EC MICROBIOLOGY
Review Article

Diagnosis and Management of Acute Compartment Syndrome in the Emergency Department

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Received: December 12, 2019; **Published:** December 27, 2019

Abstract

Acute compartment syndrome (ACS) is a surgical emergency that is usually caused by trauma or chronic syndrome. ACS patients are usually presenting with severe pain and more common among young patients with muscle bulk and strong fascial compartments. For that, extensive literature searches of the Medline, Cochrane, and EMBASE databases using the medical subject headings (MeSH) terms "compartment syndrome"; has been performed. Papers discussing diagnosis and management of compartment syndrome were screened for relevant information. There were no limits on date, language, age of participants or publication type. The first step in the clinical diagnosis is the appropriate identifying of risk factors followed by the adequate clinical examination. A combination of different signs and symptoms along with measuring the intracompartmental pressure are the main principles in the diagnosis of ACS. The initial management includes removing any restrictive dressings, correction of any present hypotension, and the use of adjuvant hyperbaric oxygen. Fasciotomy is the definitive treatment that should be done as early as possible to avoid any further complications.

Keywords: *Compartment Syndrome; Acute Management; Fasciotomy*

Introduction

The fascial membranes in the human limbs divide the muscle groups within the limbs into sections or compartments [1,2]. The compromised circulation and tissue functions as a result of the increased pressure are the main underlying mechanism of the compartment syndrome [1,2]. Accordingly, this decreased perfusion will lead to a surgical emergency called Acute compartment syndrome (ACS) [3,4]. The estimated ACS incidence per 100,000 individuals is 0.7 to 7.3 [5]. Many neurovascular deficits may persist in a lot of cases flowing ACS without the appropriate urgent treatment [6]. Accordingly, ACS is one of the most significant conditions with medico-legal claims [3]. As high as 32% of cases have legal claims of treatment delay, 23% of claimed misdiagnosis and a mean of 574,680$ per one case [7].

Young patients aged 35 years and less; have the highest incidence of ACS due to the relatively higher muscle bulk, strong surrounding fascial membranes and higher prevalence of violent injuries [3,5]. Moreover, older patients have weaker muscles and hypertension-associated perfusion pressure increase [8]. Furthermore, the male gender is considered a risk factor for ACS with a higher incidence (10 times more) in males compared to females [5]. Although most of the ACS cases occur during the first one or two days of injury, it can occur a few days later in some cases [9]. Fractures are the most common conditions associated with ACS, with tibial fractures carrying the highest risk [5,10,11]. In the same context, ACS involving lower limbs has been associated with 2% to 9% of all tibial fractures [12]. Noteworthy, ACS cannot be excluded in case of open fractures since the associated fascial tears are small [12,13]. Accordingly, they did not appropriately decompress the compartment [12,13]. It should be noted that ACS is not always associated with a history of trauma or injury, as it has been documented in cases without any of them [3]. There are many other risk factors; including, but not limited to, burns, casts, deep venous thrombosis (DVT), hematologic diseases, infections, prolonged vascular procedures, immobilization, skin and skeletal traction, insect bites and snake bites [3]. In this study, we provide an overview of the diagnosis and management of ACS in the emergency setting.

Methods

We performed an extensive literature search of the Medline, Cochrane, and EMBASE databases on 20 November 2019 using the medical subject headings (MeSH) terms "compartment syndrome". Papers discussing diagnosis and management of compartment syndrome were screened for relevant information. There were no limits on date, language, age of participants or publication type.

Diagnosis of compartment syndrome

Clinical diagnosis

The first step in the clinical diagnosis is the appropriate history taking to identify any risk factors that be associated other than injury [3]. The clinical examination may be initially inadequate since most of the signs and symptoms may be still subtle [4,5,8]. ACS clinical features are usually evident in a stepwise fashion with variable timing of appearance of each finding [1,14,15]. The earliest symptom is usually the significant pain that is not proportional to the severity of injury [3,11]. Nevertheless, pain is a very subjective clinical feature and may vary among patients with poor sensitivity [11]. Moreover, the pain may disappear in the late stages of ACS [13]. Other symptoms may include different sensory deficits including paresthesia and motor deficits manifesting as focal weakness [11,16,17].

On examination, a palpation-associated pain, the tense of the firm compartment, limb swelling, pulse reduction and reduced capillary refill time [11,16,17]. Nevertheless, motor and pulse deficits are not always present and the firm compartment is also unreliable sign [4,18]. Swelling is detected in more than 50% of the patients and the subjectivity of the sign can be reduced by measuring limb circumference in comparison to the other limb [3,8]. Although abnormal pulse oximetry may help in detecting deficits in limb perfusion, the normal one does not exclude the ACS [8,11,13]. The diagnostic accuracy of clinical features is summarized in table 1 [3,11].

Finding	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Pain	19	97	14	98
Paresthesia	13	98	15	98
Pain with passive stretch	19	97	14	98
Paresis	13	97	11	98

Table 1: *Clinical features and their diagnostic value [3,11].*
NPV: Negative Predictive Value; PPV: Positive Predictive Value.

Rely on only isolated signs and symptoms can result in misdiagnosis or delayed diagnosis; however, a combination of different clinical features can increase diagnostic accuracy [3]. A combination of detecting pain with passive stretch, paresthesia, and detection of pain in rest can result in a sensitivity of 93% and with the addition of paresis; the sensitivity may reach up to 98% [11]. The most important factors that could be associated with missed diagnosis; includes inexperienced physicians, sedated and poly-traumatized patients, injured soft tissue and reliance on clinical features [11,19-26].

Diagnostic testing

For laboratory investigations, a blood test can be done to evaluate creatine kinase (CK) and urine testing can include full renal functions and urine myoglobin [3]. A detected myoglobinuria or CK levels > 1000 U/mL with increasing levels over time; are indicators of ACS [8,11,13,27]. More than 40% of the ACS patients, caused by trauma, are associated with rhabdomyolysis [27-29]. Accordingly, a rhabdomyolysis-induced renal injury and hyperkalemia are evident as well [8,11,13,27]. Noteworthy, imaging studies have no significant value in the diagnosis of the ACS [3,19,30].

Another important diagnostic investigation is the measurement of the intracompartmental pressure [8,11,17,31]. The pressure is usually measured by direct and invasive methods; including transducer intracompartmental catheter (STC) device, needle manometry, the Whitesides' method, and the wick catheter [8,16,17]. An overview of these methods is summarized in table 2 [3]. The normal range of the intracompartmental pressure is between 0 mmHg and 8 mmHg [32]. A mean arterial pressure between 25 and 30 mmHg is associated with compromised capillary blood flow, while pain starts to manifest with tissue pressures between 20 mmHg and 30 mmHg [32]. Fasciotomy is indicated in ACS delta pressure < 30 mmHg [14].

STC Monitor Instructions	Intravenous Transducer Instructions
1. Obtain consent and prepare a sterile field. Clean and prepare the area. 2. Mark the entry site and anesthetize skin, but avoid injecting into deep tissue. 3. Turn on the Stryker device (left upper portion of the device). 4. Remove the diaphragm unit and needle from the sterile pouch. 5. Connect a prefilled 3-mL syringe to the diaphragm, then attach the needle to the other end of the diaphragm. 6. Open the lid on the device by lifting the blue latch at the bottom corner of the unit, then place the needle and syringe into the unit and secure the lid. 7. Point the device upwards and gently flick air bubbles out of the syringe. 8. Zero the device by holding it perpendicular to the site of entry and pressing the blue button. This will result in ''00'' appearing on the monitor screen. 9. Remove the needle protective cover and advance the needle 1–3 cm into the skin, while holding the device perpendicular to the entry site. 10. Insert 0.3 mL of saline by gently pressing the syringe hub. 11. Hold the device while the pressures equilibrate, and a number should appear on the device. 12. Remove the needle and device from the site. 13. Repeat for other compartments.	1. Obtain consent and prepare a sterile field. Clean and prepare the area. 2. Mark the entry site and anesthetize skin, but avoid injecting into deep tissue. 3. Attach an 18-gauge needle to i.v. extension tubing and a f our-way stopcock. 4. Fill half the tubing with sterile saline, and ensure that no air is present within the tubing. 5. Attach a second i.v. extension tube to the four-way stopcock, with the opposite end attached to a blood pressure manometer or other device capable of measuring pressures. 6. Connect a 20-mL syringe filled with air to the middle attachment of the four-way stopcock 7. Place the 18-gauge needle into the compartment, while keeping the apparatus at the level of the needle. 8. Turn the stopcock so that the syringe is open to both extension tubes. 9. Compress the plunger of the syringe, which slowly increases the pressure in the system. 10. Closely watch the saline/air meniscus. Once the pressure in the closed system has surpassed the tissue pressure within the compartment, the meniscus will move. 11. When the column moves, stop pushing the plunger and read the manometer. This number is the tissue pressure in mm Hg. 12. Remove the needle and device from the site. 13. Repeat for other compartments.

Table 2: *Intracompartmental pressure measurement [3].*
STC: Solid-State Transducer Intracompartmental Catheter.

Management of compartment syndrome

A significant decline in the ACS associated complications can be achieved by the appropriate and prompt management to maintain the normal function of the affected limb [3]. The management starts with immediate surgical consultation, removal of any limb constrictions and maintains the limb at the level of the heart (to prevent arterial inflow reduction and compartment pressure increase associated with dependent limb) [8,11,33]. The removal of any dressing, restrictive covering or cast can reduce pressure by 65% to 85% [16,17,34,35]. Next, fluid resuscitation (with isotonic saline) to restore circulating volume is advised for hypotensive patients to compensate for perfusion pressure deficits [8,11,16,17]. Moreover, adjuvant therapy like analgesics and hyperbaric oxygen should be provided as well [36-38].

The critical threshold of performing fasciotomy is variable and controversial in the literature among different individual and even different compartments [8,11,16,17,20,39]. The recommended threshold for fasciotomy in the previous literature ranged between 30 mmHg and 40 mmHg [29,39-44]. Noteworthy, the perfusion pressure is more significant than the intracompartmental pressure; which in turn varies among different individuals according to age, hypertension or any drugs [3,31,41,45,46]. The fasciotomy technique varies according to the affected limb and the number of compartments (Table 3) [3,47,48]. In rare cases, fasciotomy may not be necessary as in low-risk circumstances or if the muscles are already dead (no benefit with high infection risk) [49,50].

Compartment	Incisions
Foot	Typically includes two dorsal incisions over second to fourth metatarsals for forefoot decompression; medial incision to decompress calcaneal, medial, and superficial compartments; and lateral incision starting at the lateral malleolus extending to the forefoot between the fourth and fifth metatarsals.
Lower leg	Anterolateral fasciotomy may include single lateral incision or lateral and medial incisions together, 15 - 20 cm in length. Lateral and medial incisions are recommended for adequate decompression. If tibial fracture is present, single-incision technique can be considered (double incisions reduce soft tissue support and reduce fracture stability).
Thigh	Fasciotomy typically includes single incision, though double incisions can be used. Single incision can decompress all three compartments, but two parallel fascia lata incisions can be used to prevent muscle herniation. For lateral and posterior ACS, incisions begin at intertrochanteric line and extend to lateral epicondyle.
Forearm	Decompress using two incisions with the volar and dorsal incisions; these are usually formed concurrently.
Hand	Carpal tunnel requires decompression, as well as incisions to decompress interossei. Mid-lateral incisions on noncontact or nondominant side can be used for digital decompression.

Table 3: *Different fasciotomy approaches [3,47,48].*

Conclusion

ACS is a surgical emergency caused by increased intracompartmental pressure that can cause significant morbidity and mortality. A combination of different clinical fractures along with measuring intracompartmental pressure is needed to avoid delayed and misdiagnosis. Prompt and appropriate management is the key factor in maintaining limb function and avoiding further complications.

Funding

None.

Conflicts of Interest

No conflicts related to this work.

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Volume 16 Issue 1 January 2020