Injury, Int. J. Care Injured 48S (2017) S22–S25

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Acute compartment syndrome

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ARTICLE INFO

Keywords:
Compartment syndrome
Fasciotomy
Intramuscular pressure
Tibia fracture
Perfusion pressure

ABSTRACT

Acute compartment syndrome is a well-known complication of tibial fractures, yet it remains difficult to diagnose and the only effective treatment is surgical fasciotomy. Delayed fasciotomy is the most important factor contributing to poor outcomes, and as a result, treatment is biased towards performing early fasciotomy. Current diagnosis of ACS is based on clinical findings and intramuscular pressure (IMP) measurement, and is targeted at identifying safe thresholds for when fasciotomy can be avoided. Since clinical findings are variable and difficult to quantify, measurement of IMP – ideally continuously – is the cornerstone of surgical decision – making. Numerous investigators are searching for less invasive and more direct measurements of tissue ischemia, including measurement of oxygenation, biomarkers, and even neurologic monitoring. This article provides a brief but thorough review of the current state of the art in compartment syndrome diagnosis and treatment.

Introduction

Acute compartment syndrome (ACS) is a complication of trauma or other conditions that cause bleeding, edema, or that compromises perfusion to an extremity. Fracture or a crush injury to the limb are the most common cause of ACS [1]. The progressive limb swelling that occurs following fracture, a crush injury, or limb ischemia increases mass within the myofascial compartment due to accumulation of blood and fluid. Since muscle fascia and other connective tissues are inelastic, this increased mass causes increased pressure within the compartment, which is transmitted to the thin-walled veins causing venous hypertension [2], and progressive tissue ischemia. With the onset of cellular death, cell-membrane lysis releases osmotically active cellular contents into the interstitial space, causing further accumulation of fluid and further increase in intracompartment pressure. Arteriolar perfusion can also be compromised, leading to microvascular collapse [3]. Myonecrosis may occur within 2 h of injury in patients with ACS [4]. After 6–8 h of circulatory failure, irreversible ischemic injury has occurred to the myoneural tissues within the compartment.

Incidence in tibia fractures

Tibia fractures are the most common injury associated with ACS, and age, mechanism of injury, and fracture pattern and location all influence the risk of ACS (Table 1). Young men up to age 29 are the highest risk for ACS [5]. In terms of fracture pattern, segmental tibia fractures, bicondylar tibial plateau fractures and medial knee fracture-dislocations are very high risk [6,7]. Automobile versus pedestrian injuries, ballistic injuries to the proximal tibia and fibula [8], and tibia fractures occurring during soccer or football [5,9] are examples of mechanisms of injury associated with a high risk of ACS.

With regards to tibia fractures, Park et al. evaluated 414 acute tibial fractures, evaluating the rate of fasciotomy according to fracture location (Park 2009). ACS was most common in diaphyseal tibia fractures, occurring in 8% of cases, compared to less than 2% in proximal and distal metaphyseal fractures, respectively. Among the diaphyseal fractures, younger age was the only risk factor that was independently associated with the incidence of ACS. Several series report an appreciable incidence of compartment syndrome in patients with tibial plateau fractures [7,10] and these fractures must also be considered in the high-risk category.

Since ACS evolves after injury, one must be aware of the potential for ACS to develop if one is considering transferring a patient to another center for definitive care, and fasciotomy should be done prior to transfer if there is significant time involved before the patient arrives at the second institution [11,12].

Problems in diagnosis

Although the existence of ACS is well-known and most clinicians understand the potential limb-threatening nature of ACS, there is no clear definition of when compartment is actually

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http://dx.doi.org/10.1016/j.injury.2017.04.024
0020-1383/

Table 1
Summary of the reported incidence of acute compartment syndrome related to various patterns and mechanism of injury and presence of clinical examination findings.

Risk Factor/Clinical Finding	Risk of CS
Fracture Pattern	
Segmental tibia Fracture	48% [6]
Bicondylar Tibial Plateau Fracture	18% [7]
Medial Knee Fracture-Dislocation	53% [7]
Mechanism of Injury	
Tibia fracture during sport	20% [5]
Soccer	55% [9]
Football	27% [9]
Ballistic Injury Proximal-third tibia or fibula	21% [8]
Clinical Exam Findings (pain, paresthesias, pain with passive stretch, paresis) [17]	
One clinical finding	
Pain	25%
Paresthesias	26%
Pain with passive stretch	25%
Paresis	19%
Two clinical findings	
Pain and pain with passive stretch	68%
Three clinical findings	
Pain, pain with passive stretch, paresis	93%
All four clinical findings	98%

present. Thus, there is considerable variation in the clinical management of compartment syndrome [13–15]. The consequences of missed diagnosis are severe for both the patient and the physician and hospital [16]. The generally accepted clinical signs of ACS are worsening pain that is out of proportion to what is otherwise expected, pain with passive stretch of the involved muscle, and paresthesia in the distribution of any sensory nerves within the compartment. It has been established that the clinical signs and symptoms of ACS are poor as a screening test, with low sensitivity [17] (Table 1). Many of these clinical findings also occur in patients without ACS, perhaps due to direct tissue injury. For example, Robinson et al. reviewed 208 consecutive patients who underwent reamed nailing of a tibia fracture, and 5 percent of them developed dysfunction of the common or deep peroneal nerve [18]. Many of them exhibited isolated weakness of the extensor hallucis longus associated with numbness in the first web space. Interestingly, all of these patients had continuous compartment pressure monitoring and none developed compartment syndrome [18].

Early diagnosis of ACS is critical for avoiding morbidity [19–23]. Unfortunately, despite the common teaching that compartment syndrome is an ‘orthopedic emergency’, there are frequent delays in the time from initial assessment to diagnosis and in the time from diagnosis to surgery in patients with ACS [22]. The incidence of late diagnosis can be diminished by frequent or continuous measurement of intramuscular pressure (IMP) [23,24]. Whenever the clinical examination is not reliable, measurement of IMP in one or more compartments in an at-risk patient is mandatory. Many investigators recommend routine measurement of IMP in all patients [25–28]. However, the need for IMP monitoring has been quite controversial, and there are also well-done studies that the refute the value of pressure monitoring [29–31]. However, the studies questioning the value of IMP measurement employed clinical protocols that employed very frequent and detailed clinical assessment. For example, Al-Dadah et al. reported similar rates of fasciotomy and time to diagnosis of compartment syndrome both before and after adopting a protocol of continuous monitoring of anterior compartment pressure [31]. However, patients in both groups were assessed by trained nurses every hour [31]. These results may not be generalizable to institutions that cannot offer that level of care.

The difficulty in using specific pressure thresholds for diagnosing ACS and deciding when fasciotomy should be done is highlighted by Prayson et al. who carefully followed blood pressure and compartment pressure in 19 patients with isolated lower extremity fractures who did not have compartment syndrome by clinical criteria, or at follow-up [29]. In their series, 84% of the patients had at least one measurement in which their perfusion pressure less than 30 mmHg, and 58% had were less than 20 mm Hg [29]. Thus, single pressure measurements alone may not be representative and do not establish trends with time. In contrast, serial or continuous measurements demonstrate rising IMP or falling perfusion pressure more clearly, and are likely to be more specific for patients that truly have ACS. Consistent with this, McQueen et al. recently reported data suggesting that continuous pressure monitoring should be the gold standard for diagnosis of ACS; using a threshold for fasciotomy related to the perfusion pressure (intramuscular pressure within 30 mm Hg of the diastolic blood pressure for 2 consecutive hours or more), they demonstrated a sensitivity for diagnosis of ACS of 94% [32].

Clinicians should be aware of potential pitfalls with use of pressure measurements for decision-making in patients at-risk of ACS. First, there is spacial variation in the pressure within a given compartment, with pressures being highest within 5 cm of the fracture [33] and more centrally in the muscle [34]. It has never been established whether one should obtain pressures near the fracture to obtain the highest pressure, or measure further away (outside the zone of injury) to obtain a pressure that may be more representative of the majority of the compartment [30]. Secondly, there may be uncertainty and/or variability in measured values of IMP. Using a cadaver model, Large et al. documented significant variability in the technique of IMP measurement, and showed that only 60% of measurements done correctly were within 5 mm Hg of the known IMP [35]. Another potential source of uncertainty when calculating perfusion pressure is what blood pressure value to use, especially if the patient is under general anesthesia. Tornetta et al. recorded preoperative, intraoperative, and postoperative blood pressures in patients undergoing tibial nailing [36]. Their conclusion was that use of intraoperative diastolic blood pressure measurements for calculation of perfusion pressure may give a spuriously low perfusion pressure and lead to unnecessary fasciotomy. These authors recommend using preoperative blood