Compartment Syndrome and Its Management

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Pathogenesis

The unifying feature of all compartment syndromes, is an increase in intracompartmental pressure (ICP) within an unyielding fascial envelope that impairs tissue perfusion.

ICP rises, pressure is transmitted to the postcapillary venules, increasing the venous pressure and decreasing the arterial-venous pressure gradient (ΔP).

Increased ICP may collapse capillaries, decreasing their radius and further increasing resistance to flow.

Critical Closing Pressure

Matsen suggested that there is a “critical closing pressure” above which capillaries collapse from transmural pressure and blood flow is arrested.

Hartsock suggested that the arterial-venous pressure gradient (ΔP) is the critical determinant of capillary blood flow.

Absolute Intracompartmental Pressure Threshold

Hargens found that an absolute ICP of 30 mm Hg for 8 hours universally produced muscle necrosis in normotensive dogs.

Tissues differed in their susceptibility to increased ICPs.

Dynamic Intracompartmental Pressure Threshold

Heppenstall found that a dynamic pressure threshold (MAP − ICP) < 40 mm Hg, prevented unnecessary fasciotomy in a number of patients with absolute ICP exceeding 30 mm Hg.

These studies offer compelling evidence that a dynamic ICP threshold relative to MAP or diastolic pressure is more appropriate for selecting patients for fasciotomy.

Vascular Causes

Ischemia-Reperfusion

Trauma

Venous Outflow Obstruction

Hemorrhage

Nonvascular Etiologies

Fracture

Crush Injury

Iatrogenic

Secondary Compartment Syndrome

Clinical Presentation

The most common findings are a tense, swollen compartment with pain elicited by passive movement of the muscles in that compartment.

The pain is typically not relieved by immobilization or reduction of fractures and responds poorly to analgesic medications.

A careful neurologic examination should document sensory and motor function

Clinical Presentation

Pressure measurement should be reserved for equivocal cases, unconscious patients, and pediatric patients in whom a compartment syndrome is suspected.

A normal compartment pressure is ≤10 to 12 mm Hg.

Unusual Presentations for Compartment Syndrome

Hand compartment syndromes are usually associated with crush injuries or fractures of the carpal bones.

Forearm compartment syndromes are typically associated with direct blows, crush injuries, or fractures.

Thigh compartment syndrome is usually caused by blunt trauma from motor vehicle accidents, contusion, or crush injury

Gluteal compartment syndrome has been associated with hypogastric artery ligation or embolization during aortic aneurysm repair, hip arthroplasty, and prolonged compression during operative procedures

Prevention of Compartment Syndrome

Pharmacologic therapy to blunt oxygen radical formation during reperfusion of an ischemic limb.

Mannitol, allopurinol, superoxide dismutase, deferoxamine, thromboxane A2, and melatonin have shown promise in reducing oxygen radical formation and ICP in animal models.

Prevention of Systemic Sequelae

Myonecrosis associated with compartment syndrome may liberate intracellular potassium, phosphate, myoglobin, and creatine phosphokinase (CPK).

Treatments designed to prevent systemic sequelae of compartment syndrome are aimed at preventing further complications related to the electrolyte disturbances or myoglobinuria that result from extensive myonecrosis

Myoglobinuria

Myoglobinuria exerts its nephrotoxic effects by inducing renal vasoconstriction, tubular cast formation, and direct heme protein–induced cytotoxicity.

The management of myoglobinuria includes aggressive crystalloid infusion, forced diuresis with mannitol, and alkalinization of the urine with bicarbonate.

Current recommendations for the management of myoglobinuria include hydration with a goal urine pH of greater than 6.5, despite the fact that the use of sodium bicarbonate has not been shown to be superior to saline diuresis.

Myoglobinuria

Myoglobin is poorly cleared by conventional dialysis membranes due to its relatively large molecular weight (17,000 Da), so hemodialysis is not a useful adjunct in preventing renal injury due to myoglobinuria, although continuous venovenous hemofiltration has shown promise in preliminary studies.

Renal replacement therapy is currently reserved for standard indications, including the management of severe hyperkalemia

Criteria for Fasciotomy

Absolute Indications

- Tense compartment plus either:
- Pain with passive motion of muscles traversing the same compartment or
- Paresis or paresthesias referable to the same compartment
- Tense compartment in a patient who cannot be examined serially due to obtundation or need for other operations
- ICP minus mean blood pressure <40 mm Hg
- ICP minus diastolic blood pressure <10 mm Hg

Criteria for Fasciotomy

Potential indications:

- Acute ischemia >6 h with few collaterals
- Combined arterial and venous traumatic injuries
- Phlegmasia cerulea dolens
- Tense compartment after crush injury
- Tense compartment after fracture

Criteria for Fasciotomy

In equivocal cases, ICP measurement may assist in decision-making.

Fasciotomy is warranted if the difference between the ICP and MAP falls to less than 40 mm Hg or the difference in ICP and diastolic pressure is less than 10 mm Hg.

Contraindications to Fasciotomy

Fasciotomy is contraindicated when the extremity is nonviable, due to extensive traumatic or ischemic injury.

Crush injuries, may result in life-threatening complications from reperfusion because of the magnitude of the electrolyte shifts that result from reperfusion of ischemic muscle after fasciotomy

Lower Leg Fasciotomy

The lower leg is subdivided into four anatomic compartments: anterior, lateral, superficial posterior, and deep posterior.

Jensen et al. found that 12% of subcutaneous fasciotomies, using minimal incisions, had incomplete decompression requiring reoperation to extend the skin incision.

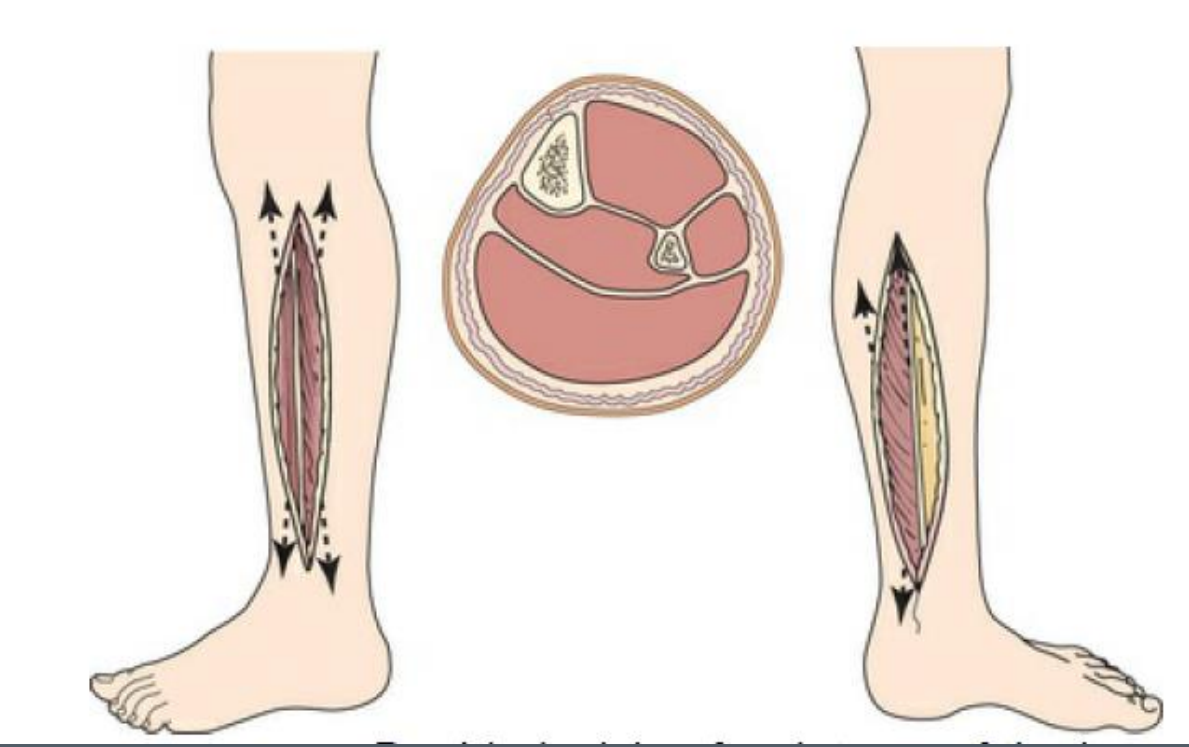
Full decompression of all compartments of the lower leg required incisions 12 to 20 cm in length.

Double-Incision Technique

A generous longitudinal incision on the lateral aspect of the lower leg between the fibular shaft and the crest of the tibia, directly over the intermuscular septum between the anterior and lateral compartments, approximately 4 cm lateral to the crest of the tibia.

The anterior and lateral compartments are opened via separate, parallel 12 to 20 cm fascial incisions using Metzenbaum or Cooley scissors

Double-Incision Technique



Double-Incision Technique

A second incision is placed on the medial aspect of the leg 1 to 2 cm posterior to the tibia for decompression of the two posterior compartments.

The saphenous vein and nerve should be avoided in the subcutaneous tissue.

The superficial posterior compartment is decompressed via a longitudinal incision along the gastrocnemius fascia.

The deep posterior compartment is decompressed by dividing the attachments of the soleus muscle to the tibia, exposing the fascia overlying the tibialis posterior and flexor muscles of the foot.

Single-Incision Technique

The single-incision technique involves a lateral incision over the fibula from the fibular neck to 3 or 4 cm above the lateral malleolus.

Anterior and lateral compartments are decompressed using the same technique outlined previously for these compartments.

The superficial posterior compartment decompressed using a longitudinal fascial incision.

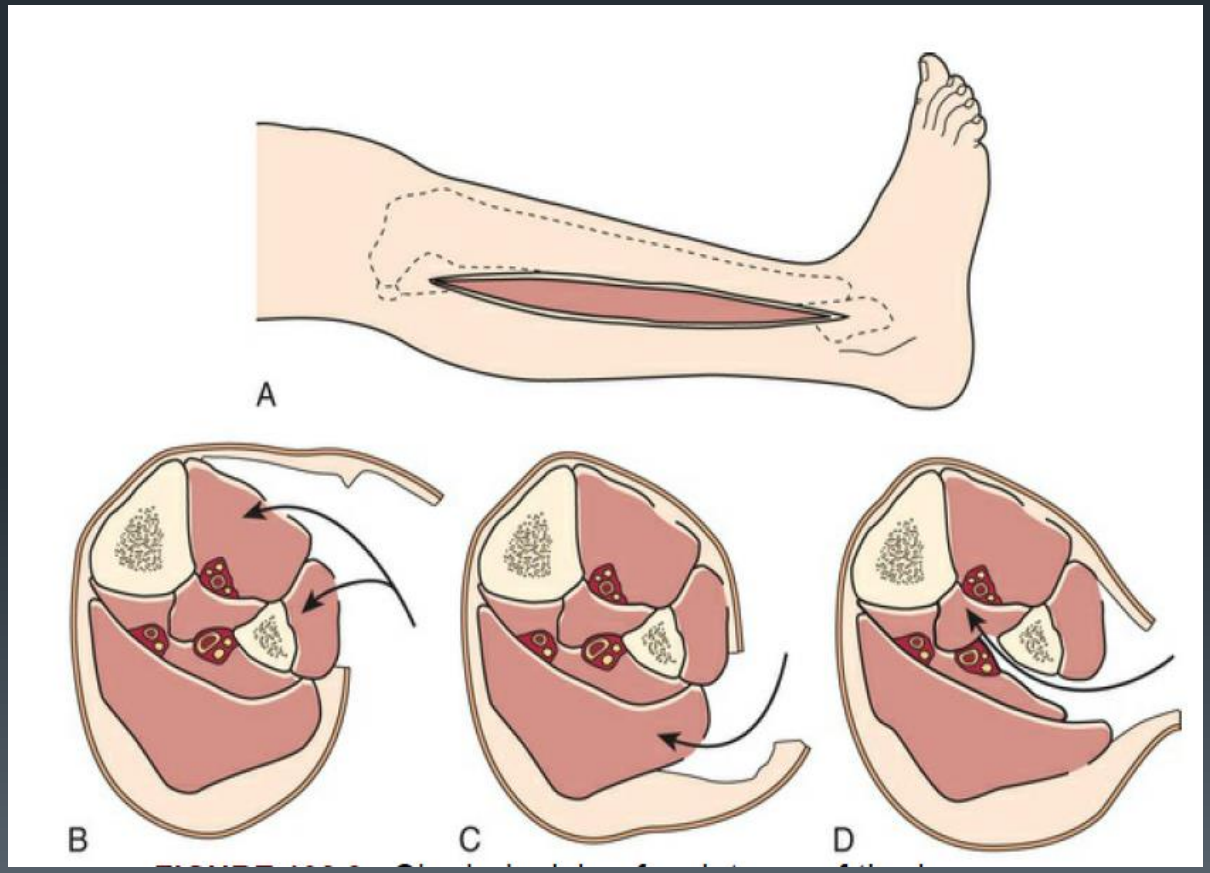
Single-Incision Technique

The interval between the lateral and superficial posterior compartments is exposed.

The flexor hallucis longus muscle is identified and dissected off of the fibula in a subperiosteal plane.

The fascial attachment of the posterior tibial muscle to the fibula is incision to open the deep posterior compartment.

Single-Incision Technique



Thigh Fasciotomy

The thigh contains three compartments: anterior, posterior, and Medial.

In most cases a single lateral incision may be used to decompress the posterior and anterior compartments, whereas the medial compartment rarely requires decompression

Thigh Fasciotomy

An incision is placed along the lateral thigh, beginning just distal to the intertrochanteric line and extending distally to the lateral epicondyle.

The iliotibial band is exposed and incised longitudinally along the length of the skin incision to decompress the anterior compartment.

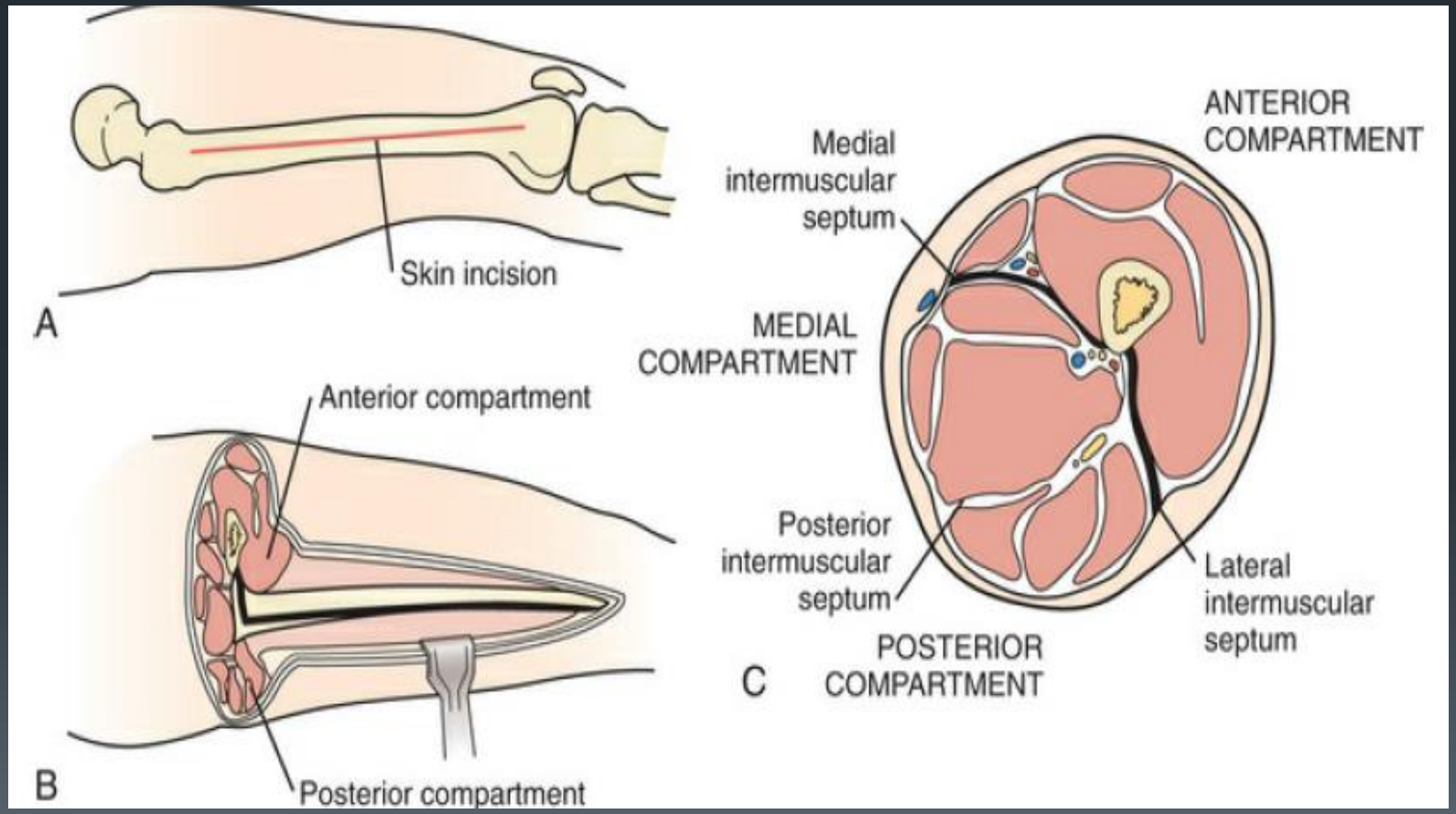
Thigh Fasciotomy

The vastus lateralis is reflected medially to expose the lateral intermuscular septum.

The intermuscular septum is incised over the length of the skin incision to release the posterior compartment.

Decompression of the medial compartment is rarely necessary, although a separate incision over the adductor muscle group will decompress this compartment

Thigh Fasciotomy



Buttock Fasciotomy

The buttock is composed of three major muscles, each with its own fascial compartment

There is no universally accepted standard incision for a buttock fasciotomy. However, a longitudinal incision is most frequently described in case series.

Each of the muscle compartments requires decompression for a complete fasciotomy

Foot Fasciotomy

The most frequently named compartments are medial, lateral, superficial, and calcaneal compartments, with an additional compartment corresponding to each interosseous muscle.

Two longitudinal dorsal incisions are fashioned.

The first incision is oriented along the medial aspect of the second metatarsal, and the second incision is placed at the lateral margin of the fourth metatarsal bone.

Foot Fasciotomy

A separate incision is required to decompress the calcaneal compartment.

Through these incisions, each of the muscle compartments can be incised, typically with fine scissors.

Forearm Fasciotomy

Within the forearm, there are flexor, lateral and the extensor Compartments.

The volar, or Henry, fasciotomy uses a single incision to decompress both the lateral and volar compartments.

A curvilinear incision begins proximal to the antecubital fossa, medial to the biceps tendon, crosses the antecubital crease, and extends to the radial side of the forearm where is extends distally along the medial border of the brachioradialis muscle.

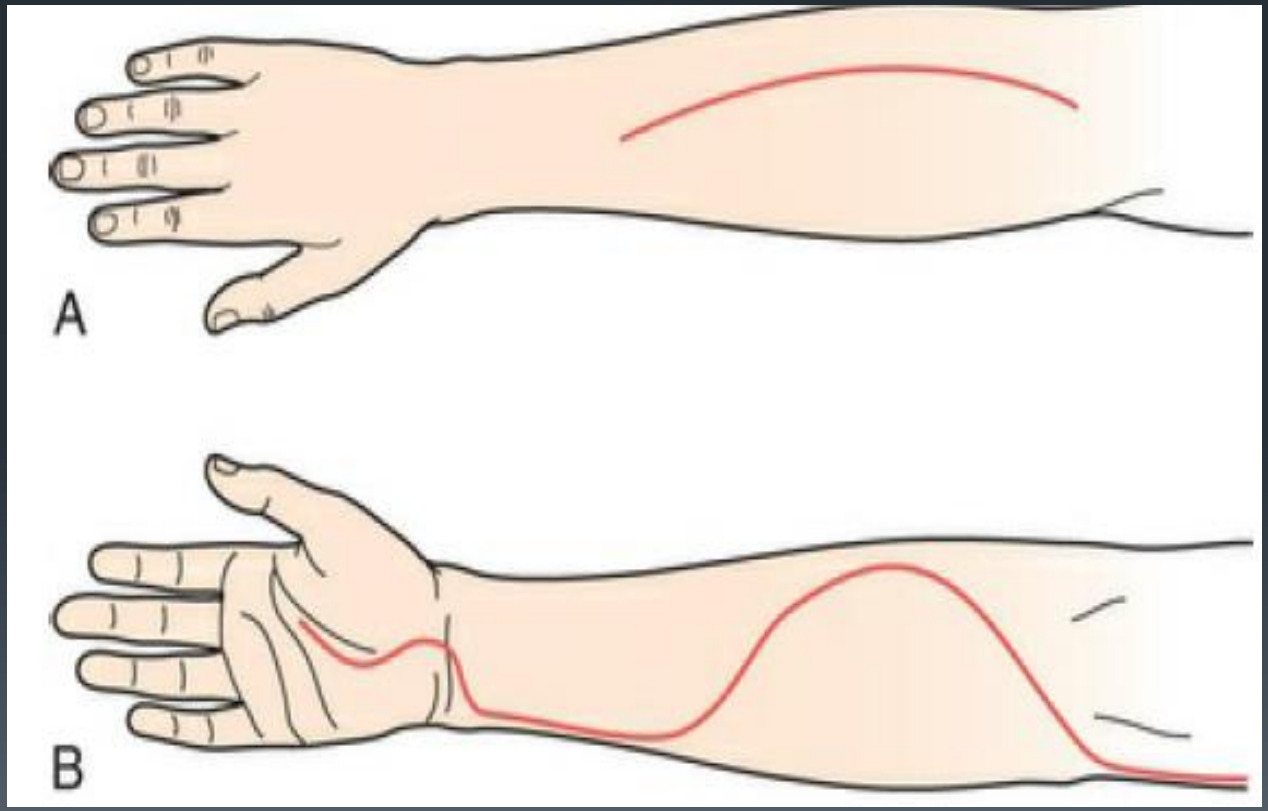
From the distal forearm the incision extends across the carpal tunnel along the thenar crease.

Forearm Fasciotomy

If the dorsal ICP is elevated, a long incision from the lateral epicondyle to the wrist is used to perform a fasciotomy between the extensor carpi radialis brevis and the extensor digitorum communis.

Carpal tunnel releases are controversial and may not be of benefit in isolated forearm compartment syndromes

Forearm Fasciotomy



Hand Fasciotomy

There are 10 compartments of the hand: hypothenar, thenar, and adductor pollicis compartments; four dorsal interosseous compartments; and three volar interosseous compartments.

All patients should have a carpal tunnel release, and most will require one to two dorsal interosseous fasciotomies.

Many patients will also require thenar or hypothenar fasciotomy.

Fasciotomy Wound Management

When muscle viability is questionable, periodic saline dressings permit caregivers the opportunity to inspect and debride the wound at regular intervals.

Vacuum-assisted closure (VAC) therapy is an alternative means of wound coverage, although the wound should be inspected at frequent intervals early after fasciotomy.

Fasciotomy Wound Management

After tissue viability is ensured and wound swelling has subsided, the priority shifts to wound closure.

The options include delayed primary closure, closure by secondary intention, gradual dermal apposition, split thickness skin grafting (STSG), and myocutaneous flap coverage.

Sequelae of Missed Compartment Syndrome

Sheridan and colleagues found that the overall complication rate increased dramatically if fasciotomy was delayed more than 12 hours.

Nearly half of the patients with delayed fasciotomies required amputation and 92% had a significant neuropathy.

Not surprisingly, delay of fasciotomy for more than 36 hours almost invariably results in amputation.

Sequelae of Missed Compartment Syndrome

After 3 to 4 days, fasciotomy is not indicated since the rate of infection and muscle necrosis is prohibitively high.

The classic late consequence of a missed compartment syndrome is a Volkmann contracture.

In this state the ischemic muscle and nerve tissue are replaced by fibrosis, leaving the compartment firm, contracted, and dysfunctional

Chronic Exertional Compartment Syndrome

Is a syndrome of exercise-induced pain and tightness that usually affects the muscles of the lower leg, especially the anterior and lateral compartments, due to increased ICP and transient muscle ischemia.

The typical patient is a young (20- to 30-year-old), athletic patient who is a runner.

The syndrome is characterized by pain beginning 20 to 30 minutes after the onset of exercise, which abates with 15 to 30 minutes of rest.

Chronic Exertional Compartment Syndrome

Symptoms are bilateral in 82%.

Physical examination often shows tenderness of the affected muscle compartment.

The differential diagnosis includes fascial hernias, medial tibial syndrome and claudication due to popliteal entrapment syndrome

Chronic Exertional Compartment Syndrome

MRI and other tests may rule out other causes of leg pain, measurement of ICP is required to secure the diagnosis.

Pedowitz and colleagues established pressure criteria for the diagnosis:

Resting ICP >15 mm Hg; ICP >30 mm Hg 1 to 2 minutes after completion of exercise; ICP >20 mm Hg, 5 minutes after completion of exercise.

One or more of these criteria are sufficient for the diagnosis with the characteristic symptoms that are reproducible on exercise

Treatment for Chronic Exertional Compartment Syndrome

Avoidance of the precipitating exercises.

Surgical decompression of the affected compartment.(only symptomatic compartments are decompressed).

Both fasciotomy and fasciectomy have been proposed to decompress the symptomatic compartments.

Fasciotomy for Chronic Exertional Compartment Syndrome

For subcutaneous fasciotomy two 2- to 4-cm transverse incisions are commonly used.

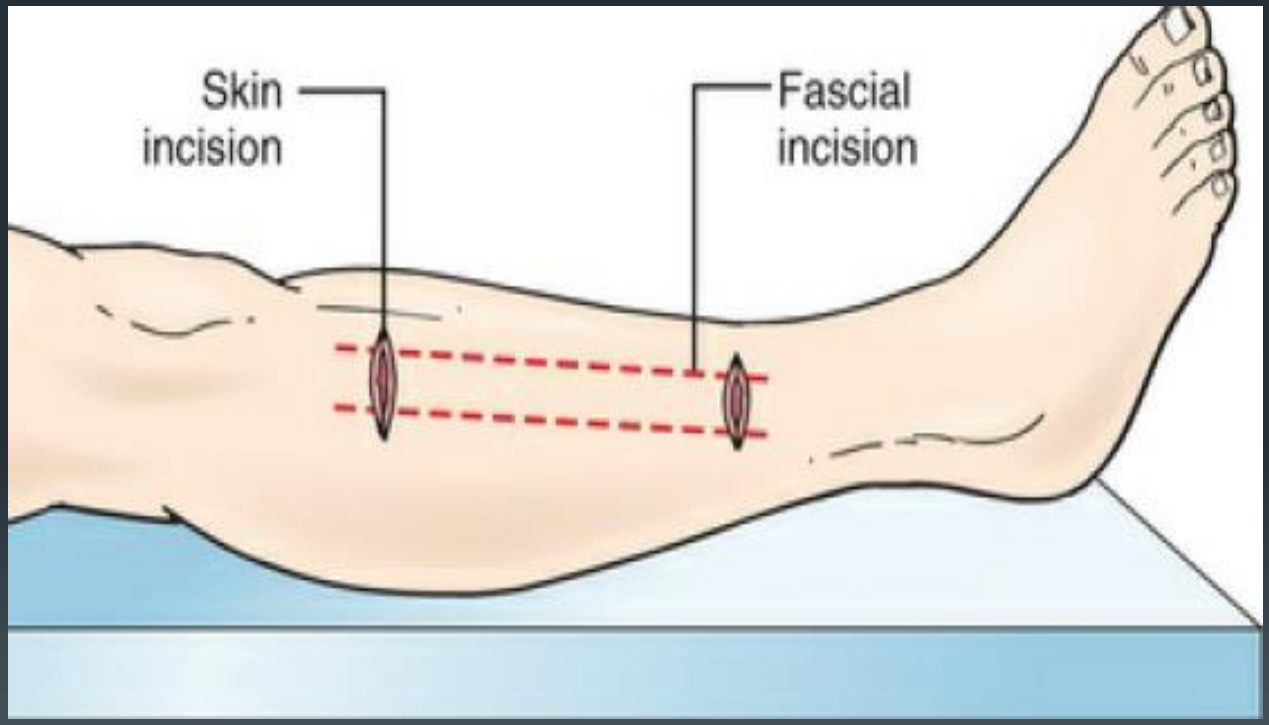
Two longitudinal fascial incisions are then performed between the two transverse skin incisions, akin to the fascial incisions used for a standard open fasciotomy.

Fasciotomy for Chronic Exertional Compartment Syndrome

For fasciectomy, a single longitudinal skin incision overlying the intermuscular septum between the anterior and lateral compartments is used.

Two standard longitudinal fascial incisions are performed in the anterior and lateral compartments, followed by resection of a 2 × 6 cm ellipse of fascia

Fasciotomy for Chronic Exertional Compartment Syndrome



Outcomes

Long-term results appear promising in case series, which describe significant reduction in pain at 2 years following anterior compartment fasciotomy in 83% of subjects.