.

Traditionally, lower extremity compartment syndrome has been associated with higher energy injuries. However, we have noted a series of patients who sustained what would be considered by most to be relatively low-energy tibia fractures during athletic competition and subsequently developed ACS. Many of these patients present with radiographs such as that shown in Figure 1, which appear benign, but are complicated with ACS. Based on these observations, we undertook a review of all patients with a tibia fracture managed at our institution in an attempt to identify patients at risk who would benefit from close observation, frequent serial examinations, and a higher clinical suspicion.

PATIENTS AND METHODS

A retrospective review of all tibia fractures treated at a Level I trauma center between July 2006 and June 2009 was undertaken. Institutional Review Board approval was obtained. This period of time was chosen because patients managed before July 2006 were not logged into an electronic database. Patients were identified by Current Procedural Terminology and International Classification of Diseases, 9th Revision codes for tibial fractures. All tibia fractures in both pediatric and adult patients, regardless of anatomic location or treatment method, were included. This search yielded 626 consecutive fractures of the tibia. The reports and records of these 626 fracture patients were reviewed, and the mechanism and anatomic location of the injury were recorded.

Using the Current Procedural Terminology code for fasciotomy of the leg, all patients who developed ACS during the same 3-year timespan were identified. Review was undertaken and all patients treated with fasciotomies for any reason other than a fracture of the tibia were eliminated. All patients with ACS were treated surgically during this time period. Thirty-four consecutive patients who underwent fasciotomies for treatment of ACS after a tibia fracture were identified.

The number of patients sustaining tibia fractures sustained while participating in sporting activities, including...
football or soccer, was tallied as well as the number of athletes who developed ACS. Chi-square data analysis was performed with SPSS for Windows, Version 16 (Chicago, IL).

RESULTS

Of the 626 tibia fractures reviewed, 34 developed ACS. These 34 patients represent 5.4% of our cohort, which is consistent with the published rate of ACS after tibia fracture.

Nine of the patients sustained their tibia fracture while playing soccer, and five of the patients (55.6%) developed ACS. Chi-square analysis showed this to be statistically significant ($P < 0.001$). In total, soccer accounted for only 1.4% of tibia fractures (nine of 626) but 15.6% (five of 34) of ACS. Eleven patients sustained a fracture of the tibia while playing American football. Three of the 11 (27.3%) developed ACS, yielding a chi-square result of $P < 0.001$. In summary, American football accounted for 1.6% (11 of 626) of our total number of tibia fractures but 9.4% (three of 34) of those patients who developed ACS.

Five of the nine soccer players and all of the American football players in our series were male. All three of the American football players and four of the five soccer players who developed ACS were male. The average age of the soccer players who sustained a tibia fracture was 16.8 years (range, 7–31 years), whereas the average age of those who developed ACS was 20.8 (range 13–31). American football players with a tibia fracture had an average age of 20.3 years (range, 13–40 years), whereas the average for those who developed ACS was 31.6 years (range, 15–40 years). All five of the adult patients (older than 18 years) who sustained a tibia fracture during competition went on to develop ACS.

All fractures progressing to ACS in pediatric patients were classified through the Salter-Harris classification, whereas those in adults were characterized by the AO classification. All pediatric fractures were Salter-Harris II injuries. In the adult population, all fractures were “A”-type injuries with the exception of two tibial plateau fractures, both of which were bicondylar or Type “C” injuries. More complete demographic information for the patients who developed ACS can be found in Table 1.

All patients who developed ACS after a sports-related tibia fracture were diagnosed before any operative intervention and treated with fasciotomies with the exception of one football player who was diagnosed on postoperative Day 1 after intramedullary nailing. Each patient with clinical suspicion of ACS underwent direct intracompartment measurements with a handheld device. An absolute pressure of 30 mmHg or greater in a patient with clinical suspicion was considered sufficient evidence to perform compartmental releases. All of the fasciotomy wounds were left open after the initial procedure with coverage by a wound vacuum assisted closure (VAC). Closure of the fasciotomies was performed an average of 4.4 days (range, 2–7 days) after the index procedure. No infections occurred and all wounds were closed primarily without the need for skin grafting. No patients reported any neurologic sequelae at their respective follow-up appointments. With the exception of two patients, both of whom were closed primarily on postoperative day 2, all patients returned to the operating room on either postoperative day 2 or 3 for irrigation, debridement, and wound VAC change before their definitive closure.

DISCUSSION

When pressures within an osseofascial compartment increase enough to impede blood flow across capillary beds, cellular anoxia and ischemia of the tissues within that compartment may result. Ischemia of up to 4 hours is well tolerated. However, after 6 hours of ischemia, muscle viability is variable and irreversible damage appears to occur after 8 hours of diminished perfusion.

Hamilton first described ischemic muscle contracture in 1850. In 1881, Volkmann provided the first full description of ischemic contracture and hypothesized that it was the result of reduced arterial blood flow. Griffiths and Foisie believed

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Sex</th>
<th>Age (years)</th>
<th>Sport</th>
<th>Fracture Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Male</td>
<td>31</td>
<td>Soccer</td>
<td>AO 41C1</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>13</td>
<td>Soccer</td>
<td>Salter-Harris II distal tibia</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>24</td>
<td>Soccer</td>
<td>AO 42A3</td>
</tr>
<tr>
<td>4</td>
<td>Female</td>
<td>14</td>
<td>Soccer</td>
<td>Salter-Harris II distal tibia</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>22</td>
<td>Soccer</td>
<td>AO 42A3</td>
</tr>
<tr>
<td>6</td>
<td>Male</td>
<td>15</td>
<td>Football</td>
<td>Salter-Harris II proximal tibia</td>
</tr>
<tr>
<td>7</td>
<td>Male</td>
<td>40</td>
<td>Football</td>
<td>AO 42A1</td>
</tr>
<tr>
<td>8</td>
<td>Male</td>
<td>40</td>
<td>Football</td>
<td>AO 41C1</td>
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arterial injury and spasm were responsible and published reports of successful treatment by excision of the damaged artery. Seddon,\textsuperscript{6,7} and Owen and Tsimboukis\textsuperscript{8} provided the classic description of ischemic contractures resulting from untreated compartment syndrome. These authors stressed the need for swift diagnosis and urgent surgical treatment with fasciotomies. Furthermore, Seddon challenged the arterial injury theory noting that the majority of his patients had palpable peripheral pulses. It was not until 1968 that McQuillan and Nolan\textsuperscript{9} described the pathophysiological mechanisms involving increased intracompartmental pressure with venous congestion and subsequent reduction in arterial flow.

Diagnosis of ACS remains challenging in many patients. Although the “5 Ps” of compartment syndrome—pain, pallor, paralysis, pulselessness, and paresthesia—do occur, their appearance generally signifies the terminal stages of the syndrome in which the patient has already sustained irreversible damage. In most cases, intracompartmental pressure measurements provide the objective evidence necessary when a diagnosis of ACS is being considered. Increasing pain and pain with passive stretch are the most reliable clinical indicators of ACS, but are often difficult to gauge, especially in pediatric patients or those with painful fractures. Furthermore, the clinical picture is variable in patients affected by this syndrome.\textsuperscript{10}

Numerous authors have suggested absolute thresholds above which fasciotomies should be performed.\textsuperscript{11-20} However, other authors have demonstrated that patients with pressures as high as 50 mmHg do not always develop compartment syndrome. The difference in the compartment pressure and the diastolic blood pressure or mean arterial pressure, also known as ΔP, is regarded as the best objective test. Although there is some debate, many authors believe that a compartment pressure within 20 mmHg of the diastolic blood pressure or within 30 mmHg of the mean arterial pressure indicates acute compartment syndrome.\textsuperscript{1,2}

Identification of individuals at risk for ACS is instrumental to early diagnosis and intervention. McQueen et al\textsuperscript{21} assessed risk factors for developing ACS. The most common cause of ACS was fracture of the tibia (36.0%) followed by soft tissue injury (23.2%) and distal radius fracture (9.8%). Of the 59 patients in their series who developed ACS after a tibial fracture, 55 were men. They reported an average annual incidence for men of 6.9 per 100,000 compared with only 0.2 per 100,000 for women. In addition to tibia fracture and male sex, McQueen et al also identified age as a significant risk factor with an average age of 30 years among patients with ACS. Patients with a tibia fracture who were older than 35 years of age had a threefold decrease in compartment syndrome when compared with patients younger than 35 years of age at the time of injury.

McQueen’s study demonstrates clearly that younger patients have a higher risk of ACS. This was also noted in our series, in which patients who developed ACS after a tibia fracture in soccer or football had an average age of 24 years (range, 13–40 years). Although our results seem to indicate that young age is a risk factor, we acknowledge that this could be the result of the fact that the majority of people playing soccer and football are young. However, other studies\textsuperscript{21,22} have shown that younger age is a risk factor for ACS after a tibial fracture. It is interesting to note in our series that 100% of adult patients (older than 18 years) who sustained a tibia fracture during athletic competition went on to develop ACS, including two patients who were 40 years old.

Although there does not seem to be a consensus as to why younger patients are at an increased risk, the literature does provide several logical theories. Developmental anatomy has shown that the osseofascial compartments do not increase in size after skeletal maturity, and as such, it is possible that young patients, especially males, have an increased muscle mass within this fixed volume compartment when compared with older patients, who generally have relative atrophy.\textsuperscript{23} This effect may be magnified in young athletes who are building muscle mass through intensive training and competition. Furthermore, older patients generally have higher blood pressure, which has been shown to be protective against ACS.\textsuperscript{24-26} One study\textsuperscript{26} looking at the thresholds of pressure for peripheral nerve viability also demonstrated that hypertension is beneficial.

Although age alone would explain an increase in the incidence of ACS after a tibial fracture during athletics, it does not explain completely the increased proportion of ACS among athletes with a tibia fracture. McQueen et al\textsuperscript{27} reported that low-energy tibia fractures are actually at a higher risk of ACS than their high-energy counterparts, whereas another study\textsuperscript{21} reported an equal incidence of ACS with high- and low-energy fractures. It is possible that American football and soccer injuries produce a high degree of local soft tissue trauma while at the same time not producing sufficient energy to disrupt the boundaries of the compartments.\textsuperscript{28} Tibia fractures during soccer and American football often are the result of direct loads on the tibia such as a kick or a blow from a helmet. These mechanisms carry substantial energy, which is transferred to the soft tissues, producing contusion, swelling, and inflammation. It is likely that these patients sustained a tibial fracture in conjunction with substantial soft tissue trauma.

In addition, although fractures that occur during a sporting activity such as football and soccer generate significant local injury, the energy may not be sufficient to disrupt the compartmental boundaries. The phenomenon that occurs when an initial injury is substantial enough to disrupt the boundaries of the compartments is known as “autodecompression” and is hypothesized by some to cause an effect similar to a fasciotomy. The concept of “autodecompression” is supported by studies that report a decreased risk of ACS in high-grade, open tibia fractures.\textsuperscript{21,27} Although there is a risk of ACS with any type of tibia fracture, some literature demonstrates decreased incidence in more severe (Gustilo and Anderson Grade III) open injuries.\textsuperscript{27}

The fact that these injuries occur during athletic competition may be a risk factor in itself. At the time of injury, the leg muscles of these athletes are being put through rigorous activity. Studies of exertional compartment syndrome have illustrated that exercise can increase compartment pressures. Although these athletes do not have exertional compartment syndrome, athletic activity is causing muscle swelling, inflammation, and injury. Although this may not be symptomatic and is tolerated well by the athlete, theoretically the threshold for
compartment syndrome may be lowered, thereby diminishing the amount of pressure necessary to elevate the compartment to dangerous levels. It may be that athletic activity in a younger patient creates a more conducive environment within a more restrictive anatomy in which a relatively low-energy fracture, in combination with localized, direct soft tissue trauma combine to generate sufficient pressures to induce ACS.

One could argue that this patient population may have had a transient increase in their intracompartamental pressures related to the swelling and inflammation inherent to athletic activity that would have decreased over a relatively short period of time without intervention. However, in a patient with a combination of subjective clinical findings and objective pressure measurements consistent with ACS, we feel that it is most prudent to proceed immediately with surgical compartmental release.

Regardless of whether there is one mechanism or a combination of several, it appears that tibia fractures sustained during soccer and American football generate a greater risk of ACS than previously thought. Since the completion of our review, patients at our institution with these fractures are generally observed overnight in the hospital with a high level of clinical suspicion for ACS and frequent serial examinations. Recognition of the potential dangers of this constellation of injuries, in this specific patient population, may allow surgeons the opportunity to identify and treat ACS early in the evolution of the problem and thus avoid the effects ACS can have on the patient’s limb and long-term function.

Based on our review, patients with a tibia fracture sustained during soccer or American football are at an increased risk of developing ACS. The heightened risk may be a function of numerous factors. These factors include gender, because these patients are often young males, who have been identified as a high-risk group as a result of specific anatomic and developmental issues. Second, these fractures appear to produce substantial soft tissue injury secondary to direct trauma, and that of the fracture itself, without reaching the threshold to create "autodecompression." Finally, vigorous exercise may create an environment of swelling and inflammation within muscles that lowers the amount of pressure necessary to increase intracompartamental pressures to those associated with ACS. For these reasons, we recommend that patients with a tibia fracture sustained during soccer or football be observed in the hospital overnight with frequent examination and a high level of clinical suspicion for ACS.

REFERENCES