Fasciotomies

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40.1 Introduction

The use of fasciotomy for compartment syndrome has been described in countless articles and chapters as the only reliable method for treatment of acute compartment syndrome. In 1881, Volkmann described the relationship between ischemic events and late muscle contractures [1]. Dr. Paul Jepson demonstrated ischemic contracture in animals and that this may be prevented by prompt surgical decompression in 1924 [2].

Acute compartment syndrome is a surgical emergency and is defined as an elevation of the interstitial pressure in a closed osteofascial compartment that results in the decline in perfusion to the tissues of that compartment and eventual necrosis [3, 4]. This can result from blunt, crush, or penetrating trauma, exercise, reperfusion, prolonged immobilization, hematoma, intra-arterial injection, or massive fluid resuscitation.

The compartment's pressure can increase due to enlargement of the tissues within the compartment, such as reperfusion, or constriction of the compartments as in casting the limb. In reality it can take little pressure to make this happen. Hartsock et al. found a reduction in capillary inflow occurs at about 25 mmHg in rat models [5]. Most literature describes necessity to perform a release when the pressure exceeds 30 mmHg [6]. While normal pressures are about 10 mmHg, no definitive pressure measurement has been identified.

Irreversible damage has been described to be dependent upon perfusion pressure, more specifically when compartment pressures reach within 10–30 mmHg of the patient's diastolic pressure [7]. Two additional studies validated this pressure to be 30 mmHg with no missed cases including "unnecessary fasciotomies or significant complications" of acute compartment syndrome [3, 8, 9].

The diagnosis of acute compartment syndrome has been classically described as the five Ps: pain, pallor, pulselessness, paralysis, and paresthesia. The pain may be deep, burning, and constant. The patient often does not want to touch or move the limb.

Indications for fasciotomy have been described with clinical symptoms and signs of "pain out of proportion to palpation," passive stretch of the compartment's muscles, and increased narcotic demand with tense swelling and paresthesia. In all honesty, if the limb has loss of sensation or pulses, the critical point of recognition has already lapsed.

Flynn et al. looked at acute traumatic compartment syndrome in the pediatric population in two large tertiary care centers and noted that the average

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time from injury to fasciotomy was 20.5 h. This raises the concern of proper diagnosis early and that speedy intervention occurs. Time delays can be seen across varying institutions [10].

If the clinical diagnosis can be made, then surgical intervention should be performed expeditiously. If there is still doubt, pressures can be taken. A transducer is connected to a catheter and inserted into the muscle bed via aseptic technique. There are several pressure measurement devices available. The more common devices are the Stryker Intracompartmental Pressure Monitor System, arterial line manometer, and Whitesides apparatus. These were all tested by Boody et al. with straight needle, side-port needles, and slit catheters. Their findings were that the arterial line manometer with a slit catheter showed the best correlation, while the Whitesides apparatus with the side-port needle showed the worse results. Overall the side port needles and slit catheters were more accurate than straight needles and that the arterial line manometer was the most accurate device with the Stryker being very accurate as well [11].

40.2 Treatment

Although definitive treatment is compartment release with fasciotomy, there are some conservative measures that can be performed. These include identifying and removing any constrictive dressings, devices, and other compressive items to expose the skin of the affected limb [3].

Further the limb should be level with the heart and not elevated. Elevation may decrease perfusion to the tissues although this is counterintuitive, with most cases of edema [12].

Further, the patient must be assessed for hypovolemia, metabolic acidosis, and myoglobinemia. This is most important to reduce the incidence of renal failure. Intravenous fluids should be given and regular labs drawn and monitored. The patient should maintain normotension, again for reducing the rate of hypoperfusion [3].

Medicinal management is uncommon. There was a case study for mannitol treatment in the setting of acute compartment syndrome, but this was in the setting of heat stroke and dehydration [13]. Trauma or prolonged ischemia requires surgical intervention.

The team must also be prepared for "crush syndrome" and its associated renal injury from myoglobinuria. Crush syndrome, also known as traumatic rhabdomyolysis, was first described by British doctor Eric Bywaters during the London Blitz [14]. When encountering thigh compartment syndrome, the mechanism of injury often leads to this condition.

When a fasciotomy is performed, it requires an adequate incision and facial release. Minimally invasive exposures should only be done by extremely knowledgeable staff as the full length of the fascia can be missed with the longitudinal incisions. All compartments must be released with preservation of vital structures, and a through debridement must be undertaken at the time of initial intervention and with subsequent debridements.

Remember to be liberal in obtaining consults from vascular, orthopedic, and plastic surgery when seeing these patients. Many times these are complex cases, and any fasciotomies undertaken must be performed with adequate supervision. Hand, foot, and buttock fasciotomies will not be discussed in detail due to their distinct specialization and need for expert intervention.

Fasciotomies are not performed when the extremity is nonviable from prolonged tissue ischemia, the patient is too unstable to tolerate intervention primarily from unstable hypoperfusion, and there is a large crush injury involving large portions of the tissue groups.

A clinically cold extremity with muscle rigor, complete neurological loss, and absent inflow by Doppler is known as grade 3 ischemia. This is irreversible and is generally contraindicated for reperfusion or other limb salvage.

40.3 Lower Extremity

If only one compartment is affected, it can be treated with a single incision and release. This is not recommended as most cases involve a greater cross section. In cases with arterial compromise

and trauma, decompression of all major compartments must be pursued.

There was debate of a single- vs. double-incision fasciotomy in the 1970s. In World War II, two incision fasciotomies were standard of care [14]. In 1967 a fibulectomy through a single incision was advocated. The concern was that two incision fasciotomies neglected to fully decompress the deep posterior compartment [15]. This is no longer advocated due to risk of damage to the peroneal artery and nerve [16].

It was Murbarak and Owen who championed the double-incision fasciotomy and showed its effectiveness and advantages over fibulectomy [17]. It is recommended by the British Orthopaedic Association and British Association of Plastic, Reconstructive and Aesthetic Surgeons [3].
In the calf there are four anatomical compartments:

1. Anterior compartment: the tibialis anterior, extensor digitorum longus, extensor hallucis longus, and peroneus tertius with the anterior tibial artery and deep peroneal nerve.
2. Lateral compartment: the peroneus longus and brevis with peroneal nerve branches from the anterior compartment.
3. Posterior superficial compartment: the gastrosoleus complex with tibial nerve branches and arterial flow provided by the popliteal artery and posterior tibial and peroneal arteries.
4. Posterior deep compartment: the tibialis posterior, flexor hallucis longus, and flexor digitorum longus with the tibial nerve and posterior tibial and peroneal artery blood supply.

Two incisions are made, one medially and the other laterally. Each measures about 15 cm in length. A scalpel with electrocaudery can make the initial incision and dissection. The facial tissue should be cut with smooth-ended scissors like a Metzenbaum. The scissors should be angled slightly away from the muscle as not to bury the cutting edge into the tissue and inadvertently causing injury. Without moving the handles, the instrument can be pushed along the length of the incision from proximal to distal. This is similar to opening a cardboard box or cutting a wrapping paper. The medial incision is made about 2 cm medial to the tibial margin in a similar location to popliteal artery exposure. The length of the incision is dependent upon the extent of muscle protrusion/edema. However, this cannot be the sole judge as with revascularization procedures the edema may increase throughout the immediate postoperative period. The saphenous vein and nerve should be identified and injury be avoided. The superficial posterior compartment is opened by releasing the gastrocnemius fascia in a longitudinal fashion from proximal to distal. The deep posterior compartment is decompressed by dividing the attachments of the soleus muscle from the tibia.

The lateral incision is set between the shaft of the fibula and the crest of the tibia. The incision then is made over the intramuscular septum of the anterior and lateral compartments. The septum is palpable and feels like a dimpling of the tissue between the two muscle groups. The anterior compartment is decompressed and then the lateral fascia. The most common injury is to the common peroneal nerve and superficial peroneal nerve. Having the lateral incision too proximal to the tibial plateau or lateral condyle can injure the common peroneal nerve and, in many patients, the superficial nerve which rests in the septum of the anterior and the lateral intramuscular compartments.
In the thigh there are three compartments:

1. Anterior compartment: the quadriceps
2. Posterior compartment: the hamstrings
3. Medial compartment: the adductor muscles

A single lateral incision is commonly used as the lateral compartment is the one typically involved. Blunt trauma, crush injuries, and femur fracture are the most common causes [3]. A single lateral incision originating just distal from the intertrochanteric line and extending to the lateral epicondyle of the femur. The IT band and fascia of the vastus lateralis are incised the length of the skin incision to decompress the anterior compartment. The posterior compartment is decompressed by reflection of the vastus

lateralis muscle medially, incising the intramuscular septum. The medial compartment is decompressed through a second incision overlying the adductor muscle group.

40.4 Upper Extremity

In the forearm there are three compartments:

1. Mobile wad: the brachioradialis, extensor carpi radialis longus, and brevis muscles, with the radial artery and nerve
2. Volar compartment: the superficial and deep flexors, with the ulnar artery and nerve and median nerve
3. Dorsal compartment: the extensor muscles

The radial or ulnar pulses are usually intact as their pressure of 120 mmHg is usually greater than the compartment pressures. This again is an unreliable marker for intervention. Most elevated pressures will be found in the volar compartment. Two separate incisions are often made to decompress the arm. Failure to do so may result in Volkmann's contracture, a permanent flexion of the hand at the wrist with the hand and fingers forming a claw.

Map out the medial aspect. From this position you can address the major nerve structures and expose the vascular beds to repair if necessary. If the clinical situation requires fasciotomy of the upper arm or hand and wrist, this can be taken in the same incision.

Start at the elbow and gently curve in an augmented S shape, the incision extending first out laterally and then coming medial with linear extension to the wrist. This can then join a lazy S of the hand if required and allow you to perform a carpal tunnel release if needed to preserve the median nerve.

From this location, the volar and mobile wad can be released. Using the same technique as described previously, a small incision can be made over the fascia with a snip of the scissors and then slide the cutting blades along the fascia to release. Separate muscle groups may require fasciotomies. Be careful not to injure the radial nerve and artery as you make a skin flap over the wrist. Skin flaps in this location can cover the median nerve and other vascular structures of the carpal tunnel for protection. Often a simple series of cuts can be made to free the tissue laterally and dorsally.

Fig. 40.1 (**a**) The fascial tissue seen cut and separated. (**b**) Muscle edema. Note how the muscle loses its structure once the fascia has been cut away

The dorsal incision is then made. Make sure after release is performed, a manual check confirms the origin and insertion points have been reached and the fascia is completely released (see Fig. 40.1).

40.5 Wound Care

All fasciotomy incisions are left open. Even though there is a movement that advocates fascial incision and then staple closure of the skin, complete tissue edema can take 24–48 h to occur and the muscle may require multiple debridements. It is therefore recommended to leave the wounds packed with sterile gauze or negative pressure dressing.

Bleeding may occur postoperatively and negative dressing pressures should be set with this in mind. 70–90 mmHg rather than 125 mmHg may be employed. Do not place the vac dressing directly on the muscle surface. Apply Vaseline gauze or Adaptic dressing to the tissue before sponge. After 48 h, intermittent suction is thought to promote healing quicker.

Fig. 40.2 Negative pressure dressing over fasciotomy site

If copious amount of drainage is experienced, the pressure may be increased to 150 mmHg or 200 mmHg and then reduced back to 125 mmHg (see Fig. 40.2).

40.6 Closure

After the tissues become soft and are more malleable, closure can be considered. A delayed secondary intention with wound vac or wet to dry dressings can be used. Split-thickness skin graft after an initial period of dressing changes is an alternative. The most ideal closure is primary.

Some recommend a shoe string technique that can be slowly tightened until closure. The initial sutures are run at the time of initial operation and then pulled closed as the edema resolves. This can be difficult given the need for tissue manipulation and pain management at the time of closure.

Others favor closure intraoperatively when tissues are able to be manipulated or local anesthetic with the vertical mattress-interrupted sutures. At times a skin flap needs to be demarcated. Granulation tissue can make this difficult to initially see. A finger can be run along the subdermal tissue and expose the planes between the fascia and subcutaneous tissue. Often freeing more generous amounts of subcutaneous tissue from the fascia below allows for an easier closure.

Large 1-0 vicryl sutures can be used. Braided is also available. Silk tends to pull into the skin more. Make generous bites of tissue to avoid skin necrosis with tightening and allow for proper elevation of the incision edges. Once the suture is in place, cut a proper length for tying and place a snap as this will allow for multiple sutures to be placed and then closed at once much like the laces of a football. Once the tissue is closed, staples can be used to better approximate the skin edges (see Figs. 40.3 and 40.4).

If more lymphatic drainage becomes an issue, a "strip vac" may be employed.

40.7 Chronic Issues After Fasciotomy

In a retrospective study of 60 patients who suffered upper or lower extremity fasciotomies, many complained of chronic issues associated with the procedure and/or injuries [18, 19] including:

Ongoing pain relating to the wound 10 %
Altered sensation 77 %
Dry skin 40 %
Pruritus 30 %
Discoloration 25 %
Edema 25 %
Tethered scars 26 %
Recurrent ulceration 13 %
Muscle herniation 13 %
Tethered tendons 7 %
Stigmatizing scars 23 %
Change in hobbies 28 %
Change in occupation 12 %

Chronic venous insufficiency due to lack of calf pump utilization is additionally noted in many patients, perhaps due to the lack of reapproximation of the fascia at time of closure. This occurs in patients equally despite vascular injury [20, 21].

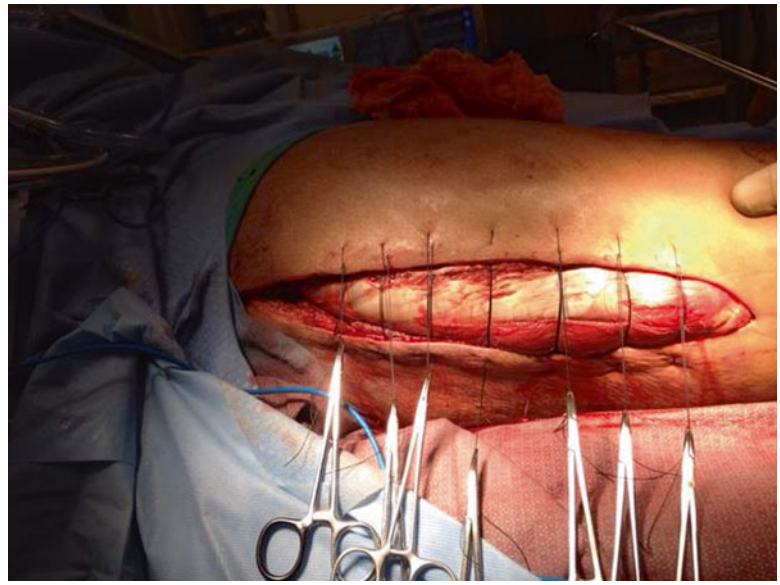

Fig. 40.3 Closure using braided nylon sutures in interrupted fashion

Fig. 40.4 Closure with the skin approximated with staples

40.8 Medicolegal Complications

Acute compartment syndrome is an extremely contested issue if not properly diagnosed and treated in a timely manner. Most often compartment pressures in these cases were not measured or measured incorrectly with malpositioning of the hardware. As stated previously, the diagnosis of compartment syndrome should be made clinically, if any doubt, the treating practitoner should trust their judgement rather than a number that may have been obtained incorrectly and perfrome the intervention.

40.9 Anticoagulation Therapy Contraindications

Many patients are on antiplatelets including aspirin, Plavix and Aggrenox, or Pletal. There is no contraindication with any of these agents.

Warfarin is also easily reversed if needed with vitamin K or fresh frozen plasma (FFP).

There is however a growing concern over Xa inhibitors including Xarelto, Eliquis, and Lixiana. There are no known reversal agents and FFP has no effect given the direct factor-inhibiting effect. However, the risk of limb loss, chronic limb dysfunction, or death with compartment syndrome is so high intervention should likely take place with meticulous hemostatic techniques being used. In these cases negative-pressure dressings should not be applied. Skin edge bleeding must be addressed and the use of thrombotic agents including Floseal, Tisseel, Surgicel, or StatSeal.

40.10 Conclusion

Acute compartment syndrome is a medical emergency requiring quick clinical decision making and clear understanding of the anatomy for successful compartment decompression. All patients with a clinical suspicion should be scrutinized, and delay can result in significant morbidity.

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