Chapter 17
In Patients with Limb-Threatening Vascular Injuries, Is There a Role of Prophylactic Fasciotomy to Reduce Ischemic Injury?

Melanie Hoehn, Megan Brenner, and Todd E. Rasmussen

Abstract Patients with unrecognized or untreated extremity compartment syndrome are at high risk of amputation and the rates following major extremity vascular injury are high. Despite this, no clear evidence exists supporting the use of prophylactic fasciotomy. The procedure itself is associated with significant morbidity. Risk factors such as ischemia time, location of injury, concurrent injuries, and hypotension should be used to stratify which patients are most likely to benefit.

Keywords Fasciotomy • Compartment syndrome • Ttrauma • Ischemia

Introduction

Compartment syndrome is a feared clinical sequelae of lower extremity injury-induced ischemia and it is associated with significant morbidity and mortality [1]. While it is generally agreed that the diagnosis of extremity *compartment* syndrome mandates immediate fasciotomies, the debate as to the ideal timing of the intervention continues. Advocates of early prophylactic fasciotomies cite that fasciotomies reduce the risk of compartment syndrome and therefore its highly morbid consequences. Opponents argue that fasciotomies have morbidity as well, and that their use prophylactically is unnecessary.

M. Hoehn, MD
Division of Vascular Surgery, University of Maryland School of Medicine, Baltimore, MD, USA

M. Brenner, MD, MS, RPVI, FACS
Divisions of Trauma/Surgical Care and Vascular Surgery, University of Maryland School of Medicine, Baltimore, MD, USA

T.E. Rasmussen, MD (✉)
Colonel United States Air Force, DoD Combat Casualty Care Research Program, Fort Detrick, MD, USA
e-mail: todd.e.rasmussen.mil@mail.mil

C.L. Skelly, R. Milner (eds.), *Difficult Decisions in Vascular Surgery*,
Difficult Decisions in Surgery: An Evidence-Based Approach,
DOI 10.1007/978-3-319-33293-2_17

There are two mechanisms by which vascular injury can lead to compartment syndrome. In cases of arterial injury and limb ischemia, the ischemia-reperfusion phenomenon is thought to play a major role. As ischemic times lengthen, microvascular permeability increases resulting in an increasing amount of interstitial edema. When reperfusion occurs free radicals further increase the permeability leading to increasing amounts of edema. This results in increased pressure within a fixed fascial compartment, mechanical injury to muscle and nerve, reversible ischemia, and eventually, irreversible necrosis [2].

Venous injuries can also lead to compartment syndrome of the extremity if ligation or transection of a major vein occurs. The venous outflow obstruction leads to venous hypertension, which reduces capillary perfusion. This results in ischemic tissue injury which further increases the edema, eventually resulting in necrosis as above.

Added to this biochemical event is the direct traumatic injury to the bone and soft tissue. Frequently these patients suffer significant bony and soft tissue injuries and develop hematoma, which all exacerbate the tissue injury and resulting edema. Occultly injured soft tissue, muscle beds, lymphatics, large vessels, and microvasculature may also play a role.

Technique

Lower extremity fasciotomy was first described by Horn and Hughes in the 1940s, initially being performed by a single incision with fibular excision to release all 4 compartments: anterior, lateral, superficial and deep posterior [3, 4]. Decades later, this evolved into a single lateral incision without fibulectomy. Today, the gold standard approach is a 2 incision, 4-compartment release. In this technique, longitudinal incisions are made on the medial and lateral aspects of the lower leg. Laterally the intermuscular septum is localized and the anterior and lateral compartments are sharply incised on each side. Medially the fascia is open to release the superficial posterior, and the soleus is taken down off the fibula to release the deep posterior compartment (Figs. 17.1, 17.2, and 17.3).

Many techniques exist for primary and secondary closure, including simple interrupted sutures, shoe lace technique, vacuum dressing, wet to dry dressings, and

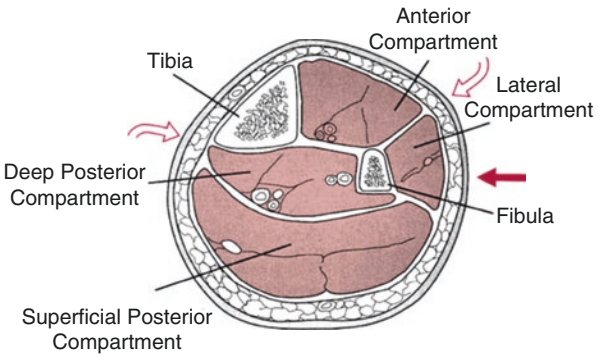

Fig. 17.1 Cross-section of calf illustrating the four compartments. *Open arrows* show sites of double-incision fasciotomy, *closed arrow* shows site of single-incision fasciotomy (This article was published in *Current Surgical Therapy*, 5th Edition. John L. Cameron, *Compartment Syndrome*, pg. 850, Copyright Elsevier ©1995)

Fig. 17.2 Demonstration of the medial incision for a four compartment fasciotomy

Fig. 17.3 Demonstration of the lateral incision for a four compartment fasciotomy

Table 17.1 PICO table

	I (intervention)	C (comparator)	O (outcomes)
Patients with limb threatening vascular injuries	Early fasciotomy	Ischemic injury	Limb salvage

skin grafting. There is also newer technology, such as the DermClose. It is a dynamic dermatotraction mechanical device which serves as an external tissue expander and has been used with some success [5].

Search Strategy

A literature search of English language publications from 1978 to 2013 was used to identity published data on prophylactic fasciotomy after lower extremity trauma. Databases searched were PubMed. Terms used in the search were “fasciotomy”, “lower extremity trauma”, “compartment syndrome”, and “ischemia” (Table 17.1).

Results

Time Course of Compartment Syndrome

Nerves are the structure most sensitive to the effects of compartment syndrome. Animal models have delineated the time course of irreversible damage to the nerves. Regardless of peak compartment pressures, if release of pressure occurred within 4 h, nerve conduction returned to baseline. After 12 h complete irreversible ischemia occurred. Between 4 and 12 h the peak compartment pressure is significant. With exceptionally high pressures irreversible necrosis occurs at 4 h. This data suggests there is a small window for reversal of the process [6, 7].

One translational study recently investigated functional outcomes in a swine model of hemorrhagic shock, hind limb ischemia, and reperfusion with prophylactic fasciotomy at 1, 3, and 6 h of ischemia. Increasing ischemic intervals resulted in incremental increases in compartment pressure without reaching >30 mmHg. While trends were observed in sensory improvement between the 3- and 6 h groups, this was not statistically significant, nor did it translate to a notable difference in functional outcomes. While this demonstrates that the use of prophylactic fasciotomies in this particular swine model of hemorrhagic shock does not improve functional outcome, all ischemic times were 6 h or less. This suggests in short ischemic times prophylactic fasciotomies may not be beneficial [8].

Risk Factors

There are several clinical features that are associated with an increase need for fasciotomies and presumably compartment syndrome. In a single large series, mechanism of injury is not independently associated with need for fasciotomy [9]. Arterial ligation and combined arterial-venous injuries both have increased risk of compartment syndrome. The level of the injury also plays a significant role. Popliteal injuries have a significant increase in the need for fasciotomies (61 %) vs injuries above the knee (19 %) [10]. Prolonged ischemia time of >4–6 h is also associated with an increased risk. Lastly, prolonged hypotension is associated with both the need for fasciotomies and limb loss [9, 11].

Complications of Prophylactic Fasciotomy

Fasciotomy, while inherently performed for limb salvage, can result in significant complications including amputation. The most feared complication is incomplete compartment release or delayed fasciotomy, resulting in a high rate of morbidity and mortality [12]. The most commonly missed compartments were the anterior and posterior deep compartments containing the main neurovascular bundles of the

leg. Patients who underwent delayed fasciotomy had a 3-fold increase in mortality and twice the rate of amputation. Chronic venous insufficiency may be a result of loss of the muscle pump and deterioration of venous hemodynamics.[13]. Nerve damage and neuropathic pain have been documented in patients after fasciotomy resulting in decreased plantar flexion, dorsal extension, sensory deficits in 53–70 %, and pain in 15–26 % which increased with exertion. Approximately 7 % rate of superficial peroneal nerve injury occurs with fasciotomy [14], leading to inability to evert the foot, and loss of sensation over the dorsum of the foot. Minor but potentially lifestyle limiting complications also occur such as pain, disfiguring wounds, infection, skin changes, and recurrent ulcerations [15, 16].

Prevention Strategies: Prophylactic Fasciotomy

Advocates of prophylactic fasciotomies stress that early fasciotomy can reduce the high morbidity associated with compartment syndrome. The largest review of prophylactic fasciotomies in patients with vascular injury is a retrospective review of the National Trauma Databank (NTDB) from 2002 to 2006. [17]. The NTDB is the largest trauma database in the US, and is comprised of voluntarily-reported patient information. Inclusion criteria were patients greater than 18 with lower extremity arterial injury, arterial repair, and fasciotomy. Patients were divided into 2 groups relative to the timing of fasciotomy – the late group had a fasciotomy performed less than 18 h after the vascular repair, while the early group was decompressed within 12 h. Outcomes were in-hospital mortality, amputation rates, complications, and length of hospital and ICU stays.

Six hundred and twelve patients underwent arterial repair and fasciotomies for lower extremity arterial injury. Most patients underwent early fasciotomies (n = 543), while a minority were performed late (n = 69). After adjusting for mechanism of injury and injury severity score, early fasciotomy was associated with a fourfold lower risk of amputation, which was maintained across subgroups defined by vessel injured, mechanism of injury (MOI), procedure performed, and presence of venous or bony injury. Multivariate analysis adjusting for gender, injury location, MOI, ISS, fracture, nerve and venous injury demonstrated a 23 % shorter length of hospital stay for the early fasciotomy group. Even after excluding the iliac artery injuries (an inherently more injured group), major lower limb amputation was significantly higher in the late fasciotomy group, and total length of hospital stay was significantly shorter in the early fasciotomy group.

Recommandations (Table 17.2)

In the setting of vascular injury, we recommend prophylactic fasciotomy for the following circumstances:

- Combined arterial/venous injuries (**Low quality, strong recommendation**)
- Ligation of major vessel (**Low quality, strong recommendation**)

Table 17.2 Studies used for early fasciotomy

	Number of patients	Major vascular injury (%)	Early fasciotomy (%)	Amputation rate (early) (%)	Mortality (early) (%)	Delayed fasciotomy (%)	Amputation (delayed) (%)	Mortality (delayed) (%)	Quality of evidence
Ritenour et al.	336	32	88	15	6	22	31	20	Low
Williams et al.	88	34	69	3.3	1.6	31	7.4	7.4	Low
Farber et al.	612	100	89	8.5	3.9	11	24.6	2.9	Low
Finkelstein et al.	5					100	100	20	Very low

- Popliteal injuries at or below the knee (**Low quality, strong recommendation**)
- Greater than 6 h of ischemic time (**Low quality, strong recommendation**)
- Associated significant bony and/or soft tissue injury (**Low quality, strong recommendation**)
- Equivocal indications and inability to perform physical exam (**Low quality, strong recommendation**)

A Personal View of the Data

Unfortunately, no randomized controlled trials exist to assess the use of prophylactic fasciotomies; however, in the setting of major vascular injury we strongly recommend the use of prophylactic fasciotomy in the majority of cases. Practically speaking an ischemic time of less than 6 h is difficult to achieve in routine practice. Additionally, significant associated injuries and inability to monitor exam are common place in trauma patients. The frequent development of compartment syndrome in vascular injury as well as the high consequence of a missed diagnosis drive this recommendation.

References

1. Finkelstein JA, Hunter GA, Hu RW. Lower limb compartment syndrome: course after delayed fasciotomy. J Trauma. 1996;40:342–4.
2. Percival T, White J, Ricci M. Compartment syndrome in the setting of vascular injury. Persp Vasc Endovasc Ther. 2011;23(2):119–24.
3. Horn CE. Acute ischemia of the anterior tibial muscles and long extensor muscle of the toes. J Bone Joint Surg. 1945;27:615–22.
4. Hughes CW. Ischemic necrosis of the anterior tibial muscles due to fatigue. J Bone Joint Surg. 1948;30B:581–94.
5. Potter MBK, Freedman LBA, Shuler MS. Fasciotomy wound management and closure. Tech Orthop. 2012;2:62–6.
6. Rorabeck CH, Clarke KM. The pathophysiology of the anterior tibial compartment syndrome: an experimental investigation. J Trauma. 1978;18:299–304.
7. Ricci MA, Corbisiero RM, Mohamed F, Graham AM, Symes JF. Replication of the compartment syndrome in a canine model: experimental evaluation and treatment. J Invest Surg. 1990;3:129–40.
8. Percival TJ, Patel S, Markov NP, Morrison JJ, Spencer JR, Ross JD, Rasmussen TE. Prophylactic fasciotomy in a porcine model of extremity trauma. J Surg Res. 2015;193:449–57.
9. Branco BC, Inaba K, Barmparas G, Schnuriger B, Lustenberger T, Talving P, et al. Incidence and predictors for the need for fasciotomy after extremity trauma: a 10-year review in a mature level I trauma centre. Injury. 2011;42(10):1157–63.
10. Abouzzi Z, Nassoura Z, Inatury RR, Porter JM, Stahl WM. A critical reappraisal of indicatins for fasciotomy after extremity vascular trauma. Arch Surg. 1998;133(5):547–51.

11. Williams AB, Luchette FA, Papaconstantinou HT, Lim E, Hurst JM, Johannigman JA, et al. The effect of early versus late fasciotomy in the management of extremity trauma. Surgery. 1997;122:861–6.
12. Ritenour A, Dorlac WC, Fang R, Woods T, Jenkins DH, Flaherty SF, et al. Complications after fasciotomy revision and delayed compartment release in combat patients. J Trauma. 2008;64:S153–61.
13. Bermudez K, Knudson MM, Morabito D, Kessel O. Fasciotomy, chronic venous insufficiency, and the calf muscle pump. Arch Surg. 1998;133:1356–61.
14. Kashuk JL, Moore EE, Pinski S, et al. Lower extremity compartment syndrome in the acute care surgery paradigm: safety lessons learned. Patient Saf Surg. 2009;3:11.
15. Giannoudis PV, Nicolopoulos C, Dinopoulis H, Ng A, Adedapo S, Kind P. The impact of lower leg compartment syndrome on health related quality of life. Injury. 2002;33:117–21.
16. Fitzgerald AM, Gaston P, Wilson Y, Quaba A, McQueen MM. Long-term sequelae of fasciotomy wounds. Br J Plast Surg. 2000;53:690–3.
17. Farber A, Tan TW, Hamburg NM, Kalish JA, Joglar F, Onigman T, Rybin D, Doros G, Eberhardt RT. Early fasciotomy in patients with extremity vascular injury is associated with decreased risk of adverse limb outcomes: a review of the National Trauma Data Bank. Injury. 2012;43(9):1486–91.