Compartmental Syndrome: A Case Report and Literature Review

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Abstract

Acute compartment syndrome of the extremities is a serious and potentially limb and, life endangering condition. Compartment syndrome of the extremities is considered a medical emergency. Despite widely described classic clinical signs and profound physiologic understanding of its mechanism, most cases show only partial, often insidious clinical expression. In conjunction with lack of uniform, reliable and easily applicable diagnostic tools, the diagnosis of compartment syndrome is a challenge, as is the decision making tree of conservative versus surgical treatment. Unconscious patients present an especially difficult subgroup of patients. In this article we will try to compile and simplify the up-to-date knowledge about the etiology, pathophysiology, diagnosis and treatment of compartment syndrome of the extremities. We will present the rigid box model of acute compartment syndrome which can aid in medical personnel education as well as assist in diagnosis and treatment decision making. Early recognition, competency in practical application of intra compartmental pressure measurement techniques and a timely performed surgical decompression are the primary requisitions of successful treatment. A keen awareness by all medical personnel and a high grade of suspicion to this elusive but devastating entity is in place.

Keywords: Acute compartment syndrome; Keen awareness; Surgical treatment; Pathophysiology

Definition

Compartment syndrome was first described by Malgaigne, and the first medical publication was that of Volkmann [1] in 1881 which used the term "ischemic contracture".

Acute Compartment Syndrome (ACS) is defined as "a condition in which increased pressure within a limited space compromises the circulation and function of the tissues in that space" [2]. Under this definition one can include also such conditions as expanding subdural hematoma, tension pneumothorax, some cases of intestinal obstructions and closed angle glaucoma; although in this article we will only discuss acute compartment syndrome of the extremities.

Etiology

ACS of the extremities is most commonly seen following injuries to the leg and forearm (40% caused by tibial shaft fractures and 18% by forearm fractures), but can also occur in the arm, foot, thigh, buttock, hand and lumbar paraspinous muscles.

Acute compartment syndrome can be classified according to its etiology as shown in Table 1, but this would be a simplification for instructional purposes, since most acute compartment syndromes are caused by a combination of factors. A good example may be a use of a surgical tourniquet which can cause acute compartment syndrome by each of the following mechanisms: muscle crush, reperfusion damage, mechanical injury to blood vessels, venous thrombosis and relative venous insufficiency or any combination thereof if the tourniquet is inflated or placed improperly [3-7] (Table 1).

Pathophysiology

Normal intracompartmental pressure is below 10-12 mmHg.

Compartmental Perfusion Pressure (CPP) = Mean Arterial Pressure (MAP) – Compartmental Pressure (CP)

Normal values of compartmental perfusion pressure are above 70-80 mmHg. Acute compartment syndrome develops when tissues within a compartment do not receive an adequate blood supply. Factors that increase CP or decrease MAP will cause decreased compartmental perfusion and ischemia. Most of the etiologic factors listed in Table 1 influence CP. Decreased MAP itself rarely causes compartment syndrome, but can happen when a limb is elevated for a prolonged period, e.g. in patient undergoing surgery in lithotomy position [8]. Even then, it is assumed to be at least partially due to reperfusion injury and an elevation in compartmental pressure.

The Rigid Box Model

The Rigid Box Model can help in understanding the interaction of factors influencing the magnitude of the intracompartmental pressure. A compartment can be assumed to be a rigid, non-expansible box (fascial envelopes, interosseous membranes and bone walls) that is filled with a mass (muscle, fat, neural and vascular structures), with very limited free space (intra- and extravascular) constantly filled by affterent

Table 1: Causes of acute compartment syndrome of extremities.

<table>
<thead>
<tr>
<th>Bone related</th>
<th>Fractures</th>
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<tbody>
<tr>
<td></td>
<td>iatrogenic - surgery</td>
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<tr>
<td>Vascular</td>
<td>Arterial injury (bleeding or occlusion)</td>
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<td></td>
<td>Venous injury (bleeding or occlusion)</td>
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<td></td>
<td>Reperpusion injury</td>
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<td></td>
<td>Decreased oncotic pressure</td>
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<tr>
<td>Iatrogenic</td>
<td>Plaster of Paris/circular dressing application</td>
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<tr>
<td></td>
<td>Invasive procedure in anticoagulated patient</td>
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<tr>
<td></td>
<td>Excessive Pulsatile irritation</td>
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<tr>
<td>Soft tissue damage</td>
<td>Crush injury</td>
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<tr>
<td></td>
<td>Muscle overuse or tear</td>
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<tr>
<td></td>
<td>Reperpusion damage</td>
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<tr>
<td></td>
<td>Burns</td>
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<tr>
<td></td>
<td>Animal bite (venomous and non-venomous)</td>
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<td></td>
<td>Pressurized fluid injury (by machinery)</td>
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</tbody>
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Even opiates is more suggestive of compartment syndrome. Pain on over time. Still, pain may just be mild. Pain irresponsive to analgesics proportion to the magnitude of injury or a constant increase in pain initially misrelated to the trauma itself. A typical sign is pain out of paresthesias, pulselessness, paralysis, poikilothermia.

Be very mild. Mubarak and Rorabeck [6] listed six classical signs of work and wellbeing of patients is tremendous. Infection and delayed fracture healing are other possible late sequelae of acute compartment syndrome [9-11].

Since acute compartment syndrome occurs most often in young patients [9], the overall impact in terms of daily function, ability to work and wellbeing of patients is tremendous.

Clinical Presentations

The initial clinical presentation of compartment syndrome can be very mild. Mubarak and Rorabeck [6] listed six classical signs of compartment syndrome, described as ‘the six P’s’: pain, pallor, paresthesias, pulselessness, paralysis, poikilothermia.

Pain

It can be the first and only sign of compartment syndrome, often initially misrelated to the trauma itself. A typical sign is pain out of proportion to the magnitude of injury or a constant increase in pain over time. Still, pain may just be mild. Pain irresponsible to analgesics (even opiates) is more suggestive of compartment syndrome. Pain on passive stretching of muscles contained in a suspected compartment may raise suspicion of the presence of an acute compartment syndrome and aid in pointing to a specific compartment within a limb. Another important physical sign is a tender or rigid area upon palpation of a limb, which anatomically correlates with a specific compartment. Every suspected compartment should be evaluated and re-evaluated, preferably by the same physician, while establishing the diagnosis.

Paresthesia

Related to nerves passing through a specific compartment. It is also a helpful sign for localization. The first sensory modality to be impaired is static two-point discrimination [7].

Paralysis

Rendered as an inability to activate muscles within an involved compartment, may be a sign of pain avoidance or of functional nerve impairment. Functional impairment will usually appear late in the course of acute compartment syndrome evolvement. Paralysis of a muscle group that is located distal to an involved compartment but innervated by a nerve passing via this compartment may be more specific to acute compartment syndrome.

Pallor

It is a result of diminished blood outflow via the exiting vessel of the compartment. One should seek for pallor in areas that are supplied by a relevant artery distal to its exit level from the compartment.

Pulselessness

Even in full blown acute compartment syndrome distal pulses may still be preserved. Although a compartmental pressure equal to or higher than systolic blood pressure is needed to abolish a peripheral sensation, this may be decreased at lower compartmental pressures. It is prudent for a physician to examine and compare pulses of both extremities, whenever possible.

The major drawback of the majority of the listed symptoms and signs is their late appearance. Patients presenting with signs other than increasing pain, pain on passive muscle stretching or paresthesias (early symptoms) are usually at an irreversible stage of tissue injury [6]. In addition, most of these symptoms and signs are inapplicable in a patient with altered conscious, patients at age extremes or in drug abusers.

The need of early diagnosis of acute compartment syndrome cannot be overstressed in this dramatic condition. The key to a timely successful treatment is a high level of suspicion, prompt and correct implementation of anatomic knowledge of limb compartments and their content, with a stress on distal sensory and motor nerve distribution.

Objective Diagnostic Methods

Compartmental pressure measurement

Several methods are described to measure compartmental pressure. A needle manometer was the first device used for this purpose. White sides [12] described a device composed of a needle connected to a manometer by a fluid filled infusion system. An interpretation of the intracompartmental pressure was done by observing the shape of a fluid-air interface (“meniscus”) within the system. When the meniscus becomes flat during elevation of fluid pressure, the pressure within the system is considered to be equal to that within the tested compartment. This system had the disadvantage of the need to inject...
additional, although small, amounts of fluids into a compartment, and
the needle became quickly obstructed and did not allow continuous
ICP monitoring. In addition, the readings had many inaccuracies
[13]. Several types of catheters were proposed and tested in trying to
overcome the above disadvantages, including side ported needles, the
wick catheter [13], the slit catheter [14], and the solid-state transducer
intracompartmental catheter [15]. Although the catheter measurement
techniques allow continuous pressure monitoring for up to 24 hours,
they still require a heparinized saline system to maintain patency of the
probe. None of the systems was uniformly agreed upon to be superior
[16,17].

Laboratory

No specific laboratory markers for compartment syndrome are
used today. A very high plasma CPK level measurement is not specific
and may be a result of trauma and ischemia. Although without evidence
of trauma it may suggest acute compartment syndrome, it is not helpful
in early diagnosis.

Magnetic resonance imaging

MR imaging can clearly identify edema of soft tissues within a
compartment. The edema appears as a high signal on T2-weighted
images [18]. Nevertheless, the swelling is present in any case of acute
trauma to some extent, and cannot be distinguished from ACS on
MRI, especially in the early stages of ACS. Thus, MRI is useful only for
chronic cases of CS [19].

Near infrared spectroscopy

Is based on the fact that light in the near infrared spectrum
passes through skin and bone and is absorbed differentially by
hemoglobin and oxyhemoglobin [20]. It was designed and tested for
cases of chronic exertion compartment syndrome with good success
in detecting changes in relative oxygenation as compared to normal
individuals [21,22]. Near infrared spectroscopy is still inapplicable in
ACS for several reasons. First, in ACS relative oxygenation may
be impaired prior to measurements being performed. Second, near
infrared spectroscopy has a limited depth of measurement (3-40 mm)
and cannot detect changes in the deep muscle compartments of the
limb. Third, no normal limits of venous oxyhemoglobin were defined
so as to be used in clinical practice. Although promising, near infrared
spectroscopy still remains clinically inapplicable.

Scintigraphy

This method uses Tcm99-methoxyisobutyl isonitril (MIBI) to
evaluate regional perfusion in muscle tissue and is widely used in
evaluating coronary perfusion. Scintigraphy was shown to be of value
in chronic exertional compartment syndrome with positive predictive
value of 89% [23], but its role in acute compartment syndrome is not
known.

Laser doppler flowmetry

This invasive modality is still under investigation.

Treatment

Initial care of a suspected acute compartment syndrome includes
immobilization of the injured limb, removal of any circular dressing
and positioning of the limb at heart level. Excessive elevation of the limb
should be avoided to allow adequate perfusion. In case of fracture of
the long bones- stabilization of the limb in a grossly normal alignment
is preferable to diminish further soft tissue damage and avoid torque of
blood vessels. Monitoring blood pressure, preventing hypotension and
oxygen supplementation are essential.

When measured intra compartmental pressure is above 30 mmHg
and clinical signs have appeared or are worsening, decompression
fasciotomy should be performed as a treatment of choice. Preventive
fasciotomy is done in cases of a limb that has suffered warm ischemia
for more than 4-6 hours, in patients with ligation of major veins in the
lower limb and with crush injury. In case of forearm or leg ACS, all
compartments must be released by a one- or two-incision technique.
Necrotic tissue must be debrided, and skin coverage of swollen and
expanded areas of the limb is performed by an elastic closure technique
that utilizes rubber tension sutures and an artificial tissue cover. An
additional surgical procedure to complete skin closure may be needed
after tissue swelling subsides (Figure 2).

The fasciotomy technique can utilize multiple longitudinal
incisions to approach each compartment individually, or a single
incision technique that allows approach to all compartments. In any
case, it is widely accepted that all the compartments of the involved
limb segment must be released in acute compartment syndrome cases.

Recently, Bedside fasciotomy under local anesthesia was found to
be a feasible and reliable procedure in selected cases [24].

The occurrence of compartment syndrome affects the time to
fracture healing and rate of fracture delayed union and non-union in
the tibia [25] a pattern which may very well be the case in other sites.

Summary

Acute compartment syndrome is a serious and potentially limb
and life threatening condition, uniformly considered as a medical
emergency. The classic clinical signs are often not distinguishable from
the signs of a “simple” uncomplicated trauma, but the toll of missed
acute compartment syndrome is tremendous in terms of loss of limb
function, lifetime disability and mortality of often an otherwise healthy
young trauma patient. Unconscious patients present an especially
diagnostically difficult subgroup of patients. Of many proposed
diagnostic tools, intracompartmental pressure measurement remains
the only widely accepted method and even it is rendered problematic
in terms of reliability and utility.

A good clinical education, a high index of suspicion, an early
recognition of the condition, competency in practical application of

Figure 2: Fasciotomy of the Hand: A hand following an isolated crush injury
and decompression of all compartments is shown. Both preoperative and
postoperative assessment of neurovascular structures is imperative.
intracompartmental pressure measurement and the confidence to take the daring decision to proceed to surgical decompression is the key to successful treatment.

References